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Foreword

Department of the Navy
Naval Sea Systems Command
1 April 2023

This revision of the U.S. Navy Towing Manual provides the latest information concerning the towing and heavy lift transport of U. S. Navy ships. Much of the updated heavy lift information is the direct result of the successful heavy lifts of USS JOHN S MCCAIN (DDG 56) and USS FITZGERALD (DDG 62) in the Far East in 2017.

Comments about or recommendations concerning the U.S. Navy Towing Manual may be forwarded to the Supervisor of Salvage and Diving, Naval Sea Systems Command. 1333 Isaac Hull Avenue ST Stop 1072, Washington Navy Yard, DC 20376-1072 or call commercial (202) 781-1731 or DSN (312) 236-1731.

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Chapter 1 - OPERATIONS OVERVIEW

1-1 Introduction to Navy Towing

Modern Navy towing, as we perceive it today, began at the beginning of World War II. Prior to WWII, the Navy owned few salvage ships of its own and depended heavily on contracted assets to perform the duties of towing and salvage. Merritt-Chapman and Scott was one of the premier towing and salvage contractors of the day and maintained an inventory of assets. They held a contract with the Navy to perform ship salvage on an as-needed, no cure-no pay basis. As the US watched the war in Europe develop, the need for specialized vessels and a dedicated service became apparent. The Royal Navy of Great Britain was forced into performing these tasks as German U-boats inflicted damage throughout the military and commercial fleet. Performing towing and salvage services on damaged vessels was most often a faster and cheaper way of putting the necessary tonnage back into service.

In October of 1941, Congress pressed through legislation that gave the Navy the contracting authority to obtain the salvage resources, public or private, necessary to perform operations that were deemed in the best interest of the country. On December 7, 1941, the Japanese bombed Pearl Harbor and four days later the Navy signed a contract with Merritt-Chapman and Scott establishing the Navy Salvage Service. This service was responsible for performing offshore salvage on east and west coasts, the Caribbean, Alaska, and Panama. To do this, it utilized leased commercial assets including tugs. The responsibility for towing distressed or disabled ships into port, however, did not lie with the Navy Salvage Service. This duty was the responsibility of the tugs attached to the naval districts.

This arrangement made it difficult to muster a large quantity of tugs to respond to large groups of casualties that often resulted from German U-boat attacks. These casualties included not only fleet vessels but merchant ships, which were logistically critical to the war effort. The US knew the value of keeping a strong logistical force operating. To help rectify these shortfalls and to better utilize the available assets, the Navy formed the Navy Rescue Towing Service. This service fell under the command of Commander, Eastern Sea Frontier, and operated exclusively on the Atlantic Coast. All available tugs were organized under this service, which was headed by Edmond Moran of Moran Towing. Edmond Moran understood the towing industry and was enrolled in the Naval Reserve to perform this duty. This organization for the most part alleviated the problems of asset allocation and allowed the rescue of many tons of ships and cargo.

The Navy operated tugs in support of their logistic requirements for many years, but as the war in Europe wore on, the need became apparent for more capable, sea-going tugs. The Navy designed a fleet tug (ATF) for the 1939 shipbuilding program. The NAVAJO (ATF 64) was the first of a fleet of 3,000 shaft horsepower, diesel-electric ocean-going tugs equipped with an automatic tensioning towing engine. Almost seventy of these vessels were constructed before the end of the war. These ships would serve the Navy well for nearly fifty years. Their towing winches proved very successful in taking disabled ships under tow. Their long range and seaworthiness also made them very suitable for combat operations.

The Navy also built many Auxiliary tugs (ATA) to be used in support of the fleet tugs. They were also diesel driven (relatively new technology for tugs) but carried about half the horsepower of the fleet tugs. They had considerable endurance and were well suited to perform operations just outside the combat zone. They would often relieve a fleet tug of a disabled vessel and continue the tow into port. This allowed the fleet tugs to return to the combat zone where they also performed some fire-fighting and salvage assistance. Rescue tugs (ATR) were wooden-hulled, used in submarine infested waters, and provided excellent fire-fighting support. Their range was limited, and although they were not considered the best vessels for long distance towing, they were excellent in coastal areas.

The early designs of the salvage ships were not particularly well suited for towing. This changed with the steel-hulled BOLSTER class (ARS 38) which were built as salvage ships but were of similar horsepower to the fleet tugs (ATF). They were originally equipped with a powered reel for towing, but it was soon discovered that they performed towing duties almost interchangeably with the fleet tugs. Automatic towing winches were diverted from the ATA program and installed on these six vessels. These ships were of excellent design and operated until the last one was decommissioned in the mid-1990's.

The primary mission of the Navy's towing and salvage ships today is not very different from the early days of these vessels. They provide support to distressed or disabled ships in the combat zone. However, during peacetime, the daily operation of these ships differs tremendously. The Navy now operates only a few open ocean towing ships. At the time of this writing, the Navy had four ARS 50 class salvage ships and the Military Sealift Command (MSC) had five T-ATF class vessels operating for the Navy. T-ATFs are manned by civilian crews and do not carry the extensive salvage equipment of the ARS class but are extremely capable towing platforms. In recent years, efforts to reduce military expenditures have resulted in not only decreases in the number of tow ships available but also an increase in the number of all ships being decommissioned. This has placed a high demand on the Navy's few towing assets and has increased the amount of work being sent to commercial firms.

U.S. Navy towing and salvage ships also provide battle damage control as an adjunct duty to their primary role as towing and salvage platforms. Fleet battle damage control is rendered in the combat zone to a battle-damaged ship casualty, often under direct enemy fire. The assistance can take the form of off-ship fire-fighting from a salvage tug’s fire-fighting monitors or of a damage control team from the salvage ship boarding the casualty.

Towing can vary from routine, well-planned activities to time-critical emergencies such as rescue or salvage towing. Routine Navy towing includes a wide variety of activities such as harbor work and offshore or open ocean towing. Navy emergency towing consists almost entirely of escort, rescue, and salvage missions. The types of vessels that may require towing include Navy ships ranging from small patrol boats to large aircraft carriers; non-combatant vessels, including targets, large fleet oilers, and supply ships; and vessels such as barges and floating dry docks.

The Navy recognizes several distinct types of towing:

- Harbor towing
- Point-to-point towing
- Rescue and emergency towing
- Salvage towing

- Special ocean engineering projects
- Tow-and-be-towed by Naval vessels

1-2 Harbor Towing

Harbor towing is limited to protected waters. Harbor towing and base support includes docking/undocking, standby duty, and safety escort duty. These services are the province of yard tugs. These vessels are incapable of sustaining long-distance, open ocean towing due to design limitations. Harbor tugs do not have the range, crew size, berthing and messing capacity, and, in some cases, the structural or hydrodynamic design needed to support open ocean towing. Their moderate horsepower, limited seakeeping characteristics, and minimal towing machinery also makes these vessels unsuitable for the open sea. The U.S. Navy currently operates three classifications of yard tugs: the YTL, the YTM, and the YTB.

1-3 Point-to-Point Towing

Point-to-point towing can be defined as towing a vessel from one harbor to another. Point-to-point towing and "open ocean" towing are largely synonymous. Open ocean towing was a natural outgrowth of harbor towing. If vessels could be moved from one end of a harbor to the other end, the next step was to move them from one harbor to another.

Until the 1960's, Navy ATAs or similar vessels, were generally home-ported in each naval district in the continental United States, Alaska, Hawaii, and at selected overseas bases. The tugs were used for coastwise towing of floating equipment, such as barges, pile drivers, and dredges. Since the 1960's, the Navy's towing fleet has declined in numbers, with whole classes of towing vessels being decommissioned. The ATF 76, ARS 6, ATS 1, and all ATAs have been decommissioned, and, in FY94, the last WWII vintage ARS 38 class salvage ships were also retired. Consequently, Navy point-to-point towing is currently performed by ARS 50 and the MSC-operated T-ATF class vessels, with an increasingly large percentage of tows contracted to commercial firms.

1-3.1 Inland Towing

Inland towing is point-to-point towing performed on inland waterways such as rivers, bays, canals, or intercoastal waterways. Inland towing in the United States largely originated on the Mississippi and Ohio River systems. This type of towing was also done on the Erie Canal and other inland man-made navigational systems managed by the Army Corps of Engineers, such as the St. Lawrence Seaway and East Coast Intercoastal Waterway. The Navy does very little inland towing.

1-3.2 Ocean Towing

Ocean towing is point-to-point towing where there are few, if any, places of refuge enroute. Open ocean towing was a natural evolutionary step from harbor towing. The demand for open ocean tows led to more advanced tug designs that could accommodate more difficult towing missions.

After harbor towing, open ocean towing is the most widely practiced form of Navy towing. Because of the unforgiving conditions faced on the open ocean; it demands the most preparation; the most robustly designed and constructed equipment; and a higher level of operator knowledge.

1-3.3 Defueled Nuclear Powered Ships

The Navy has devoted a considerable effort in developing guidelines for towing Unmanned Defueled Nuclear Powered Ships. The unique considerations of towing a nuclear vessel that is unmanned have led to the development of specific instructions that deal with this specific situation. NAVSEA has published a series of instructions to specifically deal with unmanned towing of nuclear vessels (including submarines, cruisers, and moored training ships). The information contained in those documents will not be repeated in this manual.

1-4 Rescue and Emergency Towing

The mission of rescue towing encompasses saving a stricken ship at sea and towing to a safe refuge. The vessel may be adrift at sea, or near a shore or harbor. In the latter case, a connection must be made quickly to prevent the disabled ship from going aground. On high value tows, the Navy may assign a tug to escort duty, to provide emergency towing services without the delay of mobilization.

1-4.1 Naval Task Force Standby Duty

Navy salvage ships routinely deploy to the Mediterranean and to the Western Pacific to provide salvage and towing support to the 5th, 6th, and 7th Fleets. Aside from participating in salvage exercises with foreign navies, the salvage ships perform any salvage or towing mission tasked by the Fleet Commander for the deployed Carrier Battle Group, Surface Action Group, or any auxiliary ships requiring salvage or towing assistance.

1-5 Salvage Towing

Salvage towing generally follows immediately after a salvage operation. Immediately after salvage services are rendered, preparations are made to tow the stricken vessel. The vessel may be towed to a safe haven for temporary repairs, or to a port or facility where complete industrial-level repairs are possible. The vessel may also be towed to a disposal site for sinking. In either case, tow preparations usually entail more than the normal tow system installation. The added measures include reinforcing weakened sections of the ship, either through shoring or temporary structural reinforcement, or possible special rigging to release the tow for sinking in a safe, controlled manner.

1-5.1 Combat Salvage and Towing

Ships involved in combat salvage and towing missions often escort amphibious landing forces and battle groups in hostile areas. Their job is to provide towing and salvage services to ships or landing craft that are damaged, afire, disabled, or stranded. They are also prepared to tow transport and supply ships laying off the beachhead. During amphibious landings, these rescue tugs and salvage ships can be subject to enemy fire.

1-6 Special Ocean Engineering Projects

Navy tugs often become involved with unusual projects, such as target services, submersible towing, array movements, deep ocean search and recovery, and classified operations.

Many of the attributes that make salvage ships good salvage and towing platforms also make them good platforms for performing these ocean engineering operations. Specifically, tugs that can perform open ocean tows are often equipped with heavy lift cranes, have large expanses of deck area for temporary installation of specialized equipment, and are designed to keep station or moor over a site of interest. Navy tugs can also serve as diving platforms and perform a variety of deepwater tasks, including the support and recovery of remotely operated vehicles.

1-7 Tow-and-Be-Towed By Naval Vessels

Although most towing is performed by ships that have been specifically designed and built for towing, emergency towing is sometimes accomplished by ships other than tugs. This concept is referred to as “tow-and-be-towed” or “emergency ship-to-ship towing.” In an emergency, any ship can tow another in its own or similar class, with each ship providing half the towline. Ships not specifically equipped for towing can fashion a temporary towline from anchor chains, wire straps, mooring lines, or combinations of these items.

NAVSEA General Specifications require that every class of U.S. Navy ship (except aircraft carriers and submarines) be able to tow-and-be-towed in an emergency. Definitive tech-nical instructions for U.S. Navy tow-and-be-towed operations can be found in Naval Ship’s Technical Manual (NSTM) S9086-TW-STM-010, Chapter 582, Mooring and Towing (Ref. A). This topic is also covered in Section 6-6 of this manual. In the event of a conflict between NSTM Chapter 582 and this manual regarding tow-and-be-towed operations, NSTM Chapter 582 shall take precedence. In all other towing matters, with the exception of nuclear tows, this manual is the governing document. Tow-and-be-towed operations for NATO navies are covered in Allied Tactical Publication (ATP)-43(A) (NAVY), Ship-to-ship Towing (Ref. B).

Chapter 2 - OVERVIEW OF TOWING SHIPS

NOTE
Although ocean-going tow ships are significantly different from harbor tugs, the term “tug” will be used to describe all tow ships in this manual to avoid confusion between “tow ship” and “towed ship.”

2-1 Introduction

This chapter contains a brief description of some typical design features found on ocean-going tugs. It also presents a good overview of the latest generation of the US Navy’s ocean towing ships. Modern harbor tugs utilize recent advances in propulsion and synthetic line, but ocean going tugs remain largely unchanged from earlier versions.

2-2 Requirements Placed on Towing Ships

The degree of service that the tug may be required to furnish to its tow depends upon the circumstances and principal missions of the Navy at the particular time and can cover a wide spectrum of needs. The primary requirement placed on a tug is to provide power that the tow does not have due to its construction, its service condition (i.e., decommissioned), a casualty, or a failure of its main power plant. Secondary requirements include:

- Steering for maneuverability
- Navigation
- Communications
- Security
- Damage control
- Fire protection

For long ocean tows, the tug can be called upon to provide complete logistic support for the tow and the riding crew. The tug may also be required to serve as a supply base and shop for repairs, rigging, and damage control during rescue salvage towing operations. Additionally, the tug may have to supply all the rigging for the towing system.

2-3 Design Characteristics

Most U.S. Navy ships can tow in an emergency, but only properly designed and outfitted tugs make good towing ships. The specific items to be considered in the design of an ocean tug are dependent upon the missions and services that it will be called upon to perform. Characteristically, a tug’s superstructure is set forward, allowing a clear fantail so the towing point can be close to the ship’s pivot point. The towline, secured well forward of the rudder and propellers, is allowed to sweep the rail without limiting the maneuverability of the tug. In addition to a clear fantail area, characteristics of a good tug include the following:

- High horsepower
- Slow speed maneuverability
- Large diameter propellers
- Large area rudders
- Towing machinery
- Power capstans
- Towing points
- Bow thrusters
- Deck crane

In general, a Navy ocean tug is a very versatile ship, but its design involves many compromises. Appendix K provides data on features of some commercial tugs. The design of a Navy tug will differ from a commercial tug because a commercial tug must make a profit. This influences manpower, automation, secondary missions, and a host of other characteristics.

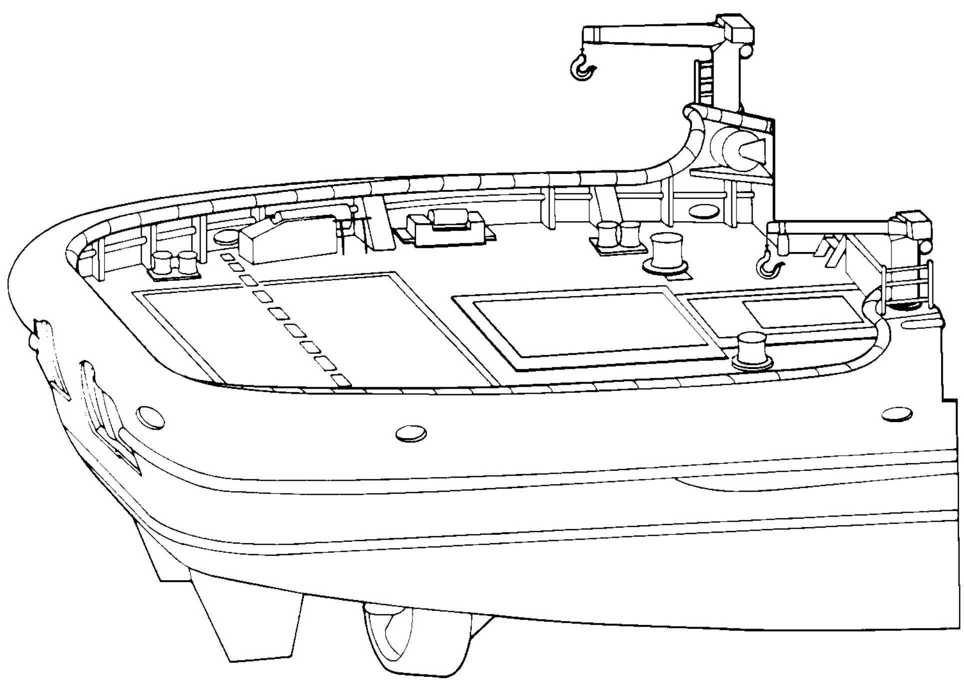


Figure 2-1. ARS 50 Bulwark Forward Limits.

2-3.1 Stern Arrangement

The stern of the tug is designed to minimize chafing and damage to both the tug structure and the hawser. Caprail radius is generous and free from unintended obstructions to the hawser's sweep from side to side as the tug maneuvers in restricted waters. Most tugs have a system to restrain the tow hawser sweep, such as vertical stern rollers or Norman pins, while towing under steady-state conditions at sea. To reduce wear on both the hawser and the tug's structure, chafing gear is often used where the towline crosses the stern.

On most Navy towing and salvage vessels, the bulwark and the caprail are gently curved upward and faired into the deck above the towing deck (see Figure 2-1). This ship's structure restricts the tow wire from leading forward of the beam at the tug's tow point just aft of the tow winch.

2-3.2 Tug Powering and Bollard Pull

The design of the main propulsion plant is a compromise among wide-ranging requirements. The tug must have high free-running speeds for reaching the scene of a casualty quickly. It also needs good economy with high towline pull for long-distance tows at reasonable towing speeds. High bollard pull is required for holding a distressed ship to prevent it from grounding and for refloating stranded ships. It is also required for along-side operations (docking, maneuvering) and other high power/near zero speed evolutions.

In the absence of a good automatic towing machine or other accurate means of measuring the towline tension, a knowledge of the tug's available towline pull and bollard pull is required for controlling the tension. Appendix K presents the methodology for estimating towline pull and bollard pull.

2-3.3 Fenders

Fenders are energy absorbing materials or devices that protect both the tug and the tow (see Figure 2-2 and Figure 2-3). Modern fendering is an important part of towing operations when alongside evolutions are required. Tugs working alongside submarines should have subsurface fenders. Small tugs working with large ships should have fendering to protect the deckhouse from being damaged during large rolls (see the wing fenders in Figure 2-2).

Three types of standard fenders are currently in use:

- Rubber
- Pneumatic
  - High-pressure (5 to 7 psi)
  - Low-pressure (1 psi)
- Closed-cell foam covered with urethane elastomer

2-3.3.1 **Features and Characteristics of Fenders**

The most significant features of fenders are:

- Energy absorption
- Durability
- Handling characteristics
- Ease of storage aboard ship
- Ease of maintenance when not in use
- Required support equipment

Other important characteristics include:

- Standoff distance
- End fittings
- Time required for deployment and recovery
- Capability of being used if damaged.

2-3.3.2 **Operating Considerations**

The following items should be considered when using fenders:

- **Energy Absorption vs. Deployment.** Rubber fenders, as seen in Figure 2-2, are an integral part of a tug's structure. These take no time to deploy but provide little energy absorption beyond simply eliminating steel-to-steel contact. Foam and pneumatic fenders require rigging and handling but are far superior in their absorbing capability.

  Large truck tires are very effective from the standpoint of energy absorption and are inexpensive. They can be rapidly deployed and are particularly useful during salvage where unusual conditions may exist. Some tires should be kept on board for emergency fendering.

- **Size vs. Capacity.** Low-pressure and high-pressure pneumatic fenders have similar characteristics. Because they are filled with air, however, they must be larger than foam-filled fenders to absorb the same amount of energy. On the other hand, equal capacity and quality foam-filled fenders will likely be more expensive and heavier than pneumatic fenders.
- **Pneumatic Fender Maintenance.** In addition to the larger size of pneumatic fenders, other attending disadvantages are the extra equipment needed to pressurize them and to check the internal pressure. Patch kits and special slings to support the fender's midsection when being deployed and retrieved are also necessary for the low pressure types.
- **Pressure Loss.** All pneumatic fenders have safety valves. When these valves relieve under high fender loads, the fenders lose nearly all their energy absorption capability.
- **Fender Displacement**. A major operating problem can arise when either the tug or the tow has a low freeboard relative to the other ship. When the heaving or rolling motions of the two ships get out of step, the fender can be rolled upward between the two ships and pop out onto the deck of the one with the lower freeboard.
- **Friction Damage.** When the tug and the tow have nearly equal freeboard, the out-of-step motions of the two ships can create a great deal of frictional heating on the surfaces of the fenders. Spraying seawater onto the rubbing surfaces helps lubricate them and keep them cool.
- **Ship Shell Plating Damage.** Care must be exercised in the fore and aft placement of the fenders to ensure that they do not bear against relatively large areas of side plating that are not well supported by internal framing and longitudinal structural members. This is especially important in quartering seas when swells will cause the two ships to pivot about the bow or stern and then slam the sides together at the other end.

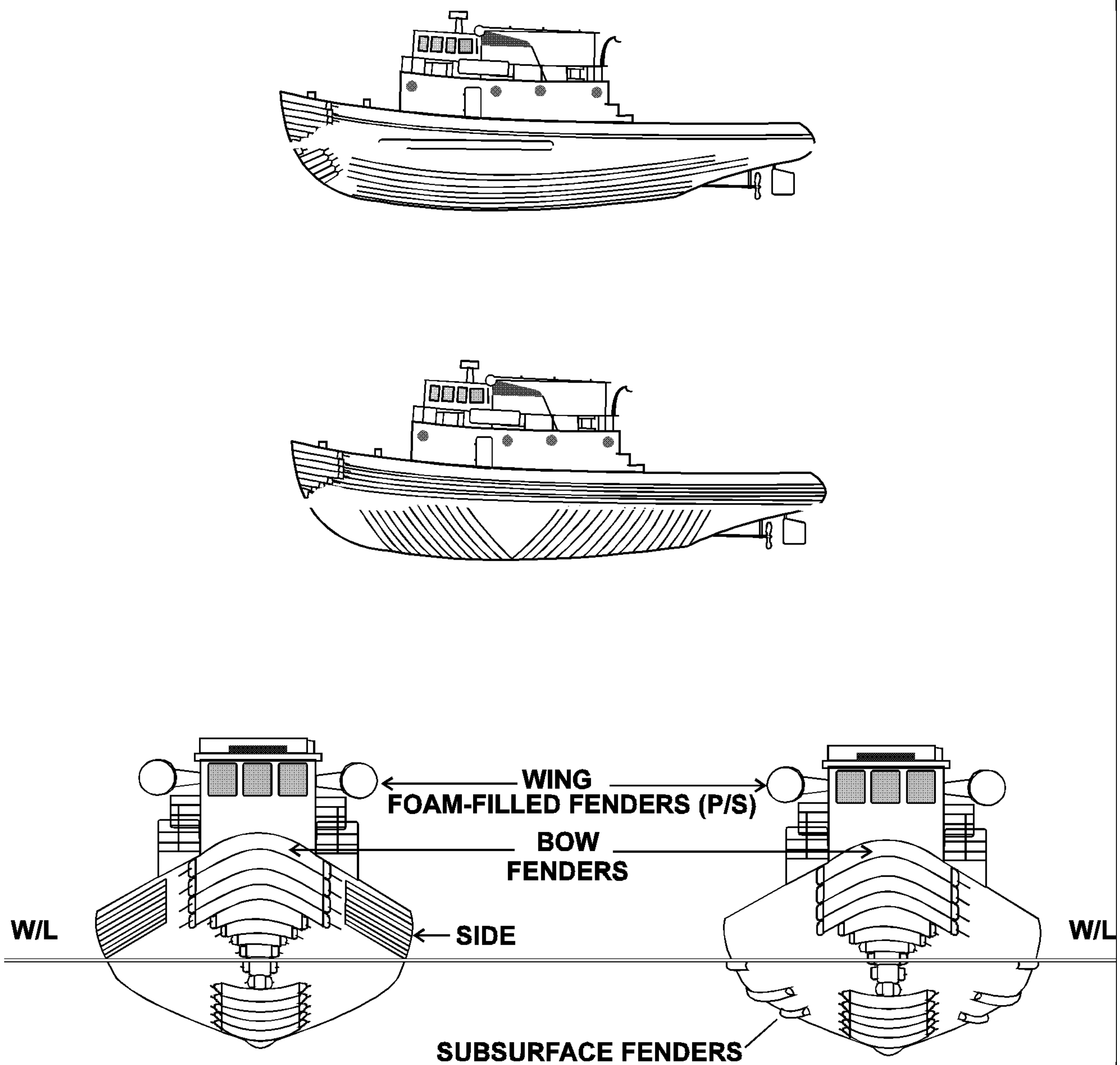
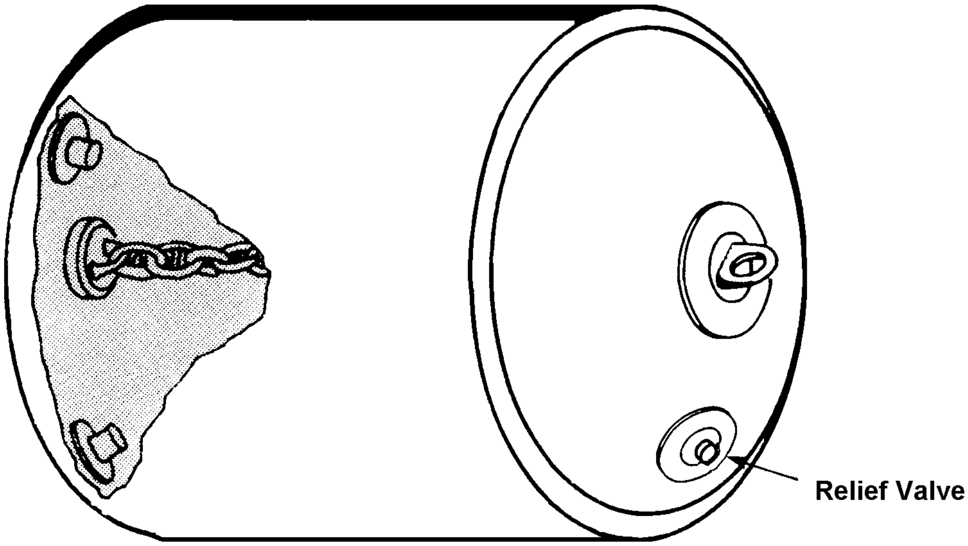
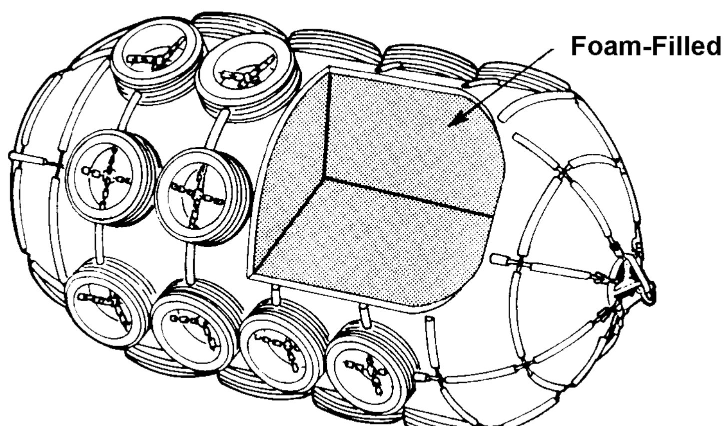


Figure 2-2. Typical Rubber Fenders.



Pneumatic Fender



Foam Fender

Figure 2-3. Pneumatic and Foam Fenders.

2-4 Yard or Harbor Tugs

The design of harbor tugs and the equipment they employ varies. The typical Navy harbor tug is a single-screw, deep-draft vessel equipped with a capstan aft, H-bitts forward and aft, towing hawsers, and additional lines for handling ships or barges in restricted waters. Harbor tugs may also be equipped with fenders, limited fire-fighting equipment, and deck equipment to support harbor operations. Twin-screw harbor tugs have greater maneuverability and ship control.

Harbor tugs are classified by shaft horsepower (shp). The U.S. Navy operates two classes of harbor tugs that are used primarily in harbors and sheltered waters. As these vessels age, the Navy relies more and more on contracted vessels to perform harbor operations. This allows the Navy to take advantage of the latest tug designs, but at the same time diminishes its fleet.

2-4.1 YTL Class

Yard tugs having 400 shp and under belong to the YTL class. The primary mission of the YTL class is moving small craft and unloaded barges from one berth to another within a harbor. YTLs can also assist in moving larger vessels because they are small enough to maneuver in tight, confined areas between the large vessel and obstructions. Characteristics of this class are small size, maneuverability, and less robust construction than larger harbor tugs. The term YTL is used to cover an entire spectrum of harbor “pusher boats.” Very few of the vessels are constructed to the same class specifications, and a large number are custom built by the naval base using them. The YTL class tugs are still in service, but hundreds have been retired as their useful life has ended (most were built during WWII).

2-4.2 YTB Class

The largest yard tugs, with 1,000 to 2,000 shp, belong to the YTB class. The larger YTBs are similar to commercial harbor tugs. YTBs can be used in open-ocean towing, but only for short distances under the most optimal weather conditions. YTBs are mostly confined to harbor operations with occasional point-to-point towing performed on inland waters or on coastwise towing routes. YTBs configured for servicing submarines have a specially designed fender system. YTBs are widely used in all Navy ports, especially overseas bases, but may also face retirement in the near future.

2-4.3 YT 802 Class and Following

Modern tugs are continually being put into service for the US Navy. The most recent complete class is the YT-802 Valiant class of harbor tugs. These are fully modern tugs utilizing Z-drive thrusters, which is an omnidirectional, 360-degree propulsion system. Each YT-802 utilizes two independent thrusters, each powered by a Caterpillar diesel engine, for a combined rated 3,600 HP. Because of the thrusters' omnidirectional capabilities, the YT-802 class has a bollard pull rating of 40 long tons or greater in any direction. However, for most towing cases, the YT-802s are designed with a winch forward and a high stern gunwale, so as to take a towing load moving in the astern direction.

As of September 2020, the YT-808 class is undergoing builder's trials on the lead vessel. This redesign of the YT-802 is slated to be the next class of US Navy tugs. Key design changes include improved off-ship firefighting capabilities, the addition of exhaust treatment equipment to meet EPA Tier 4 environmental standards, and additional bottom fendering to reduce the likelihood of damage to submarines. The YT-808 class will make the same power as the YT-802s, and should be rated for the same bollard pull once those trials are complete.

2-5 Ocean Tugs

The Navy's ocean tugs are far more versatile than harbor tugs in terms of horsepower, range and services they can provide to their tows. Ocean tugs and salvage/rescue type ships are the only U.S. Navy ocean-going ships whose primary mission includes towing. Thus, they are the only types considered to be specifically built for towing and for which towing activities have significantly influenced the design.

Most of the ocean tugs used by the Navy today are carryovers and replacements or successors to similar ships used or developed during WWII. Some of the differences between the WWII vintage and the more modern ships lie in increased horsepower and bollard or towline pull, hawser size, provisions for use of synthetic fiber hawsers, and, of major importance, vastly improved onboard equipment and accommodations.

In addition to their power, range, and endurance capabilities, the ocean tugs can work and survive in heavy weather independently of other auxiliary or support ships. They are also used in stranding and other salvage operations. Ocean tugs should have automatic towing machines and load sensing systems to reduce dynamic loads and, if necessary, rapidly release the towline.

The following section contains a brief description of modern U.S. Navy towing and salvage ships. Due to shrinking budgets, some of these vessels are no longer in service. Their characteristics are presented here for both historic and comparative purposes. For more detailed information, refer to the operations manual of each vessel.

2-5.1 ARS 50 Class

The four ships of the ARS 50 Class (see Figure 2-4) are replacements for the ARS 38 Class. Each ship carries a crew of over 100 and equipment sufficient to handle ocean towing, independent salvage, diving, damage control, and fire-fighting capabilities in times of war.

The automatic towing machine (ATM) on board the ARS 50 Class is a Series 322 winch built by Almon A. Johnson, Inc. (see Appendix Figure L-2). This double-drum ATM stores two 3,000-foot, 2¼-inch diameter towing hawsers. The ARS 50 Class also has a Series 400 traction winch for handling synthetic line up to 14 inches in circumference. The traction winch is also useful for mooring and ocean engineering operations. These vessels are extremely versatile. They are capable of supporting a wide range of missions and are excellent towing platforms as well as fully capable salvage ships.

2-5.2 T-ATF 166 Class

The T-ATF Class is a multipurpose, long-range, high-horsepower, seaworthy tug (see Figure 2-5). It can conduct long-distance tows and, when augmented with additional crew and equipment, operate in support of fire-fighting, diving, and salvage missions. These seven vessels were designed for and are operated by the Military Sealift Command (MSC). They carry approximately 20 crew members, and 18 transients.

This ship was conceived and specified to replace the Auxiliary Ocean Tugs (ATA) and Fleet Tugs (ATF) for routine towing. Because it also was designed to serve as a salvage tender, it has a large afterdeck, similar to an offshore supply vessel. Although not normally carried, various suites of special equipment can be installed on board the T-ATF to support air and mixed gas diving, beach-gear operations, off-ship fire-fighting, search and recovery operations, and oil spill recovery. This class is capable in rescue towing applications, but has limited salvage capabilities on its own. With its large fantail area, it can be augmented to perform salvage, but carries little of its own equipment.

This 7,200 horsepower tug class carries a 2,500-foot, 2 1/4-inch wire rope tow hawser. The T-ATF is equipped with a traction winch that can handle synthetic hawsers up to 15 inches in circumference. The class was originally equipped with a single-drum, diesel driven, non-automatic SMATCO towing winch relatively common to the offshore oil industry (see Appendix Figure L-3). Some members of this class have been refitted with an (Almon A. Johnson) electrohydraulic automatic towing machine (see Appendix Figure L-4)

2-5.3 T-ATS Class

The lead vessel of the new Towing, Salvage, and Rescue Ship (T-ATS) class will be designated the USNS Navajo. Contracts have been awarded and the vessels are under construction. Eight vessels are planned for the class. Five vessels were awarded to Bollinger Shipyard (formally Gulf Island Shipyard) and three vessels to Austal. The ship class will be replacing the in-service ARS 50 and T-ATF ships on a one-for-one basis. (see Figure 2-6) They will be significantly more powerful than their forebearers, with a planned shaft horsepower of 12,600 and over 150 long tons of bollard pull. The T-ATS will also be equipped with a dynamic positioning system, enabling it to keep station very precisely for improved performance while diving remotely operated vehicles and for other salvage tasks. The T-ATS was designed to be a Multi Mission Common Hull Platform based on commercial offshore Anchor Handling Tug Supply (AHTS) vessels.

The T-ATS class will be operated by Military Sealift Command under the special mission ships program and has a modular deck design to facilitate future missions utilizing containerized equipment. The planned off-ship firefighting, diving, salvage, towing, and other capabilities are each specified to meet or exceed the Navy's needs, making the upcoming T-ATS the ideal multi-role salvage vessel.

These ships replaced the ARS 6 and ARS 38 Class and have modernized salvage and towing capability. They are also equipped with off-ship fire-fighting improvements.

Length(ft):	255	Shaft Horsepower:	4200
Beam (ft):	52	Cruising Range (nm):	8000 @ 8 kts
Draft (ft):	17.5	Fuel Consumption Gal/day):	2 engines: 2100 4 engines: 4200
Displacement, Full Load	3282	Complement:	94 crew 16 transients
Propulsion, Main:	4 diesel 2 screws	Towing Machine:	Almon A. Johnson, Inc. Automatic towing machine, Series 322 (double-drum) 2-1/4-inch wire, 3000 ft. (will accept 2-1/2-inch wire) and 14-inch traction winch, Series 400
Maximum Sustained Speed (kts):	15	Bow Thruster	1 @ 500 HP

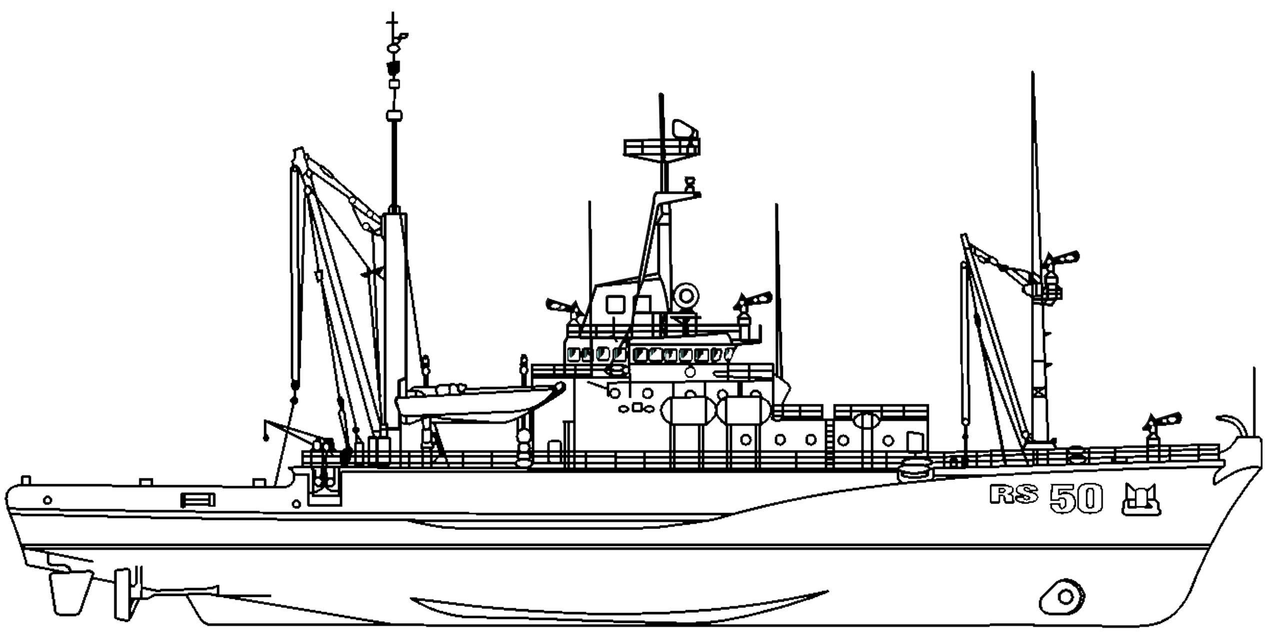


Figure 2-4 ARS 50 Class Salvage Ship.

This class of tug has replaced the ATF 76 Class. These ships have a large working space aft for VERTREP (replenishment by helicopter) and can be readily outfitted for specialized salvage and ocean engineering missions.

Length(ft):	240	Shaft Horsepower:	7200
Beam (ft):	42	Cruising Range (nm):	10,000 @ 13 kts
Draft (ft):	15.5	Fuel Consumption Gal/day):	1 engine: 4149 2 engines: 8300
Displacement, Full Load	2260	Complement:	16 crew 4 Navy communicators 18 transients
Propulsion, Main:	2 diesel 2 screws Controllable, reversible pitch in Kort nozzles	Towing Machine:	SMATCO* 2500 ft. 2-1/4-inch wire winch (15-inch Lake Shore, Inc. traction winch)
Maximum Sustained Speed (kts):	15	Bow Thruster	1 @ 300 HP

* Some vessels of this class have been refitted with Almon A. Johnson, Inc. Automatic towing machines

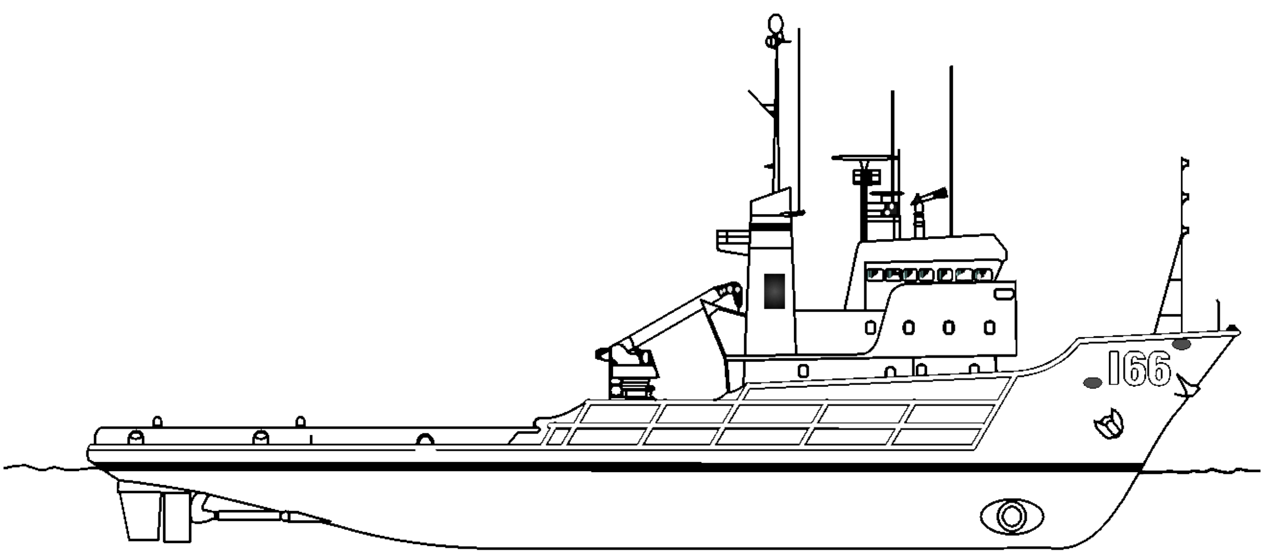


Figure 2-5 . T-ATF 166 Class Fleet Tug.

This class of tug is replacing the T-AFT 166 Class Fleet Tug and the T-ARS-50 Class Salvage Ship. Eight T-ATS ships are scheduled to be built with the first being commissioned in 2021.

Length(ft):	263	Displacement (full load):	5110
Beam (ft):	59	Cruising Range (nm):	8,170 @ 10 KTS
Draft (ft):	17.7	Maximum Sustained Speed (Kts)	15
Shaft Horsepower	12,600	Complement:	23 crew 42 additional
Propulsion, Main:	2 - 4,640 BkW mains 2 CPP fixed nozzles	Auxiliary Systems:	Towing Machine Traction Winch 40 Short Ton Crane Offship Firefighting Monitor
Bollard Pull (Short Tons)	176	Dynamic Positioning ABS DP2	2 x 900 KW Bow Thrusters 1 x 900 kw Stern Thruster

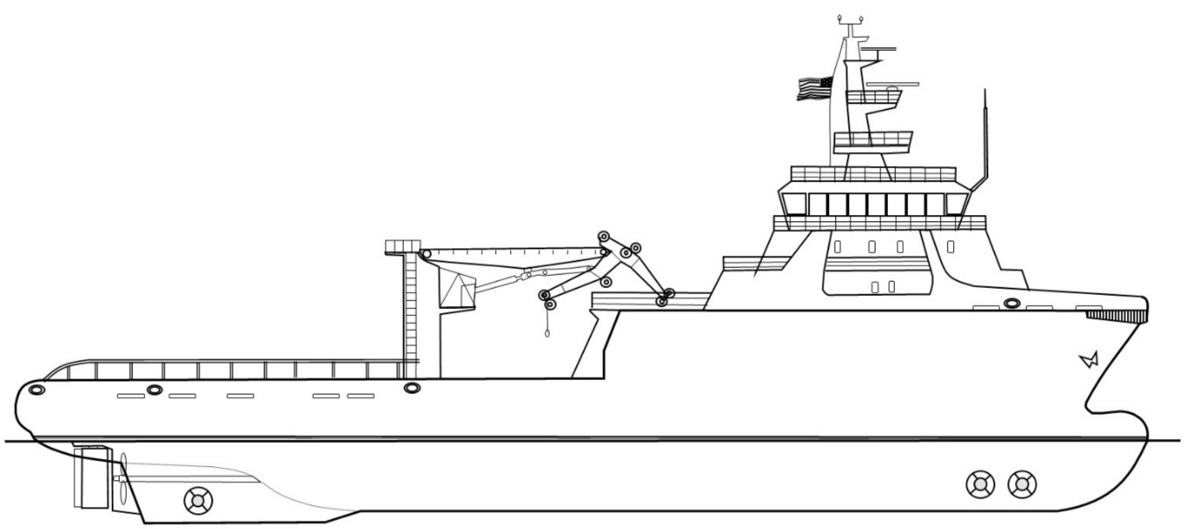


Figure 2-6 . T-ATS Class Salvage Ship

Chapter 3 - TOWING SYSTEM DESIGN

3-1 Introduction

This chapter provides guidance for preparing and planning towing operations. It contains information to assist the planner in predicting tow Speed of Advance (SOA) and determining the size of tug required to perform the tow.

3-2 Designing a Towing System

Tow system design is an iterative process. Typically there are two approaches to planning tows, First is to design the system from scratch based on desired SOA; Second is to determine the allowable SOA using the available equipment on hand. Each approach has four steps.:

Step 1. Calculate the steady state towline tension over a range of tow speeds and Beaufort Sea states. Starting with the ship to be towed:

- Determine the desired tow speed or SOA (taking the anticipated weather conditions into account) along the planned tow route for the specific time of year the tow is to be conducted. The Beaufort Scale vice the sea state scale shall be used for this estimation. Hindcast weather data along the planned route is available from the Meteorology Center or world pilotage charts.
- Calculate the steady state towline tensions for all anticipated weather conditions along the planned route. (See Section 3-4 and Appendix G).
- Calculate the steady state towline tensions over a range of SOAs and Beaufort Sea States from 1 through 9 knot SOA (in ½ knot increments) for Beaufort Sea States from 1 through 8. An Excel program can assist with these calculations and is available on the 00C2 Publications page of the SUPSALV CAC enabled website. The calculated tensions can and should be plotted or arranged in a table to allow interpolation later.

Step 2. Use the calculated steady state towline tension above for the desired SOA and anticipated Beaufort Sea state to determine the minimum bollard pull required to perform the tow. Select a suitable tug with the required bollard pull to perform the tow. The rule of thumb for specifying minimum tug bollard pull is to specify a SOA of 5 knots in a Beaufort Sea State 5.

Step 3. Once a tug is selected and determined to be available, design the system using the steady state tow tension as outlined in Step 2. The design shall be approached from a systems perspective encompassing the towing machine on the tug to the connecting pad eyes on the tow. Select the towing system components by applying the appropriate factors of safety (see Section 3-4.1, Table 3-2, and Appendix M) for all components such as the tow bridle, tow hawser, wire, chain pendants, shackles, detachable links, etc. Determine the desired hawser scope and check the catenary. Currents along the planned tow route must be accounted for in the steady state tow tension calculation. This is accomplished by adding current into the SOA for calculating as provided in Appendix G. When heading into a current add it to the projected tow speed, when having a following current, subtract.

Step 4. Make necessary adjustments. Recheck the calculations against the tug's capabilities. If calculated requirements for power or towline strength exceed the capacities of available equipment, redesign is required. Options may include:

- Reducing the SOA
- Using additional or more powerful tugs
- Decreasing resistance by changing the tow's characteristics (such as propeller removal)
- Change the routing
- Revise the schedule to tow during more favorable times of the year
- Redesign the tow system

3-2.1 Tug and Tow Configuration

The design of a towing system is dependent on the type of tow to be performed, the configuration of the tow, and the number of vessels being towed. For examples of the types of tow configurations used for Open Ocean towing for single and multiple tows, see Appendix I.

3-3 System Design Considerations

When planning a tow and designing the tow system, important considerations are:

- Tow size, type, and condition
- Expected or required towing speed
- Capabilities of available tugs (bollard pull, range, equipment, and crew)
- Towing hawser system specifications (type, diameter, maximum allowable tension, scope and configuration)
- Towline tension as determined by the steady state tow tension of the tow and respective seakeeping motions of the tug and tow
- Maximum practical towline length, as determined by navigational and hydrographic restrictions on towline catenary depth
- Operational considerations
- Proposed season and route
- Unique characteristics of the anticipated tow
- Stability characteristics of the tug

These factors are interdependent. For example, in theory, the desired towing speed would largely determine the required tow hawser size. But, in practice, tow hawser sizes for a given tug class are restricted by the size of the tow winch, drum grooves, or diameters. For large tows, using 80% of the full propulsion power of the tug determines the potential SOA for the tow. In other cases, tow speed may be limited by weather or by the condition of the tow. Given the tug and the resulting speed of the tow, the tow hawser size can be checked and an initial towing rig designed. All of these factors above must be considered to determine which one will dictate the design of the system. The towing system must then be examined as a whole to ensure that the best configuration has been achieved.

3-4 System Design Methodology

3-4.1 Calculating Total Towline Tension

Total towline tension has two major components: steady state tension and dynamic tension. Steady (or static) towline tension can be predicted with a fairly high degree of accuracy. Generally, steady state towline tensions are satisfactory for the planning of most tows. Static towline tension has three components:

- Resistance of the ship to be towed (see 3-4.1.1)
- Resistance of the tow hawser (see 3-4.1.2)
- Vertical component of wire catenary (which contributes to the total tension of the towline itself but not to tug propulsion requirements) (see 3-4.1.3)

Dynamic towline tension, on the other hand, is caused by the random motions of the sea, the tug and the tow. These values are difficult to predict with precision. Statistical analysis allow for prediction of dynamic towline tension extremes within probability limits set by the design engineer (see Appendix M). Dynamic towline tension has two components:

- Slow dynamic loads caused by the tow's yawing, sheering, and surging (see 3-4.1.4)
- More rapid dynamic loads caused by the effect of waves on the relative sea keeping motions of tug and tow (see 3-4.1.4)
- Dynamic tow tensions are beyond the scope of this manual and are only provided for reference. Generally, the safety factors from Table 3-2 provide for tow tension variables.

3-4.1.1 **Calculating Steady-State Tow Tension of the Towed Vessel**

Steady state tow tension of the towed vessel (R_T) may be estimated using the following approximation:

$$R_T = R_H + R_P + R_W + R_S$$

where:

R_T = Tow Tension

R_H = Hydrodynamic hull resistance of the tow

R_P = Hydrodynamic resistance of the tow's locked propellers

R_W = Wind resistance of the tow

R_S = Additional tow resistance due to sea state

Appendix G provides methods for calculating steady state resistance of the towed vessel and a convenient and provides the location of an Excel worksheet for predicting each of these components. Steady state resistances should be calculated over a range of speeds from 1 to 9 knots at ½ knot increments over a range of Beaufort Sea States from 1 to 8. (Refer to the towing speed limitations cited in Section 6-4.2).

3-4.1.2 Calculating Steady-State Towline Resistance

In addition to the tensions calculated in Appendix G, the hydrodynamic resistance of the towline must be included, and this can be significant for a typical wire hawser tow rig. The resistance is

Table 3-1. Hydrodynamic Resistance of the Towline.

Wire Size (in)	Wire Scope (ft)	Chain Size (in)	Chain Scope (ft)	Added Resistance (lbs) 10,000 lb. Tension			Added Resistance (lbs) 20,000 lb. Tension		
				4 kts	8 kts	12 kts	4 kts	8 kts	12 kts
1 5/8	3000	--	--	1000	4000	7200	1000	3000	5800
1 5/8	2000	--	--	900	3500	4100	700	2500	3300
2	2000	--	--	2000	2200	6000	1500	2200	4000
2	2000	2 1/4	90	2500	5100	12000	1900	3900	7900
2	2000	2 1/4	270	3100	10000	19300	2000	7200	15000
2	2000	4 3/4	270	3700	12000	24500	2700	8900	17600
2 1/4	2000	2 1/4	90	1500	5200	11500	1300	3800	8000
2 1/4	2000	2 1/4	270	3000	8000	18500	1600	6500	14500
2 1/4	2000	4 3/4	270	5000	14100	25500	4500	12900	23000
2 1/4	3000	2 1/4	90	1900	8300	17500	1600	5700	13100
2 1/4	3000	2 1/4	270	3100	12000	24800	2500	8700	20100
2 1/4	3000	4 3/4	270	5500	14400	27800	5000	13300	26000

Wire Size (in)	Wire Scope (ft)	Chain Size (in)	Chain Scope (ft)	Added Resistance (lbs) 40,000 lb. Tension			Added Resistance (lbs) 60,000 lb. Tension		
				4 kts	8 kts	12 kts	4 kts	8 kts	12 kts
1 5/8	3000	--	--	600	2200	5000	500	1900	4200
1 5/8	2000	--	--	500	2000	3300	250	1000	2500
2	2000	--	--	1000	1700	3500	300	1200	3000
2	2000	2 1/4	90	1200	3200	6500	1000	2500	5100
2	2000	2 1/4	270	1500	5100	10900	1300	4200	8800
2	2000	4 3/4	270	2500	6900	14600	2000	6800	13200
2 1/4	2000	2 1/4	90	1200	3500	6500	1100	3100	5000
2 1/4	2000	2 1/4	270	1400	5100	11500	1200	3700	8500
2 1/4	2000	4 3/4	270	3600	9300	18100	2900	5700	13200
2 1/4	3000	2 1/4	90	1400	4100	9500	1200	2500	5900
2 1/4	3000	2 1/4	270	1900	6500	15500	1300	4200	10900
2 1/4	3000	4 3/4	270	3500	10500	21500	2000	7700	17000

USE OF TABLE: Towline resistance can be selected for the case closest to the actual towline configuration. The figures can be interpolated as required if additional accuracy is desired.

- For towline scopes less than shown, make a proportional reduction from the scopes listed.
- For tension greater than 60,000 pounds, extrapolate assuming a resistance curve between 40,000 and 60,000 pounds in a straight line.

dependent upon the size, length, and catenary of the towline, which in turn are dependent upon characteristics of the selected tug and towing speed. When using a synthetic hawser, the added resistance of the towline is negligible and can be ignored in these calculations.

If a particular tug has not yet been selected, estimate the hawser resistance (Rwire) to be 10 percent of the tow resistance (RT). Experience has shown that when Rwire is significantly more than 10 percent of RT, the catenary is very deep and tension is, therefore, out of the range of concern for towline strength. If a particular towline configuration is being evaluated, Table 3-1 provides a more refined estimate of the hydrodynamic resistance.

3-4.1.3 **Calculating Steady-State Towline Tension**

Normal wire rope towline arrangements will assume a sag or catenary, as depicted in Figure 3-1. The total towline tension at any point is the vector sum of the horizontal and vertical components of the tension at that point. Figure 3-1 includes a vector diagram of the towline forces acting immediately astern of the tug. Maximum stress occurs near the stern because the hydrodynamic resistance of the entire towline is added to the resistance of the tow, whereas no hydrodynamic resistance is added at the bow of the tow. Because stress is highest near the stern of the tug, this is the point of interest to tow planners. Computing the total steady-state towline tension at the tow, even with as much as 270 feet of chain pendant, shows that the total tension is less than at the tug.

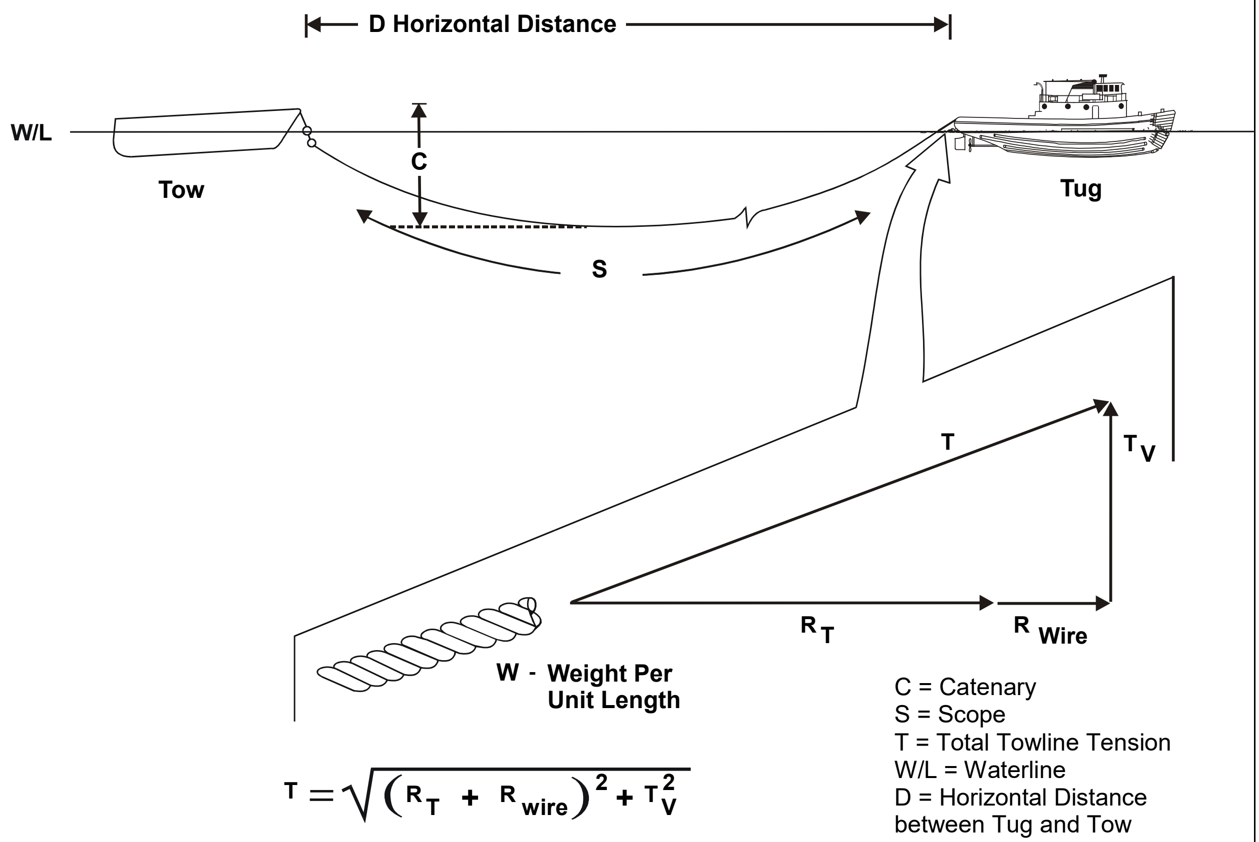


Figure 3-1. Towline Forces at Stern of Tow

The steady-state towline tension at the stern of the tug is expressed by the **Formula 3-1**:

$$T = \sqrt{(R_T + R_{wire})^2 + T_V^2}$$

where:

R_T	=	Tow resistance (Section 3-4.1.1 and Appendix G)
R_{wire}	=	Towline resistance (3-4.1.2 and Table 3-1)
T_V	=	Vertical component of the towline tension

T_V is the weight of the towline forward of the catenary low point less the slight upward component of hydrodynamic drag on the forward half of the catenary. Location of the catenary low point and the vertical component of the hydrodynamic drag are beyond the scope of this manual. Errors will tend to cancel out, however, if T_V is assumed to be the weight (in water) of one-half the scope of the wire towline. (See Table B-2 in (Ref. B) for dry weights and methods for calculating weights in water.) Do not include the weight of any chain pendant at the tow in this computation.

For example, assume that an ARS 50 is towing a ship that provides a steady tow resistance of 60,000 pounds at 8 knots. The towline consists of 2,000 feet of 2 ¼-inch IWRC tow hawser and 270 feet of 2 ¼-inch chain pendant at the tow. Table 3-1 provides a towline resistance estimate of 3,700 pounds. According to Table B-2, 1,000 feet of wire towline (one-half of the scope) weighs 8,143 pounds in water. Therefore:

T	=	Total Towline Tension
R_T	=	60,000 lbs.
R_{wire}	=	3,700 lbs.
T_V	=	8,143 lbs. (Vertical Component (1/2 the weight of the wire in water))

Solving the vector diagram provides a maximum steady-state tension:

$$T = \sqrt{(60{,}000 + 3{,}700)^2 + 8{,}143^2}$$

T = 64,218 lbs

This example supports a rule of thumb that total steady-state tension can be estimated by adding 10 percent to the predicted steady tow resistance (R_T). This method is reasonable and accounts for both the wire resistance and the vertical component of the catenary. In the previous example, adding 10 percent to predicted steady tow resistance of 60,000 pounds would yield a total tension of 66,000 pounds, a conservative estimate when compared to the 64,218 pounds seen above.

In Figure 3-1, the tug must supply excess thrust only equal to the horizontal component of the tension, that is, $R_T + R_{wire}$. While the tug must support the weight of the towline, it does not require forward thrust to do this.

3-4.1.4 **Dynamic Loads on the Towline**

While towing at constant speed in a seaway, the towline tension is not steady, but varies over time (see Figure 3-2). In addition to steady horizontal resistance (T), the towline is also subject to stress from yawing movements (T_{yaw}) and from the wave-induced motions of the tug and tow (T_{wave}), also known as dynamic tensions.

Yawing, also referred to as sheering, is the slow swinging of the towed vessel from one side of the course line to the other. T_{yaw} also includes surge – the slow change of span between the tug and towed vessel. Sheering tension fluctuates in such a way that the average value is zero. Because each swing takes several minutes, sheering tension also takes several minutes to vary from its maximum to its minimum and is sometimes called a "quasi-steady" tension.

Wave-induced tension is caused by the effect waves have on both tug and tow and is a random process with typical half-periods (the time taken to vary from maximum to minimum) of 1 to 8 seconds. Like sheering tension, wave-induced tension has an average value of zero. Dynamic tension is the accumulation of the complex dynamic responses of tug, tow, and towline to time-varying forces. While both the components of dynamic tension have an average value of zero, at any instant in time, dynamic tension can have a significant, if not catastrophic, effect on the towing system. Specifically, these damaging effects can occur when the cumulative tensions from yawing and waves are additive to the steady-state tension in the towing system.

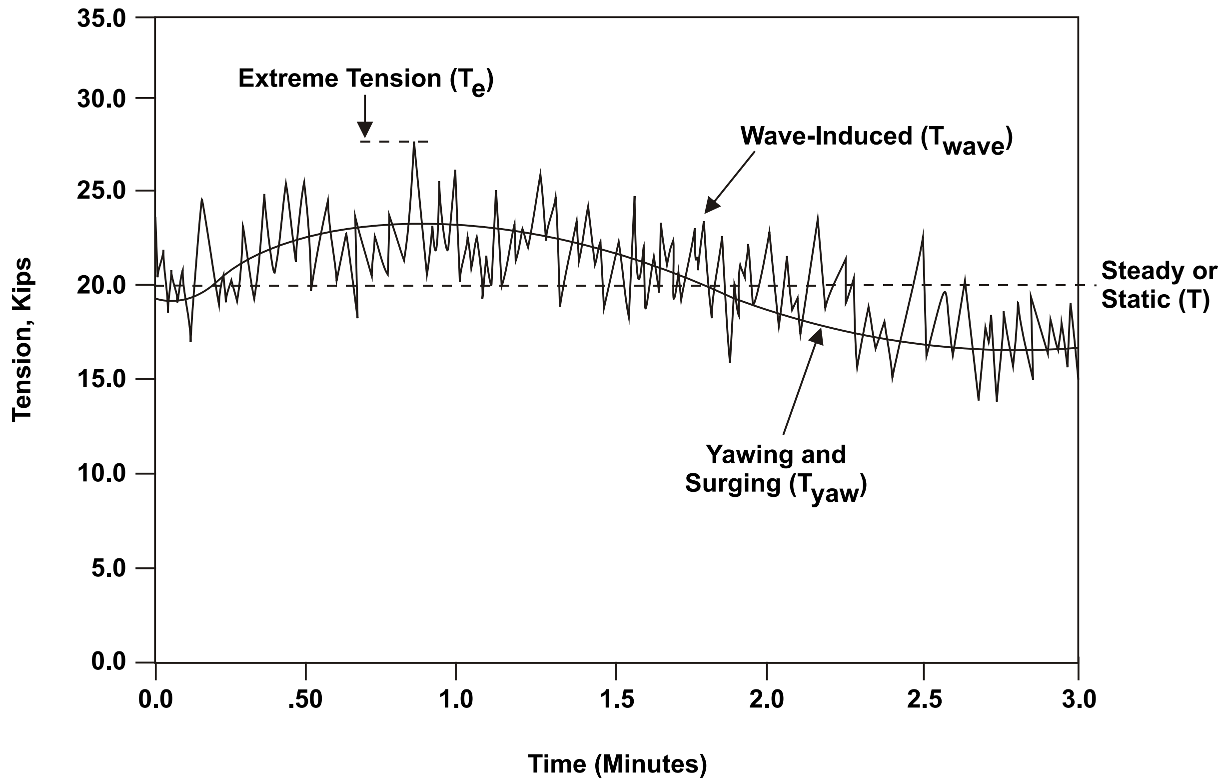


Figure 3-2. Towline Tension vs. Time

These effects can result in peak loading which can destroy the towing system through overload or metallurgical fatigue induced in system components after repeated cyclic loading.

Extreme towline tension occurs when yawing tension and wave induced tension are additive. The total towline tension or extreme tension (Te), can be expressed as **Formula 3-2**:

$$T_e = T + T_{yaw} + T_{wave}$$

where:

T_e	=	Extreme Tension
T	=	Steady towline tension (R_T + R_{wire})
T_{yaw}	=	Time-varying tension due to yawing of the towed vessel
T_{wave}	=	Time-varying tension due to wave action on the ship and on the tow.

In Figure 3-2, for example, T is 20,000 pounds. T_{yaw} varies between -3,000 and +3,000 pounds. T_{wave} varies between -5,000 and +5,000 pounds. T_e, in this example, is approximately 28,000 pounds.

The example shown in Figure 3-2 assumes constant speed and could apply to a tow that is small compared to the size and power of the tug. For large tows, where slow swings can take 10 minutes or more, and for the typical situation where the tug's power setting is constant, the tug and tow both slow down to accommodate the increased tow resistance. This is especially true when the tow sheers off to one side. A poorly behaved tow, therefore, cannot be expected to attain the speed predicted by Appendix G without a significant increase in tug power and hawser tension, neither of which may be possible nor wise.

A badly sheering tow can apply a significant additional tension peak when it "fetches up" at the end of each excursion to the side. This may dictate a further, deliberate slowing to protect the towing gear and the tow winch.

Determining the maximum values for the three components of towline tension is desirable during planning or designing a towing system, as well as managing the tow during towing operations. During towing operations, precise determination of towline tension requires precision instrumentation. Most tugs are not equipped with instrumentation sufficiently accurate to measure T_{wave}. Some tugs are equipped with tension monitoring meters sufficiently accurate for determining steady-state and quasi-steady-state tension.

3-4.1.5 **Factors of Safety**

Tow planners and operators have traditionally dealt with unknown dynamic tensions by applying large safety factors to steady-state tensions when sizing components. Recommended factors of safety for various components are presented in Table 3-2. To use this method, multiply the maximum calculated steady-state tension over the range of anticipated weather conditions along the projected tow route by the appropriate factor of safety and compare this number to the breaking strength for all of the components in the towing system. Factors of safety vary for each component in the towing system. Factors of safety compensate for many other effects such as towline fatigue, corrosion, and wear.

This approach is suitable for planning most Navy tows. The maximum breaking strength of all towing components shall be divided by the applicable factor of safety from Table 3-2 to determine the maximum allowable (steady-state) towline tension. The safety factor shall be increased appropriately if the tow is unfamiliar or there is significant uncertainty about the degree of dynamic loads or the condition of the hawser. Judgment is required when assessing the situation. If technical assistance is required, contact NAVSEA 00C (Main Swbd: (202) 781-1731).

3-4.1.6 **Predicting Dynamic Tensions**

Traditionally, the use of factors of safety were used to offset unpredictable dynamic loads. Difficulties occur with this approach, however, when using a new towing system or towing a ship or structure with which there is no previous experience. This happens when the standard design or material for a towing system has been changed.

A statistical approach can be used for predicting the impact of ship motion on towline tension in a given sea condition. This approach estimates the extreme dynamic tension level the towline is likely to encounter under certain conditions. This information can be used by the tow planner if sea conditions are known or using hind cast data for the route of transit. More importantly, the data can be used to predict acceptable risks of extreme dynamic towline loadings, rather than relying solely on traditional factors of safety which are based on steady-state towline tensions. Appendix M describes this approach in detail and is provided for reference only..

When using these statistical techniques, multiply the “extreme tension” that is calculated by a factor of safety of 1.5. This does not supersede the traditional factor of safety approach described in the previous section. Removal of the uncertainty associated with dynamic effects may eventually permit reduction in traditional towing system factors of safety.

3-4.2 Calculating Towline Catenary

When wire rope is used as a towing hawser, the catenary is the primary means of relieving the peak dynamic tensions. The weight of a wire rope towing hawser, either alone or in combination with a short segment of chain at the tow end of the towline, causes a catenary, or sag, in the towline between the tug and the tow. Variations in the towline tension tend to smooth out in the catenary. Temporary decrease of the distance between tug and tow, or a decrease in tension, is absorbed by a deepening catenary depth. An increase in the separation between tug and tow causes the catenary to decrease in depth and the hawser tension to increase. Thus, the wire catenary tends to act as a spring, softening the tug-tow interaction.

Table 3-2. Safety Factors for Good Towing Practice

Minimum Factors of Safety*

Towing Mode for Tug	Wire Rope Hawser	Wire Rope Pendant	Chain Pendant or Bridle	Polyester	Synthetic Line (Other)	Shackles and Detachable Links	Bits, Padeyes, etc.
Note	1	1	1	2	2, 3	4	5
Long Scope Wire Rope Hawser							
On automatic tension control	3 (4)***	4	4	-	-	3	3
On the Brake	5	6	6	-	-	5	5
On the pawl (dog)	7	7	6	-	-	6	6
On the hook (bitt, pad, etc.)	7	7	6	-	-	6	6
On the hook or brake with chain pendant	4	5	4	-	-	4	4
On the hook or brake with synthetic spring	4	5	5	6	-	4	4
Long Scope Synthetic Hawser with Wire Rope Pendant							
On automatic tension control	-	4	4	4	6	3	3
On the brake	-	6	6	6	10	5	5
On the Pawl (dog)	-	8	8	8	10	5	7
On the hook (bit, pad, etc.)	-	8	8	8	10	7	7

Notes:

1. Based on Minimum Breaking Strength.
2. Based on Minimum New Dry Breaking Strength. These figures are for 8” circumference and larger. For smaller lines, increase safety factor by 2. (See 4-2.2)
3. For Nylon: Breaking strength is reduced by 15% when wet.
4. Based on minimum breaking strength for links and proof load for shackles.
5. Based on Material Yield Strength.

* “Minimum” applies only to new components, good weather, short duration, or emergency conditions. Old components, possible heavy weather, long-duration use, etc., may impose uncertainties which require use of safety factors greater than the listed minimum safety factors.

** When pendant is used as a deliberate “fuse” (i.e., safety link), use the same factor of safety as for the hawser but applied to the breaking strength of the pendant.

*** See 4-3.1 for details.

Due to the hydrodynamic drag of the wire during the rising of the catenary, the spring effect is not immediate. For load increases of a sharp or sudden nature, the catenary cannot be expected to absorb the accompanying increases in towline tension completely. Using an automatic towing machine, a synthetic spring (see Section 4-6.5), or adding an additional chain in conjunction with the catenary will help provide an effective relief of changing loads over the full range of conditions.

To avoid dragging or fouling the towline on the sea floor, while maintaining sufficient catenary depth to absorb changes in tug-tow separation, it is necessary to estimate the catenary depth of the towline. A number of methods have been used for estimating towline catenary.

To estimate catenary depth, it is necessary to have the following data available:

- Steady-state tension in the towline
- Lengths of the towline components
- The weight per unit length in water of each component

The steady-state tension in the towline may be estimated by using the tension meter on the towing machine, by the calculating steady-state towline tension in Appendix G, or by using the chart in Figure 3-3, which presents the calculated tug pull available versus speed through the water. The composition and total length of the towline should be known. Table B-2 and Tables D-1 through D-9 provide the weight per unit length for various towline components. When weight in water of steel components is not given, multiply weight in air by 0.87 to obtain weight in salt water.

An initial estimate of the catenary depth of the towline may be determined using **Formula 3-3:**

$$C = {}^{T}/_{W} - {}^{T}/_{W} \sqrt{1 - ({}^{WS}/_{2T})^2}$$

where:

C	=	Catenary or sag (ft)
T	=	Steady tension (lbs force)
W	=	Weight in water per unit length (lbs/ft)
S	=	Total scope (ft) (total of all components)

Total weight in water per unit length (W) is computed as the sum of the weights of the individual towline components divided by the total towline scope.

This formula applies to single component wires hanging under their own weight. For calculating, scope (S) and weight (W), when the towline includes a bridle, the total weight of the bridle should be used, but the scope is estimated as a single leg of the pendant. This formula provides an acceptable estimate of towline catenary for towline configurations where the ratio of towline scope (S) to catenary (C) is greater than 8:1. When the ratio is less than 8:1, the catenary depth predicted by this formula does not provide an accurate estimate of the towline catenary.

Based on this formula, Figure 3-4 through Figure 3-12 show the calculated catenary for various common compositions and lengths of towline. These curves may be used for towing speeds up to 12 knots. To decrease catenary, towline scope may be shortened or the towing speed increased.

These graphs assume the chain is attached at the bullnose. If additional chain is used after a wire pendant (i.e., closer to the middle of the tow configuration) a deeper catenary will result. These figures provide estimates and care should be taken when there is a risk of bottom contact.

To quantify effects of changes in tension, a ship can draw its own curve, representing the scope actually used, and proceed along that curve to different tensions to find the new catenary.

For example, a ship using a 2-inch hawser and no chain would refer to Figure 3-7. For a scope of 1,500 feet, a new curve could be plotted in between the existing curves for 1,000 and 2,000 feet. This new curve would show that increasing tension from 20,000 pounds to 30,000 pounds would decrease the catenary depth from about 100 feet to about 65 feet. Slowing down to a tension of 10,000 pounds will almost double the catenary to about 190 feet.

Likewise, a ship could plot curves of catenary versus tension for several tension figures to provide a graphical representation of the effect of change in hawser scope. When water depth is limited, the ship can start with the required catenary depth and work backwards to determine the required scope/tension combination. In addition, some towing machine technical manuals include tables or curves to assist in solving scope/catenary/tension questions.

It should be noted that catenary depth will change with varying tensions. If catenary depth is a concern (e.g., bottom contact), expected minimum tensions should be used.

3-4.3 Reducing Anticipated Towline Peak Loads

Several aspects of the towline design can significantly affect peak towline tensions. Some are adjustable during the tow; some are not, but nonetheless should be considered during the tow planning phase. These measures include:

- Increasing towline scope
- Increasing length of chain pendant or bridle (resulting in towline weight changes)
- Inserting a synthetic spring into the towline system.
- Inserting a chain pendant midway into the towing system to increase catenary and act like a spring or poor man's automatic tow machine

The towline scope used during a tow depends primarily on four factors:

- Type of towing rig employed
- Water depth
- Catenary required to absorb changes in towline tension
- Amount of scope required to keep the tug and tow "in step"

To estimate the towline scope required, calculate the steady-state towline tension required to maintain the desired towing speed. Calculating steady state towline resistance total tow resistance is described in detail in Section 3-4 and Appendix G -

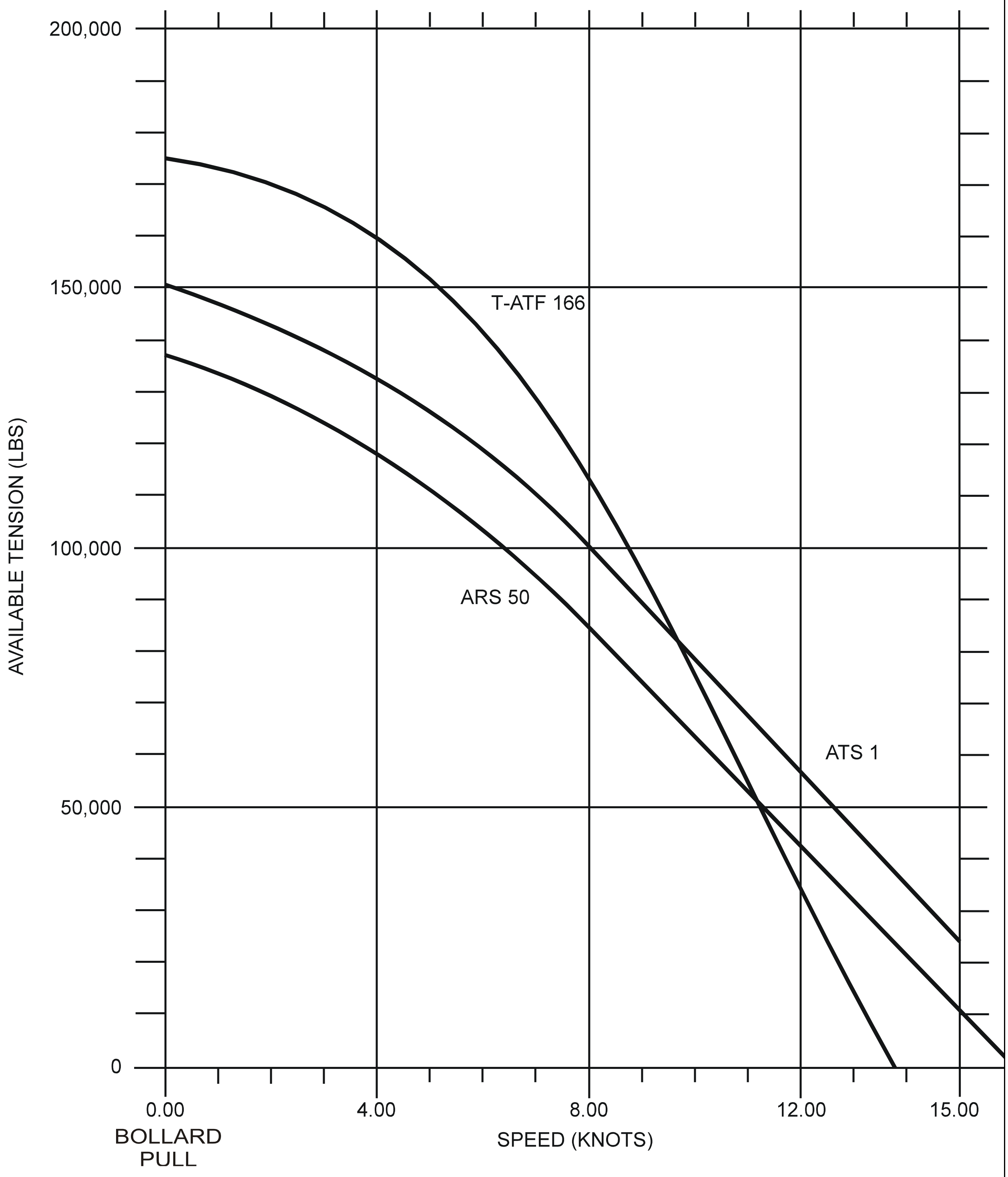


Figure 3-3. Available Tensions vs. Ships Speed for U.S. Navy Towing Ships

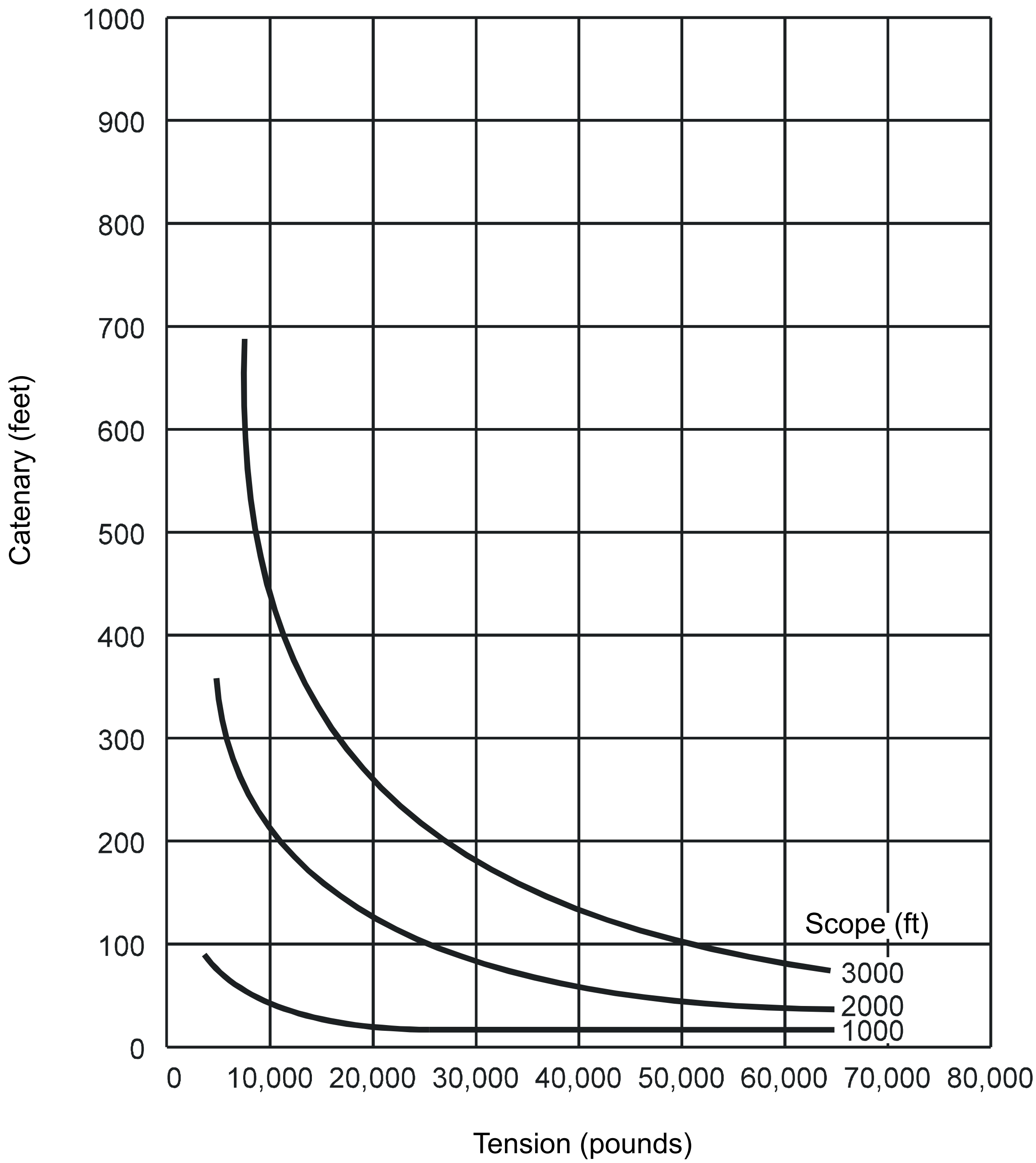


Figure 3-4. Catenary vs. Tension: 1-5/8-Inch Wire, No Chain

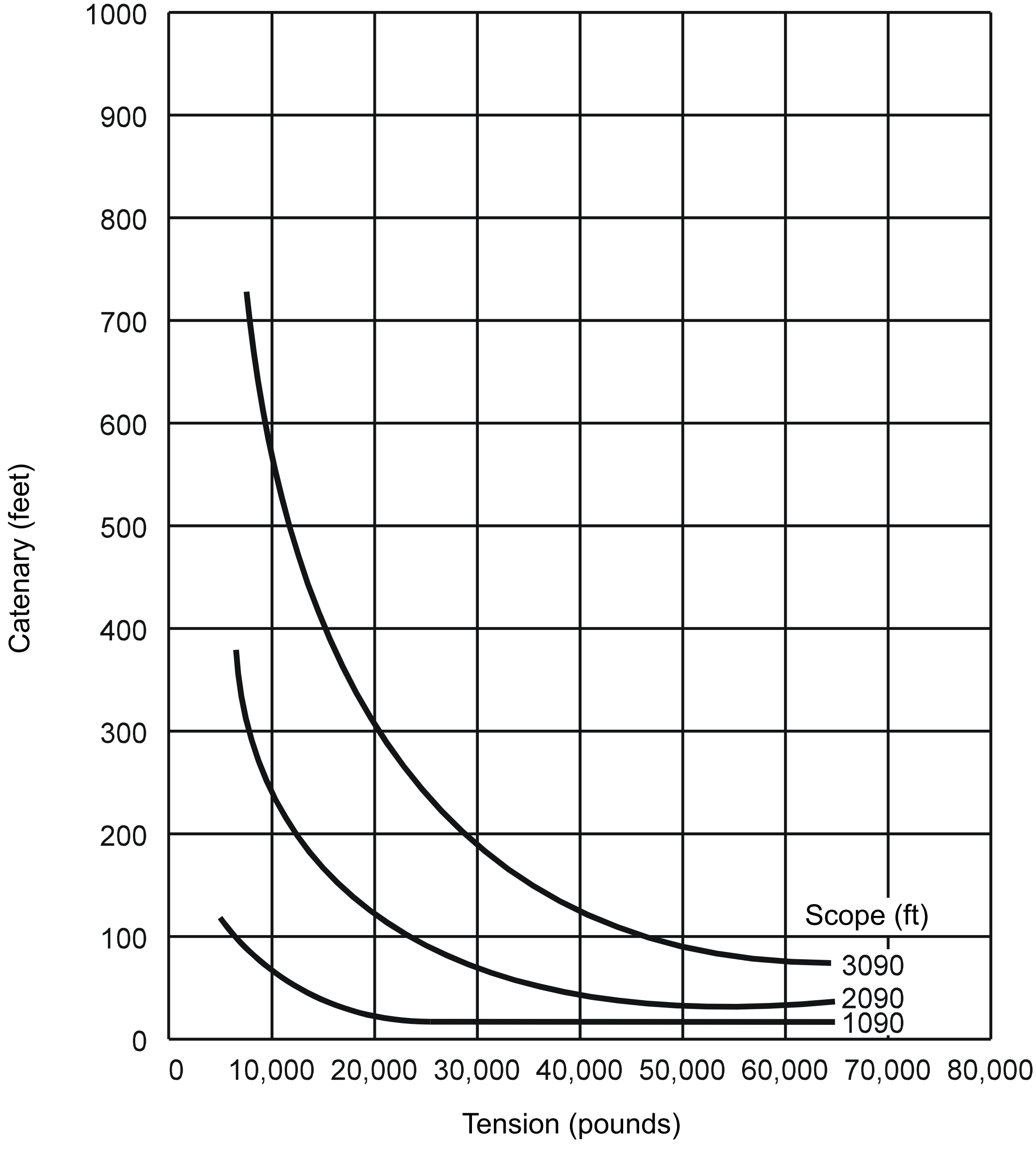


Figure 3-5. Catenary vs. Tension: 1-5/8-Inch Wire, 90 Feet (1 shot) of 2 ¼-inch Chain

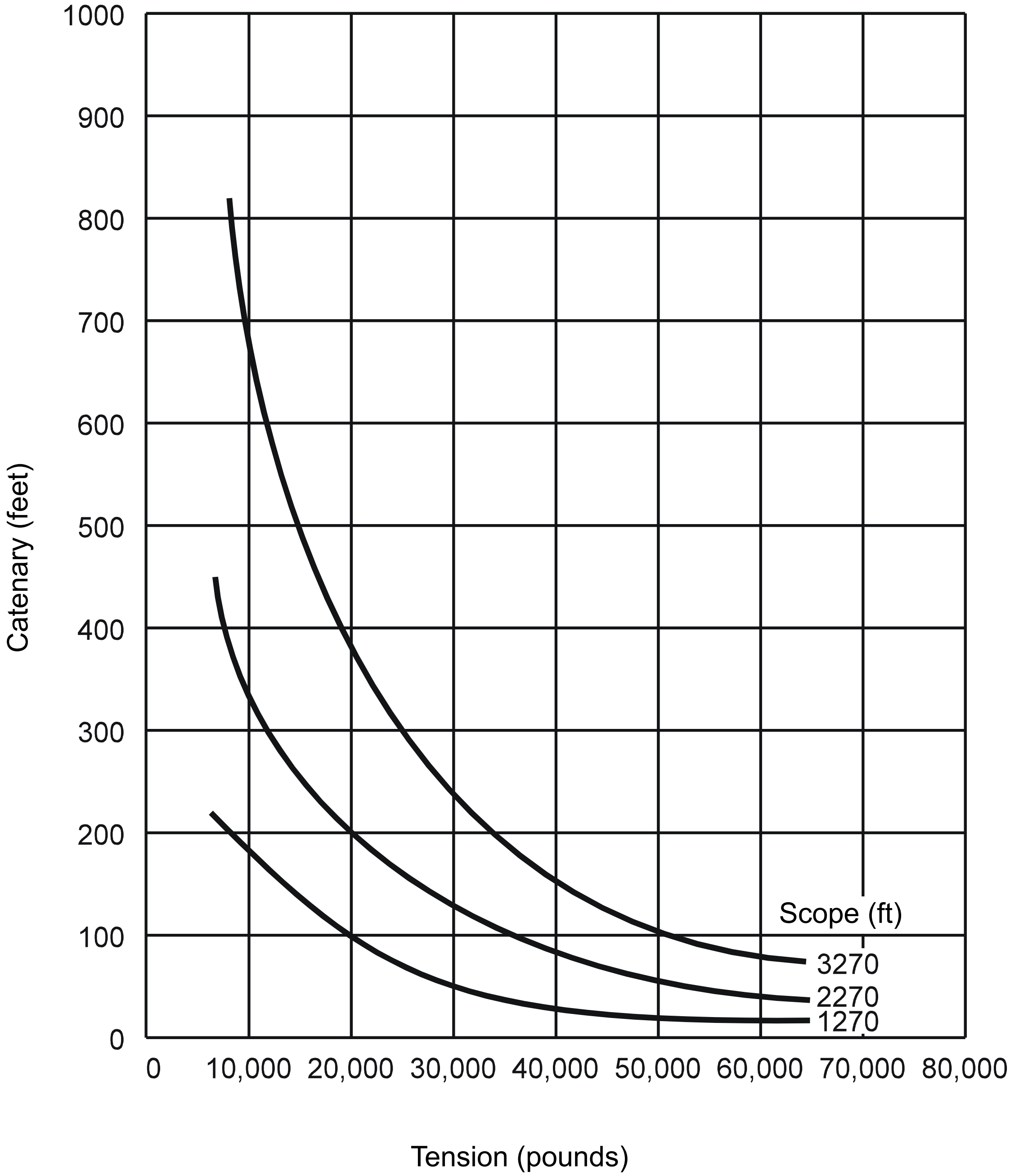


Figure 3-6. Catenary vs. Tension: 1-5/8-Inch Wire, 270 Feet (3 shots) of 2 ¼-inch Chain

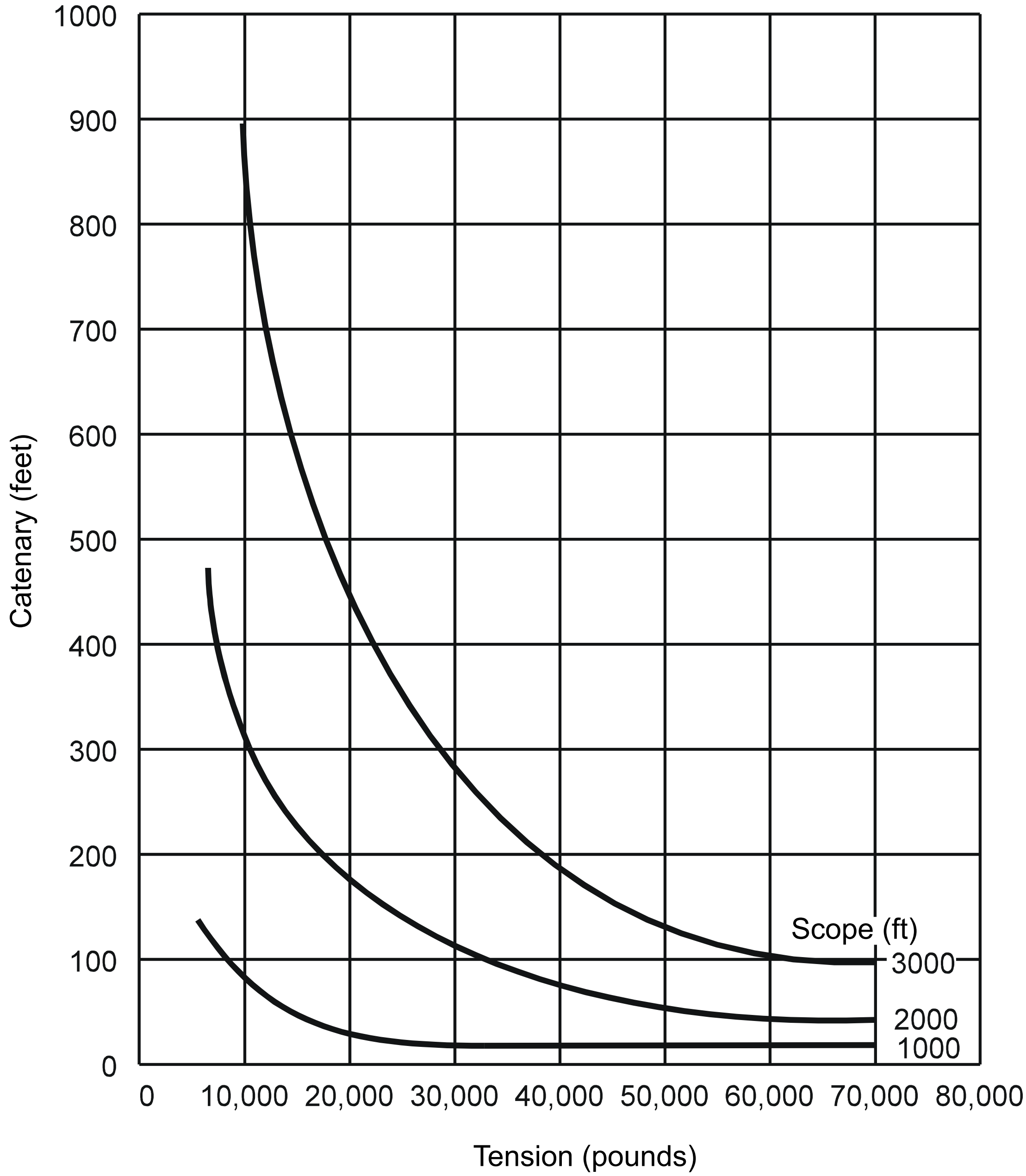


Figure 3-7. Catenary vs. Tension: 2-Inch Wire, No Chain

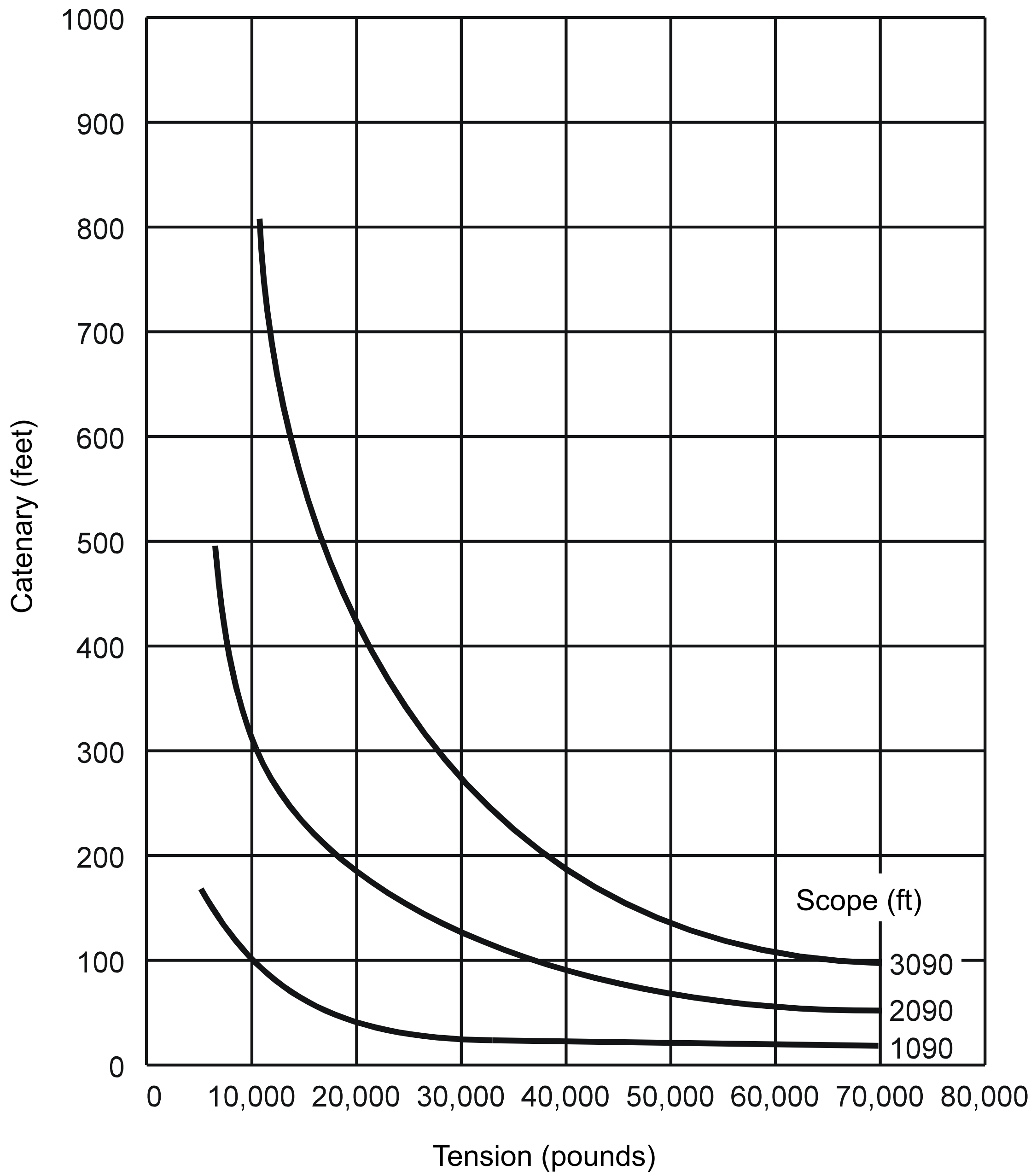


Figure 3-8. Catenary vs. Tension: 2-Inch Wire, 90 Feet (1 shot) of 2 ¼-inch Chain

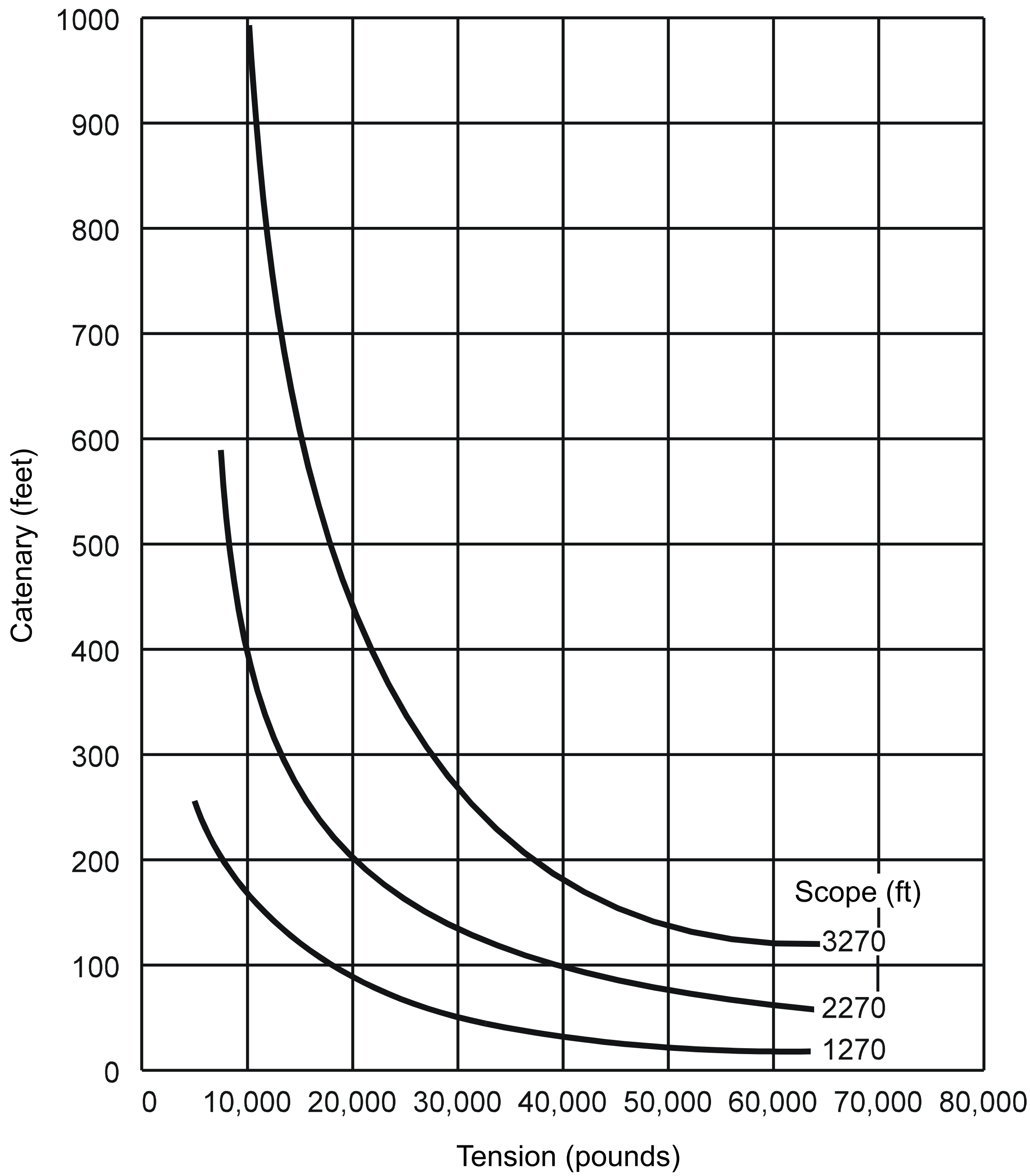


Figure 3-9. Catenary vs. Tension: 2-Inch Wire, 270 Feet (3 shots) of 2 ¼-inch Chain

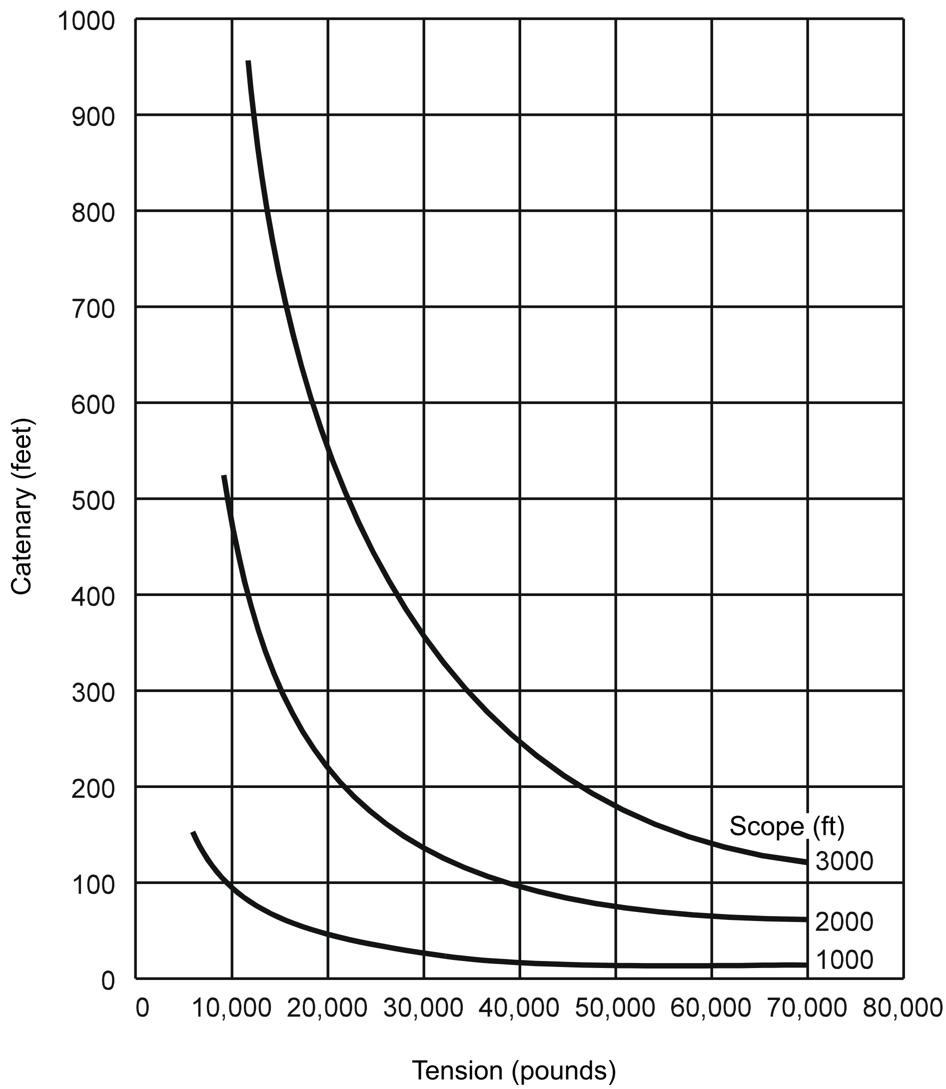


Figure 3-10. Catenary vs. Tension: 2 1/4-Inch Wire, No Chain

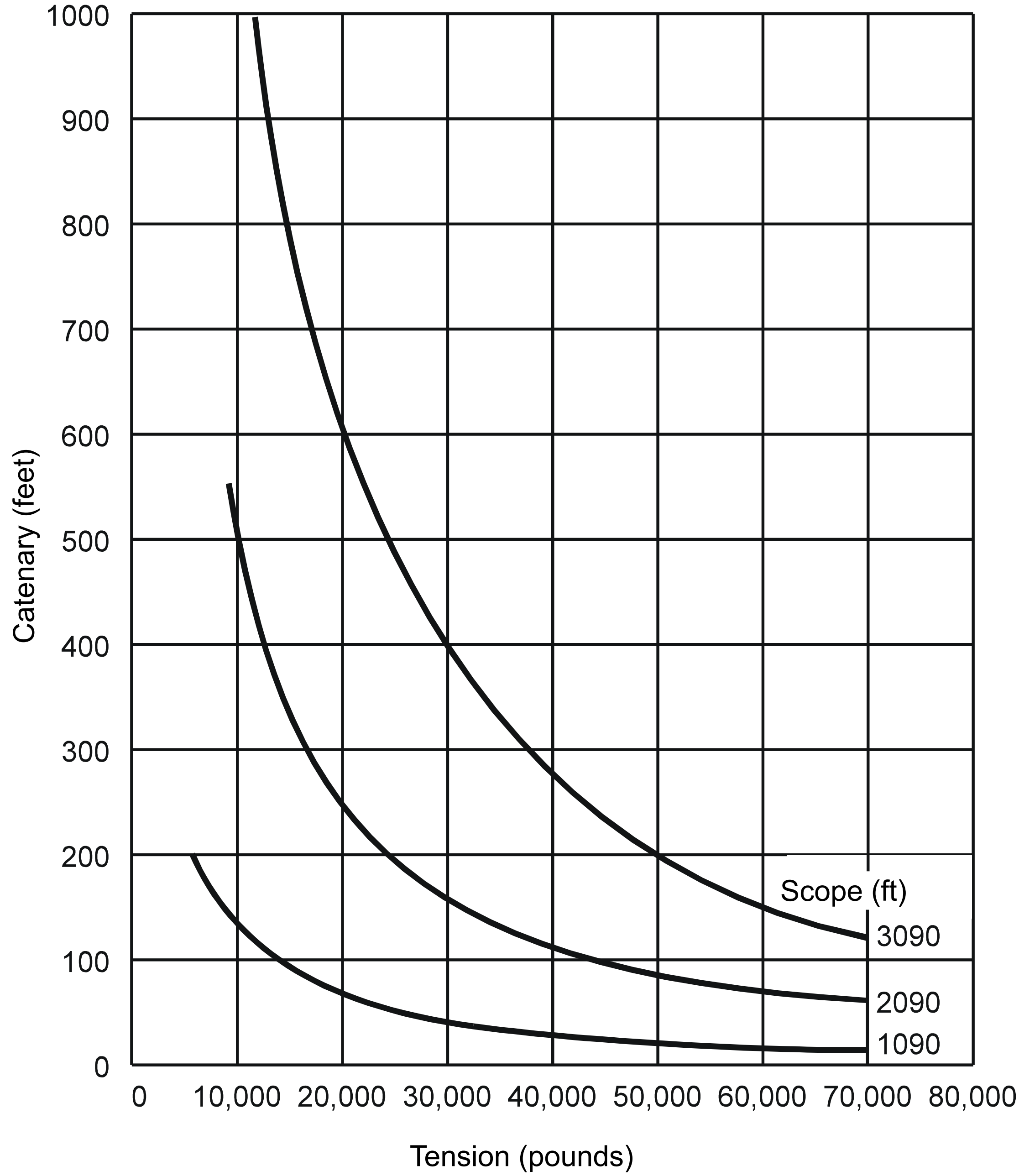


Figure 3-11. Catenary vs. Tension: 2 1/4-Inch Wire, 90 Feet (1 shot) of 2 ¼-inch Chain

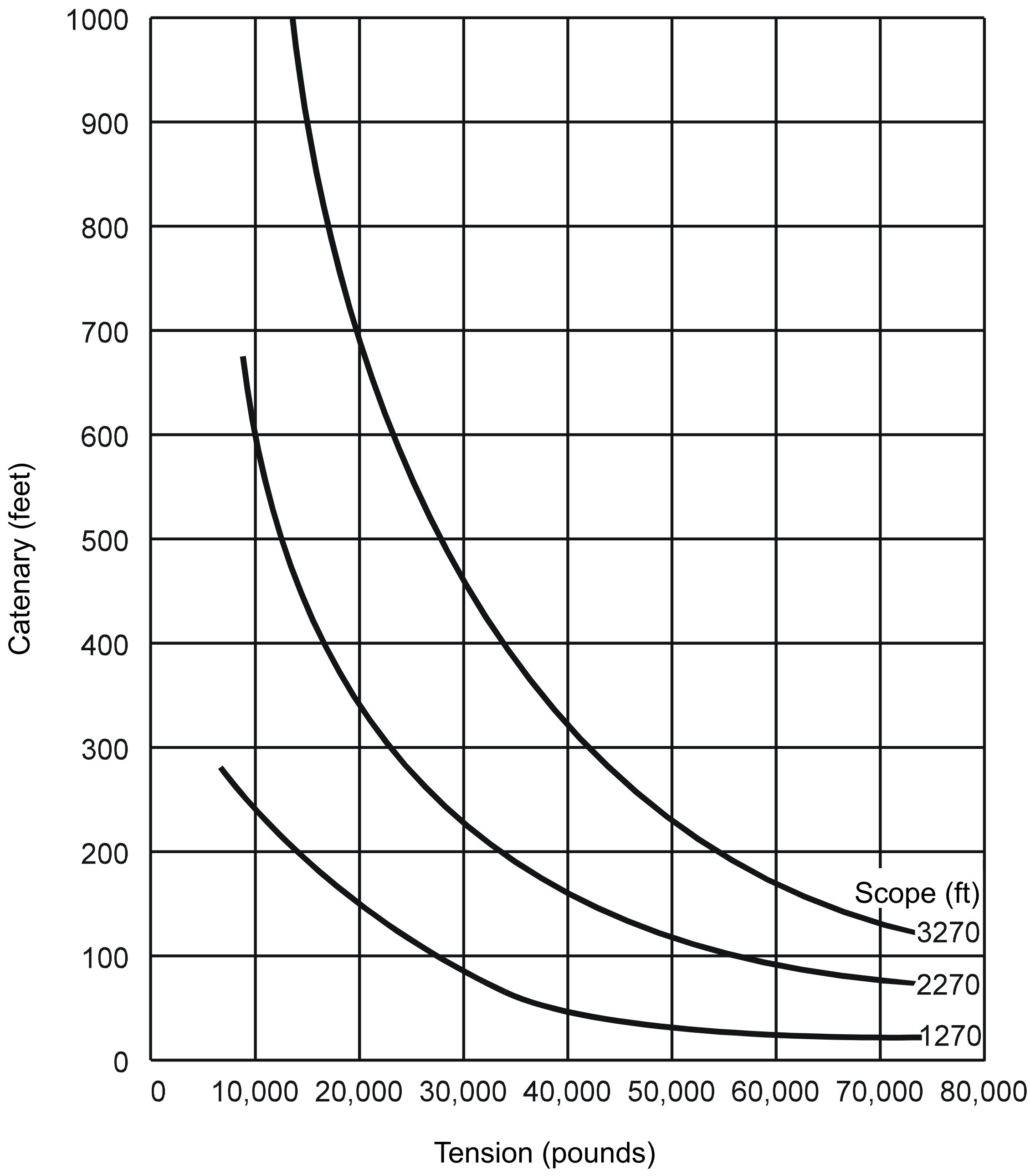


Figure 3-12. Catenary vs. Tension: 2 1/4-Inch Wire, 270 Feet (3 shots) of 2 ¼-inch Chain

Having an estimate of the steady-state towline tension, allows computation of the catenary associated with the chosen towline scope and tow rig. Section 3-4.2 presents a Formula 3-3 for estimating the catenary for tow hawser scopes greater than or equal to 1,000 feet, Figure 3-4 through Figure 3-12 will provide catenary depth directly, given hawser tension.

The following explores the ability of a wire catenary to absorb ship movements by including "stretch" of the wire.

If the effects of hydrodynamic drag are ignored, the catenary can be estimated by the separation between tug and tow as **Formula 3-4**:

$$D = S(1 - \frac{WC}{3T})$$

where:

D	=	Horizontal distance between the tug stern and the bow of the tow (ft)
S	=	Total scope of the hawser (ft)
W	=	Weight in water per unit length of the hawser (lbs/ft)
C	=	Catenary or sag (ft)
T	=	Steady tension in the towline (lbs force)

See Figure 3-1 for a graphical representation of these values.

To quantify the effect on the hawser tension for a given change in distance between tug and tow, it is necessary to develop a table or curve of distance (D) versus tension (T) for various hawser scopes. The computation is fairly direct if tension (T) is assumed for a given scope (S) of hawser; catenary depth (C) is computed, then horizontal distance (D) of the catenary. The SMART Tow system uses a GPS on the tug and tow to determine the distance between the tug and tow to aide in determining catenary depth.

Figure 3-13 shows a comparison between a 1,800 foot hawser and a 1,000 foot hawser. For instance, from an initial tension of 20,000 pounds, the 1,000-foot hawser can absorb about 19 feet of additional separation between the tug and tow before it reaches 200,000 pounds tension; the 1,800-foot hawser will not reach that tension until separation is increased by almost 36 feet. Similarly, a 20 foot stretch of the 1,800-foot hawser increases its tension to only about 75,000 pounds. The longer hawser significantly reduces the peak tensions caused by the same ship movements. A similar trend would be seen with IWRC wire. Ships with different hawsers can prepare a family of curves showing the change in tension as the separation between the ships changes.

The quantitative data shown in Figure 3-13 are based on slow changes in distance or tension. Classic catenary is limited in its ability to absorb tug and tow motions, even where there is a relatively modest average hawser tension. Effectiveness of the classic catenary in reducing dynamic loads has limitations. This is because the hydrodynamic resistance normal to the tow wire significantly impedes its rise and fall at typical frequencies of dynamic sea keeping loads. Therefore, the wire towline does not always have time to fully resume its former deep catenary when the next surge in tension occurs. Figure 3-13 should be used for qualitative comparisons of different towline configurations acting under dynamic loading.

Table 3-3. Section Modulus for Wire Rope

		Wire Diameter		
Wire Type	Load Percentage	1 5/8 inches	2 inches	2 ¼ inches
6 x 37 IWRC	0 - 20%	16.4	24.8	31.4
	21 – 65%	18.2	27.6	34.9
		multiply all values by 10%		

Table 3-4. Elongation of 1500 Feet of 6x37, 2 ¼-inch IWRC EIPS Wire Rope

Tension	Section Modulus[1]	Se[2]	Scope[3]	Catenary (ft)[4]	Distance (ft)[5]
0	31.4×10^6	0	1500	--	--
10,000	31.4×10^6	.5	1500.5	257.9	1395.5
25,000	31.4×10^6	1.2	1501.2	184.3	1471.2
50,000	31.4×10^6	2.4	1502.4	43.1	1498.8
75,000	31.4×10^6	3.6	1503.6	31.3	1501.9
88,000	31.4×10^6	4.2	1504.2	26.3	1503.0
110,000	31.4×10^6	4.3	1504.3	22.0	1503.4
125,000	34.9×10^6	5.4	1505.4	18.5	1504.8
150,000	34.9×10^6	6.4	1506.4	15.5	1505.9
175,000	34.9×10^6	7.5	1507.5	13.2	1507.2
200,000	34.9×10^6	8.6	1508.6	11.6	1508.4
250,000	34.9×10^6	10.7	1510.7	9.3	1510.5
275,000	34.9×10^6	11.8	1511.8	8.5	1511.6
288,000	34.9×10^6	12.4	1512.4	8.1	1512.3

Note: Assume constructional stretch has been accomplished through previous loadings.

1. Section Modulus (Area x Modulus of Elasticity) for 2 ¼-inch IWRC hawser is 31.4×10^6 through 20% strength of the wire; 34.9×10^6 over 20% load.
2. Change in scope due to wire elasticity. (ft).
3. Total scope of hawser after stretch. (ft)
4. Catenary depth per formula:
   $C = \frac{T}{W} - T/W\sqrt{1 - (\frac{WS}{2T})^2}.$
5. Distance between tug and tow per formula:
   $D = S(1 - \frac{WC}{3T})$

Source: Wire Rope Users Manual, 4rd Edition, Table 17

A similar analysis of the advantages of adding chain to the towline can be prepared using the methodology shown in Table 3-4. Plot curves showing the effect of adding one or two shots of chain pendant to a given hawser length. The calculation process is identical, except that the comparison will be between hawsers of the same length but with different total length and unit weights, because the weight of the chain is distributed throughout the hawser length. The analysis will demonstrate that adding only one shot of 2¼-inch chain provides a considerably softer system that develops lower peak tensions for the same change in separation between tug and tow.

Two components of wire “stretch” must also be included when determining the distance between tug and tow: constructional stretch and elastic stretch. The Wire Rope User’s Manual (reference C.) estimates constructional stretch as 0.5 to 0.75 percent for 6-strand, fiber-core (FC) wire and 0.25 to 0.5 percent for 6-strand, independent wire rope core (IWRC) wire. Constructional stretch is caused by a virgin rope’s helical strands constricting the core during initial loading. The constricted core is compressed and lengthened by the pressure exerted by the helical strands. For fiber core ropes, constructional stretch is pronounced due to the high compressibility of fiber when compared to an IWRC. Constructional stretch properties fade from wire rope early in its life, especially for IWRC ropes. Shortly after a wire rope has been repeatedly loaded, the constructional stretch characteristic is no longer exhibited. Fiber core ropes, however, will retain this property longer, especially if subjected to only light loads.

Warning
Fiber core ropes are not authorized on Navy tows.

The elastic stretch of hawsers likewise varies with load. For convenience, elasticity is assumed to be constant through 20 percent loading, with a different figure applying beyond 20 percent loading. For common Navy hawsers, the figures in Table 3-3 can be used where Section Modulus (which incorporates compactness factors and variance of elastic modulus) is expressed as the effective area of the steel in the wire multiplied by the modulus of elasticity of the steel (Section Modulus (lb) = area (in2) x Elasticity (pounds per square inch)).

For example, a 1,500-foot, 2 1/4-inch IWRC wire with a 25,000-pound load will elastically stretch:

$$\text{Change in length (ft)} = \frac{\text{load (lb) x length (ft)}}{\text{Section Modulus (lb)}}$$

$$1.2 = \frac{25{,}000 \times 1500}{31.4 \times 10^6}$$

This formula assumes that constructional stretch has already occurred. Table 3-4 has been developed for a 1,500-foot, 2 1/4-inch IWRC extra improved plow steel (EIPS) wire hawser.

3-4.3.1 **Using an Automatic Towing Machine**

The automatic payout and reclaim feature of Automatic Towing Machines (ATMs) installed on some commercial and military tugs are a very effective means of reducing peak towline tensions. US Navy T-ARS and T-ATF Class ships have automatic tow machines installed. Table 3-5 provides the range of automatic settings available on various tugs. Generally, the ATM is used when water depth precludes establishing adequate towline catenary. The towing machine can be taken off "automatic" after sufficient towline catenary is established in deeper water. However, use of the automatic feature is equally effective in deep water. Towing in the automatic mode is generally preferred; however, this recommendation is not intended to conflict with the manufacturer's approved operating procedures. For example, in calm seas, the manufacture recommends operating in manual mode.

Additional information on towing machines and winches appears in 4-5.1 and in Appendix L.

3-4.3.2 **Using Synthetic Towlines**

Use of synthetic towlines is one of the best means of absorbing dynamic tow loads. The elastic characteristics of synthetic lines have many advantages over other conventional means of reducing dynamic load tension. These advantages include, but are not limited to, the following:

- Speed of response. When compared to an automatic towing machine (ATM), synthetic lines are capable of instantaneous response. If the dynamic load has a low acceleration, both the ATM and synthetic line absorb the dynamic load comparably. If the load has a high acceleration, the ATM may not be able to respond fast enough before a tension spike impacts the towing system.
- Passive system. Once deployed, the synthetic line does not require an operator. Its shock-absorbing action requires no machinery, active input, or maintenance by the operator.
- Maintenance. The ATM is a complex machine subject to mechanical failure on occasion, particularly if not properly maintained or operated. Proper care of the ATM requires diligent maintenance and grooming to ensure dependable operation. Synthetic line is affected by other factors such as abrasion, heat, and prolonged exposure to UV light. Limiting these factors should ensure these hawsers have a long service life.

Synthetic lines are primarily used in two ways when employed in the towing system. Synthetic lines are used either as the towing hawser or as a synthetic spring pendant inserted in the towing system. A synthetic spring consists of a synthetic line pendant placed in the towing system between the steel towing hawser and the chafing chain extending from the tow. A spring works in combination with the catenary produced by the heavier steel components. It can assist in absorbing rapid acceleration peak loads while the catenary adjusts to loads applied more slowly. The synthetic spring should have a breaking strength similar to the breaking strength of the remainder of the towing system components. Important restrictions on the use of synthetic tow lines and springs are provided in Section 4-3.2, Section 4-6.5, and reference C. Incorporate these restrictions when designing or using synthetic lines in any towing system.

CAUTION
Plasma and Aramid fiber lines do not have these same properties

3-4.4 Tug and Equipment Selection

3-4.4.1 Tug Selection

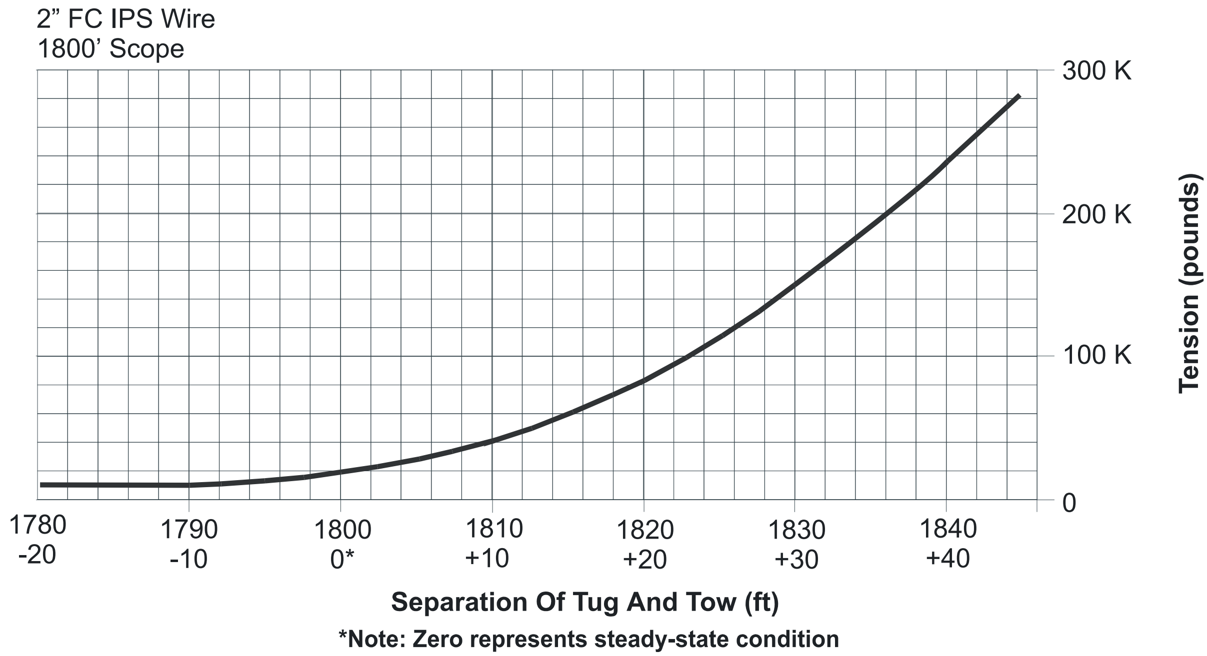
Tugs are generally selected based on required steady state tow tension requirements, availability and capabilities. It must be properly maintained, reliable, have a competent crew, have adequate bollard pull to safely conduct the tow, have proper tow jewelry to connect the tow to the tug, and sufficient range (legs) to complete the tow.

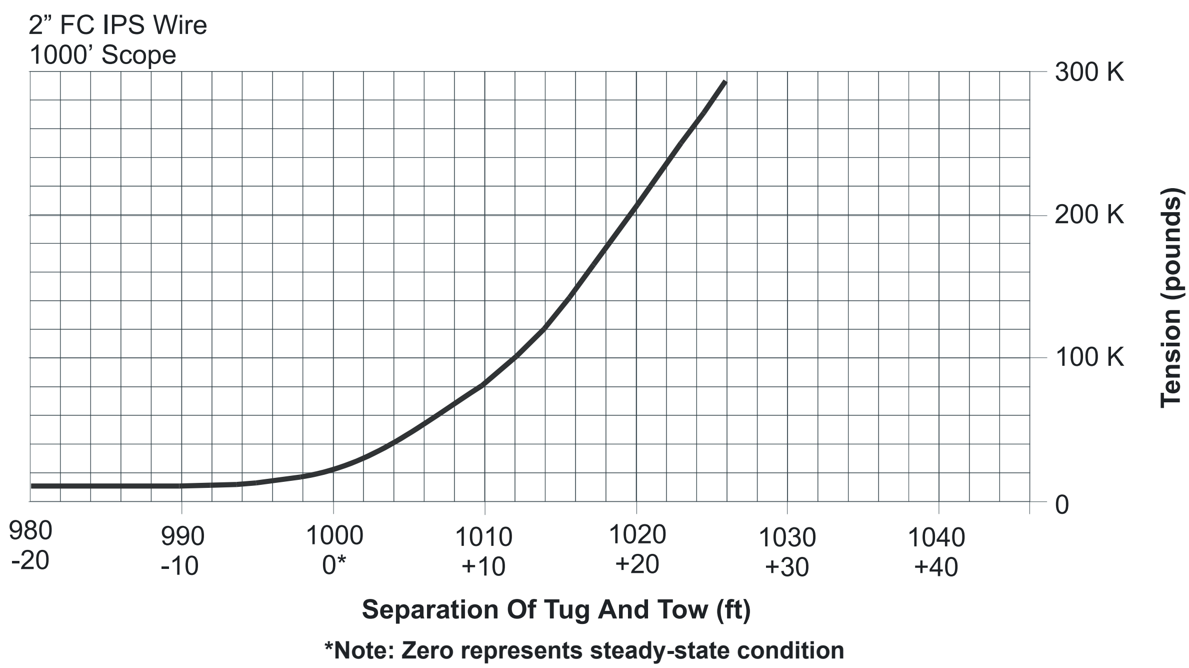
The principal measure of a tug's power is its ability to exert tensile force on the towline. The maximum force a tug can exert on the towline is defined as the tug's bollard pull. A tug's bollard pull is established by pulling against a calibrated load cell attached to a certified bollard until stall, hence the term bollard pull. The tug pulls until the maximum measured tension which can be held for minimum of ten minutes is obtained. The maximum measured bollard pull will not increase even if additional power is applied to the tug's propellers. The tug's available bollard pull combined with the hydrodynamic properties of the tug and tow determines the maximum steady-state towline tension. Generally, a tug's power plant and propeller are designed to deliver maximum power and optimum efficiency at a designated tow speed. Maximum bollard pull is delivered at zero speed. Therefore, bollard pull decreases as tow speed increases. Theoretically, when the tug reaches its maximum free route speed, all its horsepower is used in propulsion and the bollard pull drops to zero.

Each class of tug has its own unique set of available tow tension curves which are dependent upon engine power setting, ship speed, propeller rpm, and propeller pitch (for ships with controllable pitch propeller (CPP) systems). For tow planning, the maximum available tow speed is the figure of interest. Figure 3-3 shows the available tow tension versus ship's speed for U.S. Navy Ocean going tugs. Comparing the curves to the steady state towline tension as calculated in 3-4.1.3 provides the approximate maximum tow speed for an assumed condition. If the maximum speed available does not coincide with the assumed tow speed conditions, additional resistance computations should be performed to achieve a balance between tension required and tension available. A more direct method is to plot a curve of the calculated steady state towline tension directly onto a copy of Figure 3-3. The tug and tow curves will intersect at the maximum speed attainable with each tug for assumed tow conditions.

If the available tow speed exceeds the amount needed (usually for small or non-ship tows), the tug will require less than maximum continuous engine power. In this situation, a less powerful tug can be considered. Conversely, if available tow speed is less than required, a more powerful tug must be selected. When the available tug is underpowered for the desired tow speed, the most important consideration is whether it has sufficient power to keep the tow out of danger under the most severe wind and sea conditions which can be expected along the planned tow route. The rule of thumb for tug sizing is sufficient bollard pull to make 5 knots headway in Beaufort Sea State 5 conditions. This is sometimes referred to as the five by five rule. For instance, it may be acceptable if a tug is unable to make headway over the ground while towing a large ship in a sudden gale in the open sea for short durations (less than 48 hours). The same tug, however, may be considered inadequate for towing the same ship under the same conditions near a lee shore. In the case of a planned tow of a large ship, adjustment to tow dates and careful weather routing are essential. For more severe cases, adjustment of the assignments and schedules of other tugs also may be required to provide the required towing capability. Failure to adhere to this basic planning guidance can result in catastrophic outcomes and potential loss of tow.

For emergency tows, the tow will be initiated by the first available tug. Procedures outlined herein are useful in determining whether additional towing assets should be diverted to escort or take over the tow. Appendix K contains data useful in estimating the power of commercial tugs that may be needed in an emergency.





Note
These curves plot the hawser tension vs. tug/tow separation. They demonstrate the much “softer” nature of the longer scope for the same change in separation.

Figure 3-13. Distance Between Vessels vs Hawser Tension for 1,000 amd 1,800 Feet of 6x37 FC Wire.

Table 3-5. Operating Range for Automatic Towing Machines of Various Types of Ships	
Types of Ships	**Operating Range (lbs.)**
Salvage Ships (T-ARS 50)	20,000 – 110,000
Fleet Ocean Tug (T-ATF)	30,000 – 110,000

3-4.4.2 **Tow Jewelry (Gear) Selection Factors**

Once the tow vessel has been optimally sized to fit operational requirements, then the towing hardware (sometimes referred to as "tow jewelry", and connecting system components, shall be sized to accommodate the anticipated forces for those operational requirements. The mechanical properties for the components of towing systems are covered in the Appendices of this manual. Examples include wire rope and wire rope terminations (Appendix B), synthetic fiber lines (Appendix C), chain, shackles and links (Appendix D), and line stoppers (Appendix E). Engineering design factors of safety for all system components are discussed in 3-4.1.5. Towing gear is discussed at length in Chapter 4.

Hawser size is generally fixed for a given tug. If a specific size hawser is required by the type of tow, that fact, rather than the availability of tugs, may determine tug selection. The calculated steady-state towline tension values are multiplied by the safety factor to obtain the required minimum breaking strength of the wire rope hawser. With the minimum breaking strength known, Appendix B may be used to evaluate the wire hawsers carried by candidate tugs. If there is no good match, the assumed tow speed can be adjusted until a match between required hawser strength and available tugs is achieved. For a particular tug, with a specific hawser, the problem may be reversed to find the maximum allowable steady-state towline tension.

Chapter 4 - TOWLINE SYSTEM COMPONENTS

WARNING
Do not confuse pelican hook with chain stopper.

NOTE
Padeye material should be ASTM-36, ABS Grade A, or similar.

CAUTION
Chain smaller than about 3 1/4” will require a pear-shaped link or an anchor shackle to connect to the standard Smit bracket. Check dimensions carefully.

NOTE
Three different pear-shaped detachable links will satisfy all normal chain connection requirements.

4-1 Introduction

This chapter presents guidance on the use of the wide variety of components or towing jewelry available for use in towing. Tow planners and tow ships should carefully consider the relative advantages and disadvantages of each component when designing a tow rig. Consideration should be given to durability, availability, ease of handling, and other factors as appropriate.

4-2 Towline System Components

The towline system is made up of many components. The towing hawser often called the towline or bull rope is only one component of the tow system. Figure 4-1 illustrates a complete towline system. The tow system includes attachment points, rope terminations, and tension components such as chain pendants, wire rope pendants, and spring pendants. These components are joined together by the tow jewelry, such as shackles, detachable links, pear shapes, or other connecting hardware.

A tow line is the tension-carrying link between tug and tow and must be able to withstand steady state tow loads, as well as dynamic peak loads, often called shock loads. The primary materials used in tension members are wire rope, synthetic fiber lines, and chain.

These items are sized by using the calculated steady-state tow tension combined with the application of the appropriate factor of safety from Table 3-2. Size and compatibility the tow jewelry are key considerations.

The following is a list of some of the factors which influence the selection of the components of a towing system:

- Strength (static loads, dynamic loads, fatigue)
- Ability to nondestructively inspect or test
- Elasticity (stretch vs. load over a full range of loads and over the lifetime of material, set or permanent stretch)
- External abrasion resistance
- Internal abrasion resistance (related to fatigue life)
- Weight and ease of handling
- Survivability in a specific environment (effects of corrosion, ultraviolet light, sea water, acids, temperature, moisture)
- Handling (surface characteristics: slippery, sticky, pliable, minimum bend radius requirements)
- Stowage requirements (volume, shrinkage, and flexibility)
- Compatibility of fittings and terminations

In various towing applications, one or more of these factors may influence the choice of materials to be used. For example, chain is frequently selected for use as a chafing pendant or bridle because of its abrasion resistance, strength, and durability. When a chain pendant is inserted into the tow system as depicted in Figure 4-1, the chains weight acts as a spring providing elasticity through catenary action rather than through material stretching. Likewise, a polyester line may be suitable for use as a tow hawser or spring pendant due to its elastic properties, but would not be a good selection as a chafing pendant due to its lack of abrasion resistance. Wire rope is generally favored for use as a tow hawser on ocean tugs because of its strength, high abrasion resistance, flexibility, stowability, and ease of handling.

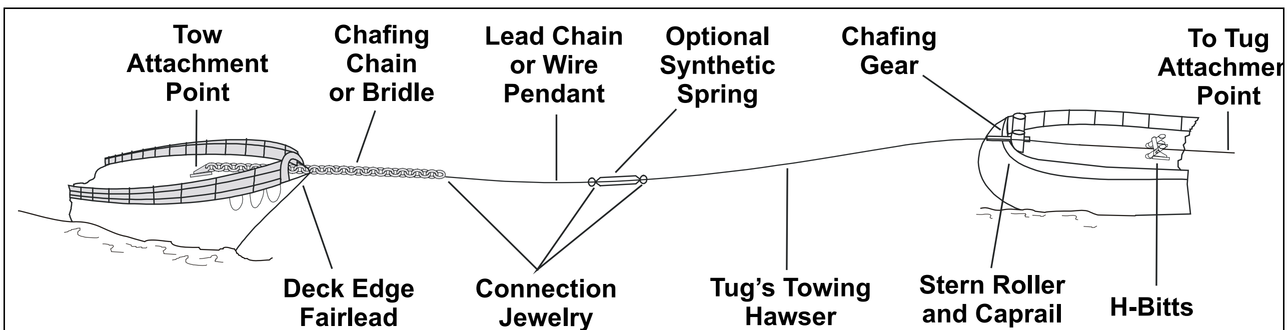


Figure 4-1. Typical Towline Connection Components.

4-3 Main Tow Hawser

The tow hawser is the primary component of the tow system. Tow hawsers are normally wire rope or synthetic line. The bitter end of the tow hawser which connects to the tow pendant is usually terminated with an end fitting such as a socket, thimble, or spliced eye. When the tow hawser is part of a tug's normal equipment, it is stowed on the drum of the tow machine, or in the case of synthetic line, in a line locker below deck. When the tow hawser is part of the tows equipment, it may be stowed on a storage drum, reel, brackets, or faked down in a tub, ready for use.

4-3.1 Wire Rope Tow Hawsers

Before the development of wire rope in the 19th century, the primary material used for towing hawsers was natural fiber line made from manila, sisal, or hemp fibers. As ships became larger, the diameter of natural fiber lines increased to the point where handling and storage became difficult. Because of its superior abrasion resistance, strength-to-weight and strength-to-size ratios, wire rope rapidly replaced natural fiber lines for tow hawsers. Wire rope was accepted for towing despite being less elastic than natural fiber lines. At first, loss of elasticity was compensated for by using long spans of hawser, where the weight of the wire rope formed a catenary in the wire and provided a measure of effective elasticity. Later, tow ships often used manila spring pendants, or "springs," in conjunction with wire rope to provide additional elasticity. Today, elastic synthetic fiber line springs are used to provide this function and are commonly used by commercial operators. Only Independent Wire Rope Core (IWRC) wire ropes are authorized for USN tows. Use of fiber core wire is not authorized for USN tows.

For wire rope in new or very good condition and used in conjunction with an automatic towing machine, a minimum safety factor of 3 is appropriate for routine short haul ocean tows where good weather can reliably be predicted for the duration of the tow (see Table 3-2). A safety factor of 4 is generally recommended for ocean tows where the automatic tow machine is used. Placing a chain pendant in the tow system can also reduce the required factors of safety on a case by case basis. Use of reduced factors of safety requires consult and approval of SEA 00C prior to use. Other conditions require higher factors of safety, as noted in the table.

4-3.2 Synthetic Towing Hawsers

When synthetic fiber line was developed for commercial applications, it began to replace manila rope for towing springs and hawsers on small tugs. Synthetic line also gained acceptance for open-ocean tows, often replacing wire rope. The elasticity of synthetic hawsers easily absorbs tension caused by random tug and tow motions.

One of the first synthetic materials to be used in towing was nylon. The Navy experienced problems when using nylon line as the peak load mitigation system. Some problems were due to nylon being weaker when wet than when dry. Consequently the use of nylon line has been restricted for:

- Open-ocean tows of less than 600 long tons displacement
- Emergency towing operations where other lines are not readily available.

- Unique or special tows approved by NAVSEA on a case-by-case basis.

NOTE
Appendix C provides the breaking strength values for synthetic line. Manufacturer's tables usually quote values for dry nylon. Breaking strength for wet nylon line is about 25 percent less than for dry line and, thus, the manufacturer's values generally must be decreased by 25 percent for towing or other "wet" uses. Wet strength reductions do not apply to other types of synthetic line.

Doubled braided polyester line is better suited for towing applications. Use of single and double braided polyester lines is authorized for all routine open ocean tows and emergency towing applications, except where otherwise dictated. The specifications of the approved polyester lines are provided in (Ref. C). All nylon tow hawsers shall be purged for all applications over 600 tons. Polyester lines should be used as replacements for all nylon lines on a size-for-size basis. Synthetic springs are discussed in Section 4-6.5.

Table 3-2 provides factors of safety for using synthetic lines as the main tow hawser. The steady state towline tension calculated in Section 3-4 shall be multiplied by the safety factor listed in Table 3-2 to obtain the required minimum breaking strength for line usage. Note the factor of safety selected depends on the tug attachment point and the degree of tension control. (Ref. C) provides data for use in evaluating one or more candidate of synthetic lines.

Smaller lines (less than 8 inches circumference), with a greater portion of their fibers exposed to abrasion and the effects of ultraviolet light and chemical attack, require higher factors of safety. Increase the factors listed in Table 3-2 by adding a value of 2.

4-4 Secondary or Emergency Towlines

Secondary or emergency towlines are required for all USN tows. The secondary towline is intended for emergency, short-term use to enable the tow to be towed to the nearest port of refuge for reestablishing the primary tow rig. The secondary towline may be of lesser strength than the primary towline (although it does not need to be).The secondary towline can be made up with synthetic line, but appropriate care must be used when rigging with synthetic line to ensure it is not damaged during deployment. If the secondary towline is of lesser strength than the primary towline, adjustment to tow speeds and weather limitations must be taken into account.

Rigging methods will vary, depending on whether the tow is manned or unmanned. Manned tows require approval by CNO. A secondary hawser is placed on the tow and is generally led down one side of the tows deck edge, rigged with a heavy messenger led outboard of the ship's structure, and terminated by a lighter floating pendant with a marker buoy trailing astern of the tow (see Figure 4 2).

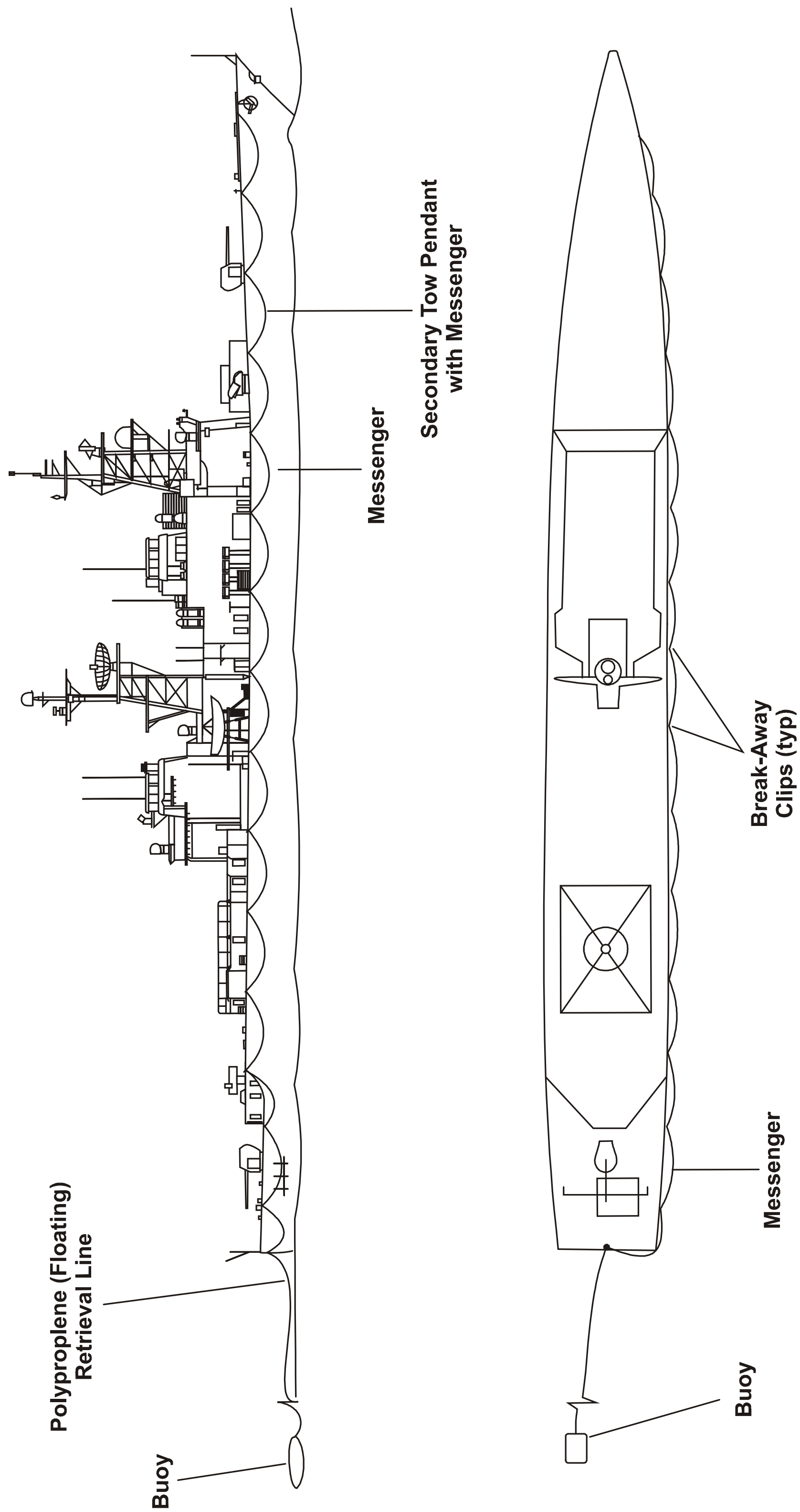


Figure 4-2. Secondary Towline System Design.

The marker buoy should be a “sausage” type float equipped with a pipe through the center of the float with a closed eye for ease of retrieval (see Figure 4-3). The installation of a swivel between the float and the messenger can help limit the likelihood of fouling while under tow. Care must be taken to mouse all connection points to ensure they do not work themselves free during the tow. This system is rigged to enable the tug to recover the trailing messenger and heaves aboard the secondary towline for connection to its towing hawser. The floating messenger should be long enough for the tug to acquire while maintaining a safe stand off distance from the tow. In most cases the floating messenger is at least 400-600 feet long. A secondary tow system can be rigged to tow from either the bow or stern.

CAUTION
Failure to adequately rig the secondary towline for deployment in adverse open ocean weather conditions can result in catastrophic loss of tow. The secondary should be designed in such a manner as to preclude having to have a man board the tow for deployment. Open ocean deployment of personnel in under less than ideal weather conditions by small boat can be extremely hazardous and may not be possible or practical in adverse weather conditions. Preparing activities frequently fail to appreciate open ocean conditions for deploying the secondary towline when installing the secondary.

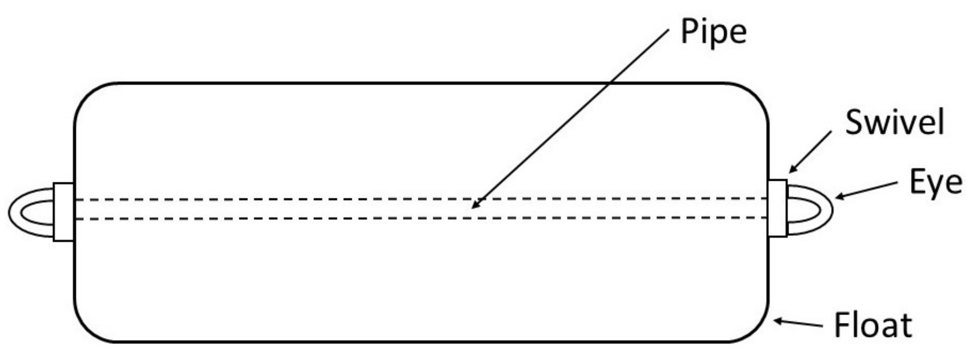


Figure 4-3. Sausage Style Float

Figure 4-4. Image of Sausage Style Float

For small tows, the primary tow pendant is rigged using the ship's anchor chain. The secondary tow pendant consists of the ship's emergency towing hawser rigged to the stern tow pad with a 200-foot floating messenger and small sausage trailing buoy. When rigging an emergency tow hawser aft, the chafing chain should be connected to the tow pad with an anchor safety shackle. Pelican hooks should not be used for these connections. For large tows or ships which do not tow well from the stern, a secondary tow hawser should be rigged from the bow and fairlead down one side of the tow, stopped off in bights, to the messenger.

CAUTION
Bights of wire hanging can be damaged or loosened if the tow goes alongside a tug or a dock.

Secondary tow wire can be secured using clips made from 3/8-inch round bar. The round bar is tack welded to the deck edge and bent up and around the wire. This allows the wire to be pulled out easily if needed. Sufficient clips should be used to exclude excessive sag and/or accidental deployment of the secondary towline wire due to its weight or accelerations generated in an active seaway. A similar method can be employed when securing chain. (see Figure 4-5). Bights can also made from small 21 thread manila line which can easily be broken when pulled. The use of synthetic line or straps on unmanned tows is not authorized as they may require cutting to deploy which would require personnel to board the tow for deployment.

Rigging a secondary towline is as much art as science. All stops should be strong enough to hold in heavy weather but light enough to be broken without damaging the secondary towing pendant or the tow during deployment. The secondary towline system shall be designed to be deployed remotely from the tug without having to place a man on the tow. It must be rigged outboard of all existing structure, including bitts and handrails, and should fall free without turns which may cause kinks in the secondary towline as they are deployed.

In all cases, a secondary towline shall be connected to appropriate hard points on the tow using the rule of threes and provided with necessary chafing protection. As a minimum for vessels above 600 Long tons displacement, the secondary towline shall be sized for a calculated steady state towline tension of Beaufort 5 and an SOA of 3 knots or greater after the appropriate factors of safety are applied.

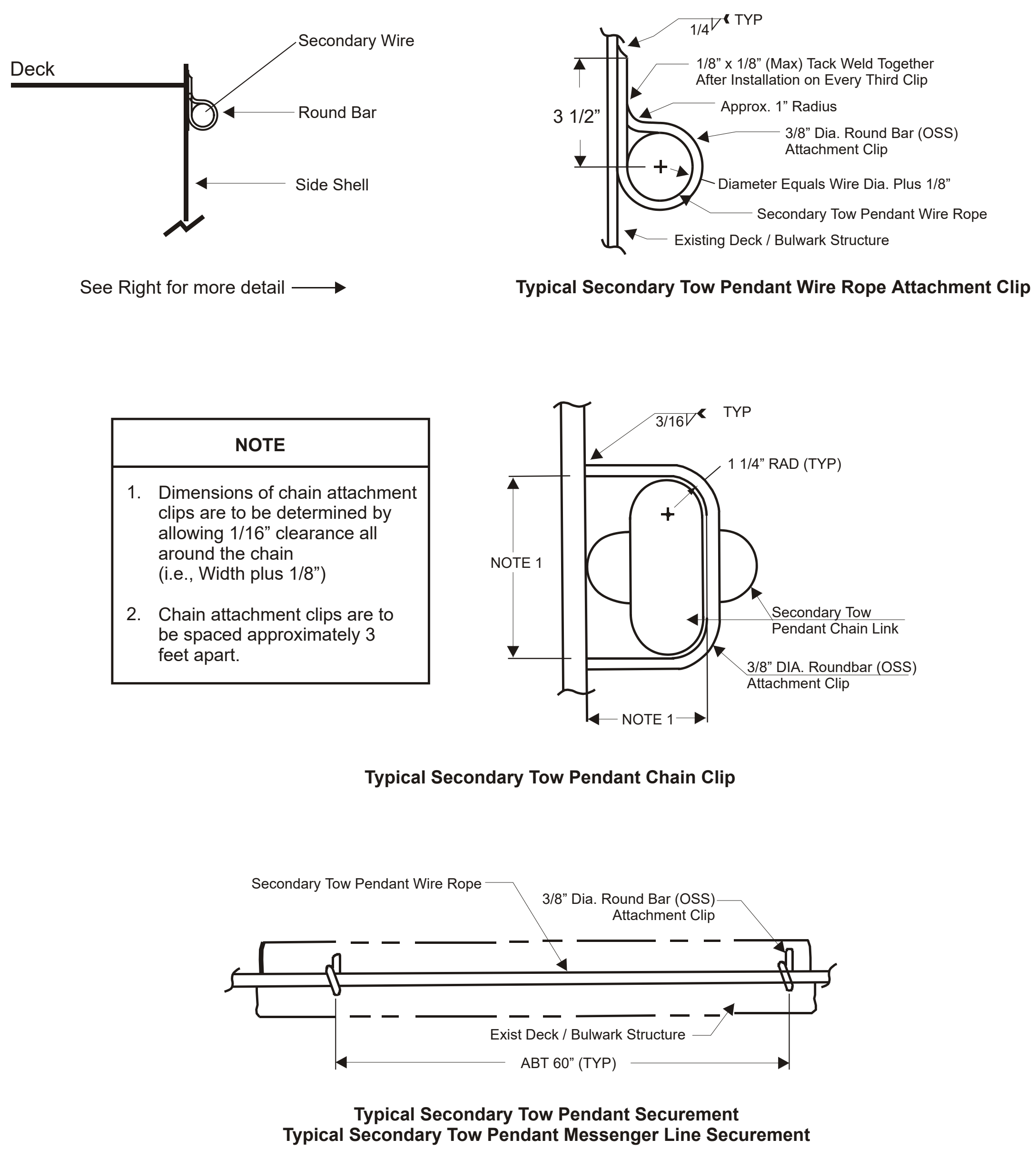


Figure 4-5. Secondary Towline System Design.

4-5 Tow Attachment Points

This section discusses various types of tow attachment points and describes the types of loading these attachment points may be subjected to. Every possible effort should be made to ensure tow attachment points are only subjected to one type of load in a known direction. Horizontal and vertical padeyes, for example, should only be subjected to forces perpendicular to the axis of the pin. See Section 4-5.3 for more information.

Tow attachment points on tugs and tows transmit the tow strains from the towline to the vessel. Attaching the tow system is of vital importance and must be given careful consideration with regard to seamanship, rigging, and basic engineering mechanics.

Towline attachment points on U.S. Navy tugs are the tow machine and/or traction winch foundations.

Tow attachment points may be a hard point specifically intended for towing, such as deck padeyes, chain stoppers, or specialized towing brackets, although most ships do not have specific attachment points specifically designed and fitted for towing. Some commercial ships are not designed to be towed, or the tow attachment is located somewhere other than originally designed. Often attachments require use of fittings or gear intended for other purposes, such as single point mooring (SPM) fittings, bitts, anchor chain holding fittings, gun turret foundations or the tow's anchor chain. Sometimes, for planned tows, a new attachment point such as a SMIT towing bracket or additional pad eyes will need to be installed. All towing attachment points shall be Non Destructively Tested (NDT). NDTs shall include visual inspections of the attachment points and surrounding areas, dye-penetrant testing or magnetic particle testing of all welds securing the attachment points to the deck. If there is any doubt about the strength of the padeye or attachment point, further testing and/or repairs are required.

For an emergency tow, a makeshift connection, such as a heavy chain wrapped around a strong foundation, may be used. In every case, the material condition of the fittings and structures should be carefully inspected.

For deck fittings designed specifically for towing, operators may assume appropriate engineering has been performed, if these fittings pass the NDT inspection. If the attachment point is inadequate or does not exist, it must be designed, fabricated, and installed to meet the calculated steady state towline tension with the applicable factors of safety. Preparing activities must ensure appropriate engineering analysis has been performed to ensure a safe connection. Tow attachment points need to be located in such a manner to ensure tow strains are transmitted to the ships structure. This may require the use doubler plates under the tow attachment points to tie into ship frames and or stringers.

When locating and installing tow attachment points it is important to consider the need for an integrated attachment point and fairlead system. The fairlead ensures the tow load is applied in the designed direction, i.e., not side loaded. Therefore, attention needs to be paid to both the tow attachment point and the fairlead. A common failure of the tow attachment system involves gross structural failure of either the tow attachment point or the fairlead. This problem is especially relevant when towing minecraft, non-oceangoing craft, wooden, aluminum, or fiberglass vessels. Fairleads on these types of vessels may not be strong enough to withstand towing strains.

Factors of safety for tow attachment points should be designed and built in accordance with the General Specifications for Overhaul of Surface (GSO) Ships, U.S. Navy, Sections 582 and 077, Naval Sea Systems Command, S9AA0-AB-GOS-010/GSO (Ref. D). The generally applied criterion is the breaking strength of the towline should not exceed 35% of the padeye, bitt, or cleat yield strength.

4-5.1 Tow Winches and Tow Machines

Although wire rope is easier to handle than wet manila line of equal strength, it cannot be faked out on deck during haul in. Powered tow winches and tow machines are used for in-haul and provide storage for wire rope hawsers, eliminating the use of bitts and hooks.

All U.S. Navy tugs are equipped with Automatic Towing Machines (ATMs). The T-ARS Class is equipped with Almond Johnson ATMs while the T-ATF Class is equipped with a hybrid ATMs which are modified SMATCO towing winches. The modified SMATCO towing winches are more labor intensive to operate. The T-ATS Class towing machinery is made by MacGregor.

The principal functions of tow machines are:

- Act as a hard point or attachment point for securing the towline to the tug.
- Pay out and heave in the towline during towing operations.
- Stow the towline as it is heaved in.
- Act as a quick-release device for disconnecting a towline if necessary during an emergency.
- Act as an automatic tension control device to limit or relieve peak dynamic loads in the towline system, thereby enhancing the life and utility of the equipment, increasing maximum speed, and increasing safety.
- Monitors and displays tow hawser conditions such as tension and scope of towline paid out.

Tow machines have a power-driven drum which serves as an attachment point and stores unused portions of the wire rope tow hawser. The powered drum is used to manage the amount of tow hawser paid in or out to assist the tug in controlling the tow. The ATM has an automatic control system which automatically pays out the towline when tensions exceeds preset tension settings. The preset tension settings for the ATM are determined as part of the tow system design and planning to manage tow strains. The ATMs on USN tugs act in a similar manor as the drag on a fishing reel, when the preset tension setting is exceeded the machine pays out wire to reduce the tension and add catenary. More sophisticated ATMs also have an automatic reclaim or haul in feature, which hauls in the amount of towline paid out under peak loading conditions when the hawser tension decreases to preset levels. This automatic haul in feature is not available on USN tugs therefore the wire needs to be recovered by the winch operator. Towing machines and winches also have a free-spooling feature which serves as a quick disconnect system for allowing the towline to run off the drum in the event the tug is forced to dump its towline due to fouling of the tow hawser or the tug is in jeopardy. The ATMs installed on the T-ARS class are equipped with a mechanical shear pin set to fail at 50,000 lbs, which allows the ATM to free wheel in the event of excessive shock loading on the ATM to prevent stripping the ATMs transmission. Care must be used when paying out or retrieving towlines on these ships to prevent accidental shock loading which may break the mechanical shear pin. Faulty mechanical shear pin spares had been procured by the Navy supply system and have since been purged from the system. If there is any doubt as to the quality of replacement shear pins contact SEA 00C for additional guidance and consultation.

Synthetic fiber line towing hawsers used by the Navy are handled by multi-sheave traction winches (see Appendix Figure L-1). In addition to providing a hard point for the towline attachment, the winch has payout and heave-in features for adjusting the towline scope. Reel-type storage is not practical for synthetic towlines, therefore these hawsers are fairlead into a stowage bin located below decks as it comes off the traction winch. Some traction winches are equipped with automatic controls, which pay out hawser to relieve high towline tensions. This automatic pay out feature does not provide automatic reclamation of the towline after peak loads have been relieved. Periodic heave-in, under manual control, may be required to maintain the desired towline scope. Traction winches for wire hawsers are often found on larger commercial tow ships.

Most towing machines and winches have a “dog” system which locks the drum and prohibits tow line payout. A dog is a pawl or ratchet type system which cannot be released under tension. When towing “on the dog,” the towing machine must be started up, engaged, and the hawser heaved in slightly to release the dog. Therefore, when towing on the dog, there is no quick-release capability. Factors of safety for towing on the dog or pawl are higher than for other methods of towing and can be found in Table 3-2.

Refer to (Ref. L) for a more complete discussion of U.S. Navy towing machines and winches.

4-5.2 Bitts

A bitt is a strong post used for belaying, fastening, and working ropes, hawsers, and mooring lines. Bitts usually appear in pairs and are named according to their use.

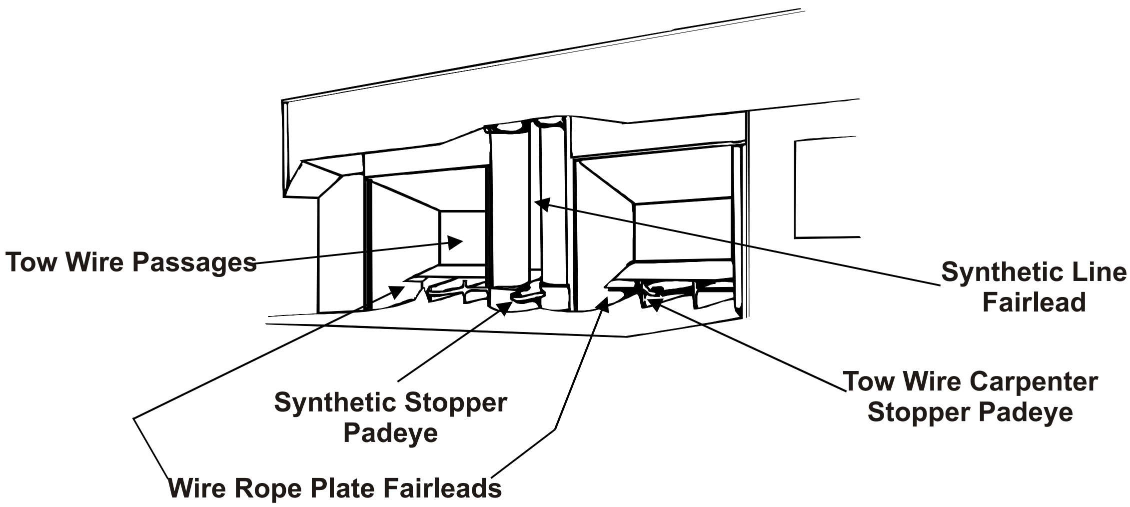
NOTE
Unless specifically designed, bitts are generally not suited as towing attachment points and are not in the proper position to be used as towing fairleads.

The term bollard is occasionally applied to bitts, but more commonly is applied to pier fittings used for securing mooring lines.

Bitts on U.S. Navy ships are designed to withstand a load equal to at least three times the breaking strength of the line they were designed to hold. See Section 6-2.6.2 for the safe working loads of specific design strengths of U.S. Navy bitts.

Towing or H-bitts are heavy steel castings or weldments secured to the ship’s structure (see Figure 4-6). Generally located near the tug’s pivot point, they provide a hard point which sustains athwartship loads imposed by a towline when it sweeps the fantail. In tugs fitted with towing machines, the H-bitts are used to fairlead the main tow hawser to the drum to prevent transverse strain on the level wind mechanism and are used to stop off the tow wire when necessary. On the T-ARS 50, the function of the H-bitts is integrated into the deckhouse structure.

Under normal towing conditions, using the H-bitts for holding the hawser is not recommended; such use is usually restricted to debeaching operations or other instances when isolating the towing machinery from hawser tension is necessary.



Aft End of ARS 50 Towing Machinery Room Looking Forward

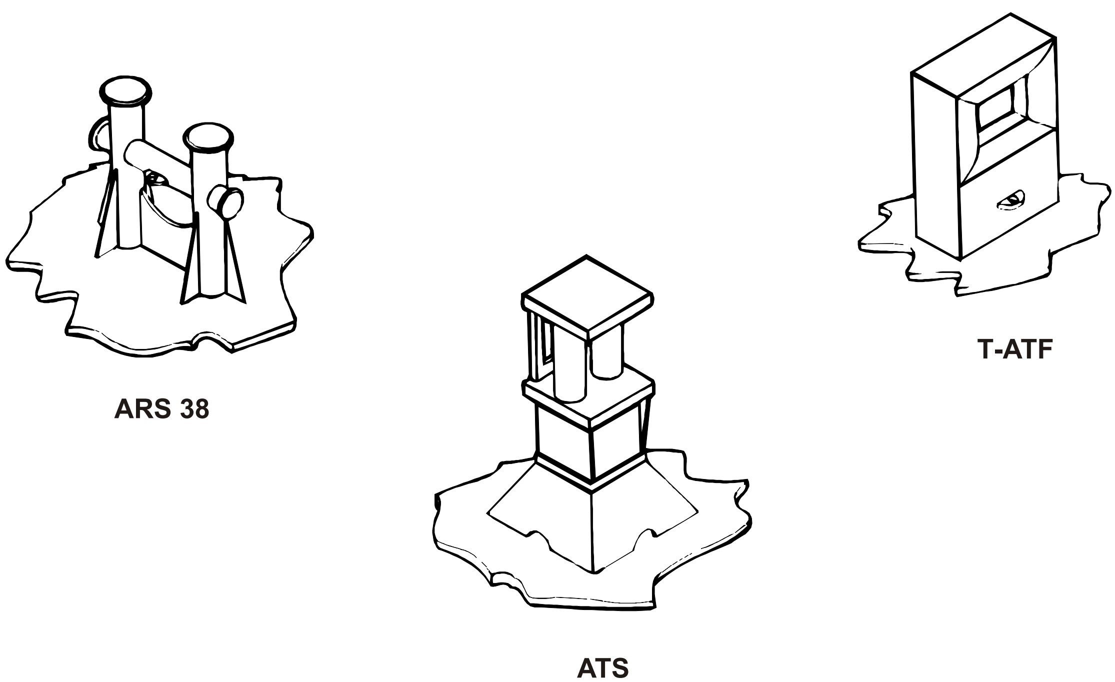


Figure 4-6. Aft End of ARS 50 Towing Marchinery Room and Typical Towing Fairleads / Bitts.

4-5.3 Padeyes

The most frequent means of attaching a towline to the towed vessel is by means of a padeye. Three distinctive types of devices are collectively referred to as padeyes. Personnel rigging the connection must understand their design features. The three types of padeyes found in towing are:

- Horizontal padeye
- Vertical free-standing padeye
- Towing bracket

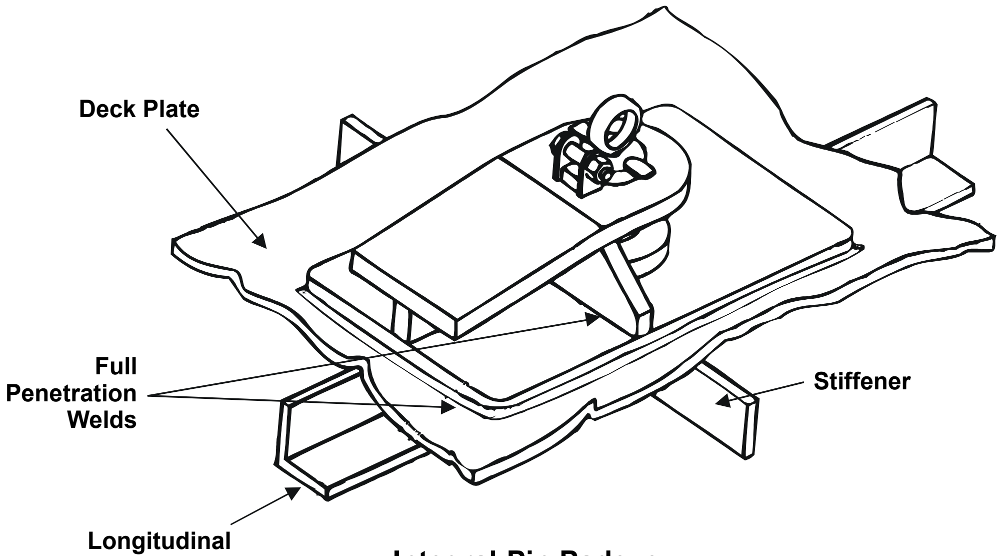
Figure 4-7 shows two different styles of horizontal padeyes. Their distinctive feature is that the pin has a vertical axis. The towline, therefore, is free to sweep in the horizontal plane, while constrained in the vertical plane. There are two types of horizontal padeyes in use today.

- The integral-pin type comes with its own pin, with the female threads located in the base plate of the padeye (see Figure 4-7, upper sketch). A locking device prevents pin rotation. This style padeye has a lower profile, so the moment arm of the towing load is correspondingly lower to the deck. This allows for lower loading moments and eases the design of the structure. Additionally, the integral-pin padeye allows the open or end link of a chafing chain to be pinned directly to the padeye, requiring no additional connecting jewelry.
- The shackle-style padeye is located on the forecastle of most U.S. Navy vessels (see Figure 4-7, lower sketch). It is the standard fitting for attaching chain stoppers to the forecastle deck. When using horizontal padeyes, there is often insufficient space to accommodate the bolt of a safety shackle due to the padeye's low profile design. Therefore, U.S. Navy chain stoppers are provided with a specially forged, screw pin shackle which is appropriate for use in a towing rig. Chain stoppers and their associated padeyes are nominally designed to 60 percent of the anchor chain's breaking strength and are generally used in groups of three. That is, three chain stoppers are used per chain pendant. Missing chain stoppers can be an issue when towing ships that have been inactivated for long periods of time as they tend to be cannibalized to support active ships. The strength of chain stoppers and their associated padeyes must be considered when using them as components in a towing system. Therefore, the chain stopper locking mechanism needs to be carefully inspected for cracks or other deformities, and the chain needs to be measured and sounded per Mil-STD 582 to ensure it is within specifications.

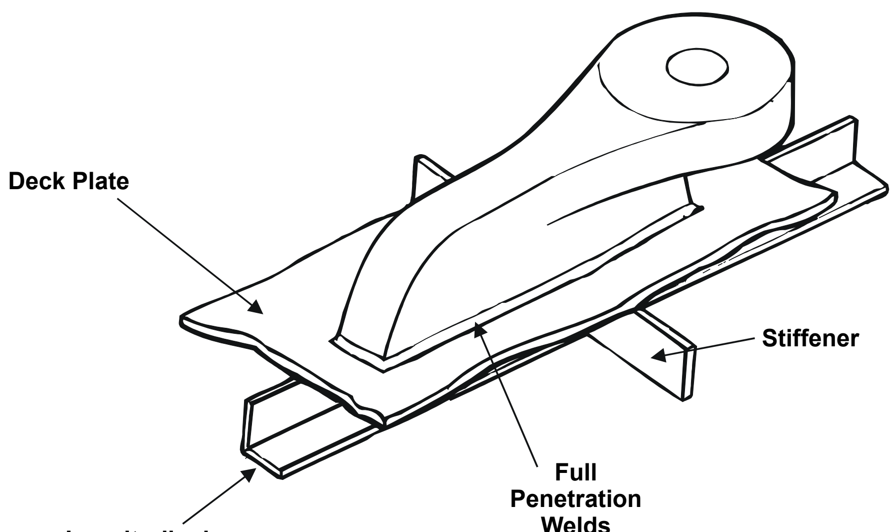
The vertical free-standing padeye comes in two basic designs as shown in Figure 4-8. The difference is in the shape of the eyehole. The eye of a shackle-pin type padeye is a cylindrical hole through the plate designed to accept the pin of an anchor safety type shackle. In the dipped-shackle type padeye, the hole is elongated and the bearing area of the hole is rounded so that the bow of the shackle can properly bear against the end of the slot. In this case, the shackle's pin is presented to the chafing pendant.

The vertical free-standing padeye is less resistant to lateral loads than the horizontal padeye. The free-standing padeye must be used with a towing fairlead strong enough to withstand the lateral loads of the towline, to minimize the risk of tripping the padeye. The width of the shackle-pin type padeye plate should occupy 75 to 80 percent of the jaw width of the shackle, to prevent it from racking and creating loads that tend to open the jaw of the shackle. In these cases the size of the connecting shackle should be reconsidered or hard steel shims added to reduce clearances to less than 1/16 of an inch.

The vertical free-standing padeye attachment point may be located at a higher point than a horizontal padeye. This generates higher loading moments on the structure. When using this type of padeye the padeye should be inspected to ensure it is tied into sufficient structure to transmit the tow strains to the tow, in some cases this may be by the means of doubler plates. If properly designed this design does not present any disadvantage over standard horizontal padeyes.



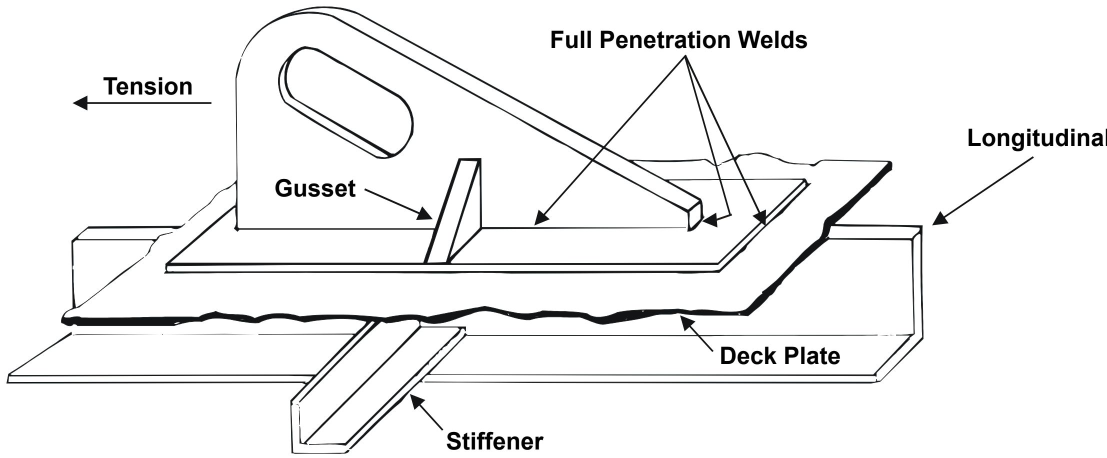
Integral-Pin Padeye



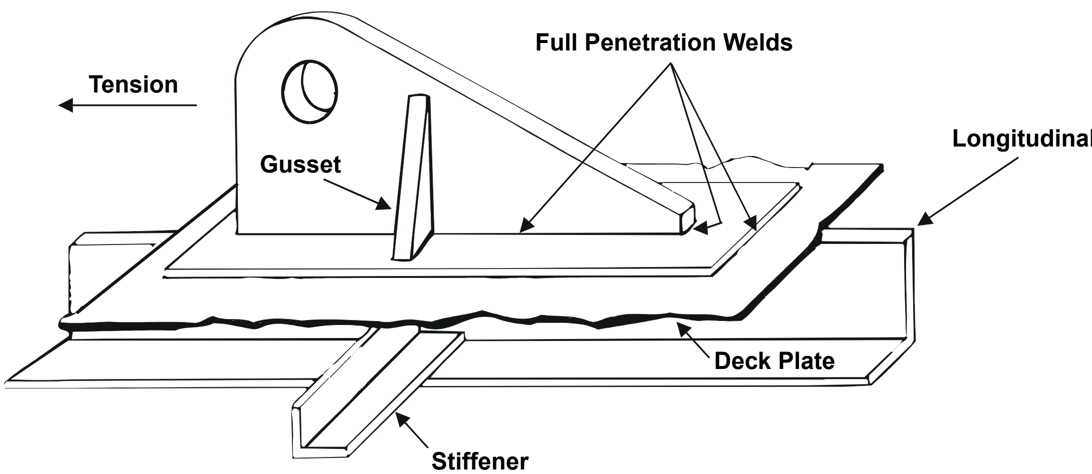
Chain Stopper Padeye

CAUTION
Chain stoppers are designed to bear only 60% of the breaking strength of the chain. Chain stopper pad eyes should, therefore, not be used as a single attachment point for pendants or bridles. They should be used only as attachments for chain stoppers.

Figure 4-7. Horizontal Padeyes.



Dipped-Shackle Type



Shackle-Pin Type

Figure 4-8. Vertical Free-Standing Padeyes

CAUTION
If time and the situation permit, a detailed analysis of the padeye and connection should be made to avoid unexpected failure of either.

4-5.4 Padeye Design

Figure 4-9 provides acceptable padeye design for situations where no suitable connection points exist. Using the calculated maximum allowable steady state towline tension determined from the results of the calculations in Appendix G and a specific plate thickness, the chart provides the minimum hole diameter and the minimum distance from the hole to the edge of the plate. Given the same predicted tension and a specific thickness for the continuous fillet weld, the chart also determines how long the padeye must be.

To design a padeye using this chart, follow these steps:

a. Use the maximum allowable steady-state towline tension determined from the results of the calculations in Appendix G. In Figure 4-9, this number is called the load or force (F). Locate this level using the numbers on the far right-hand side of the chart.

b. Choose a particular plate thickness (t). Each thickness is represented by a solid diagonal line. These lines are labeled in the lower left-hand side of the chart. Find the point where the plate thickness (t) intersects with the predicted load (F).

c. To find the minimum hole diameter (d), draw an imaginary line from the intersection point straight up to the top of the chart. The diameter measurements are displayed across the very top of the chart.

d. To find the minimum length from the hole to the edge of the plate, find the point where the diameter measurement (d) intersects with the broken diagonal line that appears in the upper left-hand portion of the chart. Look on the right-hand side of the chart to find the minimum distance to the edge (L). This minimum distance applies in all directions around the hole, including above and below.

e. To determine the minimum length for the padeye, choose a particular thickness for the continuous fillet weld (T). Each thickness is represented by a dashed diagonal line. These four lines are labeled on the bottom of the chart on the right-hand side. Find the point where the thickness (T) intersects with the predicted load (F). To find the padeye length (l), draw an imaginary line from the intersection point straight up to the top of the chart. The length measurements are displayed across the very top of the chart and are expressed in inches.

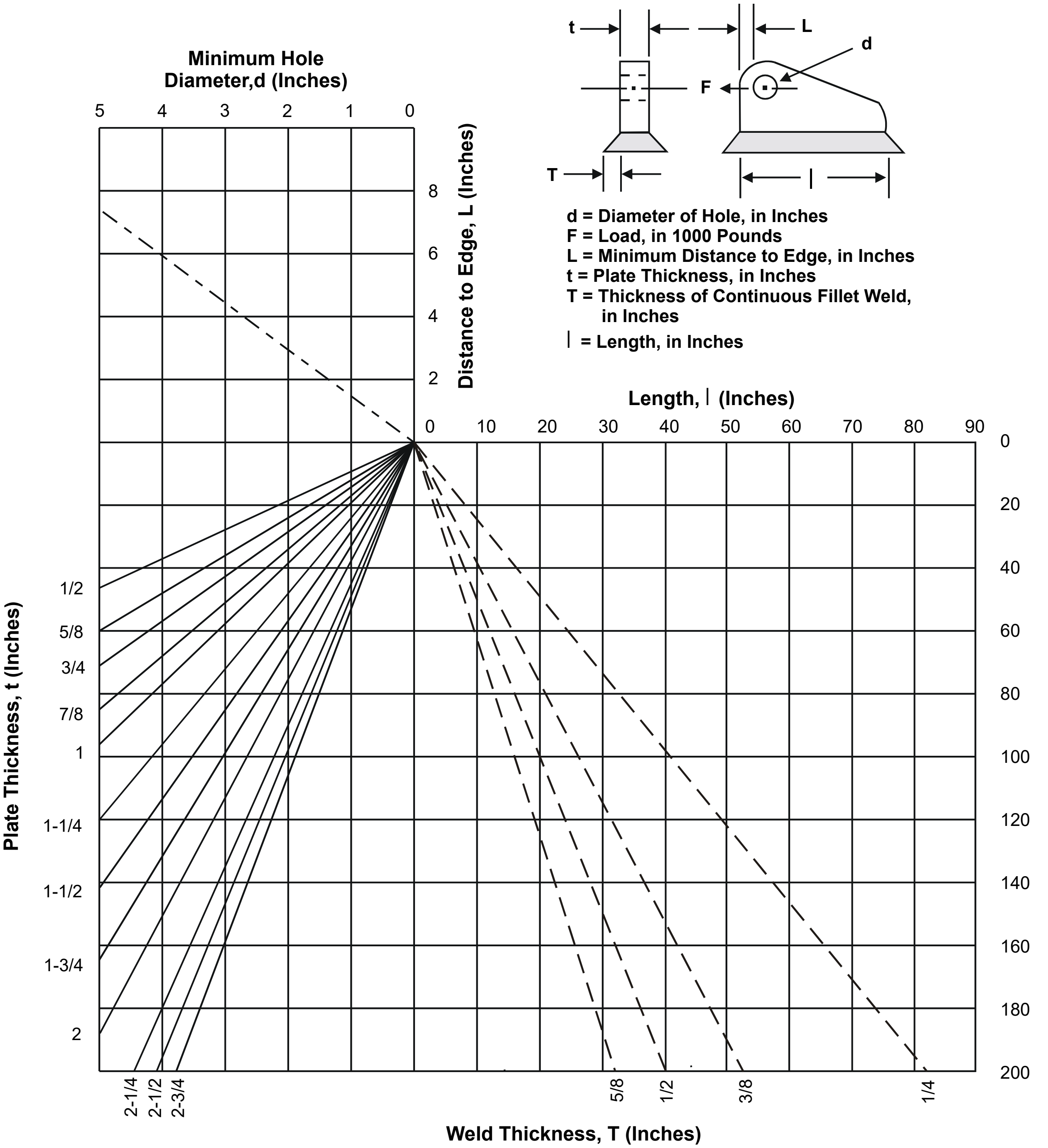


Figure 4-9. Minimum Padeye Design Requirements.

Padeye Design Example

For example you are tasked with planning a tow using an automatic tow machine with a new towing hawser. Per your calculation results from Appendix G, you estimate the towline tension (F) to be 80,000 pounds and the maximum plate thickness (t) available to fabricate a towing padeye is 1 1/2 inches. Determine the diameter (d) of the hole required and the distance (L) the hole must be from the leading edge of the plate. By using Figure 4-9 we can determine the diameter (d) of the hole required. Entering the left side of Figure 4-9 find the line corresponding to the plate thickness (t). Trace the line upward until it intersects with the estimated towline tension of 80,000 pounds from the right side of Figure 4-9. Draw a line vertically from this intersection to the top of Figure 4-9. Where this line intersects the top of Figure 4-9 determines the minimum hole diameter (d). In this case, a minimum hole diameter (d) of 2 3/4 inches is required. We can also determine the minimum distance from the leading edge of the hole to the edge of the plate (L) by using the vertical line previously drawn and determining where it intersects with the dashed diagonal line crossing the top of Figure 4-9. Going right from this intersection to the right of Figure 4-9 determines the minimum distance to the edge of the plate (L). In this case the minimum distance (L) to the edge of the plate is 4 inches. Assuming the fillet welds are 1/2 inch thick (T), what length (l) padeye is required? We can determine the length of the padeye by finding the line on the bottom of Figure 4-9 that corresponds to the weld thickness (T). Trace this line upward to the left until it intersects with the estimated towline tension from the right of the figure. Draw a vertical line from the intersection to the top of Figure 4-9. Where this vertical line intersects the top of the figure determines the minimum distance to the edge of the plate (L). In this case the minimum distance to the edge of the plate (L) is 16 inches.

The example is satisfactory for 80,000 pounds of tension. To verify the hole is of sufficient size, check the size of the shackle required. If an automatic tow machine is used, Table 3-2 shows a factor of safety of 3 is required or a 240,000-pound proof-load shackle (2 1/4-inch Grade B shackle). The pin for this shackle is 2 1/2-inches thick and will just fit the hole in the padeye. If the tow were to be performed without an automatic towing machine, but with a chain pendant, Table 3-2 would require a shackle factor of safety of 4. Appendix D and Tables D-7 through D-9 show that the minimum required Grade B shackle size is 3 inches, with a 3 1/4-inch pin. The 1 1/2-inch available plate can be used with a larger hole, taking care to maintain the minimum distance to the edge of the padeye (L) required by the load and plate thickness

CAUTION

This method yields a design with a minimum factor of safety of 3 for all failure modes. For a stronger padeye, use a higher assumed load. For instance, if a padeye with a failure load of 100,000 pounds is desired, use 300,000 pounds as the design load. The below-deck structure must be checked or altered to transmit the tow strains to the ship's structural members; this may require adding douber plates or structural I-Beams. Simply welding the padeye to the deck plating will most likely result in catastrophic failure resulting in tearing the padeye from the deck and losing the tow.

4-5.5 Deck Structure

When designing and locating padeyes, it is extremely important to examine the below-deck structure. Towing padeyes produce large localized loads which cannot be supported by deck plate alone. It is necessary to locate padeyes atop both longitudinal and transverse members to adequately distribute loading to the surrounding structure, particularly if the padeye is likely to be subject to side loads. The longitudinal member should be aligned directly under the main plate of the padeye. The transverse member location is somewhat less critical but should be located as close to the padeye as possible, preferably directly underneath.

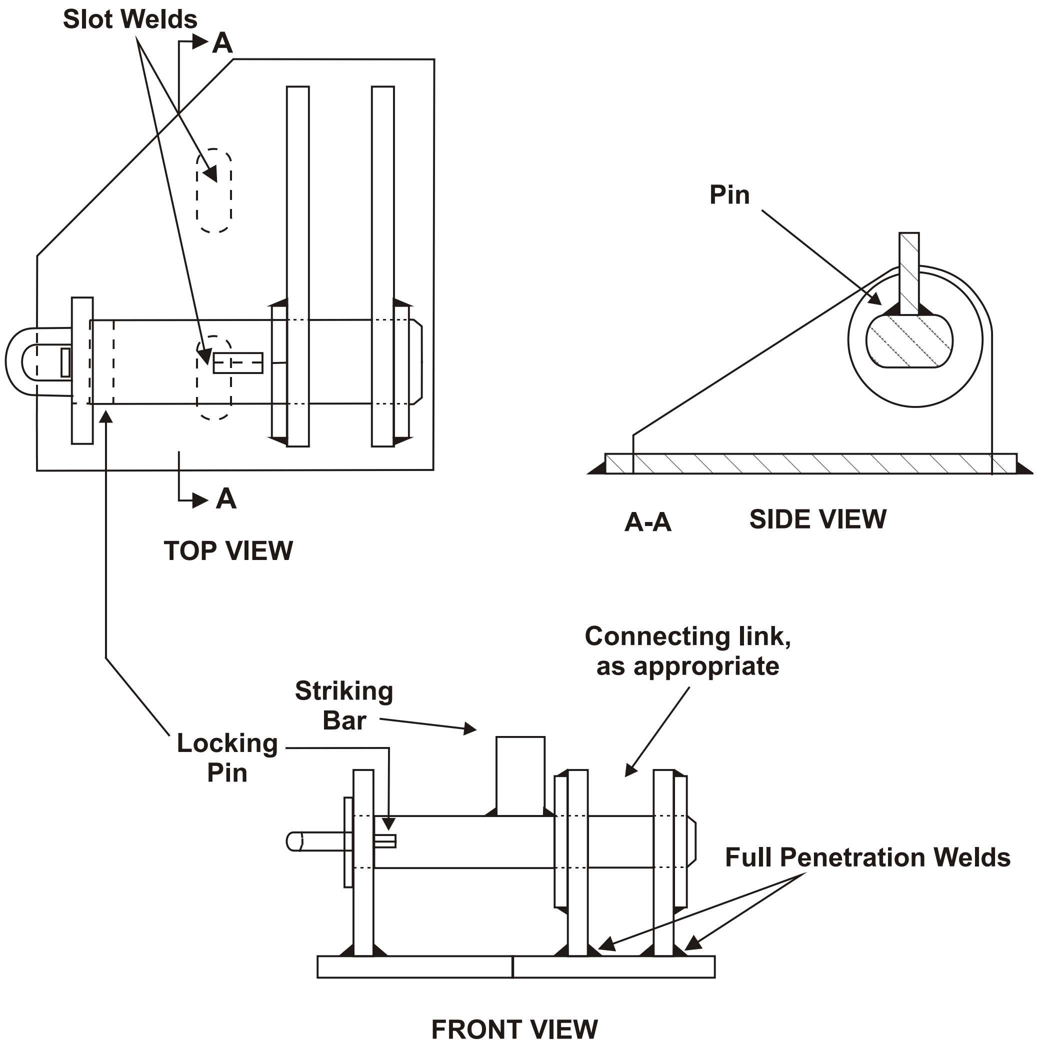
4-5.6 Smit Towing Bracket

The Smit Towing Bracket consists of two vertical plates, similar to a pair of free-standing padeyes, with an elliptical pin fitted between them (see Figure 4-10). The pin is fitted with a keeper key or locking pin and can be released in an emergency. The principal advantage of the Smit Towing Bracket is the ease of breaking the tow connection even under significant load. This is accomplished by removing the locking pin and driving the striking bar to port with a sledge hammer, allowing the main pin to slide out of the pear-shaped link. This design does not use shackles. This style of towing attachment, like the vertical free-standing padeye, is susceptible to tripping loads and is dependent upon the fairlead chock. When releasing chain for use in a Smit Towing Bracket the chain should be lowered in bites vice allowing it to run free, as free running chain can damage the bracket decreasing its load bearing capacity.

The standard Smit Bracket design is manufactured in two sizes. The larger size will accept the standard end link of a 3-inch chain. Smaller chains will require a large safety anchor shackle or a pear shaped link.

The smaller standard size Smit Bracket is designed to accept the end link of 2-inch chain, or the common link of 2 3/4-inch chain.

Sometimes the Smit Bracket design is adapted to other dimensions. In all cases, the dimensions must be checked carefully to ensure that properly sized jewelry is available to make the connection.



Caution
Chain smaller than about 3-1/4" will require a pear shaped link or an anchor shackle to connect to the standard Smit Bracket. Check dimensions carefully.

Figure 4-10. Smit Towing Bracket.

4-5.7 Towing Hooks

Tow hooks are rarely used in the United States, but are common on foreign tugs, especially European tugs. They are heavy steel hooks mounted on vertical pins which allow them to swing. Each hook is shock-mounted by using a heavy compression spring and fitted with a quick-release device for tripping the hook, much like a chain stopper. The compression spring provides a small amount of dynamic load relief for the towline system.

4-5.8 Fairleads

Fairleads are used to lead mooring lines around obstructions and align them properly with winches or capstans. Fairleads are located to accommodate lines from both sides of the ship. Fairleads may have rollers to reduce line wear. Use of roller fairleads for towing is not recommended as they are not designed to withstand the magnitude of towing strains.

4-5.1 Chocks

Most tows are rigged on the forecastle. Whether using a bridle arrangement or a single point connection, the selection of the point where the towline (or bridle legs) crosses the deck edge is critical to protect both the towline and the towed ship's structure. These robust points include bullnoses, closed chocks, and roller chocks with a generous radius (see Figure 4-11). Planned tows often will involve installation of a special fairlead, due to the radii of the chocks or other fittings being designed for mooring. Generally, most mooring chocks are not sufficient for towing. Use of closed chocks with pinned connection points are not authorized for navy tows (see figure 4-??). Emergency tows must make do with what is available, understanding that structural damage to the tow due to towline chaffing is probable. In this case, the towline component crossing the deck edge will usually be chain, heavier in size than otherwise would be required for calculated steady state tow strains alone.

When passing wire or synthetic pendants through these chocks, the chocks need to be inspected for sharp edges or irregularities as these imperfections will tend to damage the wire or the synthetic line. When passing chain through these chocks the dimensions need to be carefully checked to ensure the chain will fit.

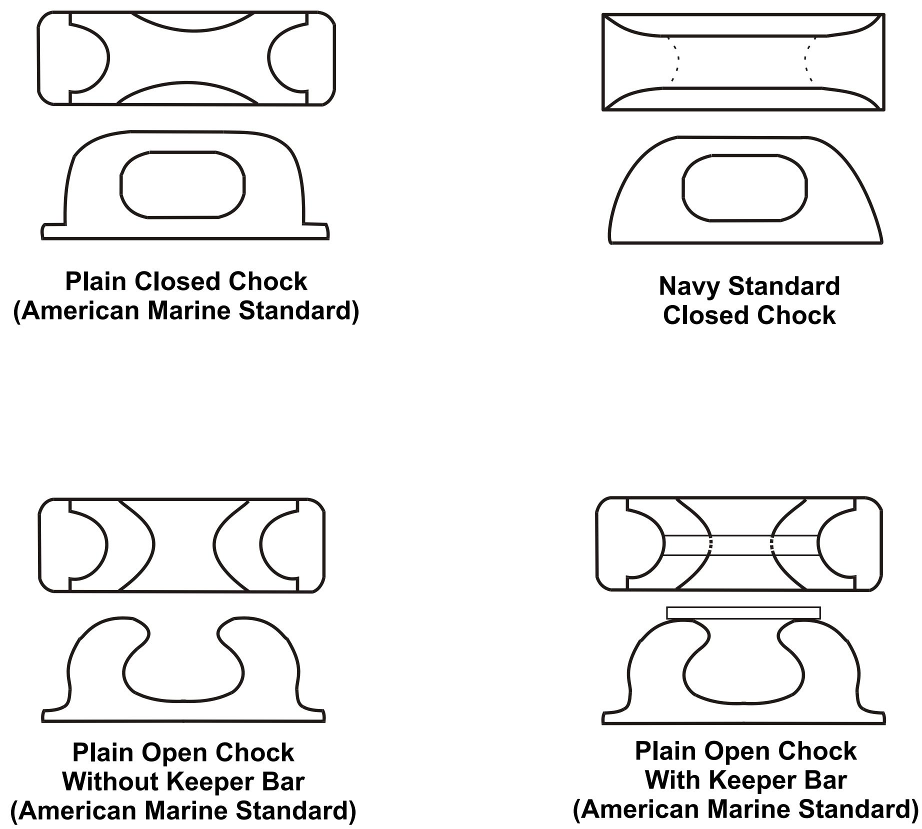


Figure 4-11. Types of Chocks.

4-6 Connecting Hardware (Jewelry)

Connecting hardware or towing jewelry used to rig the tow system include shackles, detachable chain links, special fittings such as flounder plates, splices and end terminations for wire and synthetic lines. Tow jewelry is used to connect the various towline system components to each other and the tow (see Figure 4-12 through Figure 4-16). Components of different sizes are connected by using offset plate shackles and detachable pear-shaped chain links.

4-6.1 Shackles

General purpose Navy shackles are described in detail in Federal Specification RR-C-271D, Amendment 1, Chain and Attachments, Welded and Weldless (References D and E). There are two types, two grades, and three classes of shackles. Of these twelve categories, only four can be used as towline connectors. These are as follows:

- Type I Anchor Shackles

Grade A - Regular

Class 3 - Safety Bolt and Nut

- Type I Anchor Shackles

  Grade B - High Strength

  Class 3 - Safety Bolt and Nut

- Type II Chain Shackles

  Grade A - Regular

  Class 3 - Safety Bolt and Nut

- Type II Chain Shackles

  Grade B - High Strength

  Class 3 - Safety Bolt and Nut

Examples of chain and anchor shackles are shown in Figure 4-12.

CAUTION
Special forged shackles, when used with chain stoppers and carpenter stoppers, use carefully machined screw pins and are permissible in towing. Such pins must remain accessible for inspection and service while in use.

Navy shackles are permanently and legibly marked in raised or indented lettering on the shackle's body identifying the manufacturer's name, trademark, shackle size, and recommended Safe Working Load (SWL). SWL of both Grade A and Grade B Navy safety shackles is suitable for sizing hardware for lifting purposes. However, SWL cannot be used for towing. Shackle proof loads must be used vice SWL. Only forged shackles are allowed for Navy tows. Cast components are not authorized for USN towing. Recommended factors of safety listed in Table 3-2 and Section D-14 describe appropriate methods for sizing shackles for towing. Certificates of compliance stating the shackles break strength and proof load must be supplied as part of the comprehensive tow package. The certificates of compliance must be traceable to the specific component depicted on the tow sketch provided in the Comprehensive Tow Package (CTP).

CAUTION
Screw-pin shackles, other than the special forged shackles for stoppers, must never be used for connections in towing rigs. The pin could back out due to the constant vibration set up by the hydrodynamic actions on the towline.

Although screw-pin shackles are a commonly used type of marine shackle and afford a quick and simple means of connecting and disconnecting, screw pin shackles are not authorized when making connections in Navy tow rigs. Due to the cyclic loading, excessive vibration, and alternating athwartship movement coupled with the towline surges may cause screw pin shackles to become undone.

CAUTION
Shackles and other fittings frequently come with cotter keys or pins. Cotter keys are not authorized for towing. Replace cotter keys with locking bolts with two jam nuts. The head of the locking bolt and the jam nuts shall be appropriately sized to ensure the head and shoulder of the locking bolts and the jam nuts are in contact with the safety shackle nut .The locking bolt can be peened over if desired.

CAUTION
Never weld on forged steel shackles. The welding process can weaken the shackle.

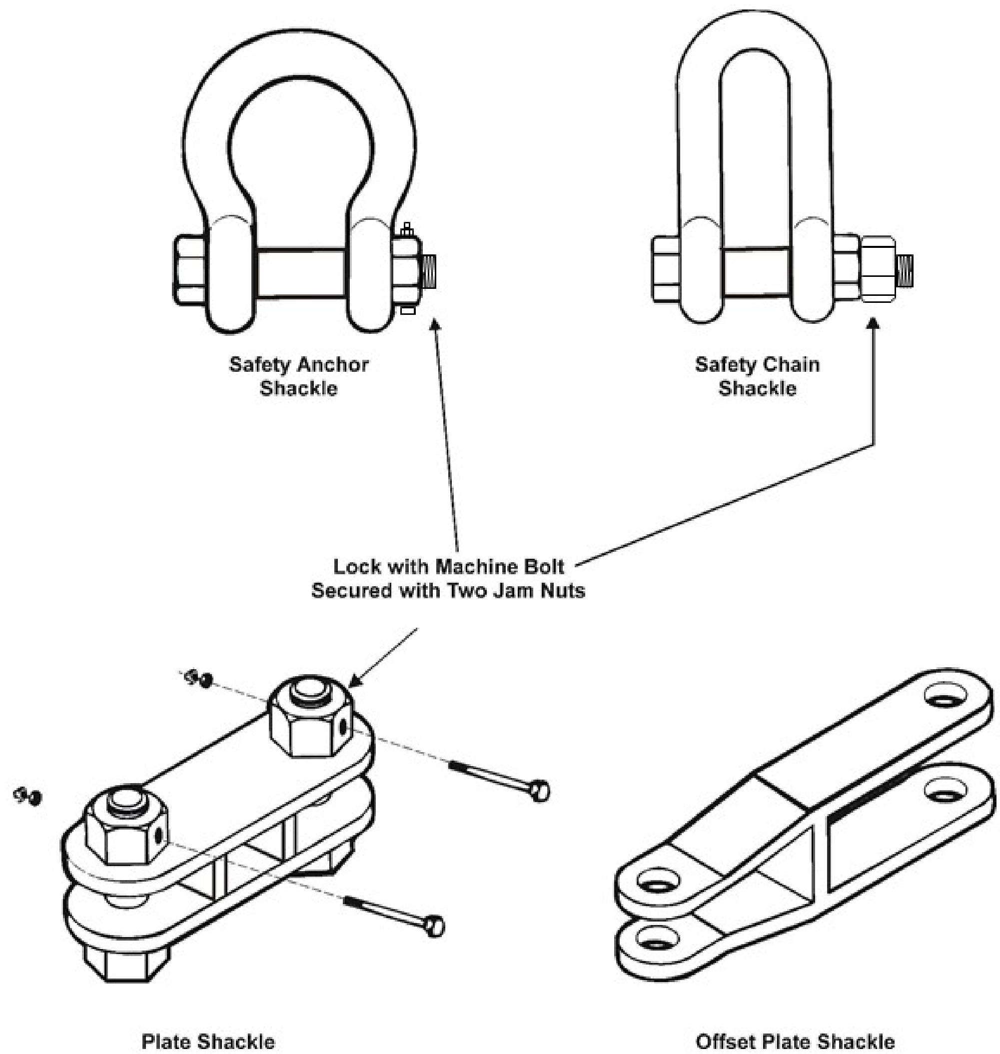


Figure 4-12. Shackles.

Navy shackles are made of forged steel; welding to these forged steel shackles reduces the strength of the shackle by as much as 30 percent, therefore shackles shall never be welded on, nor shall pins be secured by welding. The nuts on safety shackle pins must be secured by a minimum of a 5/16 machine locking bolt, with two jam nuts. Cotter pins are not authorized for this connection. Peening over the locking bolt is also good towing practice. The bolt must be appropriately sized to ensure the head of the locking bolt and the jam nuts are in contact with the nut of the safety shackle. The locking bolt should be snug without any play. If changing out or breaking the shackle connections are anticipated during the tow, additional properly sized locking bolts should be placed on board prior to getting underway.

4-6.2 Other Connecting Links

Passing a safety shackle through the opening in a link of chain or closed wire socket can be problematic. Cutting the center stud out of the end link of chain to facilitate this connection is not authorized for Navy tows. Alternative connecting devices when rigging chain and wire pendants, bridles, etc, include:

- Plate shackles (see Figure 4-12)
- Detachable links (Navy and Kenter type)
- Detachable anchor connecting links (pear shaped or detachable end link)

Plate shackles shown in (Appendix Figures I-14 through I-18) are commonly used to make connections to flounder plates and to connect chain and wire pendants.

Detachable links are similar in shape to chain links, but can be disassembled into several pieces (see Figures D-1 through D-2) and are secured with a hairpin. This allows the link to be used as a connection between chain and other components. Pear-shaped links have one end which is smaller than the other; they are used to attach components of different sizes.

CAUTION
Never weld detachable links. The welding process can weaken the links.

NOTE
When inspecting chain, inspect the detachable links to determine whether they have been properly assembled. The key slot must be in the proper place and the match marks must be identical and matched. This is necessary because detachable links are hand-fitted to ensure proper assembly and full strength. All assembled links should be visually inspected and sounded and connected with a hair pin.

Welding detachable links closed to assure security of the towing rig is not authorized for Navy tows. It is much safer to use a hairpin for securing the tapered pin in detachable links. This ensures that the link will not come apart and simplifies the eventual disassembly and re-use of the link. Use of detachable links without hairpins is not authorized for Navy tows. Details for modifying detachable links for use with hairpins are contained in (Ref. D).

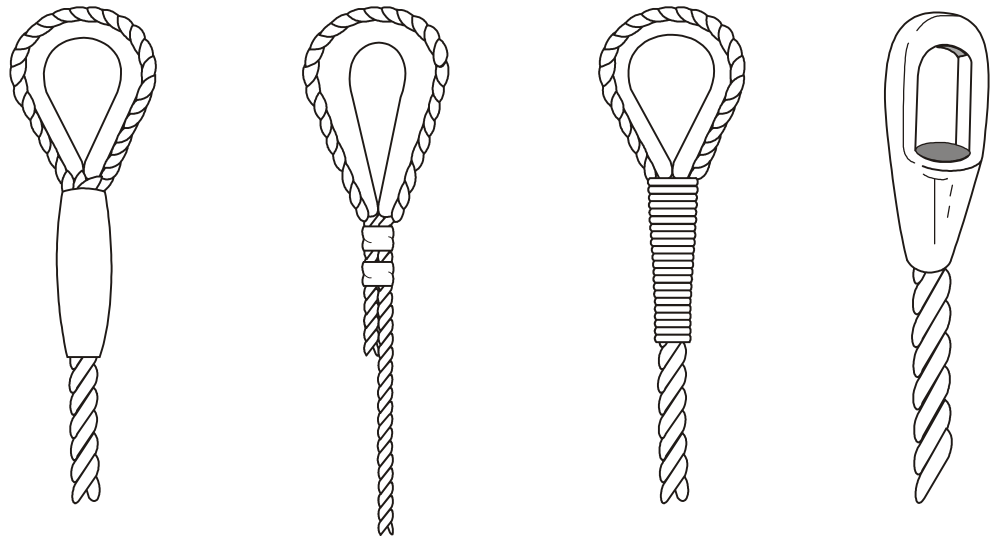


Figure 4-13. Types of Wire Rope Terminations.

Detachable links should not be used in instances where they might be subjected to bending or twisting.

4-6.3 Wire Rope Terminations

Three types of wire rope terminations are normally used in Navy towing applications: swaged, spliced, and socketed (see Figure 4-13).

The wire rope swaging process attaches fittings to wire rope by means of cold plastic flow of metal under extremely high pressures. The process uses hydraulic presses in conjunction with suitable dies. The swaged fittings are usually made of special alloy steels. An advantage of this process is low cost and high efficiency.

Swaged eyes are more common than spliced eyes. Existing swaging technology is so highly advanced that virtually all types of wire rope terminations can be made. Properly made swaged eyes develop 85 percent of the strength of the wire. Swaged terminations are applied only to wire rope with wire rope cores. A fiber rope cored wire can be swaged by replacing the fiber core at the termination with a strand of wire. Fiber cored wires are not authorized for Navy towing applications.

The second type of wire rope termination is the hand-spliced eye. This type of splice has less strength than the breaking strength of the wire. For instance, 1 5/8-inch to 2-inch hand-spliced eyes have 75 percent of the breaking strength of the wire, while 2 1/4-inch and larger wires have an efficiency of 70 percent. (See Table B-3 for more details.)

A subset of spliced wire eyes is the use of wire clips. This is the preferred over a hand-splice because it can withstand 80 percent of the wire's breaking strength. Both the hand-splice and the wire clip termination have less strength than the breaking strength of the wire and should be used only in an emergency (such as damage to or loss of the normal end fitting). See Table 4-1 and Naval Ship's Technical Manual (NSTM) S9086-UU-STM-010, Chapter 613, Wire and Fiber Rope and Rigging (Ref. F) for the proper placement and number of wire clips.

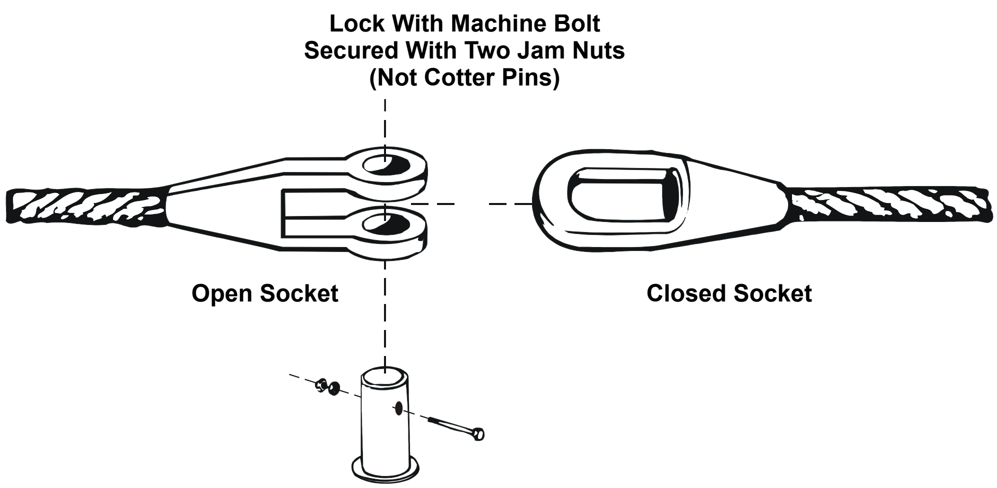


Figure 4-14. Towline Termination.

The third type of termination, the poured Spelter socket, is very common and is prepared in accordance with NSTM, Chapter 613 (Ref. F). This termination will withstand 100% of the rope's breaking strength if prepared properly and installed by a certified installer. The end of the rope is seized and the strands are unlayed all the way to the individual wires in a procedure known as brooming. This broomed end is inserted into the socket and secured in place with the poured zinc or epoxy. Use of epoxy-type poured sockets is becoming more common and may be used for Navy tows.

CAUTION
Whenever a poured socket is installed on a wire rope, the condition of the lubricant in the portion of the rope near the socket should be checked and new lubricant applied to dry areas.

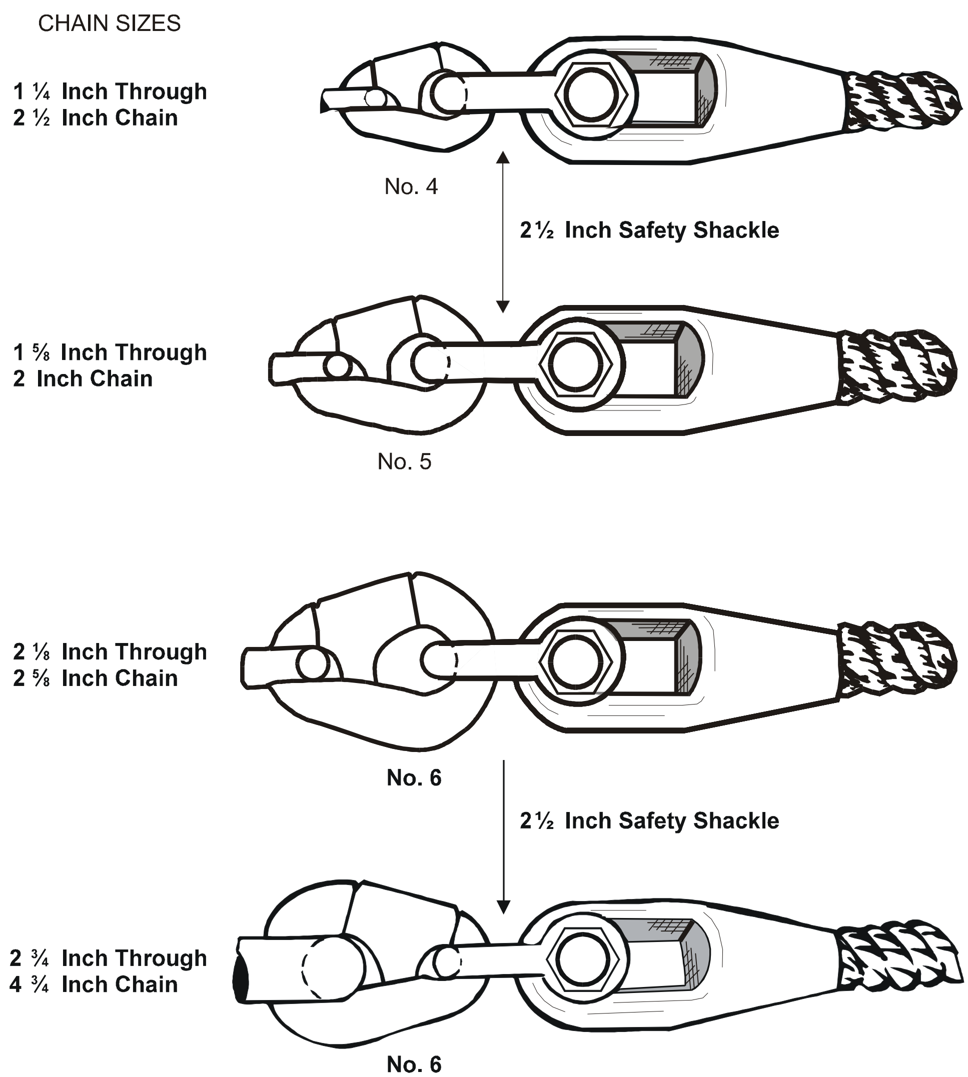


Figure 4-15. Pear-Shaped Detachable Links.

Two types of sockets are commonly used, open and closed (see Figure B-8). The open socket is fitted with a locking bolt and secured by a locking bolt with two jam nuts as previously described for anchor safety shackles. The closed socket forms an eye with a solid bail (see Figure 4-14). Figure 4-15 shows how a safety shackle can be used with one of three standard pear-shaped detachable links to connect a towing hawser to a wide range of chain sizes.

4-6.4 Synthetic Line Terminations

Generally, synthetic lines are spliced using the same methods used for natural fiber lines. However, when splicing a synthetic fiber lines, care must be exercised to maintain the stranded form. Failure to do this will cause the strand to collapse and form a bundle of tangled yarns. Also, since the felting action (tendency to mat together) of synthetic fiber is considerably less than that of natural fibers, more tucks are needed to produce a safe splice. This is generally true for lines of plaited construction. For guidance in splicing single or double braided lines, consult the manufacturer's recommendation or contact NAVSEA 00C.

The traditional standard end fitting for manila was a tear drop wire rope thimble. However, with the advent of high-strength synthetics, the eye of the line could stretch sufficiently to allow the thimble to capsize out of the eye. In addition, the higher strength of the synthetic line caused thimbles to crush and fail. A variety of solid thimbles have been developed to overcome these problems and have become standard end fittings for synthetic lines. Nylite thimbles are commonly used with Navy synthetic tow hawsers. Figure 4-16 shows the approved Navy standard thimbles.

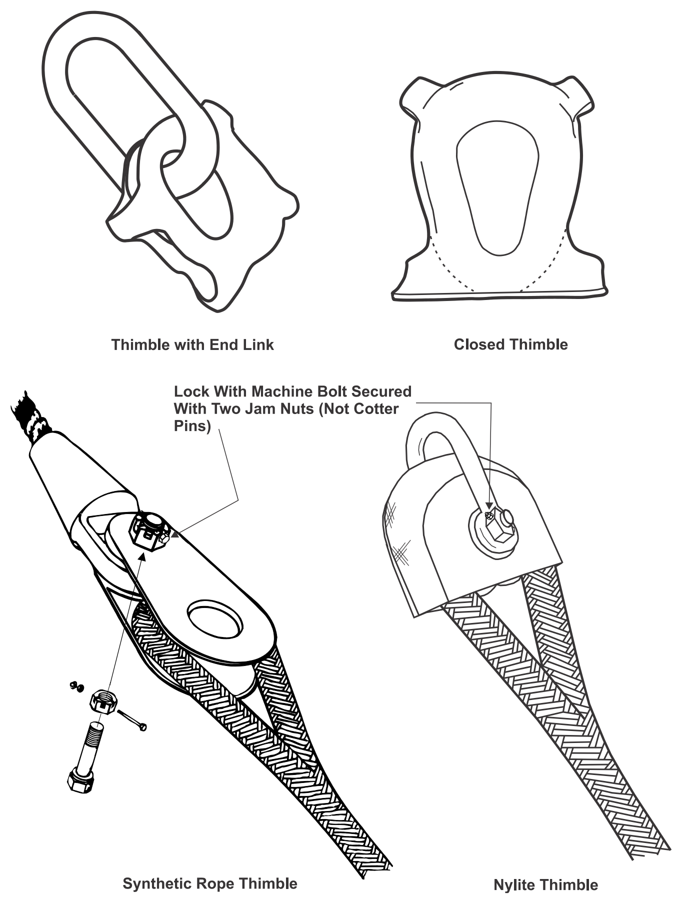


Figure 4-16. Approved Synthetic Line End Fittings.

4-6.5 Synthetic Spring

A spring is a line made of material with elastic properties. In towing, a spring absorbs shocks due to dynamic loading of the towing system; this is one reason that commercial towing companies used nylon and other synthetic fiber lines. Nylon replaced manila in hawsers and spring pendants because of its superior elastic properties, its ease of handling, its smaller size, and lighter weight compared to manila line of similar strength. More recently, polyester has replaced nylon (see Section 4-3.2) in most synthetic spring line towing applications. Reference C contains more information on synthetic springs and specifications for lines made of polyester fiber which are approved for use as tow hawsers and springs.

A synthetic spring is sometimes inserted between the towing pendant and the tug's hawser for dynamic load mitigation. Seen most frequently in commercial towing, the spring usually is a length of synthetic fiber rope, spliced together, arranged into a grommet (see Figure 4-17).

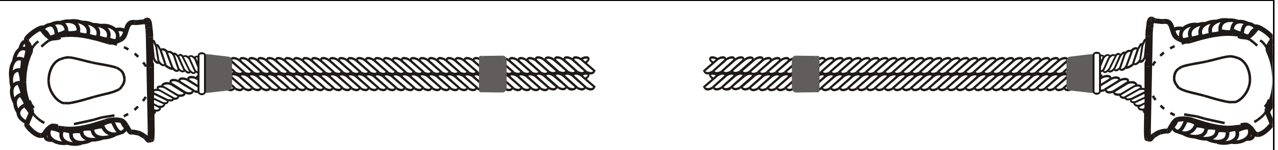


Figure 4-17. Synthetic Line Grommet.

A grommet is fabricated by splicing a line to form one continuous loop. The two sides of the loop are pulled together around two thimbles, and seized with small 21-thread manila line to form the grommet or strap shown in Figure 4-17. The line used to make the grommet must be sized so the assembled grommet will have a total safe working load that is equal to or greater than the design load for the towing system.

Although the line is doubled in the grommet, its strength is not twice that of a single line. There are losses in strength in the splices, so the assembled grommet is only 90% as strong as twice the original breaking strength. For this reason, the line used for the grommet must have a basic breaking strength equal to at least 55% of a single line spring in order to have the same total strength when fabricated into a grommet.

An alternative to the grommet arrangement is the synthetic spring consisting of a length of line with a standard eye splice in each end. Each of these eyes will normally employ a thimble. Since the spring is not doubled, the line diameter must be greater than that used in the grommet, but should be easier to handle.

At present, there is no agreement on the method to calculate the proper length of a synthetic towing spring. Commercial operators generally use a spring of 200 to 400 feet in length. For additional guidance on sizing a synthetic spring, contact NAVSEA 00C.

Example Problem: Determine the required breaking strength of a polyester grommet to be used with a 2-inch independent wire rope core (IWRC) improved plow steel (IPS) hawser, and then determine the size of polyester line required for such a grommet. The tow is made fast 'on the brake' of the tug and it will use a synthetic spring. The grommet spring will be a loop with two thimbles. The polyester line will be double-braided type.

We begin by determining the maximum working load for the wire hawser. Table B-2 (appendix B) shows that IWRC IPS in 2-inch nominal diameter has a breaking strength of 309,600lbs. Next, we need the factor of safety for the hawser. From Table 3-2 (6th line of data), the wire rope hawser has a factor of safety of 4, and a polyester member of the towing jewelry has a factor of safety of 6. Therefore, the polyester grommet should have a breaking strength of:

309,600 * 6 / 4 = 464,400lbs

Because the grommet is looped, it must have a single line strength of 5/9ths of the total strength. So the polyester line must have a minimum breaking strength of:

464,400lbs * 5 / 9 = 258,000lbs

With this information, we can use Table C-2 (appendix C) to determine that the required line size for the polyester rope is 10 inches (or larger).

Note that the grommet's weight per foot in air will be about the same as the wire hawser (6.74 versus 6.72 lbs/ft), but will be far more bulky.

4-6.6 Bridles

Tows with unusual configurations, or which have direction stability problems (such as dry docks and barges) which make towing with a single leg bridle or pendant problematic for maintaining control, a two legged bridle should be used (see Figure 4-18 and Figure 4-19). Barges with square bows are rigged with bridles as they tend to have a stabilizing effect produced by pulling from both legs of the bridle. Some barges have a hull form and/or appendages which increase the directional stability of the barge; these barges may be rigged with a single leg bridle or pendant attached on the centerline. Most deep ocean bridles or pendants are rigged using chain due to its chaffing and strength characteristics. When using the anchor chain as the towing pendant, it is good practice to swap the chain or remove the first 2 shots as these are typically the most worn portions of chain. Chain's advantage over wire comes from its greater weight per foot, which deepens the tow systems catenary and provides superior resistance to chafing. As a rule of thumb, the size of the chain to use for bridles and pendants should be at least equal to the size of the tows anchor chain. Each bridle leg should be of equal length and must be sized to take the total calculated steady state towline tension along with the applied factor of safety from Table 3-2 as the load will periodically shift from one leg to the other.

The flounder or fish plate is the component which connects the individual bridle legs to the tow hawser. The flounder plate is designed to distribute the towing force of the tug's towline to the separate legs of the tow bridle. The deployment of flounder plates on typical towing rigs is described in detail in (Ref. I). Flounder plate design is detailed in Appendix Figure I-15.

For service craft up to 500 tons, the bridle must be equal in size to the ship's anchor chain, but not less than 1 1/4-inch chain. For craft greater than 500 tons, a minimum of 1 5/8-inch chain shall be used. Ships do not need chain larger than 2 1/4 inches when towed by legacy U.S. Navy tugs. More powerful commercial tugs and next-generation Navy tugs will require larger chain bridles. Non-magnetic chain and attaching hardware shall not be used for towing bridles. The length of each leg of the bridle from the towing attachment point to the flounder plate after rigging is completed must be equal to or greater than the horizontal distance between the attachment points. The bridle apex angle, defined as the angle between the two bridle legs as measured from the flounder plate vertex, shall be less than 100 degrees, with an optimal angle between 30 and 60 degrees (see Appendix Figures I-1, I-2, I-3 for an illustration).

All towing bridles must have a backup securing system. This is normally accomplished by using wire rope of appropriate size, but not greater than 5/8 inches, in order to allow lacing through the chain links while not exceeding the minimum bending radius of the wire.

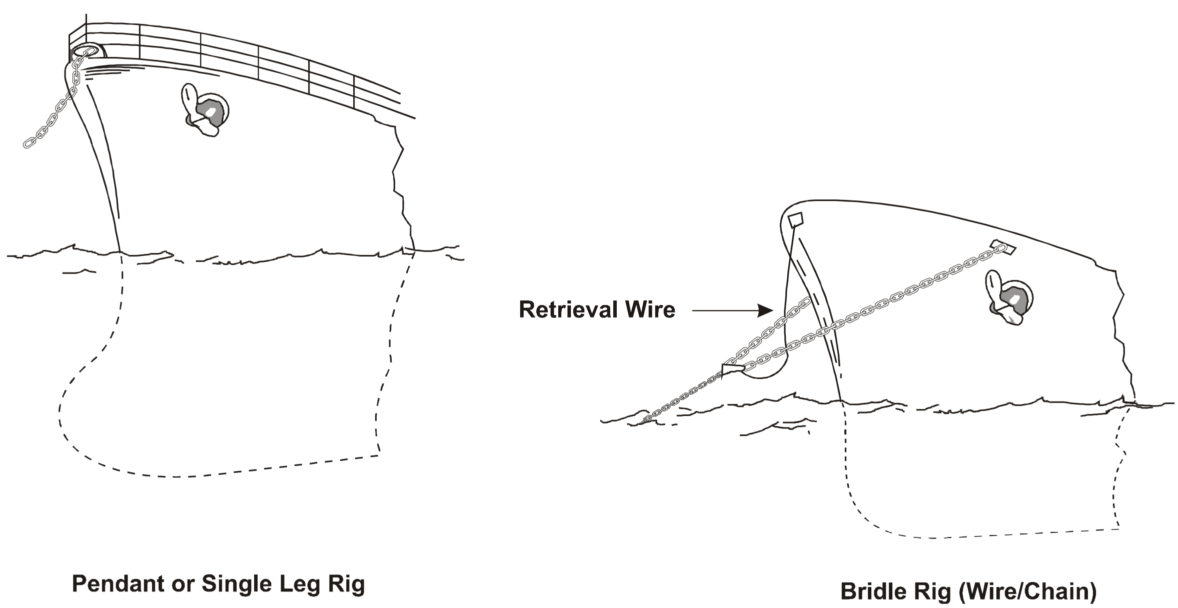
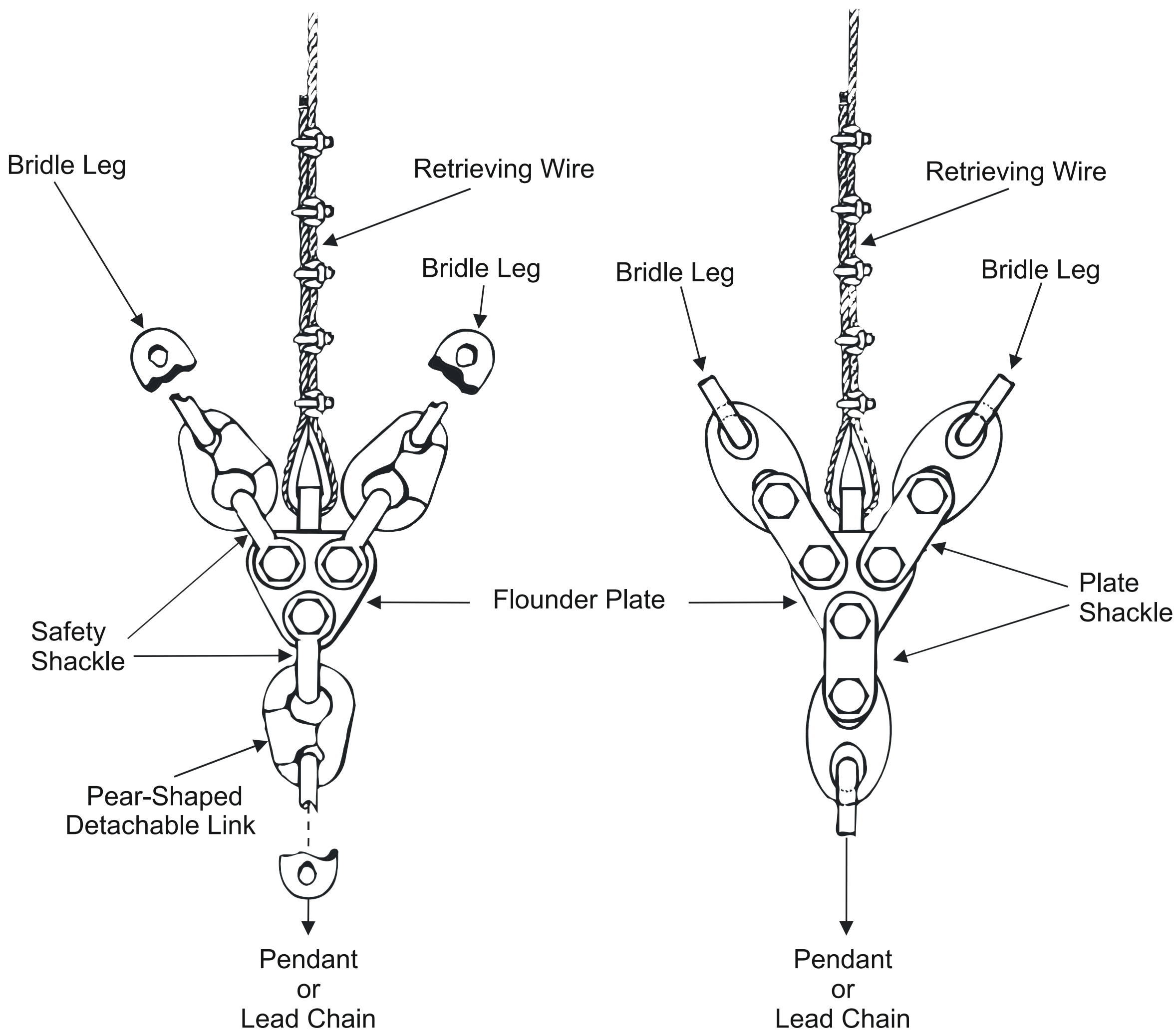


Figure 4-18. Towing Rigs



NOTE
See (Ref. A) for additional examples of bridle sizes of components.

Figure 4-19. Chain Bridles Using Plate Shackles and Safety Shackles.

Sufficient bights of wire from a second and third securing point (bitts, heavy cleats, etc.) should be equal to breaking strength of the chain. This is referred to as the rule of three's, where each bridle leg shares the load between three securing points or connections. This distributes one third of the load to each securing point. The idea is to balance the towing strains between the three tow attachment points. The backup wire must be rigged while the bridle leg is under tension. Failure to snug up the back up wires while the bridle leg is under tension will result in unequal distribution of the towing strains and increase the probability of snap loading the individual backup wires causing the backup wires to fail when tension is applied. When using a towing pad to connect the bridle, the backup wires must be laced through the portion of the chain forward of the towing pads. The backup securing point should be aft of the towing pad to prevent snap-loading. If a set of mooring bitts is used as a securing point, chain should not be wrapped around the bitts to prevent side loading and premature failure of the chain. Instead the bridle leg should be terminated by lacing the wire through the chains end link and figure eighting the wire around the bitts. There must be a sufficient number of wire clips (see Table 4-1) on each bitter end of the backup wire, aligned in the same direction. (See (Ref. I and J) for tow rig design plans)

It may not always be possible or practical to rig a backup system (i.e., submarine towing). In these cases, additional analysis of the main towing attachment may reduce the risk. Where possible, the attachment should be designed to a breaking strength well in excess of the other components.

On some ships with large bows (e.g., CV, AD, AOR, or AFS) it may be necessary to rig a one- or two-shot chain pendants between the bridle flounder plate and the towing hawser. Both bridle legs should be the same size and length and should be checked by counting the links when rigging is complete. All detachable links in the bridle legs and chain pendant must be locked with hairpins (see Section 4-6.2).

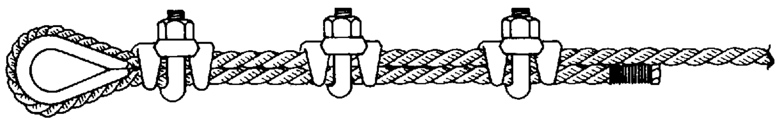
Because chain, wire bridles, and pendants are often subjected to wear and abrasion during towing, it is a recommended practice to “over design” to allow for wear, particularly for long tows. Tables in (Ref. B) and (Ref. D) provide the breaking strength and weight per foot of various types of wire and chain. These tables used together with the calculated steady state towline tensions and factors of safety obtained from Table 3-2 assist in determining whether the available wire or chain has sufficient strength for the planned tow.

Sometimes a heavy wire is used as a bridle for short tows or emergency situations, but special care is required to minimize chafing of the wire and damage to the structure from the wire’s extremely hard material. If the hard point is a considerable distance from the fairlead, a fairly short length of chain, sufficient to ride in the fairlead, may be used to save weight and sometimes to simplify the final connection to the tow, such as when using bitts as the hard point.

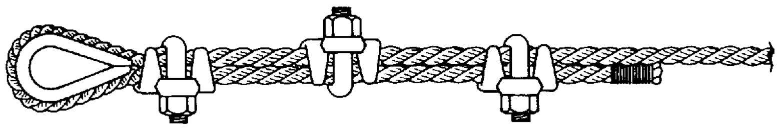
4-6.7 Pendants

A pendant is often used between the tow and towing hawser to facilitate connecting heavy jewelry components. This is called a “lead” or “reaching” pendant. The lead pendant is a wire rope pendant with the same breaking strength as the main tow hawser unless it is intended to be used as a safety link, in which case it will be of lower breaking strength (see Section 4-7 for information on the “safety link” concept). The pendant may be up to 300 feet long to permit connection/disconnection on the tugs fantail, while maintaining a safe standoff distance from the

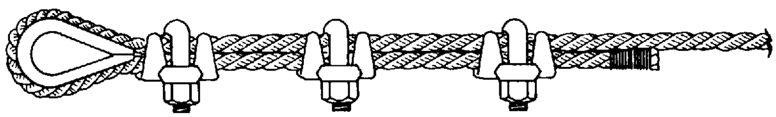
Table 4-1. U-Bolt Clips



RIGHT WAY FOR MAXIMUM ROPE STRENGTH



WRONG WAY CLIPS STAGGERED



WRONG WAY CLIPS REVERSED

Recommended Method of Applying U-Bolt Clips to Get Maximum Holding Power of the Clip. The following is based on the use of proper size U-Bolt clips on new rope.

1. Refer to the following these instructions for installing U-bolt clips. Turn back specified amount of rope from the thimble or loop. Apply first clip one base width from dead end of the rope. Apply U-Bolt over dead end of wire rope with live end resting in saddle. Use the old sailors adage “Never saddle a dead horse” when attaching cable clamps. Tighten nuts evenly, alternating from one nut to the other until reaching the recommended torque.
2. When two clips are required, apply the second clip as near the loop or thimble as possible. Turn nuts on the second clip firmly, but do not tighten. Proceed to Step 3.
3. When three or more clips are required, space additional clips equally between first two – take up rope slack - tighten nuts on each U-Bolt evenly, alternating from one nut to the other until reaching recommended torque.
4. Prior to use, apply a load to test the assembly. This load should be of equal or greater weight than loads expected in use. Next, check and retighten nuts to recommended torque.

In accordance with good rigging and maintenance practices, the wire rope and termination should be inspected periodically for wear, abuse, and general adequacy.

Inspect periodically and retighten to recommended torque.

A termination made in accordance with the above instructions, and using the number of clips shown in part 2 of this table has an approximate 80% efficiency rating. This rating is based upon the nominal strength of wire rope. If a pulley is used in place of a thimble for turning back the rope, add one additional clip.

The number of clips shown in part 2 of this table is based upon using right regular or lang lay wire rope, 6 x 19 classification or 6 x 37 classification, fiber core or IWRC, IPS or EIPS. If Seale construction or similar large outer wire type construction in the 6 x 19 classification is to be used for sized 1 inch and larger, add one additional clip.

tow while operating under heavy weather conditions. If a wire rope pendant is used as the lead pendant for the tow, it must be protected from chafing. In most cases this is accomplished by inserting a short length of chain to provide chafing protection.

Chain pendants frequently are employed when using a single-leg attachment between the hawser and tow. This attachment generally runs through a centerline bullnose, chock, or fairlead near the tow's centerline. A chain extending forward from the apex of a towing bridle is also called a lead chain. The purpose of the lead chain is to add weight to the end of the towline system. This improves the spring in the system by increasing the towline's catenary. Sometimes the chafing/lead chain is the tow's anchor chain, which can be paid out to the total length desired. Sometimes a chain riding pendant is inserted into the towing configuration to increase the catenary and provide "spring" to the towing system. Whenever possible the first two shots of the anchor chain should be removed as they typically are the most worn shots of the anchor chain. During emergency tows of merchant ships, the tow's anchor chain is frequently used as a tow pendant.

4-6.8 Retrieval Pendant

A retrieval pendant is a wire rope leading from the deck of the tow to the end of the towing pendant or flounder plate. The retrieval pendant is intended to facilitate recovery of the tow gear so it will not drag the seafloor or foul the ship's appendages when the tow is disconnected. The retrieval pendant is often handled on the deck of the tow by a hand-powered winch or a deck capstan. It must be capable of being handled by the riding crew or by a boarding party put aboard the tow. The wire must be strong enough to lift the flounder plate, bridle, and/or pendant, but it is not intended to be exposed to towing loads. Examples of retrieval pendants are shown in Figure 4-18 and Figure 4-20 and throughout (Ref. I).

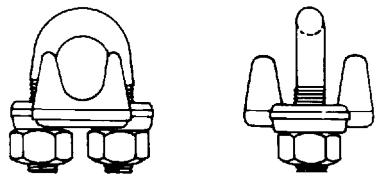
When sizing a retrieval pendant use a factor of safety of 4:1 for lifting the weight of the bridle but the pendant should not be less than 5/8-inch wire rope.

4-6.9 Chain Stoppers, Carpenter Stoppers, and Pelican Hooks

The term "stopper," as used in seamanship, describes a device or rigging arrangement used to temporarily hold a part of running rigging or ground tackle which may come under tension. There are many types of stoppers and methods of attaching them to the tension members. Most stoppers cannot be released under load and require the held line to be heaved in to slack the stopper and allow its removal. Some stoppers, however, such as the pelican hook and carpenter stopper, can be released when under load.

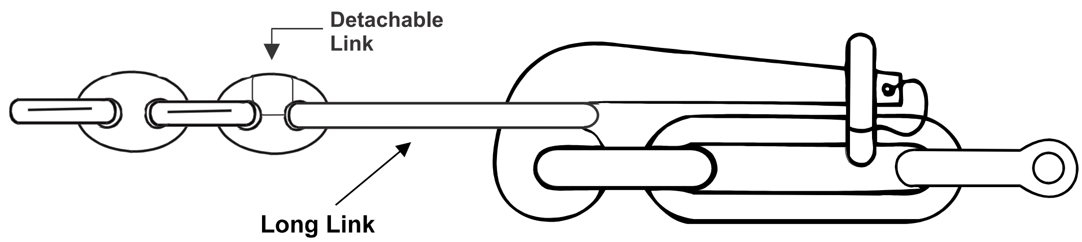
In towing applications, the stopper is usually connected to deck padeyes by means of chain shackles. It is used to hold a towing pendant on deck during the hookup and breaking of a tow. A chain stopper is sometimes employed as a quick-release device (see Figure 4-20). Stoppers are nominally rated to hold 60 percent of the breaking strength of the chain or wire for which they have been designed. Care must be used when considering their use. Chain stoppers should not be confused with pelican hooks. Pelican hooks are significantly weaker than chain stoppers of the same nominal size and are unable to grasp the chain in the desired manner.

Table 4-2. Applying U-Bolt Clips.

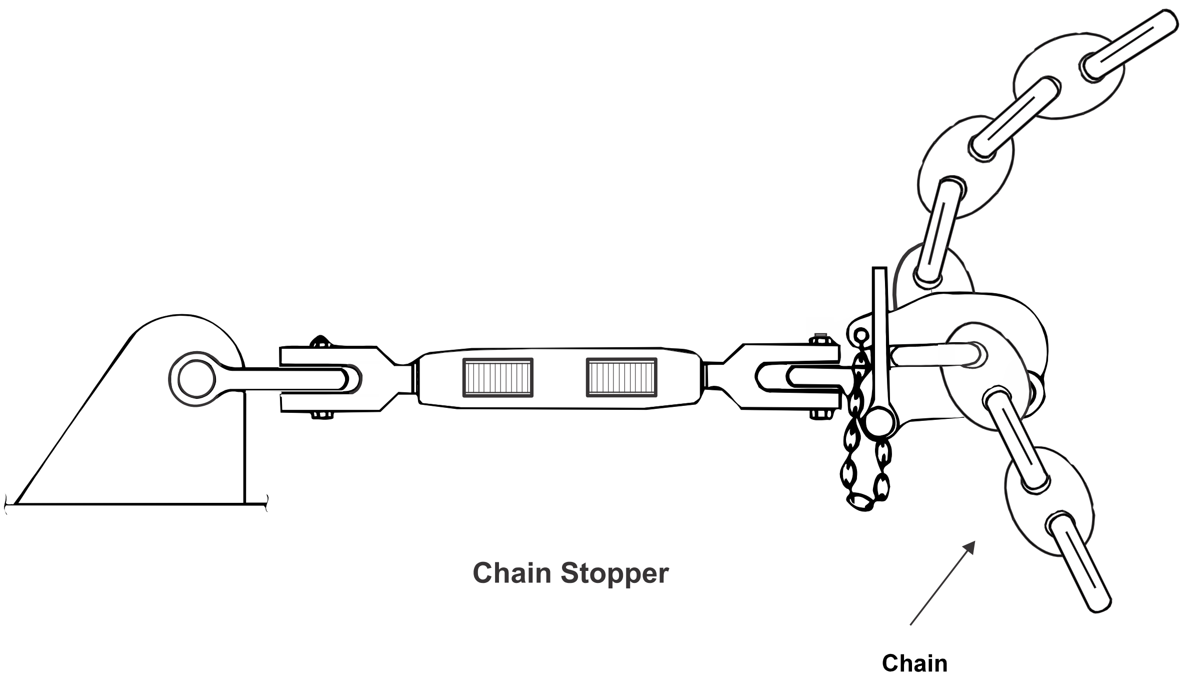


Clip Size	Minimum Number of Clips	Amount of Rope to Turn Back (inches)	Torque (Ft./Lbs	Weight (Lbs. per 100)
1/8	2	3 1/4	4.5	6
3/16	2	3 3/4	7.5	10
¼	2	4 3/4	15	20
5/16	2	5 1/4	30	30
3/8	2	6 1/2	45	47
7/16	2	7	65	76
½	3	11 1/2	65	80
9/16	3	12	95	104
5/7	3	12	95	106
¾	4	18	130	150
7/8	4	19	225	212
1	5	26	225	260
1 1/8	6	34	225	290
1 1/4	7	44	360	430
1 3/8	7	44	360	460
1 1/2	8	54	360	540
1 5/8	8	58	430	700
1 3/4	8	61	590	925
2	8	71	750	1300
2 1/4	8	73	750	1600
2 1/2	9	84	750	1900
2 3/4	10	100	750	2300
3	10	106	1200	3100
3 1/2	12	149	1200	4000
If a pulley (sheave) is used for turning back the wire rope, add one additional clip.				
If a greater number of clips are used then shown in the table, the amount of turn back should be increased proportionally.				
The tightening torque values shown are based upon the threads being clean, dry and free of lubrication.				
Above values do not apply to plastic coated wire rope.				

Pelican hooks can be used to grasp chain through an end chain link attached to the bitter end of a chain. They cannot grasp a chain in the middle like a chain stopper can (see Figure 4-20). They can be used as quick release devices, although they do not have the holding strength of chain stoppers.



Pelican Hook



Chain Stopper

WARNING
Do not confuse pelican hook with chain stopper.

Figure 4-20. Pelican Hook and Chain Stopper.

Carpenter stoppers are used when it is necessary to develop a grip on a wire rope and hold it to the breaking strength of the wire (see Figure 4-21). Advantages of the carpenter stopper include its quick application and release, ability to develop full tension without damage to the wire, and low maintenance requirements. Figure 4-21 depicts a typical carpenter stopper.

WARNING
Old-style carpenter stoppers with smooth covers are condemned and should not be used. These old models are made of cast metal and are subject to explosive brittle fracture upon impact. Serious injury to personnel may result from flying fragments.

CAUTION
A carpenter stopper should not be used unless it is specially designed for the lay, helix, number of strands, and diameter of the specific wire rope. The stopper and the wire should both be clean and free from sand or other abrasives.

Three types of carpenter stoppers have been used in the U.S. Navy:

- The “old WWII” style
- The “improved 1948” style
- The “modified-improved 1968” style

Only the last style listed is approved. It can be identified by four heavy ribs on the hinged cover and will have a Boston Naval Shipyard test date of 1968 to 1973 or be manufactured by Baldt after 1973.

Refer to Appendix E for more information on the use of carpenter stoppers.

4-6.10 Chafing Gear

Chafing gear is used to reduce wear on both the towing hawser and the tug’s bulwarks. Chafing gear includes materials such as mats, battens, strips of leather, canvas, grease, worming, parceling, roundings, and serving (see Figure 4-22). Material specifically manufactured for chafing gear is also available and works very well. These materials lessen or prevent towline chafing and are applied at the point where the towline crosses the stern rail or other structure. Often times used fire hose is also used a convenient form of chaffing gear..

Another method to control chafing is to periodically adjust the scope of the wire to reduce the wear on any one point. The amount of time between adjustments will depend on the behavior of the tow and the sea state. This is called “nipping” the wire or “freshening the nip.”

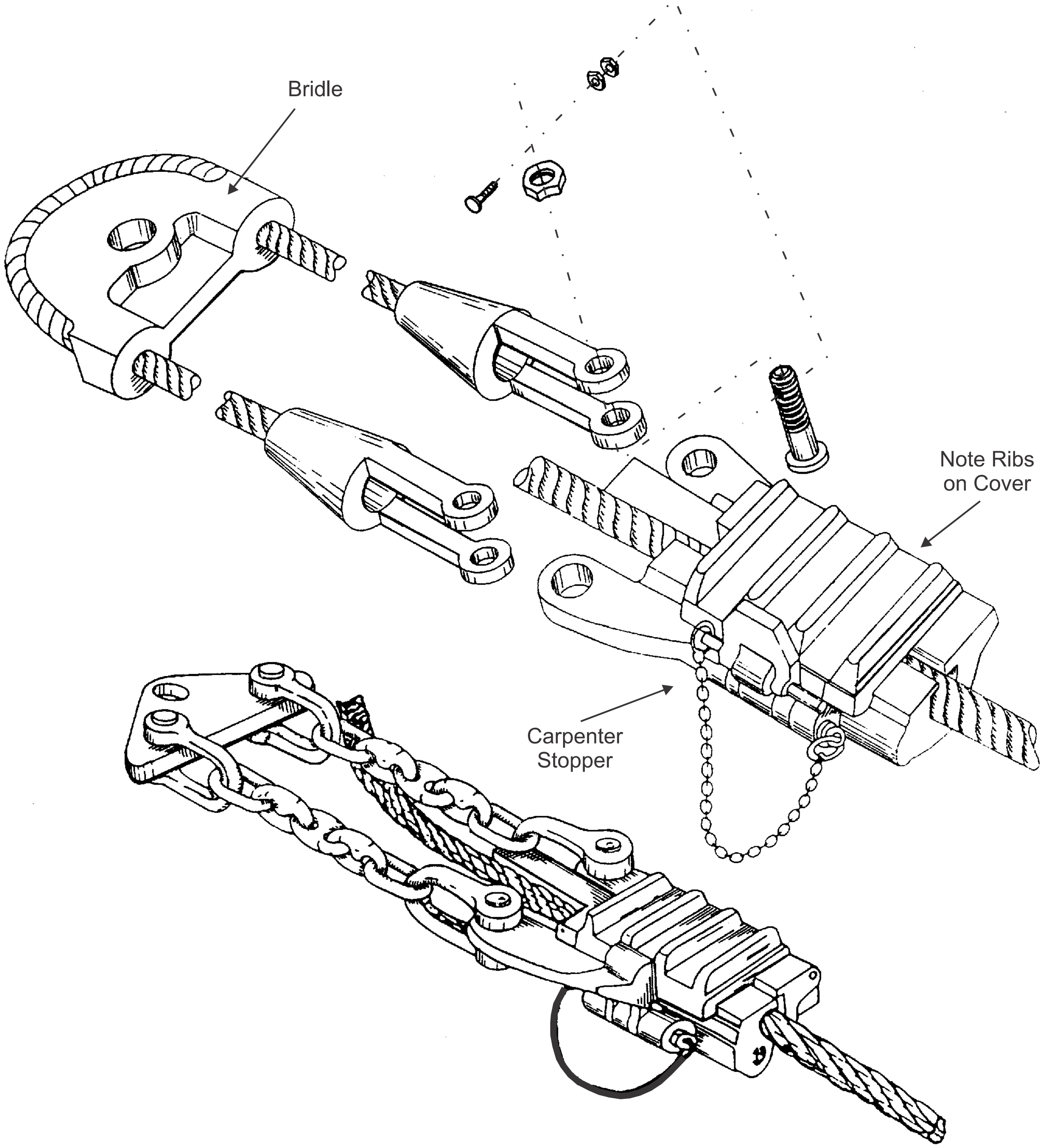


Figure 4-21. Carpenter Stopper

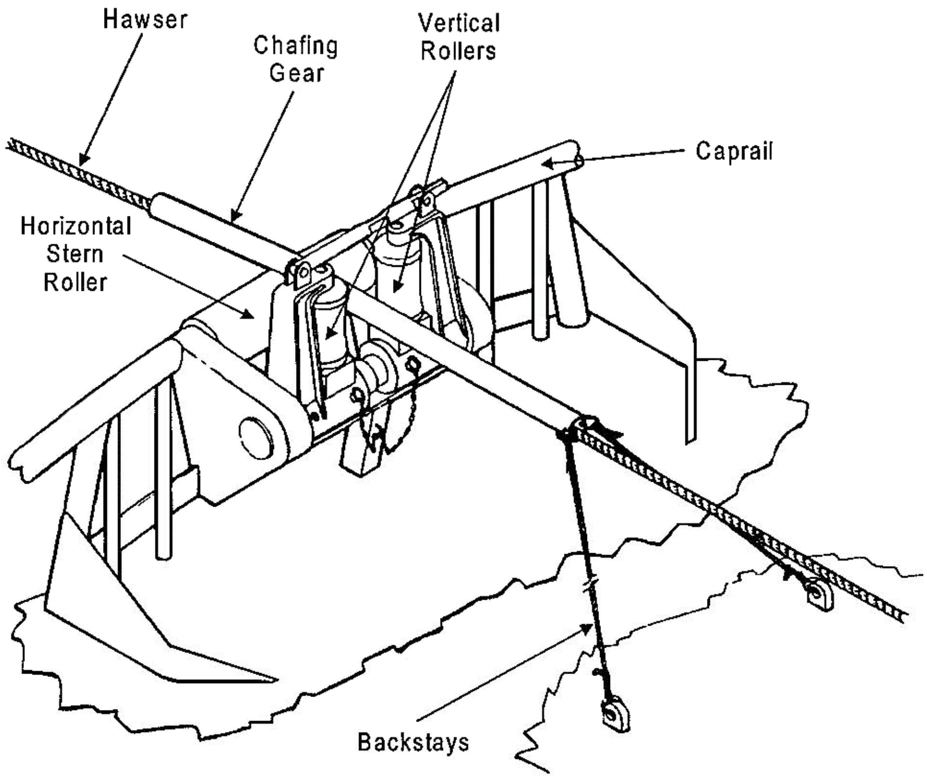


Figure 4-22. Chafing Gear and Stern Rollers.

4-7 Fuse or Safety Link Concept

A safety link, sometimes called a fuse pendant, is the component designed into the tow rig to fail at predicable loads. A safety link is analogous to a safety valve or a circuit breaker. The safety link's primary characteristic is its predictability; it ensures where a failure will occur in the event of an overload. The safety link should not fail under anticipated towline tensions of a planned tow. The tow preparing activity should identify the safety link in the Appendix H documentation and provide the specific details to the tow master to ensure tow design limits are not exceeded.

Since every towing system has a weak point, often times it is prudent to intentionally incorporate a safety link to control where the tow will fail to aide in recovery of the tow and prevent damage to the tug or tow due to overload. A wire rope pendant is usually selected as the safety link, and is sized to have a breaking strength 10 to 15 percent lower than the main towing hawser. If a towing system overload occurs, the failure will not damage the tow hawser and it can be reconnected.

The breaking strength considers the hydrodynamic resistance of the towline, which creates a higher tension at the tug end of the hawser. Such pendants should never be subjected to chafing or other unusual service.

CAUTION
Since the safely link is the weakest point in the tow system, this will determine the safe working load. Tow planners must ensure the safety link is capable of withstanding all expected loads.

4-8 Line Handling Devices

WARNING
Motions of the tug and tow can cause the towline to change positions rapidly and without warning. Personnel must be aware of the potential danger of a sweeping towline and remain clear of all areas within the sweep radius.

Towing requires extensive manipulation of lines. Virtually all of the lines used in towing operations are far too heavy to be handled by anything other than machines and unique devices designed for towing. The following sections detail the function of line handling devices used in towing.

4-8.1 Caprails

CAUTION
Whenever the surface of a caprail becomes rough, steps should be taken to repair or replace it to protect the hawser. Caprails should be kept free of any nicks or burrs.

The caprail is the riding surface on top of the bulwark (see Figure 4-23). The towing hawser bears on the stern caprail as it passes astern of the tug and enters the water. Caprails are installed in several configurations. They can be fabricated from pipe or plate. On newer tugs, they have large radius surfaces contoured to the tug's deck layout. It is important to keep the caprail smooth and free of nicks and burrs which will damage both synthetic and wire towing hawsers. In current design practice, the bearing surface of the caprail is hardened to a minimum Rockwell C hardness of 40.

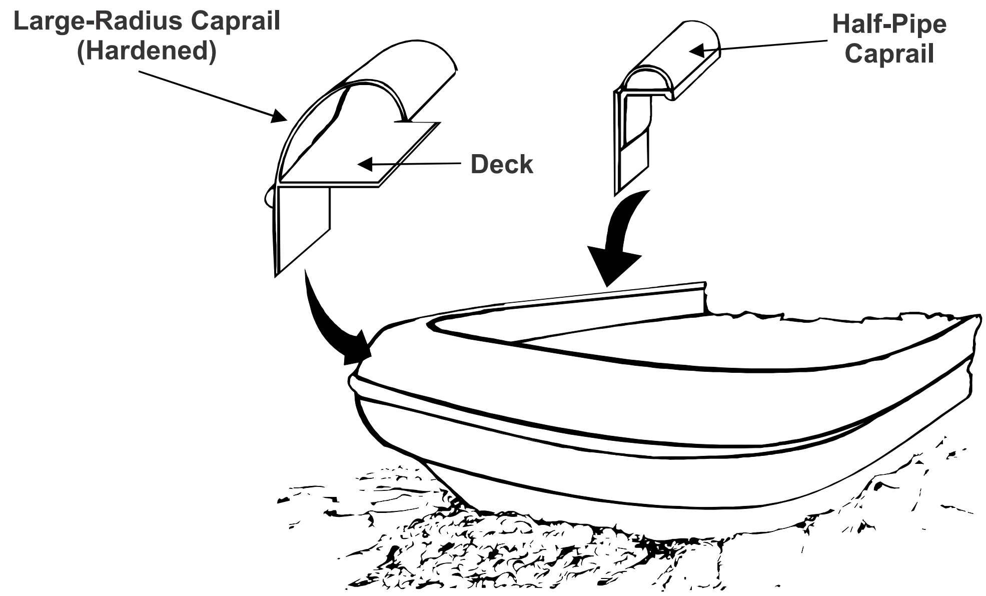


Figure 4-23. Caprails.

4-8.2 Tow Bows

Tow bows are transversely installed beams or pipe which bridge the caprails on the afterdeck of the tug (see Figure 4-24). Their function is to keep the towline clear of all deck fittings and to furnish a protected area below the sweeping tow hawser where personnel can pass safely. Tow bows are available on T-ARS 50 Class tugs and are most common on European tugs.

4-8.3 Horizontal Stern Rollers

Horizontal stern rollers minimize chafing during heave-in and payout (see Figure 4-22). A stern roller is a large-diameter roller, set in the stern bulwarks on the centerline and faired to the caprail. The roller rotates with the movement of the wire, constantly changing the contact point. This movement spreads the wear from the wire. Because it is also hardened, the stern roller resists scoring, thus providing a smooth surface for the wire to ride on. The T-ATF 166 Class is equipped with a stern roller but the T-ARS 50 Class is not. The T-ARS 50 Class tugs have a large-radius, hardened steel transom to minimize wear on the towing hawser.

Chafing gear should be used even if stern rollers are available. When towing with a constant towing scope, chafing comes from port/starboard movement of the wire. Horizontal stern rollers do not reduce chafing in this manner. Therefore freshening the nip is also necessary on tugs with stern rollers or large radius bulwarks.

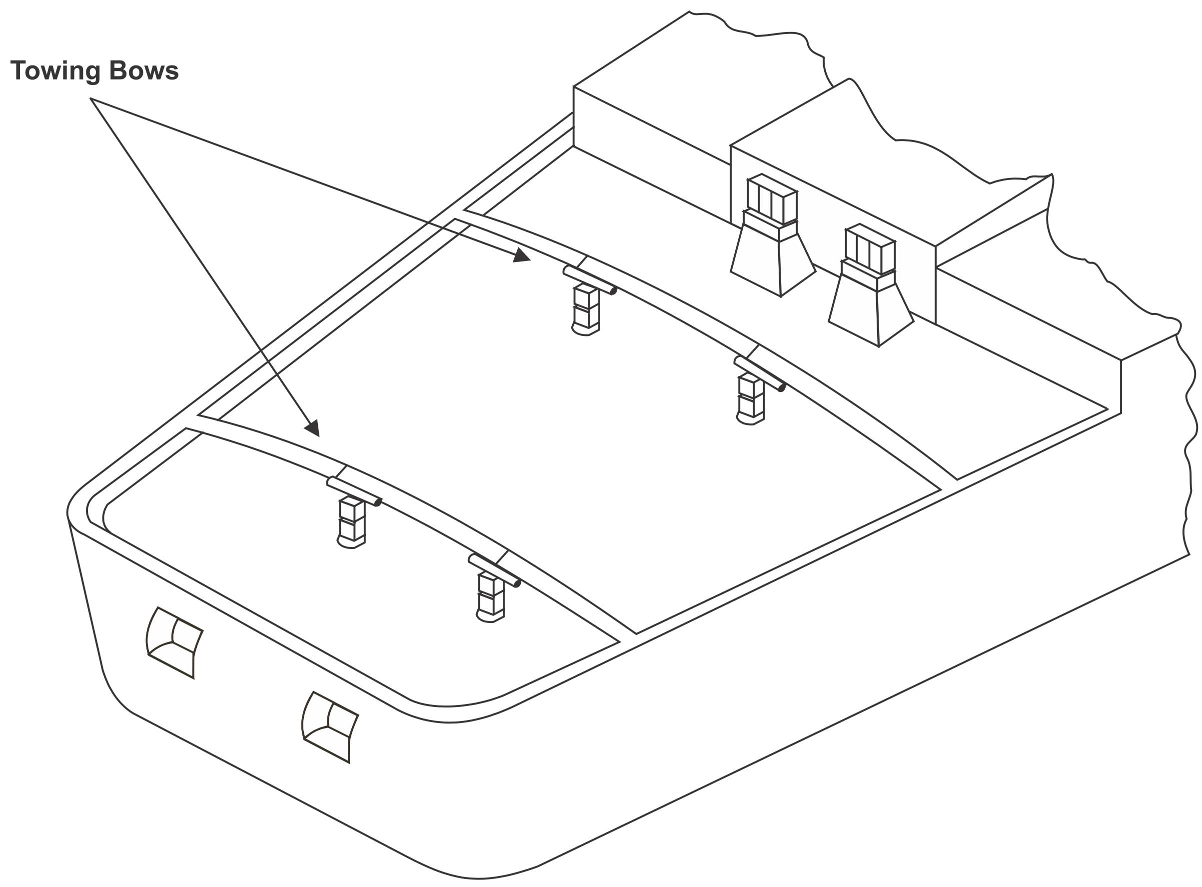


Figure 4-24. Towing Bows.

WARNING
The vertical stern rollers and Norman pins onboard the T-ARS 50 Class ships will drop when a load of 50,000 pounds or more is applied to mid-barrel height. The resulting uncontrolled sweeping of the towline may injure personnel or damage equipment.

4-8.4 Capstans and Gypsy Heads

Capstans rotate on vertical shafts and are used for line handling, but not as towing machines (see Figure 4-25). The prime mover of a capstan is often located below deck. This permits the capstan to be mounted so that the line travels relatively close to deck level. A gypsy head, which is similar to a capstan, rotates on a horizontal shaft and is usually powered as an auxiliary of a winch. Gypsy heads, like capstans, are used for line handling, but not for towing.

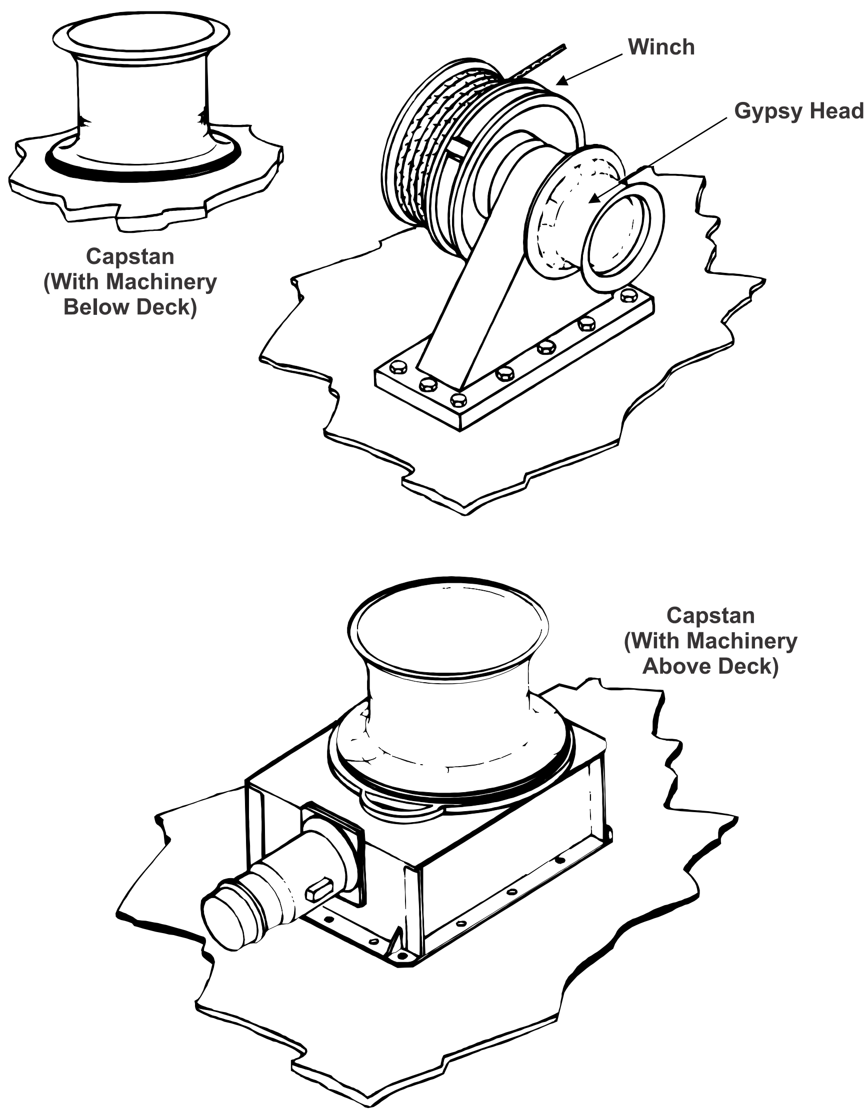


Figure 4-25. Capstans and Gypsy Heads

4-9 Sweep Limiting Devices

Sweep limiting devices restrict the horizontal sweeping of the wire across the tug's fantail.

4-9.1 Vertical Stern Rollers

Vertical stern rollers restrain the towline laterally during heave-in and payout, and during long-distance straight towing by preventing the wire from sweeping across the tugs fantail. The vertical stern rollers or pins are normally operated hydraulically from a remote location (see Figure 4-26 and Figure 4-27). Onboard the T-ATFs, the hook-shaped items on either side (just outboard of each vertical roller) are hydraulically operated "capture hooks," often used instead of the vertical rollers to provide lateral restraint for the towline. On the T-ARS 50 Class, the vertical stern rollers drop when the side force at mid-barrel height exceeds 50,000 pounds.

CAUTION
Using vertical rollers may put the tug "in irons," seriously limiting the tug's maneuverability.

The presence of the towline in the stern rollers limits the maneuverability of the tug because it moves the tow point from the towing machine to the caprail.

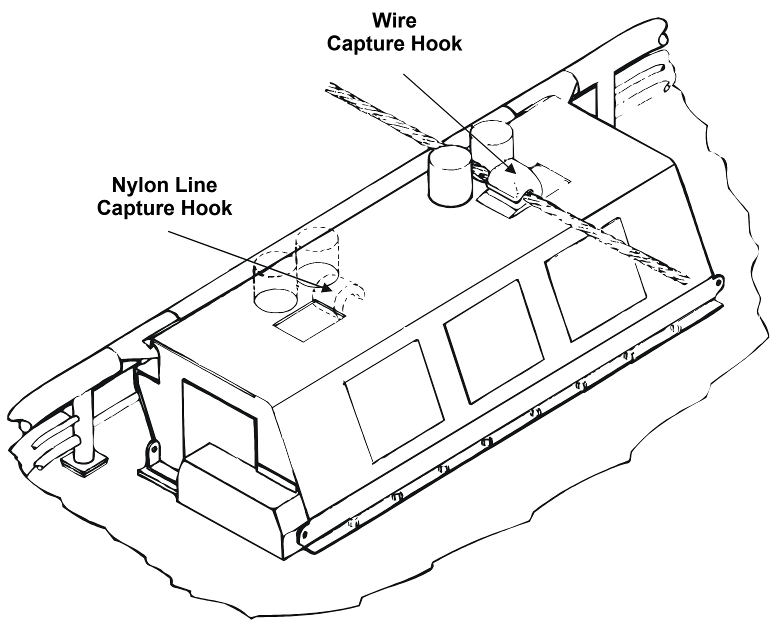


Figure 4-26. Stern of T-ATF 166 Class

NOTE
Stern rollers should be properly maintained and lubricated to ensure rotation and smooth surface conditions. Rollers can become frozen and their surface areas grooved and scored from towline wear. Such conditions directly contribute to the abnormal wear of the towline.

Vertical stern rollers act as fairleads for the towing machine. The long distance between the stern rollers and the towing machine enables the tow hawser to naturally reel itself on to the drum and reduce the strains on the level winding mechanism. The stern rollers are normally used to capture the towing hawser when picking up or disconnecting a tow. The vertical rollers also limit the amount of lateral movement of the towing hawser as the tow yaws from port to starboard.

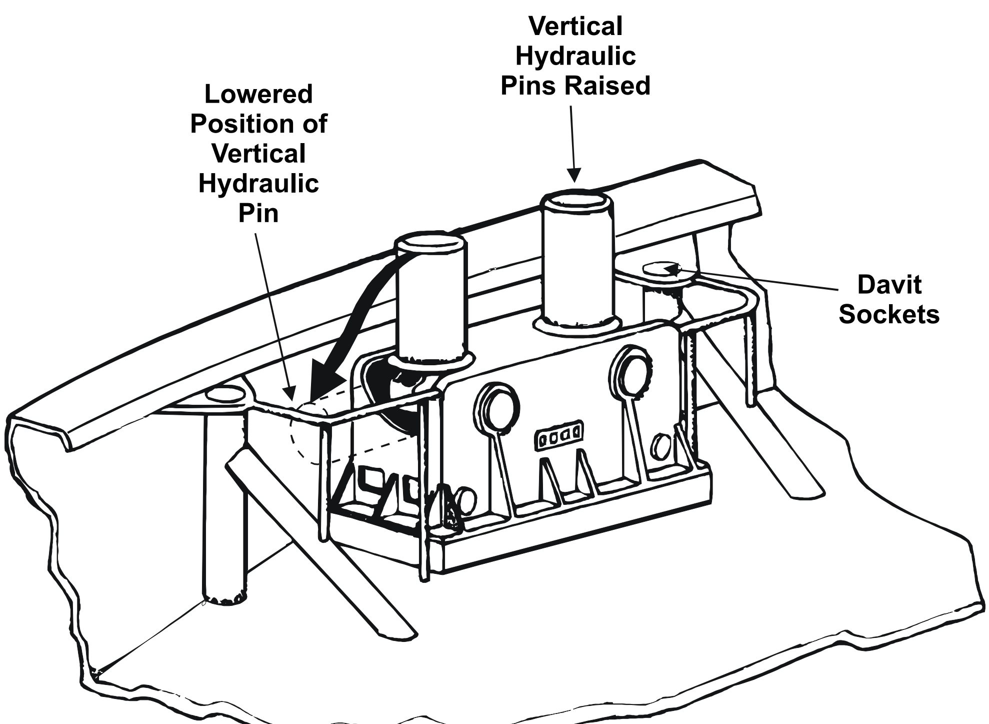


Figure 4-27. Stern Rollers (ARS 50 Class).

Vertical stern rollers are designed only as a fairlead device and are not designed to withstand the same lateral loads as the H-bitts. Strong side loads commonly seen in towing situations can very easily carry the assembly away and collapse the pins. On the T-ARS 50 Class, the rollers will fold down to their stowed position when a lateral load of 50,000 pounds is applied at mid-roller height. The towline is usually restrained in a stern roller assembly only under light sea conditions. The vertical stern rollers should always be dropped when maneuvering in restricted waters or rough seas.

When the towline rides against a vertical stern roller, it is being bent over a smaller radius. This causes towline fatigue and possible failure at lower towline loads. Chafing gear is required on the towline when it is scheduled for long periods in the stern roller. Slacking off a few inches, or "freshening the nip" regularly, is a good practice to reduce wear on the wire. Wire grease is often used to reduce chafing at these hard points. This is especially true when using a capture hook (as on a T-ATF 166 Class) as there is little room for chafing gear.

4-9.2 Norman Pins

The primary function of Norman pins is to limit the arc of sweep across the tugs stern (see Figure 4-28 and Figure 4-29). Norman pins also help keep the hawser out of the propellers during slack wire conditions. Ocean tugs generally are provided with sockets along their aft bulwarks into which Norman pins are fitted. Some tugs have two sets of Norman pins, with one set that may be inserted into the stern caprail.

Retractable or movable Norman pins have various designs, ranging from simple, removable round stock or pipe to remote controlled, hydraulically operated devices. On older ships, the round pins could be removed from any socket and moved to another location. This necessitated personnel moving about on the fantail and subjecting them to hazards; with remote controlled pins, the procedures are now safer. Newer tugs and salvage ships, such as the T-ARS 50 Class, have remote controlled, hydraulically operated Norman pins in fixed locations. On board the T-ARS 50 class, the Norman pins are set to drop when the lateral force at mid-barrel height exceeds 50,000 pounds. The hazard potential is formidable. When the pins start inclining toward the horizontal, the wire (with 25 tons force propelling it) can jump the pin and sweep forward.

Current design practice requires that the wire bearing surface of the Norman pins be hardened to a minimum Rockwell C hardness of 40.

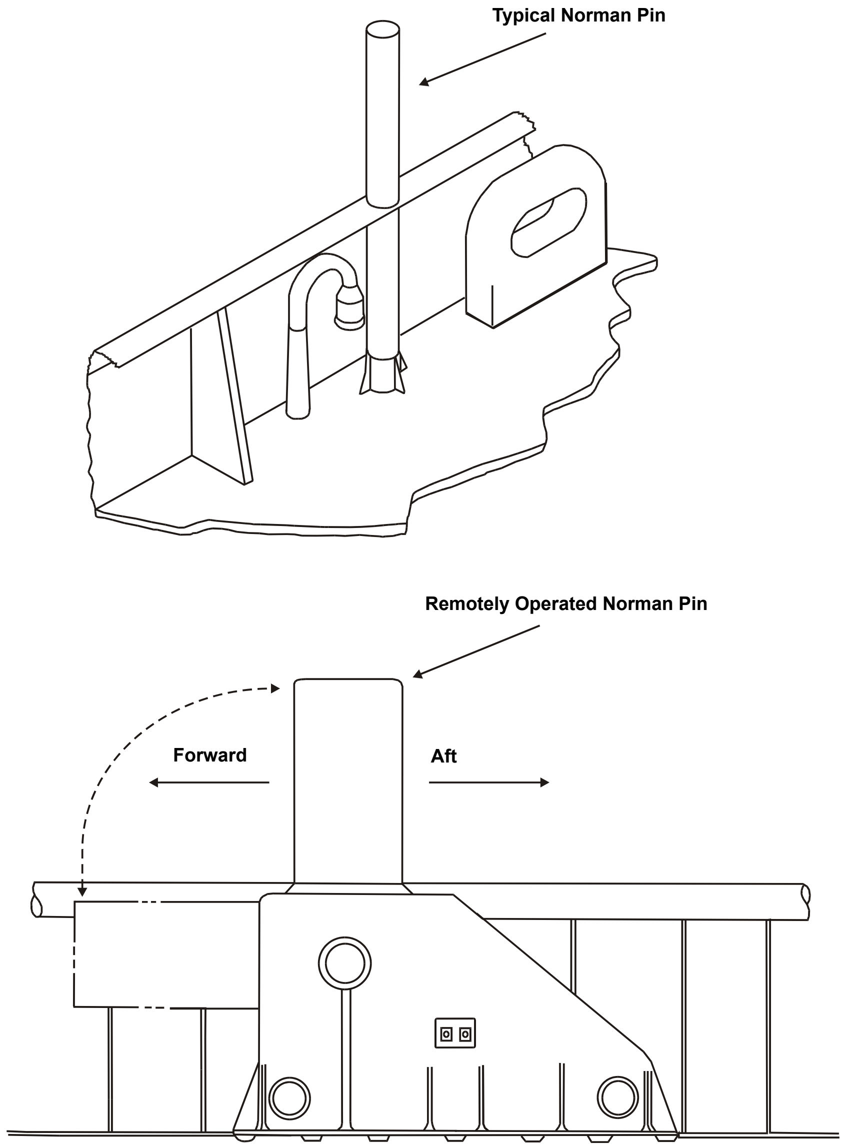


Figure 4-28. Norman Pins

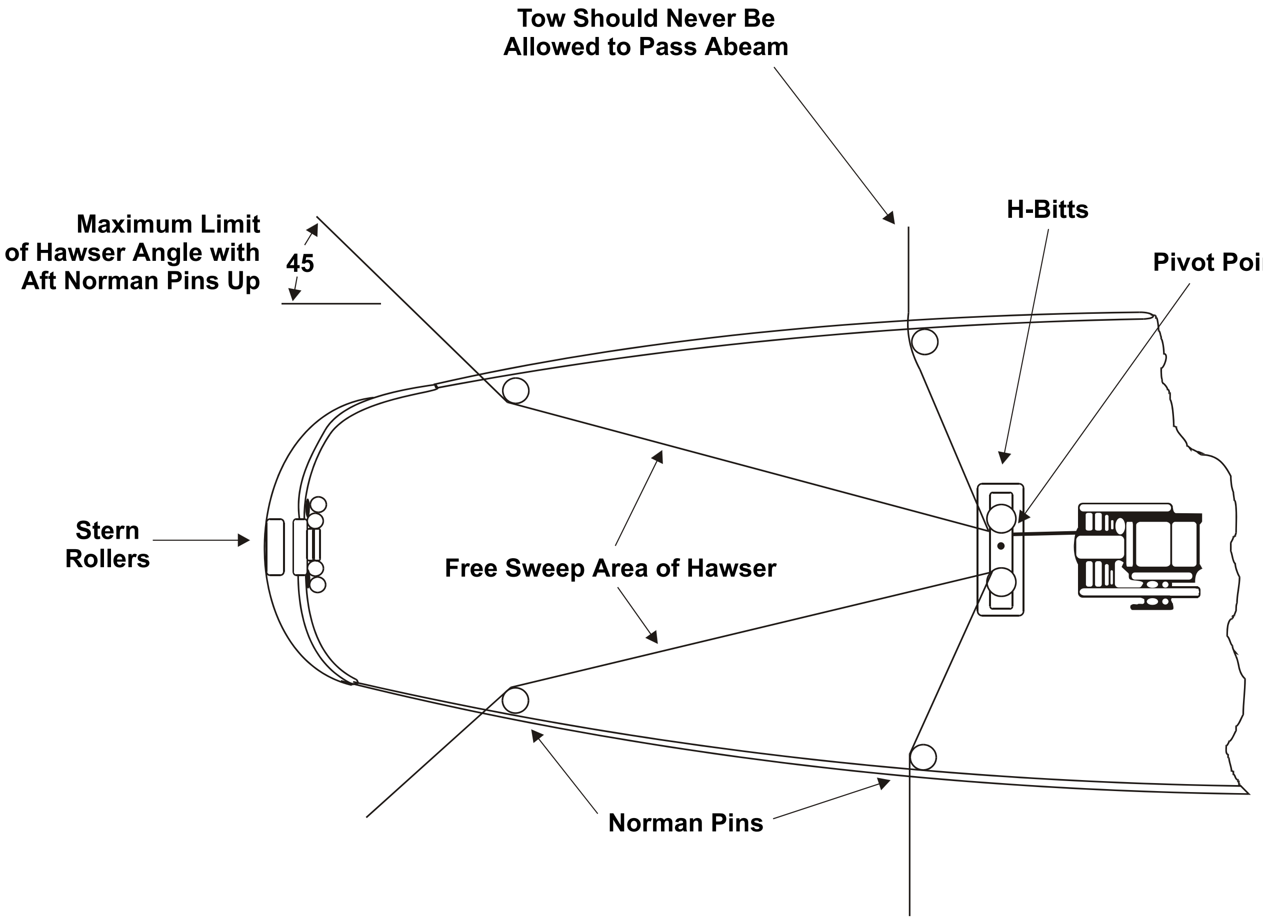


Figure 4-29. Norman Pin Use.

4-9.1 Hogging Strap

CAUTION
A hogging strap may be necessary to prevent the towline from jumping the stern rollers when towing a high-bowed ship at short stay. A hogging strap may be subject to excessive vertical loads. Care should be taken not to part the strap. Failure of a hogging strap may result in the loss of tug control or ranging up by the tow.

The hogging strap limits the relative movement between the towline and the stern in both vertical and horizontal planes (see Figure 4-30). Movement in the vertical plane is caused by the stern of the tug dropping faster than the towline or by a tow ranging up. A hogging strap can be attached to the towline with a shackle or a special saddle-like or riding fitting. The limitation of using a shackle type hogging strap is that the shackle creates high load concentrations where it rides on the tow hawser. Saddle-like fittings are preferred because they have a large radius roller which increases the area of contact and distributes the load over a wider arc. Because the hogging strap transfers the tow point aft from the H-bitt, it can cause reduced maneuverability.

4-9.2 Lateral Control Wire

A lateral control wire is similar in configuration to the hogging strap, but it has the added feature of variable scope. Instead of a fixed-length strap holding the towline to the deck, a snatch block is secured to the deck and the lateral control wire is led through it to a deck winch, lateral control winch, or capstan. In this manner, the line can be fully slacked to let the towline sweep free or can be taken in to give either partial or full snugging like a hogging strap. The lateral control wire is helpful in keeping the towline out of the propellers during slack wire conditions.

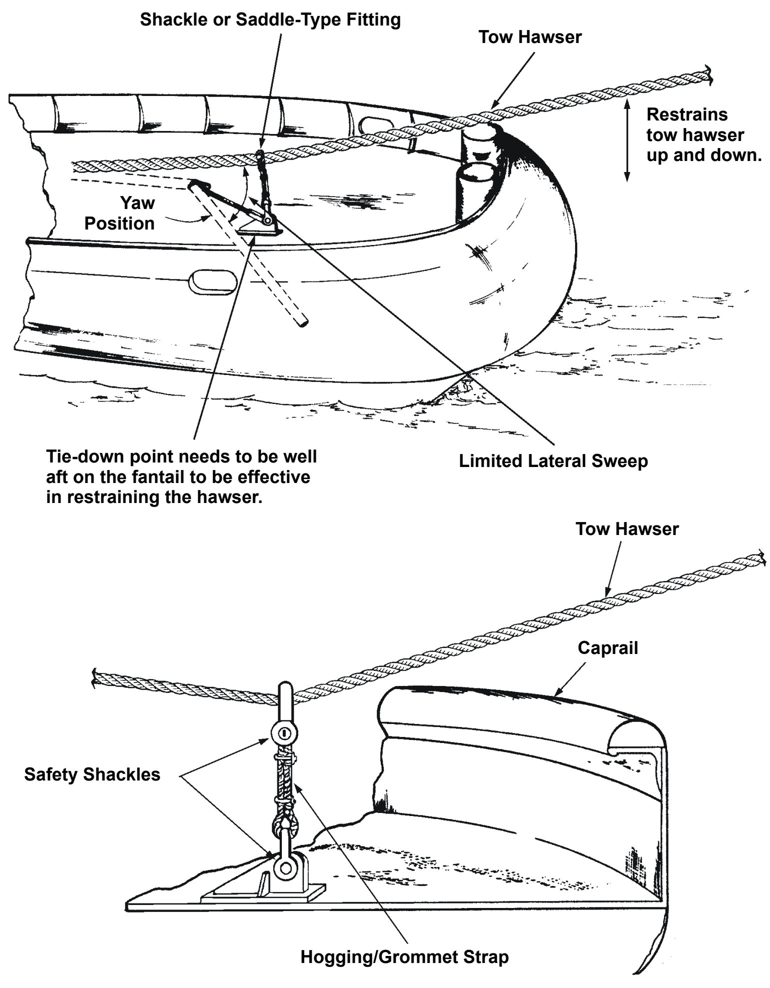


Figure 4-30. Rigging of Hogging Strap on Ships without Horizontal Stern Rollers.

Like the hogging strap, the lateral control wire moves the tow point aft and can put the ship in irons by limiting its maneuverability.

4-10 Cutting Gear

Most Naval ships are equipped with oxy-acetylene cutting equipment. Additionally, some tugs and most salvage ships are equipped with hydraulic cutters.

WARNING
Wire rope stretches far less under load then most natural and synthetic fiber lines. If it fails under high loads, wire rope has a smaller zone of danger to bystanders if loose ends “snap back.” The elongation under load is sufficient, nonetheless, to be dangerous. The recoil can be extremely violent and all personnel should stay well away from any potential recoil path.

Oxyacetylene or exothermic cutting equipment is most suitable for cutting chain while hydraulic cable cutters are best suited for cutting wire. Personnel safety is paramount when cutting any member of the tow assembly; therefore, every effort must be made to reduce the tension prior to cutting. This is particularly true when cutting wire or synthetic lines. The greater the distance between personnel doing the cutting and the cutting point, the greater the safety to the personnel. Securing the cutting torch to a boat hook is a good practice. Seizing a wire tow hawser on both sides of the intended cut is also prudent. Cutting a synthetic line with an axe is hazardous and should not be done under tension. The use of stoppers to control snap-back decreases the hazards involved when cutting any chain, wire or synthetic line.

Chapter 5 - TOW PLANNING AND PREPARATION

5-1 Introduction

Every tow is unique, the planning, preparation, and execution have to be carefully considered for each specific case. Tow planning must be meticulous, uncompromising, and farsighted. Admiral Nimitz provided a valuable guidance for operations when he said:

“The time for taking all measures for a ship's safety is while still able to do so. Nothing is more dangerous than for a seaman to be grudging in taking precautions lest they turn out to be unnecessary. Safety at sea for two thousand years has depended on exactly the opposite philosophy.”

Incidents involving loss of tows have demonstrated an absolute need for a thoroughly professional approach to tow planning and preparation. Tows have been damaged and lost by inattention to the basic principles of proper planning and preparation. A comprehensive tow plan must cover all aspects of the tow and anticipate worst case scenarios. Planning a tow includes training personnel, practicing basic procedures, and devising safe evolutions.

This chapter discusses tow planning and preparation in general terms.

5-2 Lessons Learned

As naval towing has evolved, several obvious lessons have been learned. The results of these lessons first appeared in the first Navy towing document, COMINST P-03, and are as valid and meaningful today as they were in 1944 when the document was published. The document noted when planning towing operations, avoid the following situations when possible:

- Keeping tugs waiting while tows are being prepared or disposed of after the mission has been accomplished. In this connection, when the draft of the towing tug is too great for the depth of the water at either terminal, advance arrangements should be made to deliver or to take over the tow before the arrival of the deep sea tug.
- Employing large tugs to do work smaller and less powerful tugs can do.
- Employing small tugs to undertake work beyond their capacity.
- Employing tugs designed or especially suited for combat zone duty in rear areas. Large salvage tugs are well suited for combat towing, emergency salvage, and or fire fighting in combat areas.
- Employing tugs which cannot survive moderate damage in forward combat areas. Survival factors include stability, reserve buoyancy, and subdivision, as well as being armed to ward off attacks by scouting threats.
- Routing tugs with large tows over areas where the water is too shallow for the hawser’s catenary. Arrangements should be provided for shortening the towline where necessary. Tows are frequently lost or involved in difficulties due to the towline fouling on submerged objects.
- Unnecessarily employing tugs for standby duty on salvage or rescue operations. Tugs should not be ordered to stand by unless there is a high creditability their services may be needed and they are capable of rendering the service likely to be required.

- Diverting rescue tugs from areas where tugs equipped with rescue facilities, such as salvage or fire fighting, may be required.
- Employing tugs for tows which could be undertaken by other craft scheduled to make the same passage, or by a ship which could be more easily made available than a tug.

5-3 Staff Planning

The primary objective of staff planning is sequencing all actions required for preparing the tow. Orchestrating preliminary, operational, and post mission requirements is a fleet or group staff planner's mission. Care must be taken in planning a tow, contracting, and funding tow preparing activities sufficiently in advance to adequately prepare the tow ahead of the planned tow out date, selecting the proper tow gear, specifying required bollard pull, tug selection, selecting a tow route, identifying ports of refuge, coordinating entry restrictions/requirements with the various Captains of the Ports (COTPs), verifying and brokering arrangements with assist tug companies for emergency entry assistance at the identified ports of refuge in the event they are required prior to tow departure, selecting the best time for departure based on historical weather data vice arbitrary contractual or other external factors not related to actual tow performance, and completing comprehensive tow packages 30 days prior to departure. Failure to take these factors into account in advance could result in loss of life, tow, catastrophic environmental damage, or destruction of property.

5-3.1 Definition of a Navy Tow

If either the tow ship or the tow are USN vessels the tow is considered a Navy tow. Therefore the applicable sections of this manual apply. In some cases there are special instructions for specific types of tows such as defueled submarines which provide further detailed instructions for preparing and conducting the tow. While these amplifying instructions provide additional details for preparing and conducting the tow, the provisions of this manual also apply. Technical clarification of towing requirements or guidance on applicable instructions is available from NAVSEA 00C at https://supsalv.navy.mil/.

5-3.2 Tow Ship Selection

For planned tows, planners should be able to match tug characteristics to the type of tow to perform the tow in a cost effective manner. Because the fleet has been reduced in size, planning appears to be easier because the potential combinations of choices are less with fewer towing assets. All of the remaining fleet tugs have been transferred to MSC in the TATF-166 and TARS-50 Classes. In many cases, routine tows not requiring the capabilities of the large MSC ocean going tugs are contracted through MSC or Regional Maintenance Centers (RMCs).

5-3.3 Operational Considerations

5-3.3.1 Support

Tow planners must determine support requirements for the tow at the point of origin, en route, and at the point of debarkation. Support considerations include identifying industrial facilities required for preparing the tow, temporary berthing and messing for riding crews, refueling, provisioning, returning special issue equipment, tasking orders, and coordinating logistics for making up, getting underway, disconnecting the tow, line handling, pilot services, sailing times, sailing restrictions as dictated by local COTPs, and tide conditions, . A pre tow conference is highly recommended a minimum of 24 hours prior to getting under way to ensure all parties clearly understand their respective roles and actions on the day of ships movement. Many of these functions may be passed to the tow master.

5-3.3.2 **Riding Crews**

The tow sponsor is responsible for providing riding crews for the towed vessel. While direct financial support for riding crew transportation, messing, and berthing also resides with the tow sponsor, there are aspects of a riding crew which have to be integrated into the planning process for the towing ship. Tow planners along with the tow master will determine:

- If there is a need for joint training of the riding crew with the tug's crew for special tows
- If the riding crew will be berthed on the tug
- When the riding crew needs to report to the tug.

5-3.3.3 **Manned Tows**

Manned tows should only be planned as a last resort when the safety of the tow and/or the unique circumstances of the tow warrant a manned tow (such as a rescue tow, when a salvage crew is required to keep the tow afloat until it reaches port, or when highly specialized personnel familiar with the tows systems plant are required). While a manned tow can add to the general safety of the tow, it also complicates logistical requirements and may introduce additional risks for evacuating personnel in case of foundering, fire, or loss of tow. Therefore, requests for manned tows should only be made after a comprehensive personnel risk assessment has been performed and the tow's value is considered worthy of placing personnel in harms way. Historically, manned tows have experienced a disproportionate number of fires while under tow. Safety considerations must be based on the crew's ability to influence the safe conduct of the tow vice convenience. The tow's value can be either its replacement cost; value of its safe and timely delivery; or cost of consequences of loss from a tactical, strategic, or a public relations standpoint. Manning a planned tow should be the last resort. Frequently, rescue tows require personnel on board to make the tow connection and to respond to changes in the tow's material condition. A riding crew can also respond to emergencies such as fire, flooding, hawser or bridle chafing, and towline loss. The tow must be adequately supplied and equipped to support a riding crew. Crew accommodations should include berthing, messing, and sanitary facilities, all of which must be properly ventilated.

Under normal conditions, most planned point-to-point tows are undertaken without a riding crew. All tows can be unmanned if properly planned.

Riding crews shall be limited to personnel required for maintenance and security during the voyage.

Factors governing a decision to conduct a manned tow with a riding crew include:

- Safety of the riding crew
- Reduction of risk of towed ship loss by assigning a riding crew
- Material condition of the tow
- Flooding alarms and other monitoring devices installed on board

See section 5-6.1 for more considerations.

With the exception of rescue tows, approval for all manned tows must be in writing from the Fleet Commanders and CNO in accordance with existing directives.

5-3.3.4 **Tug Selection**

When selecting the tug and support crew, consideration must be given to any anticipated complications during the tow. For instance, if damage control or salvage is required, (towing a rescued vessel) experienced salvage personnel are essential. An MSC operated fleet salvage tug or similar vessel should be supplemented with a salvage crew. MSC and commercial tugs have limited manning, and although capable, may be insufficient in number to perform all required tasks without additional personnel. These tugs are typically augmented with personnel from a Mobile Diving and Salvage Unit (MDSU) or commercial salvors with a salvage master and a SUPSALV representative. For example, yard tugs are not suitable for open ocean point to point tows.

5-3.3.5 **Unsuitable Tows**

Many ships are unsuitable for open ocean towing. Table 5-1 lists vessels which are not recommended for open ocean towing, along with supporting rationale as to why they do not qualify. Of course, any vessel can be towed, but the vessels listed in Table 5-1 cannot be towed without serious risk. Correcting the disqualifying condition can make these craft safer for tow, but in their normal operational configuration, they should not be towed in the open ocean.

Table 5-1. U.S. Navy Craft Not Recommended for Open-Ocean Tows.

CRAFT CLASSIFICATION	REASONS FOR NON-RECOMMENDATION
LCU, YCU Landing Craft LCM8, LCM6 Landing Craft YFU, UFB, LWT	Low freeboard. Light construction of bow door locking mechanism. Structure can be strengthened to reduce risk.
YFNG, YFNX Lighter, YNG Gate Craft, YSR Sludge Removal Craft	All have deck-mounted equipment which requires installing special protection before towing.
YPD Pile Driver, YD Crane LSMR	All tend to be top-heavy (have high center of gravity) and may also have poor watertight integrity. Topside high weights may require removal and stowage prior to open ocean towing to attain adequate stability. All require special preparations.
YSD (formerly Seaplane Derrick), YM Dredge	Low freeboard and high weights reduce sea-keeping ability. Weights may require removal and stowage to improve stability at sea.
YTL Small Harbor Tug PTF Patrol Boat	Hulls considered too small for open-ocean tows. Should be transported as deck cargo.
Mini-ATC, LCPL MK2, MK3, MK4, MK5 personnel boats	Low freeboard. Light construction with poor watertight compartment and weak to no attachment points for towing.
MK1, MK2 65’ utility boats, MK4 50’ utility boat, MK3, MK4 40’ utility boats	Low freeboard. Deck mounted equipment.

5-3.1 Selecting the Navigation Track

The tow route should be determined using pilot charts as an aid. Locations along or near the track where a lee can be found should be noted. These lee areas can be utilized, when practicable, to effect inspection, tow repair, or shelter/safe haven in heavy weather. Routine navigational issues must be reviewed in the context of having a vessel in tow. Pilot charts, navigational charts and Fleet guides must be consulted for any restrictions for towing in general, as well as the type of tow. The navigator shall be familiar with charts of all areas to be crossed, including potential safe havens. He shall account for geographic features such as lees of headlands, effects of river outflows, and tidal currents to determine the relative safety of a particular haven. When entering a safe haven, the Navigator shall be aware of water depths where the tow wire may snag, and stand ready to recommend shortening the towline as required.

An early consideration in selecting the navigation track is the predicted weather en route during the time the tow is desired and prevalent currents. Frequent contact should be made with the Naval Meteorological and Oceanographic Center (METOC) or other reputable commercial sources to aide in route planning and maintain an up-to-date weather picture, and adjust the planned track accordingly. Anticipated heavy weather will drive the size of the jewelry as well as the tug. Optimum Track Ship Routing System (OTSR) should be used whenever possible, to predict the weather along the planned navigational track and make changes to avoid adverse weather along the route. When using a commercial tug, OTSR support can be provided if requested by the tow sponsor. A longer course on a favorable weather track should be selected in favor of a shorter one with unfavorable weather. Little time is gained by taking a shorter track through bad weather.

Once the navigation track has been selected, calculate total distance and estimate fuel required for the type of tow. If refueling is required either at the tow termination or en route, contingencies must be formulated early in the planning process. Tugs should have sufficient range to preclude refueling at sea whenever possible.

The tug usually hands off the tow to harbor tugs, pilots, and pilot vessels at some point before mooring. If there is any confusion, an accident may occur. Conversely, it should be understood how far off shore the harbor tugs are willing to go when accepting or delivering the tow. Both parties should clearly communicate and understand their respective weather and sea condition limitations on their abilities. If possible, a pre tow conference of all vessel captains involved (tow ships and harbor tugs) should be conducted prior to getting underway. Participants at the pre tow conference should be the actual captains and pilots to be used during the planned movement vice company representatives whenever possible speaking on their behalf. Failure to do this frequently results in confusion during ship movements as the assigned captains are not adequately briefed on the planned movement and may have pre-conceived notions as to how the movement is going to be conducted or may not be able to accomplish tasks their company representatives have committed them to. All transfer procedures and special requirements can be worked out during this meeting.

5-4 Tow Responsibilities

Primary commands involved in a towing operation are the tow sponsor and the towing command. Frequently the sponsor will task and fund an assisting command such as RMCs to perform some of the tow preparations. This section details the definitions, interrelationships, and specific responsibilities of the parties involved in a towing operation.

5-4.1 Sponsoring Command Responsibilities

The sponsoring command is the command requiring the tow, and is responsible for preparing the tow. Often times these functions are delegated to the preparing activity and the tow master. In either case, it is highly recommended a single Point of Contact (POC) be designated to oversee all aspects of the tow preparation. This POC will coordinate with the preparing activity, track the progress of planning and physical preparations, coordinate actions with the tow master, set up pre-tow conferences, and coordinate with the NAVSEA Technical Authority (SEA 00C2). Basic responsibilities of the sponsoring command include:

- Reviewing applicable Type and Fleet Commander numbered instructions and operational orders
- Completing the comprehensive tow package and submitting it for review a minimum of 30 days prior to the scheduled tow date
- Ensuring a hard copy of the comprehensive tow package is provided to the tow master, the preparing activity, and placed in the DC space on the tow. Also an electronic copy should be filed with NAVSEA 00C23.
- Providing Objective Quality Evidence (OQE) for attachment points and tow jewelry (shackles, pendants, chain inspections, pad eyes, back up wires, etc.) OQE is quantitative or qualitative evidence based on facts that can be measured and verified.
- Providing a complete sketch of the tow rig which clearly identifies all tow components from the tug to the tow. This sketch shall include a complete bill of materials to aide in identifying the weakest link and forensic analysis to track failure trends.
- Identifying weather restrictions
- Identifying Ports of refuge along the planned route
- Identifying restrictions or limitations identified by the COTPs for entering the identified ports of refuge
- Providing hull and machinery certifications for the tug
- Identifying the weakest link
- Providing steady state towing calculations for all planned transit conditions and speeds. In particular these calculations should identify the limiting conditions for conducting the tow.
- Providing bollard pull certificate for the tug.
- Providing a flooding and fire alarm schematic.
- Scheduling pre-tow conferences
- Preparing the tow
- Assembling the towing rig
- Completing Certificate of Seaworthiness (see Appendix H)
- Determining when there is a riding crew requirement
- Designating a receiving activity
- Returning all towing equipment, including towing bridle, to preparing activity or tow originator once the tow has been completed.
- Towing machine/towing winch certification
- Tow hawser certification
- Commercial vessels (U.S. Coast Guard Inspected) - Master’s Towing Certificate

5-4.2 Towing Command Responsibilities

The towing command is the command that performs the tow. The Commanding Officer or Master is responsible for:

- Determining sailing date and time
- Determining the transit route
- Ensuring the comprehensive tow package is complete and submitted
- Selecting towing rig and determining trim conditions
- Inspecting and accepting the tow
- Maintaining and protecting the tow during transit
- Delivering the tow and obtaining a receipt from a receiving activity

5-4.3 Assisting Command Responsibilities

An assisting command is often a naval shipyard (NAVSHPYD), Regional Maintenance Center (RMC), private shipyard (through the cognizant RMC or Naval Station. Assisting command responsibilities may include:

- Designing the towing system
- Installing temporary towing hard points on the tow
- Installing fire and flooding alarms or electrical systems on the tow
- Supplying a riding crew
- Providing temporary messing and berthing for a riding crew at ports of embarkation and debarkation
- Conducting NDT testing
- Verifying pedigree of tow jewelry
- Inspecting the chain and documenting per NSTM Chap 582

5-5 Review Instructions and Operational Orders

An important preliminary step in any tow is to review all pertinent instructions governing the type of tow being performed. Fleet and Type Commander Instructions provide general towing and periodic reporting procedures to be followed during the tow. Specific guidance for towing defueled, nuclear powered submarines is provided by NAVSEAINST 4740.9 (Series). Operational tasking, such as a Letter of Instruction sent via naval message, will be promulgated to naval vessels performing a tow. All governing instructions should be reviewed for applicability to the tow being performed.

5-6 Preparing the Tow

A tow's hull design may require taking numerous steps in preparing the tow. Examples include cranes, pile drivers, dredges, dump scows or other equipment designed for operation in sheltered waters. Tow preparations may include removing high weights, securing booms, dredge ladders, and other deck structures; adding or removing ballast or adjusting trim; stiffening the hull; and removing hull protrusions for transiting the Panama Canal. Heavy moveable objects must be secured by welding heavy metal brackets and should be designed the worst sea conditions. Large roll and pitch angles should be expected and taken into consideration when designing sea fasteners for heavy objects.

Hulls not considered seaworthy for open-ocean tows should be transported as deck cargo on semi-submersible heavy lift vessels, ocean going barges or LSD type ships.

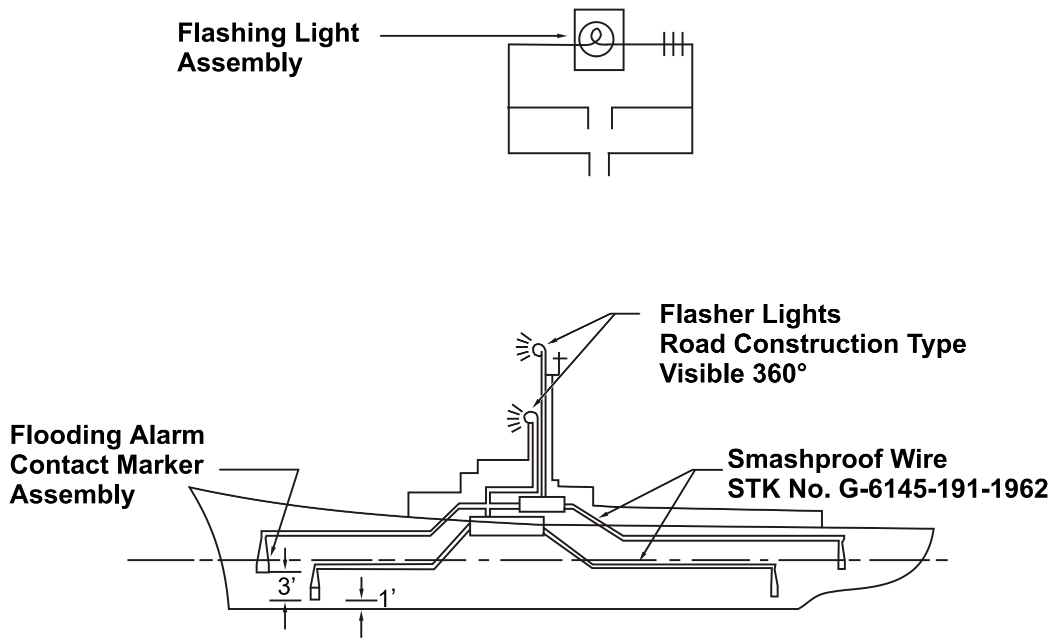
5-6.1 Installing Flooding Alarms, Draft Indicators, and Other Alarms

All unmanned tows shall be equipped with flooding alarms. Flooding alarms alert the tug if there is a flooding problem on the tow, allowing time for corrective action to be taken before the tow sinks. The tow preparing activity is responsible for installing flooding alarms. Unmanned tows must be equipped with high and low alarms rigged with multiple bulbs, and independently wired flooding alarm lights in all major compartments closest to the keel. The flooding alarms should be placed at one foot and three foot above the lowest portion of the compartment along the centerline or the most likely place water will collect during the tow.

A schematic diagram of an acceptable flooding alarm is shown in Figure 5-1. No attempt has been made to provide detailed specifications or installation instructions because these vary with the type and size of the tow. The number and location of the electrode blocks or alarm switches to be installed in an unmanned tow are determined by the activity preparing the tow and agreed to by the towing command. Installation should be sufficient to provide coverage of major hull subdivisions. Alarms should be securely rigged and properly serviced to ensure performance and reliability. SUPSALV has developed the SMART Tow system with wireless flooding and fire alarm sensors, eliminating the need for running wires between compartments and possibly compromising condition Zebra. In addition, the SMART Tow allows for interrogating the sensors from the tug thereby eliminating the need to conduct PAX transfers to determine which sensors have been activated. This greatly increases the safety of the tow and personnel and allows the salvage team to formulate a dewatering plan prior to transferring to the tow.

5-6.1.1 **Flooding Alarm Sensor Mounting Requirements**

There are a variety of alarm types. Electrical contact alarms are actuated when water closes the circuit when it makes contact with both electrical contacts. This type of alarm is simple in design and is highly reliable. When used in the engine room, however, oil in the bilge may coat the wires as flooding progresses and render the alarm useless. Deployment locations for these types of alarms should be carefully considered. Several types of float alarms are also available. As the



NOTE

This sample diagram is not intended to restrict or limit the number of alarms considered necessary to provide adequate protection to all important watertight spaces.

Figure 5-1. Examples of a Flooding Alarm Schematic

water rises the float is lifted until it makes contact with a switch thereby closing the circuit an activating the alarm. Care must be used when deploying these types of alarms to ensure the float remains in a vertical orientation to ensure the float does not get hung up or wedged. When using either the electrical contact or float type alarms it is critical that they are securely fastened to fixed equipment/bulkheads to prevent them from being dislodged during the tow. More than one tow has been affected by false alarms resulting from the sensors activating the alarms due to being displaced during the tow. Recently, wireless fire and flooding alarms sensors with magnetic mounts have been developed to simplify deployment and use. These sensors are capable of transmitting through multiple bulkheads and decks, thereby eliminating the need for hard wires.

The following guidelines are provided when installing flooding alarm sensors:

- Installing flooding alarms may require piercing watertight decks and bulkheads. Penetrations should be as high as possible. Every attempt should be made to use watertight penetrations such as stuffing tubes to minimize the rate of cross compartment flooding. If no existing watertight penetrations are available, the size of the hole for passing the wires should be kept to a minimum and should be sealed with RTV or other water resistant sealants to obstruct and reduce the rate of allowable flooding.
- Low level alarm sensors shall be installed one foot from the lowest point in the compartment, when considering the tows orientation when it is in its final tow trim and list condition.
- High level alarm sensors shall be located three feet above the lowest point in the compartment.
- Float type switches are recommended. However, if using electrical contact alarm sensors, they shall be securely mounted on a suitable nonconductive, nonporous material such as Melamine. Plywood is not considered a suitable material; C-clamps are not suitable for securing these devices.
- Areas where flooding alarms are to be installed shall be certified gas-free to prevent explosion and fire from electrical contact sparking.
- When placing alarms in wide flat-bottomed compartments, it may be necessary to place alarms on both the port and starboard sides of the compartment.

5-6.1.2 **Wiring and Power Requirements**

Power for fire and flooding alarms must be capable of providing continuous power to the alarm lights for a minimum of 24 hours after actuation. Electrical calculations demonstrating sufficient power shall be included in the Appendix H submission. Power for the flooding alarms should be separate and independent from the navigation lights power source. The most commonly used source for supplying this power are 12 volt marine batteries. It is highly recommended these power supplies be augmented with the use of solar charging panels and/or wind generators. With the advancements of LED technology and strobes, the power requirements have been greatly reduced.

The following is provided for alarm wiring:

- Low level flooding alarms should be wired to actuate the low level alarm lights (white), while the high level alarm lights (amber). Existing ships wiring may be used to support this installation.
- All wiring should be secured and protected from chafing, and weather damage.
- Where practical, an alarm panel shall be installed to indicate which compartment alarm has been activated. Frequently this panel has a series of knife switches which need to be physically tripped to determine which alarm has been actuated. The Navy’s SMART tow system relays the information to a laptop computer on the tug’s bridge identifying which alarm has been triggered.
- NAVSEA has developed the SMART tow system which utilizes a radio link from the tow to a laptop console on the tug. This system allows the tow ship to determine the location of the flooding alarm without boarding the tow. Indications of low battery power and ground faults from alarm wires are also indicated. This system has been packaged for at sea use and includes all power sources, lights, alarms, and wiring. This system is available for issue from NAVSEA 00C.

5-6.1.3 **Alarm Lighting Requirements**

- Two high alarm and two low alarm lights shall be installed and should be placed high enough on the tow to be visible from 360 degrees. The high level alarm lights shall be positioned four feet above the low level alarm lights.
- High level alarm lights shall be equipped with an amber lens.
- Low level alarm lights shall be equipped with a white lens.
- Flooding alarm lights should be checked to ensure their visibility during daylight hours. The lights shall be visible from 360× and at a minimum distance of 2,000 yards during bright daylight.

5-6.1.4 **Audible Alarms**

Audible alarms can be used to provide notification during fog or heavy rain. These alarms must be loud enough to be heard by ship's personnel over the noise of the engines while underway. Items such as fog horns can be a considerable power drain. It is recommended these be rigged for intermittent operation (a few seconds of sound; every few minutes) to avoid the need for excessive power supply sources such as batteries. Installation of audible alarms is optional.

5-6.1.5 **Requirements for Other Alarms**

Depending upon the tow, its equipment and cargo, other alarms such as fire, radiological, or combustible gas may also be required. Specifications will be provided to the tows preparing activity. Wiring and powering requirements provided above apply to all additional alarms.

5-6.1.6 **Draft Indicator Requirements**

The tow should have large, special waterline marks to allow the tug to check the trim of the tow visually by day and by searchlights at night. Marks should be painted on the bow, stern, and amidships on both sides, in highly visible paint. White or international orange are recommended. These marks need not be painted below the waterline, but must give the tug a clear indication of a change in the tow's trim. See Figure 5-2 for samples of waterline marks.

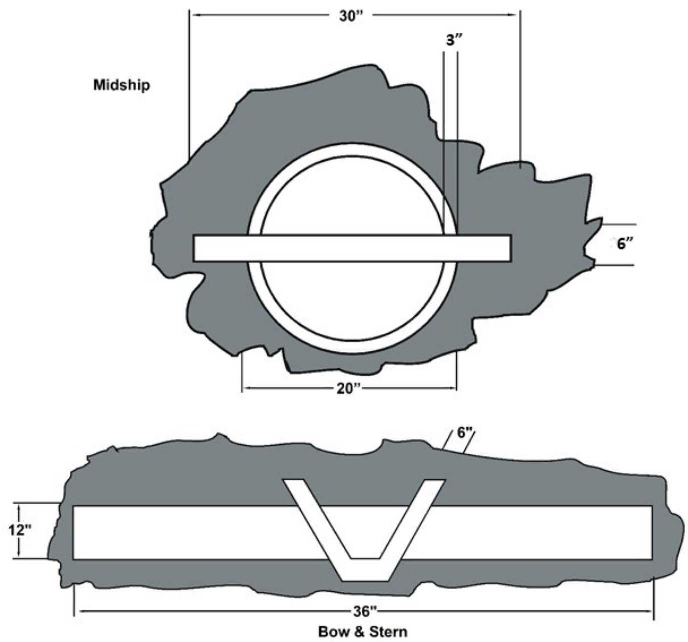


Figure 5-2. Special Draft Markings

5-6.2 Towed Vessel Propeller Preparation

Propellers can be a valuable tool or an unpleasant obstacle during a tow. Propellers while creating drag, also aide in controlling the tow. In either case, they require special attention. Tow planners must decide whether to remove propellers, lock them in place, or allow them to free-wheel. The procedure of allowing free-wheeling propellers is not recommended, but cannot always be avoided.

5-6.2.1 **Removing Propellers**

For long-distance tows, fixed-pitch propellers may be removed to reduce towing resistance. For some hull forms, however, the added drag of locked propellers may be desirable for better directional stability. Tows with multiple propellers such as aircraft carriers may require removal of the two inboard propellers to reduce drag while allowing the outboard propellers to provide directional stability. Economic factors may be considered when determining the feasibility of removing the propellers. For instance, if the vessel is being transferred, but not decommissioned or drydocked, it may be best to not remove the propellers. However, if the vessel's propeller might be of use as a spare for its sister ships, removal may be beneficial. When laying up vessels it is important that the shafts be locked with the propellers in the dry docking position to allow for future removal if needed.

Propellers create considerable resistance in either the locked or freewheel configuration. Typically, the propeller resistance is the largest drag force which contributes to the tows directional stability, particularly in the absence of rudder control. If the propeller is removed, the directional stability may be compromised, which will most likely result in the use of additional assistance tugs when towing in confined waters. Water brakes or similar devices are frequently used for stability when the propellers have been removed.

Controllable pitch propellers may be adjusted to manage propeller drag forces, if set in “maximum forward” pitch condition, they offer the least resistance to towing, if set in a “zero pitch” condition, they offer the maximum resistance to towing.

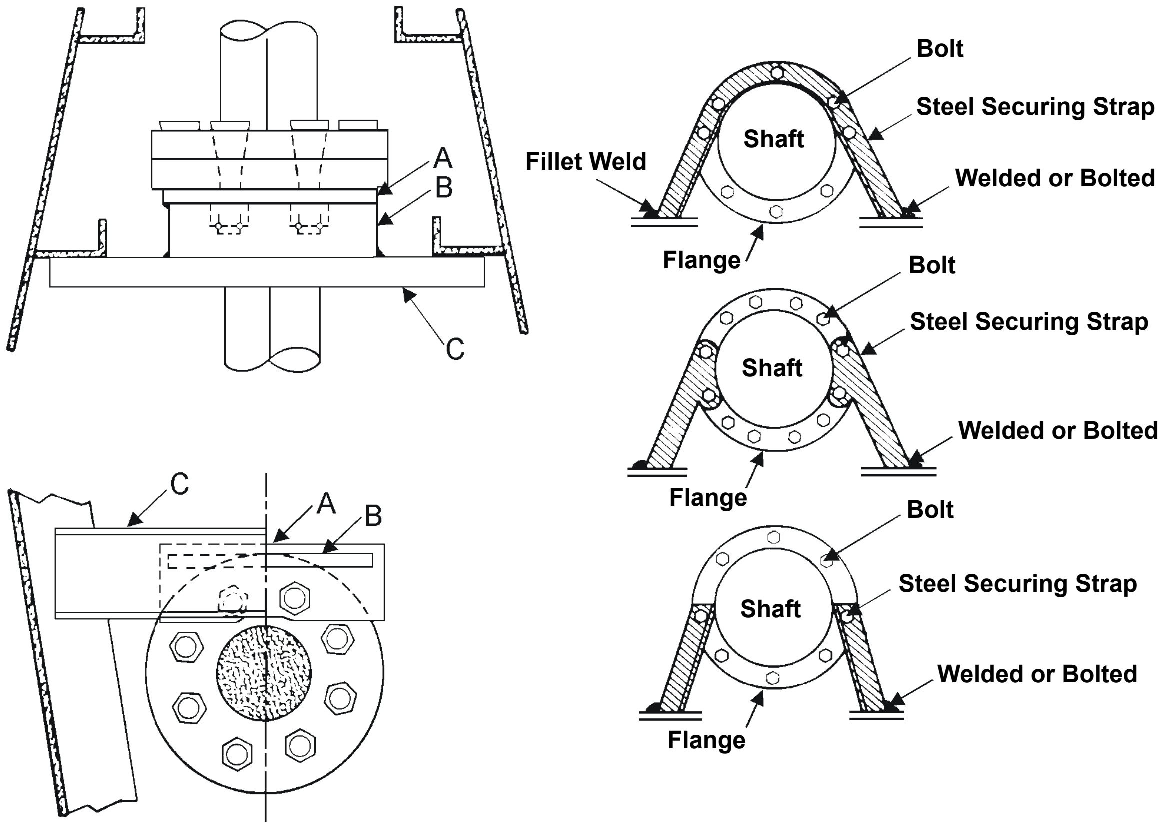
5-6.2.2 **Locking Propellers**

When propellers remain in place and are not allowed to free-wheel, lock the shafts by installing a shaft-locking device or by another suitable method as illustrated in Figure 5-3. Shaft locks should be designed to transmit rotational forces to ship structure.

5-6.2.1 **Allowing Propellers to Free-Wheel**

If propellers must be allowed to free-wheel due to the condition of the towed vessel’s propulsion train, all propulsion machinery must be disconnected from the shafts and adequate lubrication must be provided.

CAUTION
Do not allow main reduction gears to rotate unless they are properly lubricated. This requires full lube oil pressure.



A. Heavy Plate, ¾” to 1” cut to accommodate two (2) of the coupling bolts
B. Intermediate, horizontal plate cut to accommodate and welded to “A” and “C” with full fillet.
C. Deep channel or angle beam welded to the nearest hull frames with full penetration filet weld.

Figure 5-3. Securing the Propeller Shaft

A means for lubricating shaft bearings must also be provided. The stern gland on the shaft will normally be water-lubricated. This must be taken into account while ensuring water does not flood the space.

5-6.2.2 **Stern Tube**

No water leaks are allowed at the stern tube. The tow should be equipped with extra packing material for the stern gland to allow emergency repair during transit if required. The gland should be tightened to prevent any leakage and allow at least two inches of thread room before its tightest position. Double nutting with locknuts to prevent backing off is highly recommended.

5-6.3 Ballasting or Loading for Proper Trim

Proper trim is important, as it can affect stability, towing characteristics, and speed. Shifting ballast, fuel, cargo, or equipment on board can bring about desired trim.

Follow these guidelines when adjusting the tow's trim:

- Trimming by the stern has proven to aide in stabilizing the tow, by keeping the tow directionally true while under tow. A trim of one foot by the stern for each 100 feet of wetted hull over the tow's length is a good rule of thumb when determining the amount of trim required; deep draft tows may use slightly less than one foot per 100 feet.
- Completely fill all tanks or leave them empty to ensure there is no adverse free-surface effect.
- Ensure all normally dry compartments are dry to avoid free surface effects and to provide greater reserve buoyancy.
- Ensure bilges are free of oil and water to ensure bilge flooding alarms are not tripped by sloshing water. Oil in the bilge is a fire hazard and could foul alarm electrical contacts.
- Close all sluice valves to prevent liquids from flowing between adjoining tanks.
- Ballast landing craft or craft with blunt or raked bows, such as dry-docks and barges, to prevent heavy pounding. Pounding can be destructive to the vessel's bottom and other structural members. Preventing or reducing pounding also reduces shock loads on the towing rig.
- Ensure the tow has zero list.

5-6.4 Ballasting for Proper Stability

Stability of the tow, in the case of an unmodified or undamaged Navy commissioned ship, can be determined by reviewing Chapter II(a) of the ship's Damage Control Book. Similar information for commercial ships should be available in the ship's Trim and Stability Booklet, as well as in the Deadweight Survey. When formal documentation of the ship's stability is not available, stability may be approximated by timing the ship's roll period. This method is reasonably accurate and is used by the U.S. Navy, U.S. Coast Guard, and other regulatory bodies to confirm the accuracy of inclining experiments and other similar stability determinations. For small craft, timing roll period is the approved method for determining stability.

The roll period can be estimated accurately enough even in fairly calm water by watching the masthead. Time several successive rolls (from extreme port to starboard back to extreme port is one period), then divide the total time by the number of rolls observed to obtain a good estimate. To determine the adequacy of the roll stability, compare the time period with the value calculated from the following formula:

$$T = \sqrt{Beam\ (ft)}$$

where:

T = Time in seconds.

For adequate stability, the time in seconds for a ship to roll from port to starboard and back to port must be equal to or less than the calculated time (T) in seconds. For example, for a ship with a beam of 100 feet, the time observed for the ship to complete a roll period must be less than the 10 seconds calculated. If the observed time is longer than the calculated value, stability generally is considered inadequate. Equally important is frequent checking for a change in the tow's roll period. Even if overall criteria are satisfactory, promptly investigate any increase in period, since this suggests flooding and/or additional free surface.

Each commissioned ship in the U.S. Navy has a Damage Control Book containing specific measures for improving a ship's stability. This book also contains stability characteristics for various loading conditions that meet the Navy's stability criteria.

For small craft and barges that do not have a Damage Control Book, follow a few general guidelines when attempting to improve stability:

- Completely fill any slack tanks
- Lower, secure or off-load high weights
- Secure any large hanging weights and add ballast.

In addition to improving stability, completely filling tanks or adding ballast will decrease freeboard.

5-6.5 Two Valve Protection

The intent of this requirement is to provide two boundary protection against seawater ingress to the tow. Redundancy is especially important in unmanned tows, where any remedial activities will be delayed.

Two boundary protection is required for all overboard connections that penetrate the hull lower than four feet above the full load waterline. Two boundary protection may be achieved by two closed valves, or by a single closed valve plus a bolted blank inboard of it, or by an external hull blank plus either a closed valve or a bolted blank. Valves in all cases must be wired shut and marked. A list of all locked-closed sea valves must be made and submitted in accordance with Appendix H -.

Single boundary protection is permissible for any hull penetrations between 4 and 20 feet above the full load waterline, or below the Main Deck, whichever is lower. Single boundary protection may be achieved by either a single closed valve or a blank. Valves must be wired shut. Drainage systems that are in good condition which are not equipped with shell valves should not be modified and are exempt from this requirement.

Only weathertight closures are required from 20ft above the full load waterline and above, or above the Main Deck, whichever is lower. Attention should be paid to any potential loose connections or deterioration. Drainage piping that shows excessive rust or other damage may become a potential flooding path in heavy weather, and should be repaired to prevent the ingress of water. Large openings such as vents and air intakes that are not equipped with weather protection, or large openings due to damage or industrial activity, must be sealed. Spray foam and plywood are NOT considered suitable for towing, and a more robust solution must be used, preferably welding.

Tows involving inactivated Navy vessels imply that the preparing activity has met the requirements of Naval Ship's Technical Manual (NSTM) S9086-BS-STM-010, Chapter 050, Readiness and Care of Inactive Ships (Appendix M -, REF G). This NSTM calls for two boundary protection by installing either external (preferred) or internal hull blanks for all sea connections and for all sea valves to be wired shut. Tow inspectors should still be attuned to the potential for flooding on inactivated vessels, and a thorough inspection and record must still be made.

For active Navy ships, or those which have recently been decommissioned or removed from active service, defined as within one calendar year, an exception to the installation of blanks prior to towing is allowed. In this case, the ship's custodian and/or decommissioning OIC must certify in writing that all piping systems and associated valves with hull penetrations four feet above the full load waterline and below are closed and in good material condition. All sea valves will be wired shut and two valve protection (two valves, in series, wired shut) will be obtained where possible. Any instances of single valve protection must be specifically noted within the document submitted by the ship's custodian and/or decommissioning OIC. The rationale for this exception is that active and recently decommissioned ships should exhibit piping systems in known good material condition. This exception should not be allowed in any case where damage, age, or uncertainty are factors.

5-6.6 Inspecting the Tow for Structural Damage

Every tow should be inspected to ensure that its structure is capable of withstanding the effects of towing. If the tow's structural integrity is in question or if the structure shows signs of extensive deterioration or damage, a qualified structural engineer should be consulted.

In emergencies, such as salvage and rescue towing, structural reinforcement and load distribution may be accomplished by using shoring. See Figure 5-4 for typical timber framing practice. Protection against slamming damage may be effected by pressing up the bow section of the hull with water. This action may require counter-flooding or shifting of cargo. Tows rigged for stern towing (secondary or emergency rigging), should receive similar attention.

Inspections may reveal damage and/or deterioration of frames, bottom or weld seams. When this occurs in the forward one-fifth of the vessel's length, the vessel should be dry-docked or ultrasonically tested, and repaired as necessary. While in dry dock, check bottom, sides, decks and inner bottoms. All defective welds and plating should be repaired or replaced.

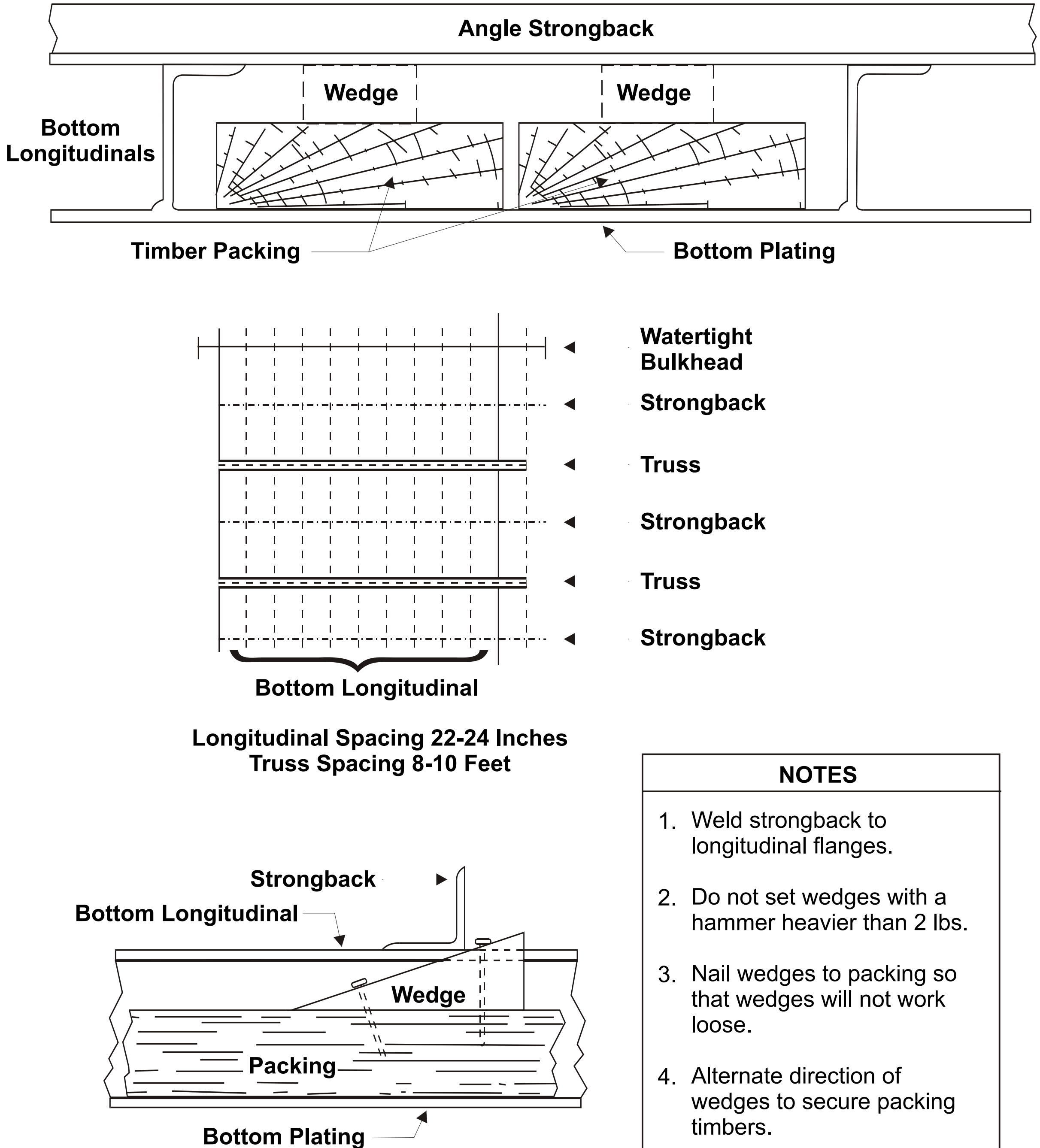
5-6.6.1 **Barge Hull Thickness**

CAUTION
Many barges and barge-like vessels tend to be more susceptible to damage and deterioration than conventional ship type vessels. They should therefore be inspected for hull strength prior to towing.

Table 5-2 lists minimum barge hull thicknesses based on barge length and frame spacing. Bottom plate thickness in the forward one-fifth of the vessel must meet these minimum values for safe towing.

These values are the minimum thicknesses required to meet the 1991 American Bureau of Shipbuilding (ABS) 10, Rules for Building and Classing Steel Barges (Ref. H). If actual thicknesses are less than 75% of these values, consider reinforcement. The values in Table 5-2 are for the forward section; thicknesses in the mid-section can be seen in Table 5-3. A 75% criterion also applies to the mid-section values. Reinforcement should be considered if there are any signs of serious corrosion or excessive out of plane damage (buckling, frame tripping, etc.)

To avoid special dry docking before towing, barges, cranes and other service craft should be thoroughly examined during routine maintenance. Plate thickness and weld inspections should be conducted regularly during scheduled dry docking, or by regular underwater ultrasonic inspection while in service.

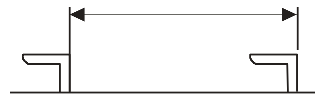


NOTES

1. Weld strongback to longitudinal flanges.
2. Do not set wedges with a hammer heavier than 2 lbs.
3. Nail wedges to packing so that wedges will not work loose.
4. Alternate direction of wedges to secure packing timbers.

Figure 5-4. Reinforcing Bottom Plating in Barges.

Table 5-2. Minimum Plate Thickness for Forward One-Fifth of Barge Bottom.



Barge Length	Frame Spacing (inches)						
	18	**21**	**24**	**27**	**30**	**33**	**36**
100 ft.	0.250	0.271	0.292	0.313	0.334	0.355	0.376
120 ft.	0.261	0.282	0.303	0.324	0.345	0.366	0.387
140 ft.	0.272	0.293	0.314	0.335	0.356	0.377	0.398
160 ft.	0.282	0.303	0.324	0.345	0.366	0.387	0.408
180 ft.	0.293	0.314	0.335	0.356	0.377	0.398	0.419
200 ft.	0.304	0.325	0.346	0.367	0.388	0.409	0.430
220 ft.	0.315	0.336	0.357	0.378	0.399	0.420	0.441
240 ft.	0.326	0.347	0.368	0.389	0.410	0.431	0.452
260 ft.	0.336	0.357	0.378	0.399	0.420	0.441	0.462
280 ft.	0.347	0.368	0.389	0.410	0.431	0.452	0.473
300 ft.	0.358	0.379	0.400	0.421	0.442	0.463	0.484
320 ft.	0.369	0.390	0.411	0.432	0.453	0.474	0.495
340 ft.	0.380	0.401	0.422	0.443	0.464	0.485	0.506

NOTE

Intermediate values may be obtained by linear interpolation. Above thicknesses are for new plates as shown on plans. Shoring should be used if the plating thicknesses are 25% below these values.

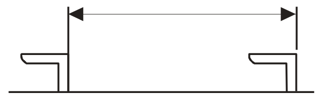
5-6.7 Locking the Rudder

Because a drifting rudder will cause the tow to behave erratically, the rudder should be locked amidships. The method used to secure a rudder depends upon the tow's steering gear.

CAUTION

Do not use temporary lashings or other makeshift measures to lock the rudder of a towed ship. Lock the rudder amidships for towing

Table 5-3. Minimum Plate Thickness for Mid-Section.



Barge Length	Frame Spacing (inches)						
	18	**21**	**24**	**27**	**30**	**33**	**36**
100 ft.	0.286	0.316	0.346	0.376	0.406	0.436	0.466
120 ft.	0.299	0.329	0.359	0.389	0.419	0.449	0.479
140 ft.	0.312	0.342	0.372	0.402	0.432	0.462	0.492
160 ft.	0.326	0.356	0.386	0.416	0.446	0.476	0.506
180 ft.	0.339	0.369	0.399	0.429	0.459	0.489	0.519
200 ft.	0.352	0.382	0.412	0.442	0.472	0.502	0.532
220 ft.	0.365	0.395	0.425	0.455	0.485	0.515	0.545
240 ft.	0.378	0.408	0.438	0.468	0.498	0.528	0.558
260 ft.	0.392	0.422	0.452	0.482	0.512	0.542	0.572
280 ft.	0.405	0.435	0.465	0.495	0.525	0.55	0.585
300 ft.	0.418	0.448	0.478	0.508	0.538	0.568	0.598
320 ft.	0.431	0.461	0.491	0.521	0.551	0.551	0.611
340 ft.	0.444	0.474	0.504	0.534	0.564	0.594	0.624

NOTE

Intermediate values may be obtained by linear interpolation. Above thicknesses are for new plates as shown on plans. Shoring should be used if the plating thicknesses are 25% below these values.

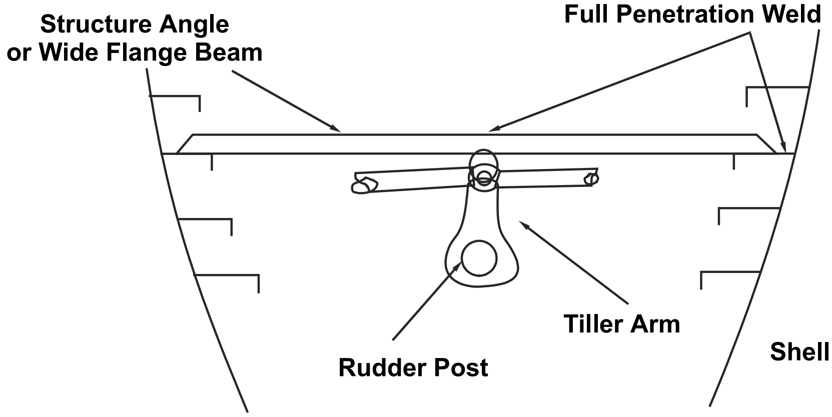
All thickness dimensions are given in inches.

- Yoke or tiller arm steering gear. Structural steel can be welded across the tiller arm to suitable ship's structure on either side. (An independent engineering evaluation is required to ensure that both securing device and ship's structure are adequate). Figure 5-5 depicts an example of such an arrangement.
- Vane type steering gear. Extend an emergency wrench (or wrenches) with a heavy channel or beam to reach a strong ship structure. Use full penetration welds on both the wrench and the ship structure (see Figure 5-6).
- Hydraulic steering gear. The rams can be secured by positioning the rudder amidships and securing the hydraulic system to maintain a hydraulic lock. Split pipe better known as clam shell locks with welded tabs cut to the proper length, (i.e. there should be no gaps between the end of the pipe sections and the cylinder and yoke ends). The pipe should be heavy

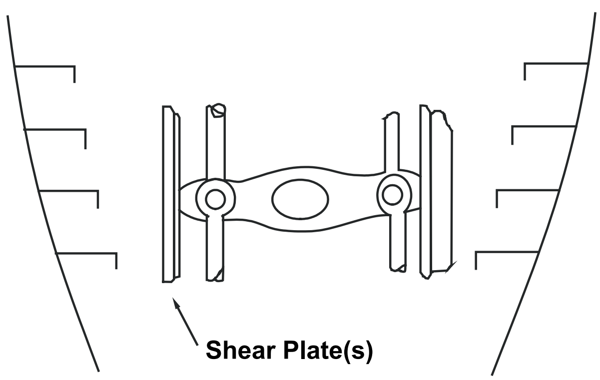
gage pipe schedule 40 or stronger. The clam shells shall be secured by 5/16 inch machine bolts every 3 inches along the length of the flange. Wrapping sheet rubber around the piston to prevent scoring of the piston by the clam shells is advisable if there is any chance the tow will be reactivated in the future. Both rams must be secured. Welding a plate or structural member to the yoke and to the foundation or ship's structure adds security. Refer to Figure 5-6.

Regardless of the securing method, an independent check (by an industrial facility, structural engineer, or mechanical engineer) of the rudder securing method should be accomplished to ensure they are adequate to withstand the forces generated by wave slap on the rudder. Forces on the rudder, even at low speeds may be large enough to buckle undersized clam shell locks. It may not be possible to use any of the illustrated arrangements when conducting rescue tows in unfavorable weather conditions. Chain falls or come-alongs may be used in conjunction with tiller arms or quadrants as temporary locking mechanisms. Chain vice wire rope should be used whenever practical for emergency rigging of rudder locks. Hydraulic systems for operating the rams may be isolated in some installations to assist in locking the rudder. Isolation techniques are only temporary and a permanent locking mechanism should be installed. For manned tows, if the steering machinery is operable and reliable, they may be used to aide in steering the tow.

CAUTION
Radiator type clamps are not authorized for securing clam shells.



Fore & Aft Tiller Arm



Athwartship Tiller Arm

NOTE
To maximize lever arm, it may be necessary to use shear plate(s) to secure tiller arm to deck. See Figure 5-6 for typical shear plate example.

Figure 5-5. Securing the Rudder (Single)

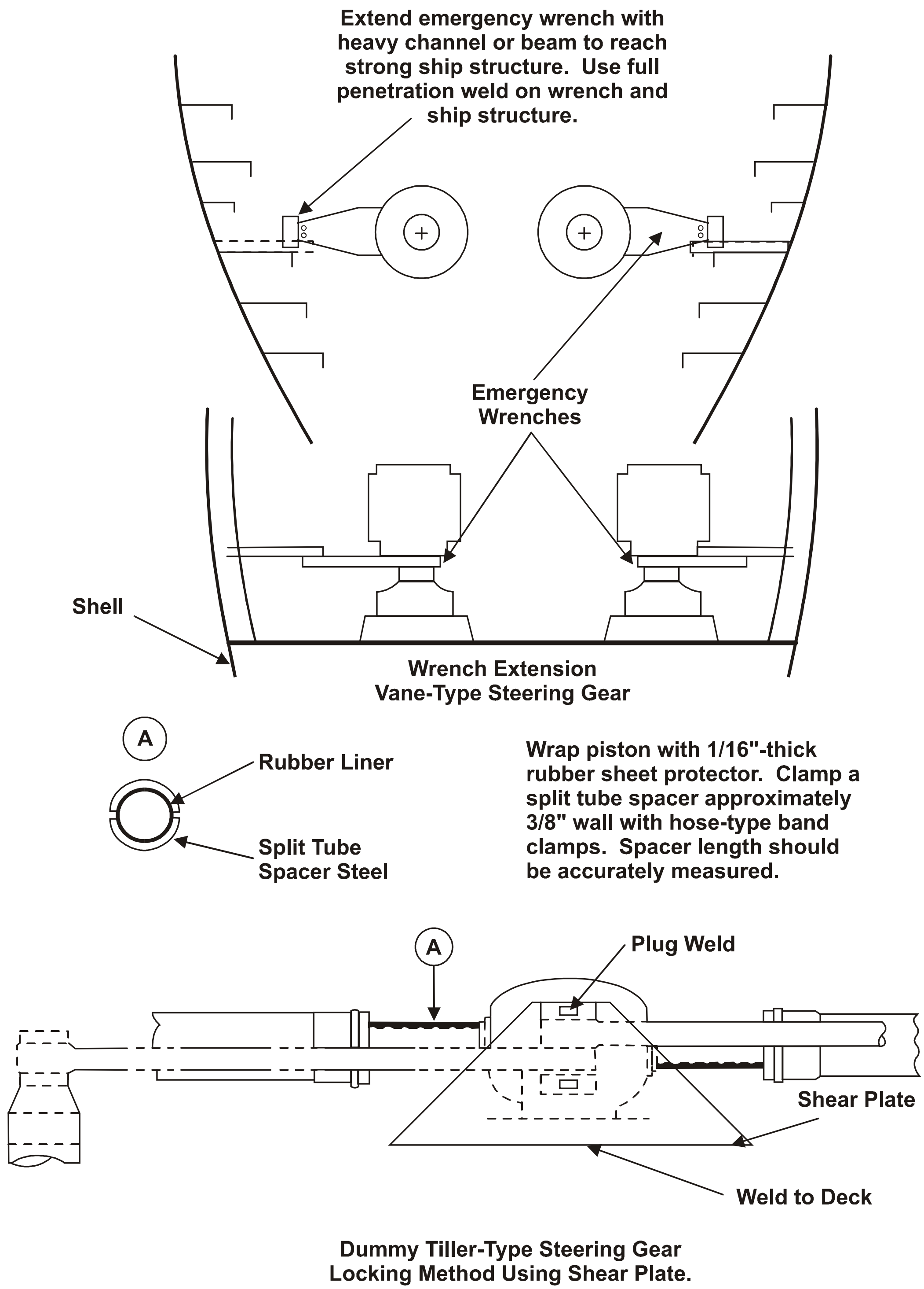


Figure 5-6. Securing the Rudder (Twin)

5-6.8 Installing Navigational Lights

The preparing activity must ensure a tow is equipped with proper navigational lights. Specific requirements concerning the correct positioning, number and color of lights are contained in Code of Federal Regulations (CFR) Part 81-72 COLREGS, Implementing rules (Appendix M -, Ref. I).

Navigational lights should be equipped with solar switches to increase battery life and meet COLREG requirements. The use of solar charging panels is also encouraged as they reduce the number of batteries required for navigational lighting, and extend battery life virtually indefinitely. Alternately, a single solar switch can be added to the system. Towing lights generally have a 10 foot leader wire for attachment to batteries. If that length is insufficient, Navy type DHOF-4 cable is suitable for connections. Ensure that all wiring is well secured and protected from damage by the elements.

Table 5-4 lists battery capacity requirements for one 60-watt, 12-volt DC sidelight or stern light for tows of various durations. Individual batteries for each light may be used to eliminate the power loss in long cables. Standard Navy 12-volt lead-acid batteries protected by steel containers provide the necessary ampere-hour capacity.

Table 5-4. Battery Capacity Requirements.

Length of Tow	12/Day Operation 60 Watt Light (Amp-Hr)
5	300 Amp-Hr.
10	600 Amp-Hr.
16	960 Amp-Hr.
21	1260 Amp-Hr.
30	1800 Amp-Hr.

5-6.9 Selecting the Tow Rig

Selection of a tow rig should be based on the specific tow characteristics of the planned tow. Tow rig selection can be based on past performance and the unique needs of the upcoming tow. Although most Navy tows are simple, single-tug, single-unit operations, some tows are considerably more complex, consisting of a single tug with multiple towed units. Large and unique tows may require using more than one tug. The following factors should always be considered when selecting a towing rig:

- Identify the best type of tow rig required for all conditions anticipated during the tow (Tow route, anticipated weather conditions, available ports of refuge, emergency procedures).
- Ensure tow rig is adequate for anticipated tow conditions over the range of speeds and anticipated weather conditions during the tow. If in doubt, use a higher factor of safety.
- Ensure adequate chafing protection is taken into consideration.

- Ensure all tows have a secondary or emergency tow rig installed in the event of a primary tow rig failure.
- Ensure all tows are rigged with an emergency anchoring system.
- Anticipate modes of failure and provide for all potential contingencies as outlined in the Appendix H - checklist.

Before towing a new or unique configuration, ensure the tow rig design complies with appropriate engineering and design criteria as outlined in this manual and in accordance with prudent seamanship. Examples of several towing configurations and arrangements are provided in Appendix I and throughout this manual. Technical assistance and on scene support for tow planning and implementation is available from NAVSEA 00C upon request.

5-6.10 Preparing Tank Vents

Tank vents should be covered with canvas socks to prevent water entry, but should not be plugged. Prohibiting the venting of air or gases from tanks or enclosed spaces due to minute increases in barometric pressure caused by temperature changes can increase differential pressures across bulkheads and tank walls resulting in catastrophic failure of those pressure boundaries. In some cases, these failures have resulted in explosions, severe buckling of decks and bulkheads, or compromising water tight integrity. Ensure hatches, scuttles, doors, portholes and other watertight closures are provided with pliable gaskets and material condition ZEBRA is set throughout the tow.

If vents are subject to flooding in heavy weather (such as vents near the waterline), it may be necessary to design covers which allow venting but minimize the risk of flooding.

5-7 Emergency Systems

Adequate fire fighting equipment and materials, as well as damage control equipment and associated fuel for 24 hours of continuous operation, should be placed on board the tow prior to starting the tow. Generally, it is not advisable to plan transfers of emergency equipment to the tow during emergencies due to unknown weather conditions, lack of daylight, combined with the tugs limited at sea transferring capabilities which could hinder safe and successful transfers. Care must be taken when using water for fire fighting or dewatering as the collected water may create a larger problem by negatively impacting the tows stability which could result in capsizing the tow. Many times, it is more effective to isolate the fire or water intrusion to the affected spaces and maintaining condition ZEBRA than to attempt to extinguish the fire or perform dewatering operations. If the tows bilge pumping system is inoperative, portable lightweight pumps or educator systems may be considered. Required suction lifts, discharge head pressures, and flow rates need to be carefully considered when selecting portable pumps for fire fighting and dewatering operations. The tugs crew and/or damage control party should thoroughly familiarize themselves with the operation of the emergency equipment and whenever practical should have the opportunity to demonstrate their ability to operate the equipment prior to getting underway. All pumps should be flow tested, all generators shall be operated, and all mechanical equipment shall be tested within 72 hours of the tows departure. These tests should be documented and attached to the comprehensive tow package. For larger tows, use of the ships fire main system may be used for distribution of fire fighting water. When using the ships fire main system, the riding crew must be trained in its operation and needs to be thoroughly checked to ensure it is operational as these systems are frequently cannibalized for valves and associated parts during demobilization or prolonged lay up.

5-7.1 Electrical Power

Electrical power is required on the tow for:

- Fire alarms
- Lights
- Flooding alarms (audible and visual)
- Pumps
- Communications equipment
- Crew accommodations
- Winches and capstans
- Radiological alarms

All electrical and other systems should be inspected and tested periodically to ensure reliable operation. These systems should be tested as close to departure as possible. If electrical power is supplied by an installed or portable generator, sufficient fuel should be provided. Batteries for battery powered systems should be checked for capacity and condition. All batteries should be topped off within 24 hours of the tows departure. Use of solar charging panels or wind generators for recharging the batteries while underway is highly recommended. All batteries should be placed in highly ventilated spaces to prevent the build of hydrogen gas. Hydrogen gas is highly explosive. Batteries exposed to the weather must be protected in watertight containers which will not permit the batteries to leak to ground. It is essential that all exposed wires and connections be adequately protected from the elements. Wires should be secured to prevent chafing and grounding.

5-7.2 Fire-fighting

The need for fire fighting equipment must be evaluated by the tow planner on a case by case basis and is dependent on several factors. Some factors include the value of the tow, potential ignition sources, consequences of fire, and the effectiveness of fire fighting equipment and personnel, should be considered when deciding how to address this requirement. Potential for fire on unmanned planned tows should be relatively small as all ignition sources will have been removed during demobilization. Tugs involved in rescue and salvage towing scenarios will most likely have an increased potential for fire.

Risk of fire can be greatly reduced by removing as much of the combustible material on board as possible. It is virtually impossible to remove all combustible material from a tow as items like insulation and cabling are difficult and expensive to remove completely. However, removing paper products, furniture, combustible liquids, and paints, are relatively easy to remove and greatly reduce risk of a fire. A comprehensive survey all compartments should be conducted to identify spaces which contain ignition sources that can not be removed. These spaces should be annotated in the remarks section of Appendix H. Maintaining condition ZEBRA and sealing as many compartments as possible will reduce the chance of a fire spreading.

Fire fighting equipment should be compatible with determined risk. Capacity and portability of installed fire fighting equipment will determine the effectiveness of any fire fighting effort. Active Navy ships should have three or more portable fire fighting pumps on board. The Navy has replaced gasoline driven P-250s with newer self-priming, diesel-driven P-100s. Gasoline driven pumps should never be used as gasoline is highly volatile ignition source. P-100 pumps have a flow rate of about 100 gallons per minute at around 85 psi. The 3-inch suction hose (same as the P-250) is capable of a maximum suction lift of about 20 feet. The discharge connection is typically a 2 1/2-inch Y-gate which can be connected to two 1 1/2-inch standard fire hoses. Only one hose should be used at a time due to pressure and flow limitations. Connecting two hoses is prudent however, to allow quicker response in the event of a ruptured line. Pumps and associated gear are generally located on the weather deck and should be located in or near the designated repair lockers.

If connecting to the ship's installed fire main system, the required pressure and flow rate needed to operate the fire fighting system must be determined to ensure adequate pumps are installed. Navy ships typically use 50 foot lengths of 1 1/2-inch fire hose from 6 to 8 inch headers. These headers should be charged to approximately 150 psi. Accesses to spaces deemed as potential fire hazards should contain pre-positioned portable fire extinguishers and fire hose. These items should be staged in places allowing the boarding crew to begin fire fighting without endangering their safety.

5-7.3 Dewatering

All planned Navy tows are recommended to have flooding alarms. These alarms alert the tug of the tow flooding, and allow ships force to assess the severity of flooding. The Navy SMART tow system not only alerts the tug crew of flooding but also identifies which spaces are flooding. Due to the high level of compartmentation on naval surface vessels, leaving flooded spaces secured is usually the best course of action to maintain the tows overall stability. Limited manning on commercial and MSC tugs also inhibits the crew’s ability to conduct round the clock dewatering operations. Additionally, high lift suction requirements combined with the need to clearly identify where pumped water should be relocated, severely limits the tug crew’s ability to conduct effective dewatering operations. In practical application, dewatering equipment, such as pumps and hoses, used to control flooding or remove water are placed on board to facilitate the salvage team’s ability to commence dewatering operations vice the tug crews ability to respond to flooding. If the flooding can be contained with patches or other repairs, water can be removed or relocated to restore the vessel to its stable condition. If the flooding cannot be stopped, this equipment can be used to limit the effects of flooding. If the rate of flooding is slow, dewatering pumps may be able to keep the vessel in a stable condition until it reaches port or repairs can be made.

5-7.3.1 **Deciding to Use Dewatering Equipment**

Installing or using dewatering equipment should be made after careful consideration by both the tow planner and the tow ship’s Commanding Officer or Master. Dewatering equipment is not required for all Navy tows. High value tows with little compartmentation may require the use of dewatering equipment. Critical or damaged compartments may require rigging for dewatering while smaller adjacent compartments may not. Most planned tows are of decommissioned vessels which have been prepared for long term storage. These hulls have a high degree of water-tight integrity as hull penetrations having welded blanks installed. Flooding is unlikely in these cases.

Highly compartmented vessels tend to limit the amount and rate of water intrusion which can negatively affect the tows stability. When preparing a tow, the level of compartmentation should be considered when determining the need for dewatering equipment.

Generally, operational ships should have a large capacity for dewatering. If one of these ships are picked up in a distressed or damaged status, tow ship personnel should familiarize themselves with its installed systems. Operational USN ships are equipped with flooding effect diagrams or plates as part of their damage control system. These diagrams tell the effect of compartment flooding. In the absence of these drawings, a flooding matrix should be developed to show the effects of compartment flooding. This flooding matrix should be verified by a Naval Architect.

The effectiveness of dewatering pumps on ships with high freeboards when transferring water over the side from low in the hold is extremely questionable. When using large dewatering pumps it is unlikely the boarding crew will be able to relocate them, therefore sufficient lengths of hose must be available to reach areas of the vessel that require dewatering.

5-7.3.2 **Choosing Equipment**

When preparing a compartment for dewatering, care should be used to identify potential flooding sources. For example, a damaged ship may have some patching, or a ship may have had a rudder casualty. The size and amount of equipment chosen should be able to overcome any flooding from these sources. Leakage from a large patch may produce a greater amount of flooding than leakage around a rudder post. Pumps should be sized accordingly. P-250s, P-100s or equivalent pumps are often readily available on Navy ships and provide good pumping capability. Submersible pumps may also be used effectively.

Pumps may need to run continuously to overcome flooding until repairs have been made. Sufficient fuel should be carried on board to operate the pumps for a minimum of 24 hours, although more is desirable. Provisions will need to be made to refuel if the operation will last longer. Tow planners should be aware of the capabilities and limitations of the tug and boarding crew. If refueling is not an option, additional fuel storage will be required.

5-7.3.3 **Pre-staging Hoses**

Pre-staging hoses for potential dewatering is always a good idea. When pre-staging hoses; hoses should be staged in such a manner as to not compromise the watertight integrity of the tow. The boarding crews ability to rig hoses and operate the dewatering pumps shall also be considered. Locating suctions in the bilge and running hoses throughout large compartments will aide the boarding crew and save valuable time in the event of an emergency. Hoses should be rigged as high up and as near to compartment accesses as possible. Final connections can be completed after the decision to open the compartment and run pumps is made.

5-7.4 Marking Access Areas on Tow

Marking all internal routes to fire and flooding alarms as well as spaces subject to flooding is required for all planned Navy tows. Preparing activities charged with marking internal routes should assume riding crews and boarding parties are not intimately familiar with the internal layout of the tow.

Further, preparing activities need to be cognizant of the fact that boarding parties will be required to navigate internal spaces in complete darkness using only handheld flashlights. Therefore, special care must be taken to ensure all routes are clearly marked with light reflecting materials which highlight the routes to and from the alarms and exits. The goal is to eliminate confusion when navigating through spaces during an emergency and thereby enhance personnel safety.

The reflective materials should be green and red similar to those used for navigation aides utilizing the red right when returning to the exits. Green and red reflective materials should consist of reflective numbers and arrows that illuminate 2-3 markers at a time when highlighted with a handheld flashlight. The application of this practice should have green markers and arrows marking the route from the exits to the alarms; with red markers and arrows on the opposite side of the bulkheads and decks from the alarms to the exits. Markers will typically consist of a combination of reflective tape and paint. A line painted down the center of the passage provides a continuous route marking.

Whenever possible, temporary emergency lighting should be provided. This lighting can be provided by utilizing ships lighting systems in combination with portable generators. This lighting can also be provided by installing temporary lighting powered by batteries or portable generators.

Route markings will aid security patrols in making their rounds, adding to the efficiency of the patrol while aiding boarding parties in the event of an emergency. Whenever possible a potential boarding party should become familiar with the tow prior to getting underway. Sufficient means for personnel to board a tow at sea should be provided. See Figure 5-7 for examples. Boarding ladders should be placed as close to amidships as possible to facilitate ship motions in an active seaway. Preparing activities frequently overlook the need to design the boarding ladders for access by small boats and/or tugs in a seaway. Building of structural platforms to gain access to the boarding ladders is discouraged as frequently these platforms hinder tugs from being able to come along side when performing personnel transfers. All boarding ladders shall have a white reflective background to allow for quick identification (night or day).

5-7.5 Preparing for Emergency Anchoring of the Tow

All Navy tows should be equipped with an emergency anchoring capability. Exceptions require approvals from SEA 00C. In many cases deploying the emergency anchor is the last option before grounding. All tows must be able to deploy an emergency anchor, recovery of the anchor, however, is not required. When preparing an emergency anchoring system the following items should be included:

- Sufficient ground tackle and anchor-handling equipment must be provided.
- The anchoring system must allow for anchoring in a minimum of 60 feet of water with a scope to depth ratio of 3:1. While the capability to anchor in 60 feet of water is a good rule of thumb, if water depths along the proposed tow route are predominantly deeper than 60 feet, additional anchoring capability may be required. Mid-ocean anchoring is not practical or required.
- Normally the ship’s anchor and chain are used if in serviceable condition. The ship’s anchor chain and connecting jewelry should be inspected in accordance with NSTM 582. If other jewelry is brought on board, it must be as large as or larger than the tow’s chain and anchor.

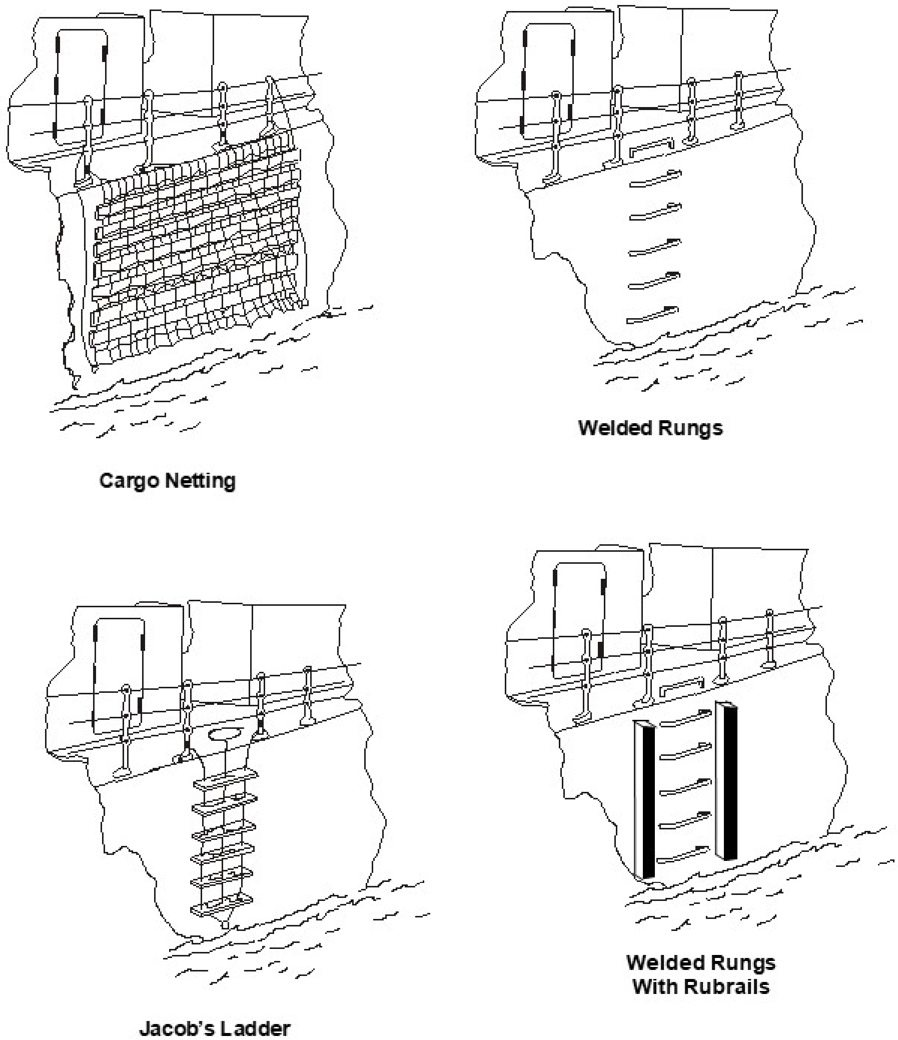


Figure 5-7. Sample Provisions for Emergency Boarding of Tow and Sea

- When sealing the chain hawse pipe to prevent water from entering compartments or tanks, it may be possible to use cloth filler and cement to plug the opening.
- If the tow is scheduled to make port stops along the tow route for refueling or may need to be anchored at its final destination, activating the tow's installed anchor handling system or providing an external anchor handling system may be prudent.
- The emergency anchoring system should be rigged for quick release. This can be accomplished through the use of a specially made billboard anchoring system (see Figure 5-8) or releasing the brake on the anchor windlass. If using the anchor windlass, the windlass brake should be inspected to ensure it is intact and operational. This can be accomplished by releasing the brake gradually until the chain begins to run. When using this technique, ensure no personnel or assets are under the anchor when testing the anchoring system. Care must be taken to prevent the anchor chain from running free during the test. Using

wire straps weaved through the anchor chain secured to pad eyes or structure to prevent the chain from running free is recommended. A sledge hammer should be placed on the foc'sle by the windlass brake bands to aide in releasing the chain stoppers and the windlass brake band.

When releasing the emergency anchor, care must be used to control the rate of anchor chain pay out to prevent shock loading of the ground tackle, or the bulkhead termination pad eye in the chain locker. Frequently, the bulkheads in the chain locker are degraded due to corrosion. Free running chain can also be very dangerous to personnel and equipment as it tends to snake across the deck and jump off the deck in a very violent manner.

The anchor chain and/or wire should be able to run over the side without risk of obstruction.

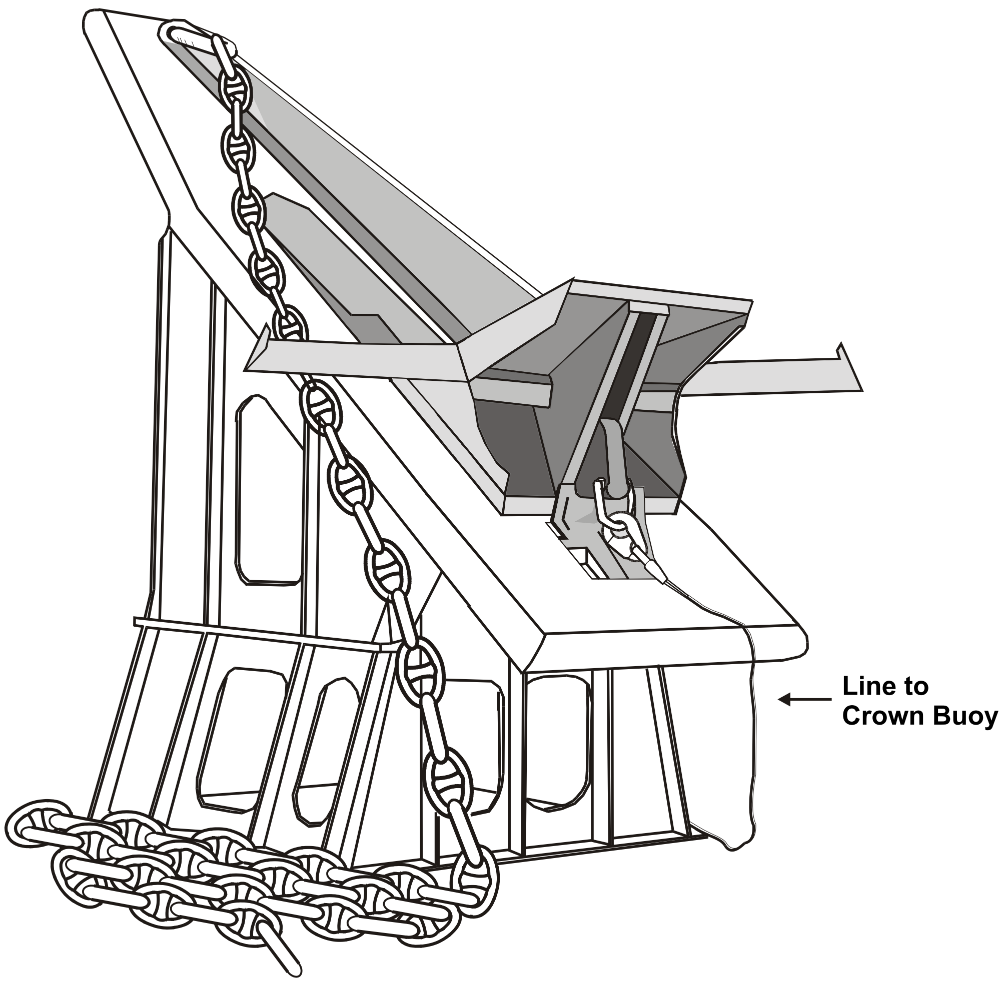


Figure 5-8. Billboard

5-8 Completing the Comprehensive Tow Package for Ocean Tows

In order to document the tow's preparation and planning a comprehensive tow package is required for all USN tows. All documentation related to the tow's preparation should be included in the package along with rationale for deviations in the preparation as related to this manual. The preparing activity is responsible for assembling the comprehensive tow package. The tow master is responsible for ensuring the package is complete. The comprehensive tow package should be completed with the exception of last minute ship checks approximately 45 days in advance of the planned tow date. The tow master, the preparing activity, and NAVSEA 00C should all have a copy of the comprehensive tow package. The NAVSEA 00C copy should be delivered in electronic form via CD or e-mail. The comprehensive tow package consists of the following items:

- Tow Specifications
- Tug Specifications
- Tow Hawser Size
- Connecting Shackle Size
- Appendix H -
- Steady State Tow Calculations
- Sketch of the Tow Configuration
- Objective Quality Evidence for Tow Jewelry and Attachment Points
- Weather Routing Plan
- Tow Limiting Conditions
- Projected Tow Route
- Identification of Ports of Refuge

5-8.1 Tow Specifications

Tow specifications must include the class, displacement, and unique characteristics for the specific tow.

5-8.2 Tug Specifications

Tug specifications must include bollard pull certificate, class certifications, hull and machinery certifications, tow hawser size, tow hawser certification, tow machinery specifications, tow winch brake rating, tug range, tug draft, and connecting shackle certification.

5-8.3 Tow Hawser Certification and Size

The size of the towing hawser to be used for the tow along with applicable certifications must be provided in the comprehensive tow package. This includes the secondary tow pendant information and backup tow hawsers on the tug. In the case of the TATFs, the backup or redundant hawser may be a synthetic line and traction winch in the event of loss of the primary tow wire.

5-8.4 Tow Shackle Certification and Size

Information and certificates for the tugs connecting jewelry need to be provided as part of the tow package. This can be a combination of shackles, detachable links, or plate shackles.

5-8.5 Appendix H

Appendix H is a checklist for preparing a vessel for open ocean tow. The checklist is designed to be used by the preparing activity to aid in preparing a tow for sea and acceptance by the tow master. Appendix H provides general requirements which must be completed before the towing activity will accept a planned tow. If the preparing activity has questions concerning the checklist or tow preparations, it should relay those questions to the tow master via email or message. The preparing activity is responsible for completing the Appendix H - checklist. Items which are not applicable or cannot be accomplished by the preparing activity must be documented in the remarks section of the checklist and submitted to the tow master. Technical clarifications of requirements or waiver of the requirements specified in Appendix H should be directed to the technical authority for towing (SEA 00C).

5-8.6 Steady State Tow Calculations

Steady state tow calculations for the range of anticipated tow speeds and weather conditions as provided in Chapter 3 - of this manual must be submitted as part of the comprehensive tow package. These calculations should be used to set tow limiting conditions with regard to SOAs and weather.

5-8.7 Sketch of the Tow Configuration

A sketch of the tow configuration from the deck connections on the tow to the winch on the tug must be submitted for all Navy tows. This sketch should clearly identify all components and jewelry in the tow rig traceable to the pedigrees for all the components.

5-8.8 Objective Quality Evidence for Tow Jewelry and Attachment Points

Objective Quality Evidence (OQE) for all tow jewelry components must be submitted as part of the comprehensive tow package. This evidence consists of certificates of compliance and inspections for tow jewelry per NSTM 582, and tow wire certifications. The OQE for the tugs connecting shackle is also required. The jewelry should be stamped or permanently marked. Marking the jewelry will assist in forensic investigations and trend analysis.

5-8.9 Weather Routing Plan

The weather routing plan and limitations must also be included in the comprehensive tow plan. Information from Navy METOC or a commercial weather routing service shall be included.

5-8.10 Tow Limiting Conditions and Identification of Weakest Link

The comprehensive tow package shall clearly identify the weakest link in the towing system. When identifying the weakest link all components in the towing system must be considered to include the braking mechanism on the tow machine. The weakest link will be the key factor in determining towing limitations.

5-8.11 Projected Tow Route

The planned tow route to include specific way points shall be provided in the comprehensive tow plan.

5-8.12 Identification of Ports of Refuge

Identification of the ports of refuge along the tow route must be provided as part of the comprehensive tow package. Limiting conditions for using these ports of refuge as specified by the respective Captains of the Port (COTP) must also be identified. Assist tug Points of Contact (POCs) and COTPs for each identified port of refuge must also be included. Identifying these POCs and discussing the tow with the POCs in advance of the tow will aide in making entry into these ports of refuge less stressful in the event they are needed. It is strongly recommended these POCs be contacted as the tow proceeds from one port of refuge to the next along the projected route to confirm information obtained in previous communications are still applicable and assist assets are still available. In the event planned assets are not available or entry conditions have changed, the tow may need to be postponed until the required resources are available.

5-8.13 Determining Seaworthiness

The towed vessel must have adequate watertight integrity, structural soundness, and intact stability to be considered seaworthy. The preparing activity shall complete a Certificate of Seaworthiness for ocean tows. In the event a commercial tug is used to conduct the tow, a trip and tow certificate from an independent marine surveyor must be completed prior to conducting the tow. The certificate includes general characteristics, type of cargo, towing gear, lights, speed limitation, and similar items. A sample Certificate of Seaworthiness and its endorsements can be found in Appendix H -. The tow master or designated representative should also inspect the tow to determine overall seaworthiness. The tow master is the final authority for determining the overall seaworthiness of the tow and towing configuration.

5-8.14 Towing Machine/ Towing Winch Certification

The towing machine/towing winch shall be inspected and tested prior to conducting capital ship and nuclear tows. After all discrepancies are addressed, an annual certificate shall be issued to the Commanding Officer or the Master of the vessel as well as the sponsoring command.

5-8.15 Commercial Vessels (U.S. Coast Guard Inspected) Master's Towing Certificate

The towing vessel shall provide a copy of the Master's Towing Endorsement which became effective by the USCG TASC of 21 May 2001.

5-8.16 Preparing for a Riding Crew

After receiving approval to use a riding crew, the Commanding Officer or the Officer-in-Charge of the riding crew must ensure:

- Adequate training and drills are performed. These drills include fire fighting; flooding and other material condition drills; drills for abandoning ship, boat launching, communicating with the tug and securing a secondary towline.
- Establish security watches of machinery, watertight integrity, towline, navigational lights, communications, and other watches as necessary.
- There is an adequate method of boarding the tow at sea. When feasible, fixed ladder rungs are preferred. Figure 5-7 depicts several methods for boarding ladders.
- Radios, pumps, handheld lights, spare batteries, hoses, tools, fire-fighting equipment, portable cutting gear, and handling gear are positioned in the designated DC locker or designated space for use by the riding crew. The towing plan must also consider requirements for messing and berthing quarters for the riding crew, auxiliary power, fuel, damage-control equipment, and life-saving gear.
- Communication between ships is provided as stated in Section 6-2.9.

5-9 Accepting the Tow

5-9.1 Inspecting the Tow

Prior to accepting a tow, the Commanding Officer or Tow Master of the towing ship must inspect the tow to confirm its seaworthiness and readiness for tow. The inspection should include, but not be limited to items listed in Figure 5-7 and this section.

- Review the comprehensive tow package, the towing inspection checklist, shown in Appendix H -, to ensure it is thorough, adequate, and properly completed.
- Inspect tow rig, appendages, and attachment points to ensure that the tow is properly rigged per, applicable instructions, this manual and/or guidance from the tow sponsor.

WARNING
Substituting materials can be dangerous as well as detrimental to the tow. Substitutions shall not be made unless there is a complete knowledge of the material being substituted. Material substitutes frequently introduce a new and unpredictable weak link. Substituting a stronger material may change the location of the potential failure point in the rig to a position that is hazardous to personnel.

CAUTION
A screw-pin shackle shall not be used as a replacement for a safety shackle in towing. A safety shackle will deform under load and still hold, while a screw-pin shackle's pin can work itself out of the shackle.

- Inspect the towline, bridle, and associated towing gear for wear and to ensure improper substitutions have not been made in fittings and materials. Typical items to look for include:
  - Mild or cast steel substituted for forged steel in safety shackle pins.
  - Stainless steel substituted for other high strength alloys.
  - Improperly sized components.

Note whether a retrieving wire is rigged and if proper mooring lines are available.

- Ensure cargo is properly secured to prevent shifting in heavy weather.
- Ensure liquid cargo tanks are pressed full or left empty to avoid free surface affects.

WARNING
Use the applicable safety precautions when entering voids and unventilated spaces. Failure to do so may result in injury or death to personnel.

- Check all accessible spaces to ensure they are completely dry and watertight.
- Check to ensure vents to tanks and other closed spaces are properly covered or sealed.
- Ensure hatches, scuttles, doors, portholes, and other watertight closures are provided with pliable gaskets for setting condition ZEBRA.
- Ensure running lights and flooding alarms are operating properly, batteries are fully charged and battery life is computed to be sufficient for the transit.

- Ensure required salvage pumps and associated equipment with fuel to support 24 hours of operations are safely stowed on board the tow.
- Ensure required fire fighting equipment with fuel, hoses, chemicals, and overhaul gear, is safely stowed on board. Require a flow test of all fire pumps to ensure they are in good operating condition and are capable of taking a suction.
- Ensure all high-value items on the tow are locked up and inventoried on the tow report form.
- Ensure provisions have been made for quickly releasing the towline in an emergency.
- Ensure a provision has been made for streaming a pickup line for the secondary towline.

5-9.2 Unconditionally Accepting the Tow

Upon satisfactory completion of the tow preparations, reviewing the comprehensive tow package, and conducting a tow inspection, the Commanding Officer or Tow Master of the tug shall accept the tow, notify his operational commander, and proceed with the mission.

5-9.3 Accepting the Tow as a Calculated Risk

If unsatisfactory conditions of seaworthiness or readiness are found and the differences cannot be resolved at the local level, the Commanding Officer or Tow Master of the towing ship should notify his operational commander stating why the tow is unsatisfactory. The report should include recommendations for correcting each deficiency. If conditions or circumstances are such that a calculated risk is involved, the Commanding Officer or Master of the towing ship shall state that he will accept the tow as calculated risk by notifying SEA 00C and the Fleet Commander via naval message.

5-9.4 Rejecting the Tow

If the tow is in such poor condition that towing would potentially endanger the tow or the tow ship, the towing unit must reject the tow. Every effort shall be made to correct any unsatisfactory conditions prior to reaching the decision to reject a tow. But if the Commanding Officer or Master of the towing ship feels the tow poses a serious risk, he shall notify his operational commander stating why the tow is unsatisfactory. The report shall include recommendations for correcting the deficiencies.

5-10 Preparing for Departure

With all other prerequisites completed, the suggested items to complete prior to departure include:

- Reconfirm the date and time of departure with tasking authorities
- Recheck the weather forecast and suggested track immediately prior to departure.
- A final tow conference shall be held within 48 hours of departure. Discuss harbor maneuvers with local tug operators. A final tow conference of all parties involved with the tows departure will provide a forum for clearing any uncertainty about maneuvers. This is particularly useful when accepting a tow in an unfamiliar port.

5-11 Completing the Delivery Letter or Message

Once the tow has been completed, the Commanding Officer or tow master of the receiving activity will complete an acceptance letter confirming receipt of the tow. A sample acceptance letter is included in Appendix H -.

Chapter 6 - TOWING PROCEDURES

NOTE
Riding lines may not be necessary if there is sufficient tug power available to control the tow.

WARNING
Motions of the tug and tow can cause the towline to change positions rapidly and without warning. Personnel must be aware of the potential danger of a sweeping towline and remain clear of all areas that may be within this sweep.

WARNING
Boarding a derelict vessel can present many unknown hazards. Safety is paramount during these operations.

CAUTION
When combatting a sinking tow, conditions can deteriorate rapidly. The boarding party should have sufficient survival gear and should be prepared to abandon at any given moment.

6-1 Introduction

This chapter will provide some guidelines for operating while underway with a tow, picking-up a tow, and releasing a tow. This information represents the cumulative knowledge of many operators gained during years of towing. Although this will provide guidance for a number of situations, each tow is a unique event with its own unique hazards. Caution and adherence to safety guidelines will help minimize risk to personnel during this dangerous evolution.

6-2 Initiating the Tow

A tow can be picked up at a pier, in the stream, or at anchorage. When rescuing a disabled vessel or recovering a lost tow, it may be necessary to pick up a tow at sea. Ocean-going tugs should not be asked to maneuver unassisted in restricted waters. If possible, the tow should be delivered to the ocean-going tug by harbor tugs. At the very least, harbor tugs should be available to assist the tug and tow in navigable waters.

Positive communication between the tow ship, pilot, and assist tugs is essential and should be established as early as practical. Good communication between the tow ship and any assist tugs is also necessary for a safe underway.

6-2.1 Accelerating with a Tow

CAUTION
When picking up a tow, increase speed slowly and gradually and maintain an even strain on the towing gear. If a tow hawser tension readout is not available on the bridge, have this information provided by the Towing Watch.

When getting a tow underway, always build up speed slowly. Gradual accelerations and decelerations prevent tension spikes which can damage the tow jewelry which can result in injury to personnel. Sudden increases in speed can cause tension spikes which can increase towline tensions tenfold potentially placing the tow and crew in danger. Matching an increase in towline scope with speed helps maintain catenary depth and reduces towline tension.

Tows frequently begin in restricted waters or narrow channels where wind and waves may force the tow aground or into the path of other ship traffic. Even if the tows steering gear is in operable condition, initial tow speeds are most likely insufficient to supply adequate water flow over the rudder to control the tow. For these reasons, prudent seamanship dictates harbor tugs should remain made up to tow or in close proximity to effect an emergency response until the tow master has positive control within navigational restraints.

Towline resistance increases dramatically with speed, yet water depth may not be deep enough to increase the scope of the tow hawser in order to establish a sufficient catenary. An automatic tow machine's features are especially useful in this situation. Synthetic springs can provide an excellent means of tension reduction while getting underway (see Section 4-6.5).

6-2.2 Getting Underway from a Pier

Getting underway from a pier with a tow requires the tow master be particularly aware of tides, currents, and wind. In addition, the tow master should discuss intended procedures with the harbor tug master and pilot before getting underway.

When determining tugs to be used for assistance, consideration must be given to expected sea conditions. The size and number of tugs must be sufficient to control the tow until the tow ship can establish sufficient speed to take control.

CAUTION
Care should be exercised when alongside in a seaway. The motions of the tug and tow may be sufficient to part mooring lines, resulting in damage and causing the tug to lose control of the tow.

Good communication between the tow ship and harbor tugs is critical at this phase. If the tow and tug are not kept in line, at a near constant distance, large strains and damaged tow gear could result. If the tow gear breaks, the harbor tug should be large enough to keep the tow under control to avoid a catastrophe.

Once the towing ship and the tow are in the channel, the towline should be set at short stay in keeping with the depth of confined waters to be crossed. Keep the catenary shallow to avoid snags.

6-2.3 Getting Underway in the Stream

At times it is necessary to accept a tow in the stream. In this case, use the following procedure. The approximate channel course should be taken by the tow ship with bare steerage and assisting tugs should bring the tow to the tug's stern.

Heaving lines are used to send a messenger line to the tow which is then attached to the primary pendant (see Figure 6-1). Depending on the height of the tow's bow or other configuration considerations, it may be desirable to send a heaving line from the tow to the tug. Either way, the tug should always have spare heaving lines on deck in case they are needed. Once a messenger is passed, the pendant is heaved in and the tow connection is made.

CAUTION
The tow should be steadied on the riding lines prior to attempting hookup. Surging can produce high loads on the riding lines very quickly.

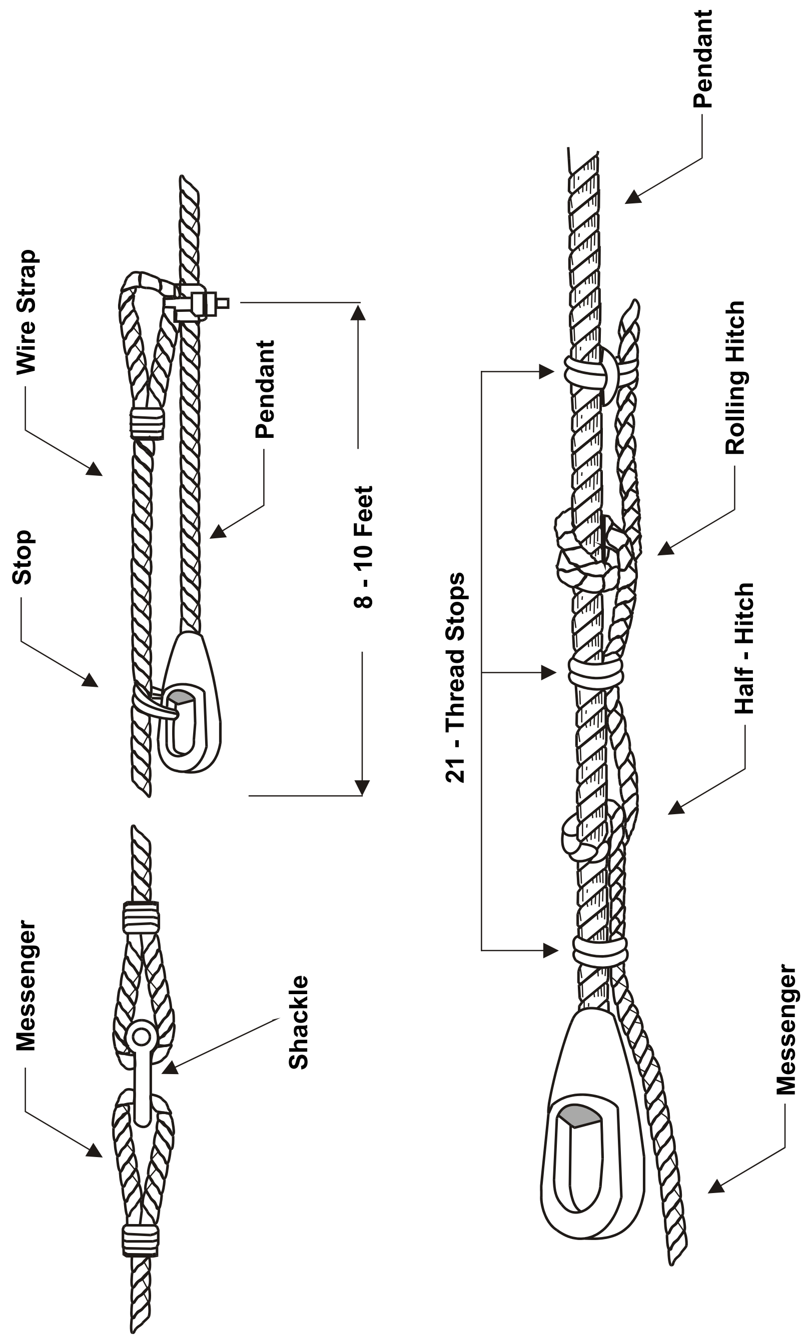


Figure 6-1. Methods for Securing Messenger to Towline.

If the harbor tugs are limited in their control of the tow or are not available (rescue towing) or if the tug desires to control the tow with its own power, riding lines can be used (see Figure 6-2). When the tow is brought close to a tug's stern, a riding slip line is rigged with its eye on the bitts and then passed to the tow, reeved through a suitable deck chock on the tow, and led back to bitts on the tug. A second riding line may be rigged for increased control. A messenger line is then sent to the tow and attached to the primary pendant. The primary tow pendant is heaved in and the tow connection is made.

Using two riding lines is also a good method for lateral control, especially when towing a small vessel at very short scope in shallow restricted waters prior to final streaming of the tow.

Regardless of attachment method, it is best to have all items to be used in passing the pendant rigged on the tow before leaving the pier. An evaluation of the capabilities of the assets available should be made when deciding the correct method for hook-up.

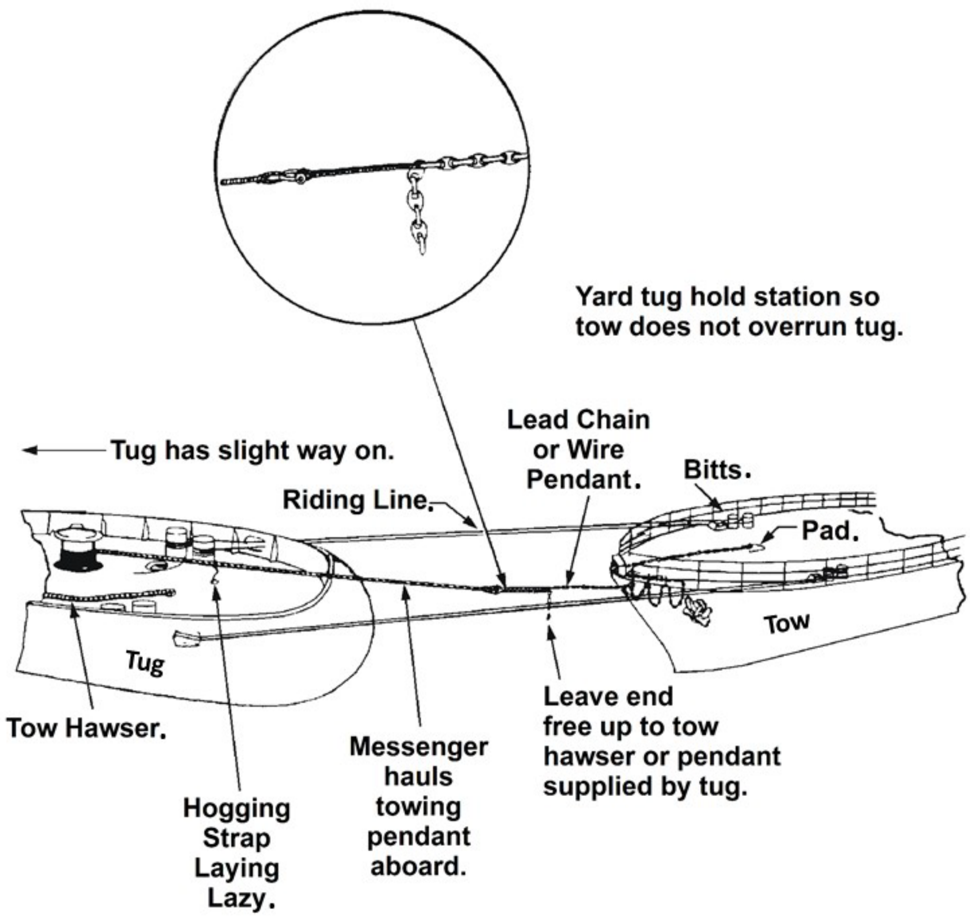


Figure 6-2. Accepting a Tow in the Stream.

6-2.4 Getting Underway while at Anchor

At times it is necessary for the tug to make up to a tow with either or both vessels at anchor. This may be due to limited pier space, shallow harbors, or simply the master's preference. Suggested procedures for getting underway in several situations are listed below.

- Tug underway/tow anchored. In moderate seas, the tug should come alongside the anchored tow and tie up with her stern as close as possible to the bow of the tow. The tow then passes a line to the tug, which is used to pull a messenger and then a portion of the tow's chain pendant to the tug. As the chain comes down on the tug's faintail, a stopper is passed on it to restrain it while the tug's crew rigs the remaining towline connection. When the connection is made, the chain stopper is released and the tug maneuvers clear. Assistance of a harbor tug is usually required. When headed fair, the tow weighs anchor, once the anchor is housed, the tug can start ahead slowly accelerating. Significant time is required to establish sufficient catenary in the tow hawser and come up to towing speed. If the tow has no power to its anchor windlass, the crew should rig an appropriate retrieval line and buoy so that the anchor can be slipped and recovered later.

If unfavorable conditions for going alongside prevail, passing the hawser can be difficult. Expert seamanship is required to prevent the tug from drifting out of range on a downwind approach. It may be preferable to anchor, as discussed below.

- Tug anchored/tow anchored. Rather than passing the towline while underway, it is often advantageous for the tug to anchor upwind or up current from a large ship. While at anchor, the tug can prepare the towline for passing. The tug veers its anchor chain until within a short distance of the tow's bow. When the tug's stern is close aboard the tow's bow, the towline can be passed and the connection made. With the towline connected, the tug can use its engines to come ahead and weigh its anchor, veering towline as necessary. With the tug free to navigate, the tow weighs anchor and the tow commences. If the tow does not have power, it may be necessary to slip the chain and anchor and mark the anchor's position with a buoy for later retrieval.
- Tug anchored/tow underway with steering tugs. The tug anchors and settles out into the wind and current. A steering tug brings the tow up to the stern into the current or wind. A pendant or lead chain is passed to the stern of the tug. Using the tug's stern capstan, a messenger is heaved on board until a sufficient amount of chain is brought on board to pass a chain stopper. The connection is made, the chain stopper released, and wire paid out as appropriate. The tug weighs anchor and begins accelerating at a very slow rate of speed. This method is safe, simple, and expeditious.

6-2.5 Recovering a Lost Tow

There are occasions when a tug must recover a lost tow at sea. Towline chafing, a mechanical break, or other circumstances may cause the tow to separate from the tug, making it necessary to recover the tow. In other cases, the original tug may become disabled or even abandon a tow. Procedures used to recover the lost tow will be affected by the availability of personnel on the tow, sea and weather conditions, existing contingency plans, and other assets available. See Section 6-2.7 for a discussion of approaching a drifting tow.

- If the tow is unmanned and the weather and seas favorable, a boarding party may be put on board the tow, a messenger passed, and the tow reconnected by routine procedures. The risks involved in sending a boarding party and the difficulty of passing a new towline justify rigging a secondary, emergency towline. If the emergency towline has been used, the tow shall proceed to the nearest port to re-establish the primary towline and re-rigging of the secondary tow line.

- If the tow is unmanned and the weather does not permit sending a boarding party, the tow ship shall attempt to retrieve the secondary pendant by means of the floating pendant or marker buoy. The tow ship can either recover this using one of its small boats or by grappling the floating pendant directly from the tow ship. The secondary tow pendant is rigged to deploy as the tow ship takes a strain. (See Section 4-4.)
- If the tow is manned, it may still be necessary to send a boarding party onboard. If the riding crew is not sufficiently large or able to safely and adequately handle re-rigging of the tow, the tug should provide knowledgeable assistance.
- The tug may use one or more of its small boats to act as a warping tug on a drifting tow, if the tow is not too large. The small boat can keep way on the tow near shoal water, or maintain a tows head into the seas, thereby facilitating recovery. The small boat may also change the heading of the tow as directed by the tow master.

6-2.6 Emergency Connection to a Disabled Vessel or Derelict

Devising a means of attachment is a critical concern when rescuing a disabled vessel or derelict. This is particularly important in the case of rescue towing, when time and shoreside support may not be available for installing padeyes and fairleads. Suggested attachment points of sufficient strength to tow in an emergency include:

- Using the ship's anchor chain
- Using installed bitts or padeyes
- Wrapping a chain around a foundation structure such as a gun mount or winch
- Welding a padeye to the deck

The preferred methods are to use the ship's anchor chain or installed padeyes. The other methods are to be used in emergency situations and may be necessary due to damage to the tow or other unusual operating constraints.

For situations where a padeye must be welded to the deck, refer to Section 4-5.4 and Figure 4-9 for acceptable padeye design specifications. These figures provide means for constructing a well-designed padeye. In an emergency situation, however, when detailed calculations cannot be performed, it is recommended that the largest available material be used. These calculations can be performed after installation, when the tow is out of danger, as a check against proposed towing speeds. If the installed padeye is too small, speed should be limited until a more appropriate padeye can be constructed.

All towing bridles, when rigged correctly, must have a backup securing system. This is normally accomplished by using wire rope of appropriate size (able to lace through chain links) and taking sufficient bights of wire from a second securing point (bitts, heavy cleats, etc.) and lacing the wire rope through the after end of links in the chain bridle (no fewer than four bights). Size and number of bights of wire should equal the strength of the chain used in the bridle. If a towing pad is used to connect the bridle to the tow, the backup wires must be laced forward of the towing pads. The securing point should be aft of the towing pad to prevent snap-loading. If a set of mooring bitts is used as a securing point for the bridle on the tow, the wire should be laced thorough the chain links that remain astern of the bitts after the three or more "figure eights" are secured on the bitts. There must be a sufficient number of wire clips (see Table 4-1) on each bitter end of the backup wire, aligned in the same direction (See Appendix I and Appendix J for tow rig design plans.)

It may not always be possible or practical to rig a backup system (i.e., submarine towing). In these cases, additional analysis of the main towing attachment may provide some reduction in uncertainty. Where possible, the attachment should be designed to a breaking strength well in excess of the other components.

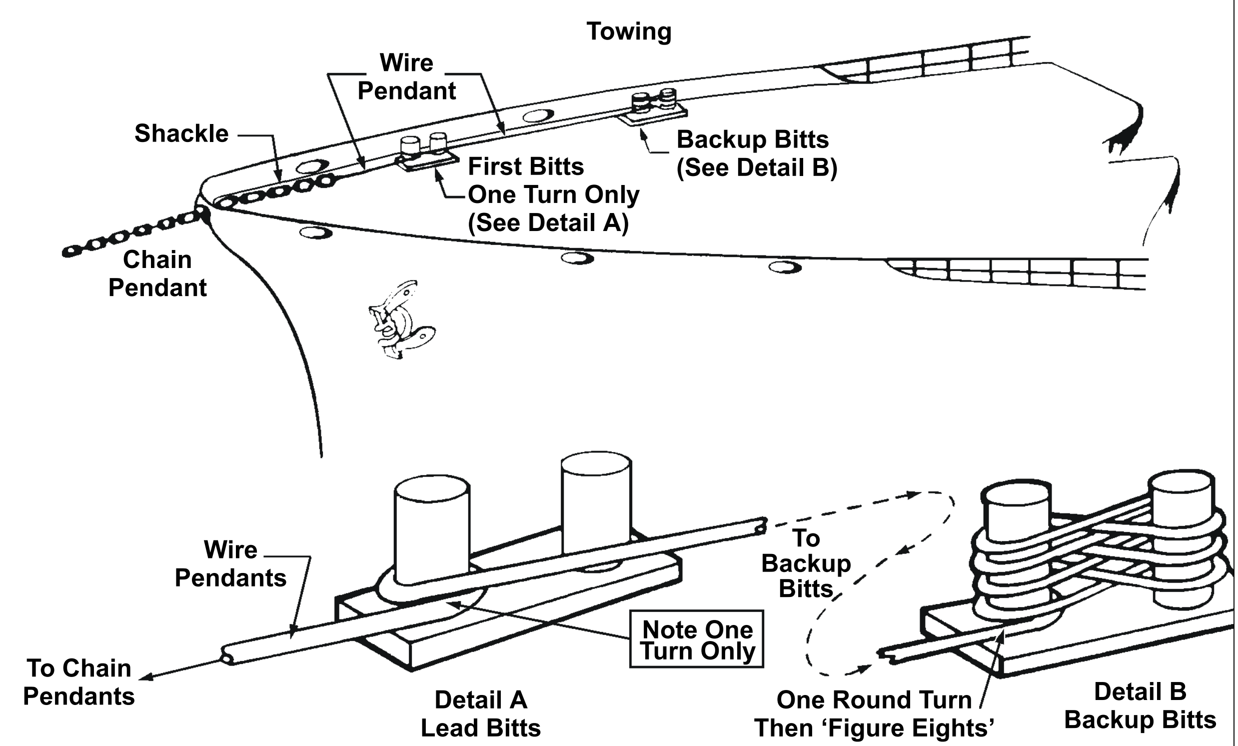


Figure 6-3. Sharing Towing Load Between Bitts.

However the attachment point is affected, it may also be necessary to cut through the bulwark or to remove other fittings from the deck in order to provide a clean sweep for the towing pendant. When rigging a special attachment for towing, twin problems of attachment point and fairlead must be resolved.

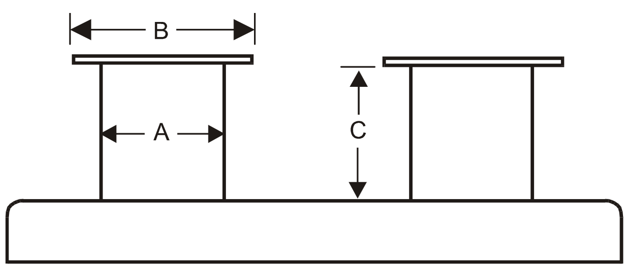
6-2.6.1 **Using the Anchor Chain**

Often the simplest, strongest, and most efficient connection method is to shackle the pendant into the tow's anchor chain with the correct connecting link.

WARNING
In no case should the stud of the common chain link be removed to provide a connecting point to a chain.

The usual method is to stop off the anchor and break the chain. Make sure that the inboard section will not be pulled down into the chain locker due to its own weight after it is cut. This can be accomplished by rigging two stoppers and cutting between them. In an emergency situation, it may be easiest to cut the chain and lose the anchor. However, it is safest and economical to rig stoppers and save the anchor.

Table 6-1. Information on U.S. Navy Bitts.



Nominal Bitt Size	A Barrel Size (inches)	B Top Plate (inches)	C Barrel Height (inches)	Maximum Moment* (inch-lbs)	Maximum Pull at Upper Edge* (pounds)	Maximum Pull at Mid- Barrel* (pounds)	Maximum Size Synthetic Line
4	4 1/2	6	10	134,000	13,400	26,800	3
8	8 5/8	11 1/2	13	475,000	36,500	73,000	5
10	10 3/4	13 3/4	17	1,046,000	61,500	123,000	6 1/2
12	12 3/4	15 3/4	21	1,901,000	90,500	181,000	8
14	14	17	26	3,601,000	138,500	277,000	10
18	18	21	32	6,672,000	208,500	417,000	12

*These numbers are safe working load with a factor of safety of 3 on Material Ultimate Strength.

Next, connect the bitter end of the chain directly to the towing pendant brought through an appropriate deck edge chock. The anchor chain can then be veered to provide chafing protection and any desired additional catenary to the towline system for improved dynamic load mitigation. In this case, the ship's chain stopper system may not align ideally with the fleet angle of the chain, but in most cases the alignment will be sufficient. If the alignment produces sharp bends or other potential failure spots, this area should be inspected periodically and appropriate operational steps taken to reduce risk of a failure.

Another method involving a tow's anchor chain is to suspend the anchor from a wire strap, or cut it loose completely, and tow through the hawsepipe. The rigging for this procedure is complex and sometimes hazardous. Furthermore, this method often results in the chain bearing against a sharp forward or upper outer lip of the hawsepipe, which may consist of a much smaller radius than would be ideal for chain.

6-2.6.2 **Using Installed Bitts**

Mooring bitts are a possible choice for securing a tow hawser. U.S. Navy bitts are designed to withstand the breaking strength of the mooring line for which they are designed, with a factor of safety of 3 on ultimate strength. Since different types of synthetic lines will have different breaking strengths, Table 6-1 lists the capacities of Navy bitts. The chart also contains some typical dimensions that will help to identify existing bitts and shows how each of these dimensions are measured. The maximum pull can be applied to either barrel (not both), in any direction.

The strength criterion for bitts in commercial ships is similar, except older ships and Navy support craft which may have been designed for manila mooring lines. Consider this when employing bitts for towing of commercial or older Navy ships. In all cases, the strength of the bitts must be discounted if obvious corrosion or poor maintenance is evident.

Attaching a chain directly to the typical-sized bitts found aboard ships is feasible, but removing slack is difficult. Such a connection is susceptible to shock load from sudden rendering and has a higher possibility of failure. An improved connection where slack can be minimized can be made using wire that is the same size as the towing pendant. (See Figure 6-3.)

In Figure 6-3, note that the chain provides chafing protection at the deck edge, but wire is used to make the final connection. As stated earlier, when using mooring bitts as an attachment point, a backup securing system should be used. The reason for using backup bitts is to share the load. To accomplish this, the loaded part should make only one turn around one barrel of the first bitts. The first turn will absorb 50 to 75 percent of the total load on the wire, depending on the barrel diameter, and pass along 25 to 50 percent to the backup bitts. The wire should be secured to the second bitts by making one turn on the first barrel and then making figure-eights with the remaining line. Backing up to a third set of bitts is not necessary.

If two turns are taken around the first set of bitts, only about 6 to 12 percent of the total load is passed on to the second bitts. Thus, effective load sharing is voided.

If the wire required is too large to fit on the bitts, synthetic line may be used. This synthetic line is subject to the same restrictions as synthetic towing hawsers. Minimum bend radius for all components should be checked. The same principles are applicable to synthetic line load sharing.

When using mooring bitts as bridle attachment points, heavy channel iron must be welded across the bitts to prevent the bridle from jumping out.

6-2.6.3 **Using a Gun Mount or Foundation**

Another way to make an attachment is to pass a chain around a gun mount or foundation of a deck machinery installation or to rig a wire rope strap with a large eye on one end around the bitts (see Figure 4-13).

6-2.6.4 **Placing a Crew on Board**

In an emergency, the presence of a functioning crew aboard a disabled ship is of considerable help when making the connection. If the ship has auxiliary power and is able to operate its anchor windlass or other winches, passing the towline assembly is a relatively simple task, complicated only by adverse sea and weather conditions.

Connecting to a derelict poses the immediate problem of placing a boarding party onboard. A derelict vessel can present many unknown hazards to personnel. The boarding crew should consider personnel safety as paramount. If any potentially dangerous conditions were found during the pre-tow inspection, these should be briefed to the boarding party prior to attempting to board the tow.

If there are no means of boarding, grapnels may be heaved on deck or fabricated pipe boarding ladders may be used to get a man aboard. This person can then lower more conventional means such as a Jacob's ladder. The boarding party may have to carry an assortment of tools and rigging devices to help haul the messenger on board and hook up a tow. These tools may include:

- Welding and cutting equipment
- Various size shackles
- Wire straps
- Rigging lines
- Battle lanterns
- Personal safety gear
- Sheaves for rigging
- Hand-held radios

6-2.7 Approaching a Drifting Tow

There are as many variations of approaching a drifting tow as there are variables in wind and sea. Good seamanship is required to approach and safely take in a drifting tow of any size. Absolute coordination between the tow master and the fantail crew is essential. Direct communication with personnel on the tow and all parties is crucial.

6-2.7.1 **Establishing the Relative Drift**

The first step in approaching a tow to be picked up at sea is to establish differential drift between the vessels involved. This is critical for positioning the tow properly and avoiding a collision. Despite obvious differences in size and configuration, vessels' rates of drift are also affected by a host of other variables, including displacement, draft, stability, trim, damage, seas, wind, sail area, location of the superstructure, and currents. The above water hull configuration determines the tow's relative heading into the wind. Depending on trim, ships having a greater portion of their superstructure aft tend to head into the wind; ships having a greater portion of superstructure forward tend to lie with the wind from aft of the beam to astern. A midship superstructure will normally cause a ship to lie with the wind abeam. With relative drift between tug and tow determined, and the state of the seas and wind taken into consideration, the tug can make its approach.

6-2.7.2 **Similar Drift Rate**

Figure 6-4 describes a tug's approach across the wind and seas where similar drift rates exist. The tug begins an approach leading to pass close aboard on the weather bow; the messenger and towline can then be passed. The tug keeps station while passing messengers and making the connection.

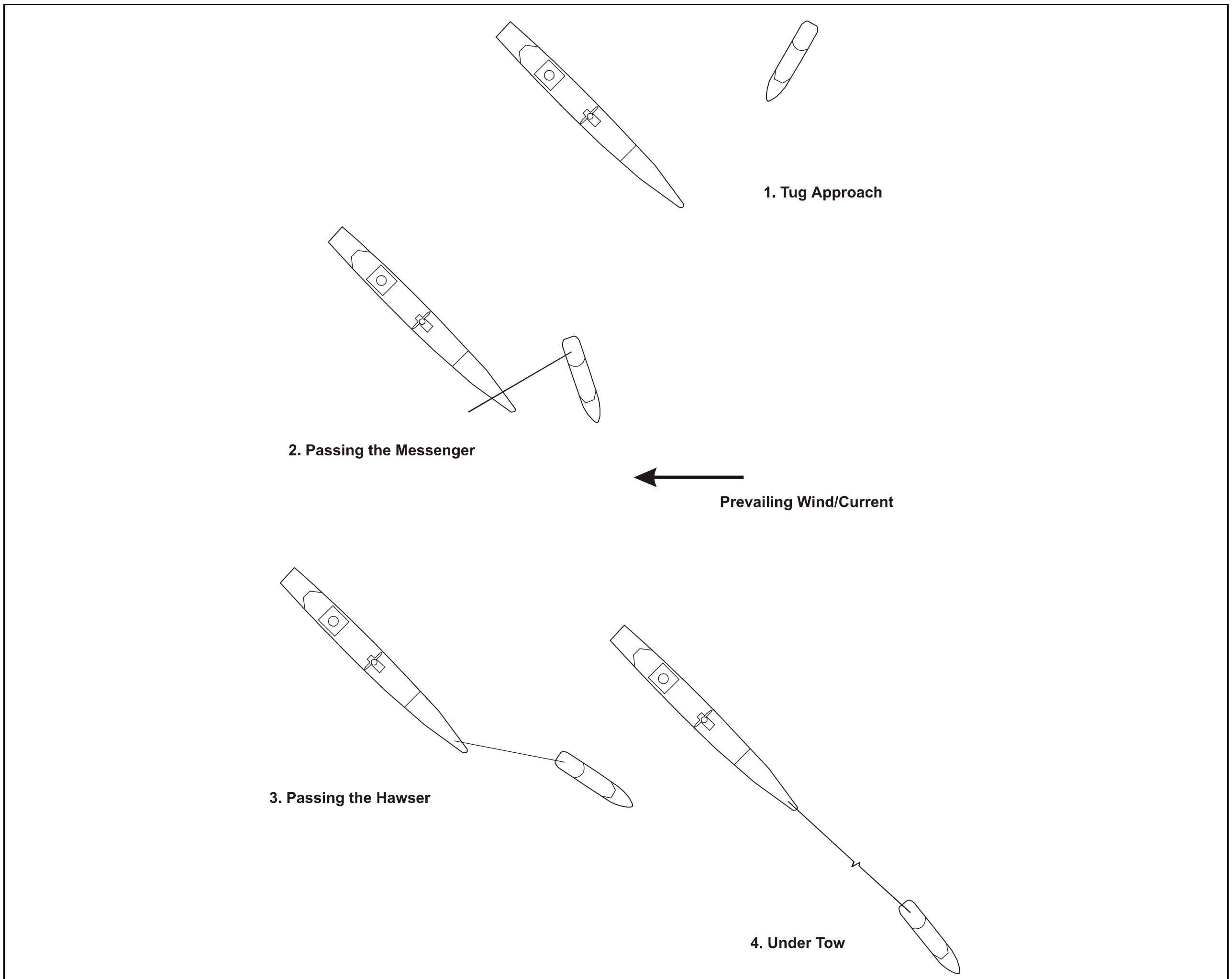


Figure 6-4. Across Sea/Wind Approach - Similar Drift Rate.

6-2.7.3 **Dissimilar Drift Rate**

Where dissimilar drift rates exist, a downwind approach may be executed, as seen in Figure 6-5. When approaching a ship lying broadside to the wind, tug speed should be slow, but fast enough to offer good steerageway. Because on-station time is short, a messenger must be passed quickly. The towline can be passed in the lee of the ship's bow. This situation requires a special effort to keep all lines clear of the propellers. Once connected, acceleration should be slow and maneuvering sequences gradual.

CAUTION
Approaching at too small an angle in the lee of a larger vessel can be dangerous. When working in the lee of a larger ship, establish an attitude that permits the tug to maintain a safe distance from the more rapidly drifting tow.

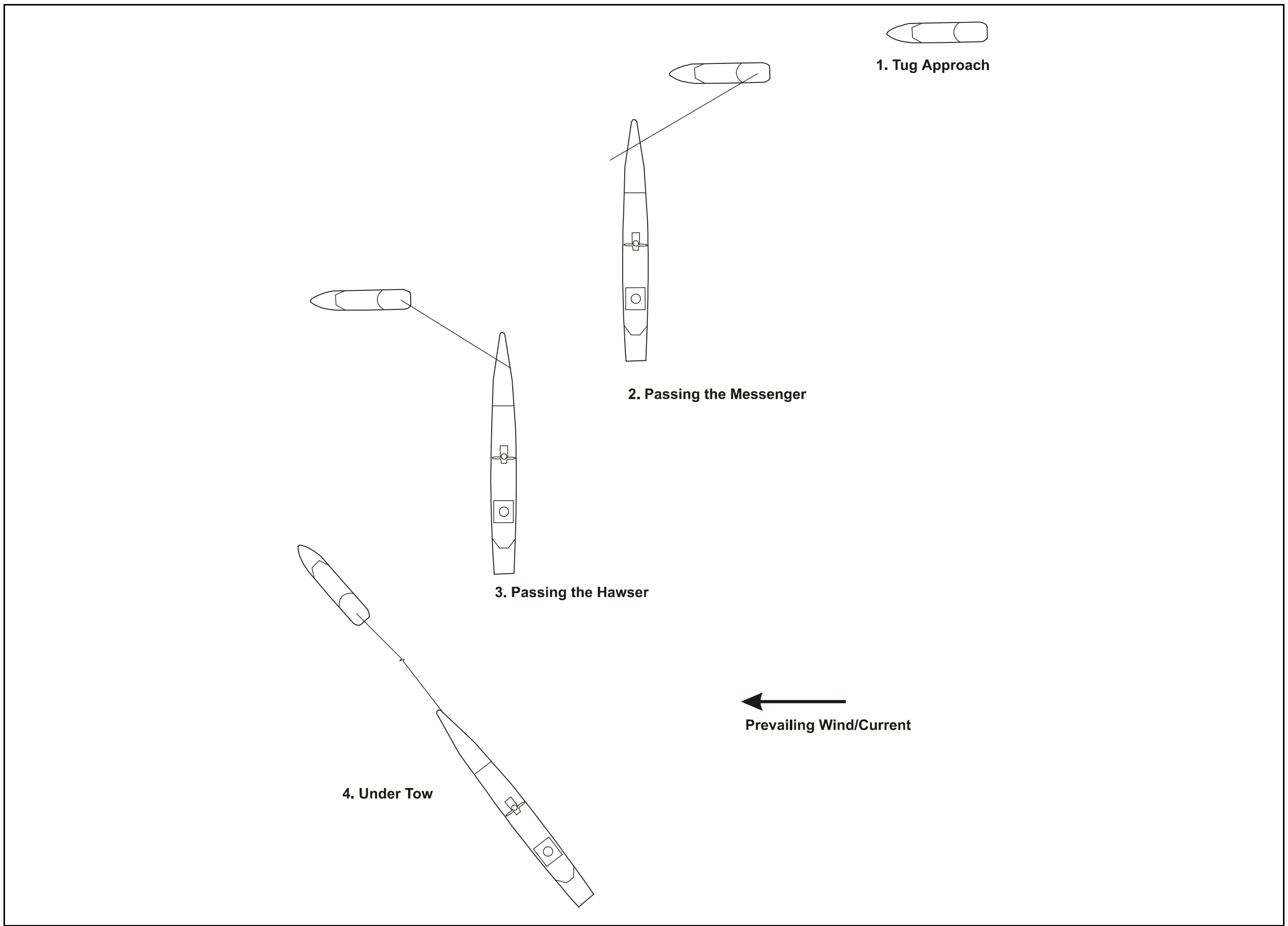


Figure 6-5. Downwind Approach Crossing the "T" to Ship Lying Broadside to Wind/Sea.

6-2.8 Passing the Towline

A towline is passed by messenger to the tow. It is generally preferable to have the tug pass the messenger and towline. The messenger may be passed by a hand-thrown heaving line, rocket, line-throwing gun, small boat, buoyant float, helicopter, or any other expedient means. The hand-thrown heaving line, backed up with a line-throwing gun, is a common and practical way of passing a messenger. An experienced seaman, under favorable circumstances, can accurately throw a heaving line over 100 feet. Backup heaving lines should be coiled and ready on deck to minimize time between attempts, should the first attempt fail. Time considerations and attendant dangers, however, make it prudent to give as much time as possible to pass the messenger. Use of a line-throwing gun, therefore, is the preferable procedure.

- In some cases it may be imprudent to navigate close to a distressed ship. In this event, a boat can be used to pass the messenger. Line, free for running, should be faked down in the boat and on board the tug, with the maximum amount possible in the boat.
- Buoys, life jackets, salvage floats, foam fenders, or drums can be attached to the messenger's bitter end and floated to the distressed ship. This can be expedited by the tug crossing the disabled ship's bow with the messenger streamed.
- Line-throwing guns can carry the bitter end of the messenger; an experienced seaman can safely and accurately fire the gun a distance of over 300 feet. A heaving line can also be used effectively for shorter passing distances.

After a sufficient length of the initial messenger is on board, it may be run through a block and the bitter end passed back to the tug where the tug's machinery can haul the heavy messenger and towing assembly on deck. The tow pendant is then made up to an available strong point on the derelict.

6-2.9 Communications between Ships

In a towing situation, most communication between ships is by radio. Loss of radio, radio silence, weather, or foreign language barriers may require an alternate means of communicating. The most commonly accepted methods for communicating between ships at sea are identified in the International Code of Signals, Communicating Ship-to-Ship NWP-14-1 (Appendix M -, Ref. J). These are by no means the only means of communicating. Prearranged signals and codes, as well as standard Navy procedures such as those in NWP 14, are valuable and highly useful tools available for communicating during towing operations.

6-3 Ship Handling and Maneuvering with a Tow

CAUTION
Small increments of rudder angle are recommended when changing course under tow. This will ensure the tug maintains control of the tow and prevents the tow from ranging up on the tug. Never permit the tow to pass forward of the tug's beam, as the tug or tow hawser may be severely damaged.

When the tow is underway, the tug begins to accelerate slowly to towing speed. Rudder orders should permit slow and orderly course changes. It is important not to subject a tow or towline to excessive dynamic loading. Slow course and speed changes will prevent excessive strain. If an automatic towing machine is installed, a low tension setting can be employed and the tow streamed as speed is increased. Once desired scope is achieved, the setting on the automatic towing machine may be increased to the desired value.

6-3.1 Tug Steering

Maneuvering characteristics of the tug can be dramatically affected when towing another vessel. The ability of the tug to maneuver itself under all conditions is essential.

The position of the tow point (the point where towline tension is applied to the tug) and the tension on the towline can create a moment opposing rudder moment and restrict the turning motion of the tug. The tug’s ability to steer is increasingly hampered as the tow point is located farther aft. The effect is aggravated at low or zero speed. The term “in irons” describes a condition where the opposing moment of the towline is the same as or greater than the turning moment created by rudder and other hydrodynamic forces. The tug is then rendered incapable of steering (see Figure 6-6). Being in irons can be catastrophic for a tug, especially when maneuvering in confined waters or in a poor orientation with respect to the sea. There have been instances where the tug has capsized as the tow overtakes the tug. A tug also can be rendered in irons when it cannot make headway under its own power because of the towline making contact with the bottom. In this case, the tug is effectively anchored by the stern. The tow, however, is not anchored and may close rapidly. To avoid being run down, the tug should shorten the wire and regain headway at once.

Ideally, the position of the tow point should be located at the tug’s natural pivot point, to allow the tug maximum freedom of rotation in steering. The tug’s natural pivot point is dependent on hull and rudder design; it is usually located on the center line at about one-third of the tug’s length from the bow. This is why the towing winch is mounted as far forward from the stern as possible, although it is doubtful that any towing winch is located exactly at the pivot point itself. From a practical standpoint, the towing point is designated as the towing winch or towing bitts, if installed.

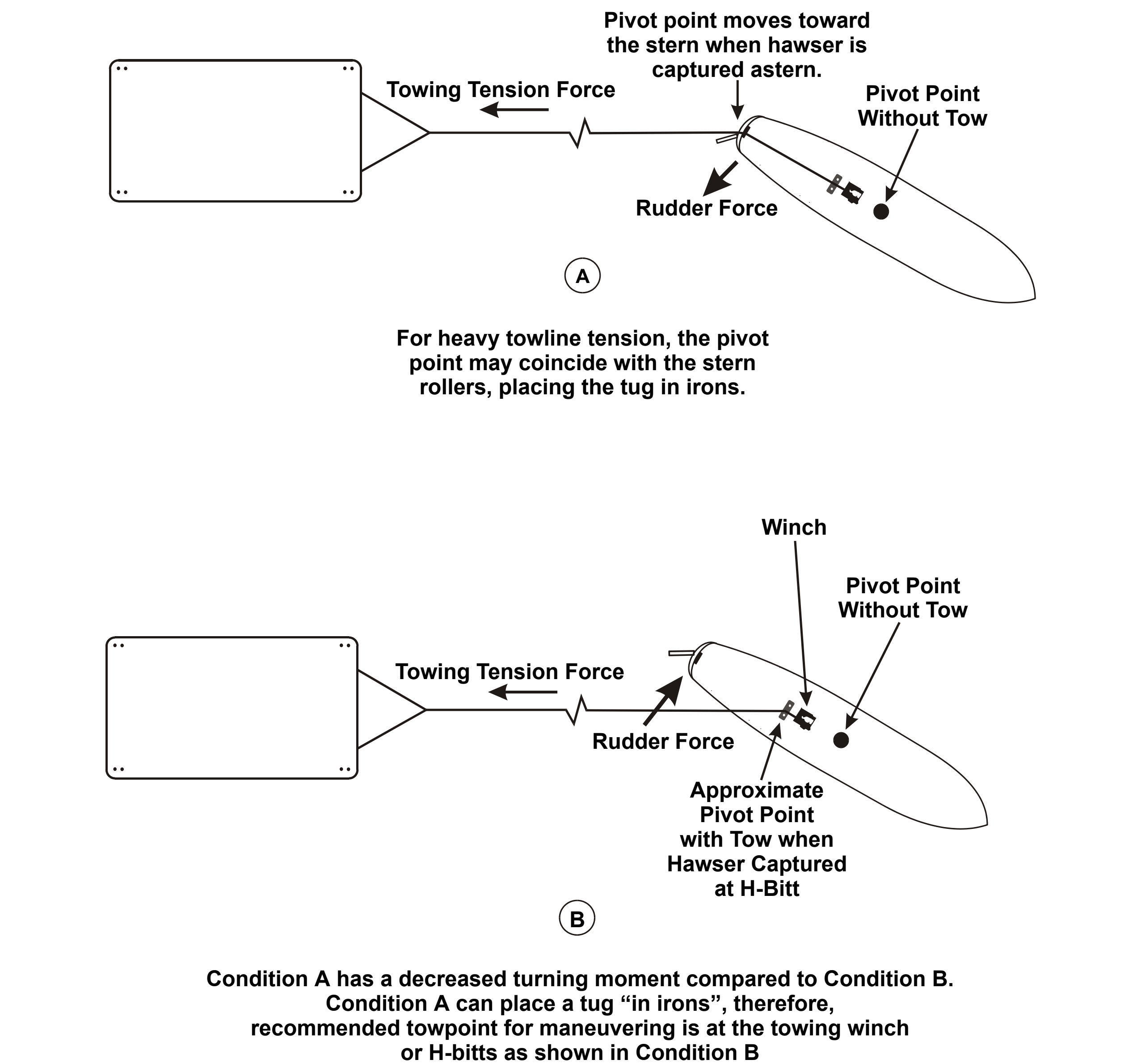


Figure 6-6. Effect of Towpoint on Steering.

There are times, however, when the towing point is located farther aft—for example, on a Norman pin, hogging strap, or stern roller. During long ocean tows, these configurations may be preferred since they will restrict line sweep and therefore chafing of the towline. If little maneuvering is needed, moving the tow point aft may be acceptable. In any configuration, it is imperative the operator be aware of the possible maneuvering restrictions imposed on the tug and take the necessary precautions to avoid being caught in irons.

6-3.2 Keeping a Tug and Tow in Step

When a tug is at sea with a tow, the two vessels move distinctly and separately in surge, sway, heave, roll, pitch, and yaw in response to the surface waves. The degree and timing of motion that either vessel experiences depend on the individual vessel's characteristics. No two vessels will respond to the surface waves in exactly the same pattern. In cases where the surface wave pattern is characterized by a single predominant wavelength, it may be possible to minimize the difference in the timing of the tug and tow motions. This involves adjusting the towline scope to place the tug and the tow on crests of the predominant waves at the same time. By placing both vessels on the crest at the same moment, they will move in response to the waves in the same direction at approximately the same time. Adjusting timing of a vessel motions in this way will reduce dynamic tension in the towline. This practice has been referred to as keeping the tug and tow "in step." In tandem tows, this is rarely possible.

As the tug approaches shallow water, such as a coastline or channel, the wave frequency will change (increase). The length of the tow should be adjusted, in conjunction with a possible change in speed.

Keeping "in step" applies equally to all towing situations, whether towing on the dog, hook, brake, or on an automatic towing machine. The benefit of being in step is to lower peak tensions.

6-3.3 Controlling the Tow

6-3.3.1 Active Control of the Tow's Rudder

The tow's rudder can be used to stabilize an unwieldy tow or to maneuver in close quarters. Improper or excessive use of the rudder, however, can cause the tow to become directionally unstable. The decision to use active steering of the tow will depend on the reliability of the tow's steering machinery and qualifications of the riding crew. A decision whether to use active steering rests with the tow master.

6-3.3.2 Yawing and Sheering of the Tow

Most tows will yaw, that is, oscillate in heading about the base towing course, usually in response to wave action on the tow's bow or stern. This is not a serious problem in and of itself. Many tows, however, will also sheer off to the side, where the tow's track is offset from the tug's track. This may be especially prevalent in beam winds for ships with large deck houses aft. Drydocks are particularly susceptible to mean wind conditions.

The vessel may remain at a nearly constant sheer angle or sheer from side to side, remaining at each side for as much as 10 minutes or more. Excessive sheering will cause excessive chafing of the towing rig, additional strain on the towline, reduction in tow speed, and possible collision or stranding in restricted waters. In extreme cases, the tow can range up to a position abeam or even ahead of the tug. This is common with submarine tows.

Sheering may be initiated by an external force or disturbance such as wind or wave action. Tows with bulbous bows tend to sheer more than those with “fine” bows. Improperly rigged bridles can also cause sheering. Legs of unequal length can generate a sheer problem with the tow.

Yaw can also lead to sheering. Depending on the tow’s inherent maneuvering characteristics, the amount of yaw and sheer may range from small to substantial. In general, a tow is considered directionally unstable if the sheer angle continues to increase from swing to swing, despite an absence in the force initially causing the motion. The following paragraphs discuss ways to control the factors that influence yawing and sheering.

6-3.3.3 **Trim**

Before undertaking the tow, the towed vessel should be trimmed by the stern slightly as described in Section 5-6.3. Trimming by the stern makes the towed vessel less susceptible to yawing.

6-3.3.4 **Speed**

Yaw of the tow may be increased or decreased with a change in speed; a range of tow speeds may be attempted in an effort to obtain a desired reduction in yaw.

6-3.3.5 **Use of Rudder or Skegs**

If the tow is tracking poorly but is steerable, the rudder can be used to reduce or eliminate yawing and sheering. Active use of the rudder, however, increases drag and adds the risk of steering machinery failure at a permanent rudder angle. Hull damage may cause the tow to take up a permanent sheer angle. In this case, permanent adjustment of the rudder can significantly improve the tow’s behavior.

If excessive yawing occurs on a movable twin-skegged tow, each skeg can be splayed at an outboard angle. Although the drag will increase, the directional stability should improve. Outboard splaying is commonly done on barges and the technique has been successfully applied to twin-ruddered ships and floating dry docks. All such rudder or skeg movements should be made in moderation to achieve optimum towing performance with minimum increase to drag forces.

6-3.3.6 **Location of the Attachment Point**

A point of bridle entry into the tow may be selected to offer an optimum angle, and thus eliminate or reduce excessive yaw or sheer. Steps must be taken to prevent towline chafing and to ensure that a fairlead is sufficiently robust. As an example, the LST 1179 Class requires either a bridle or an off-centerline pendant because of the bow doors. Towing is performed through a mooring chock on the side. These ships tow quite steadily with a very slight sheer.

6-3.3.7 **Propellers**

A locked propeller, essential to prevent internal bearing and gear damage, will create a larger drag than a free-wheeling propeller, thereby resulting in reduced towing speed. The additional drag in the stern due to a locked propeller, however, may decrease the tendency of the vessel to sheer off from the intended track. Refer to Section 5-6.2.1 through 5-6.2.1 for information on preparing the propellers for tow. Unlocked propellers, will cause shaft rotation and overheat without sufficient lube oil.

6-3.3.8 **Steering Tug**

The addition of an operational ship astern of the tow can offer effective steering control. The trailing ship can use its engines and rudder to maintain slight tension on a line to the tow. Following steering orders from the tow master, it can assist in keeping a tow from sheering off.

6-3.3.9 **Sea Anchor or Drogue**

An object towed from the stern of a tow to create drag which resists yawing motions. Nets, anchor chain, line, wire, kite anchors, mine-sweeping gear, and a wide variety of other drogues have been used as stabilizing devices on small tonnage or shallow draft ships, especially those with fine hull forms. Care should be taken to prevent snagging of the drogue in shallow water.

6-3.3.10 **Bridle vs. Single Lead Pendant**

Certain hull forms are more conducive to being towed by a single lead pendant. Submarines and ships with bulbous bows or forward sonar domes tow better on a single pendant than on a bridle. In general, fine lined ships should be towed with a single leg and broad beamed ships towed with a two leg bridle.

6-3.4 Backing Down with a Tow

CAUTION
Except in an emergency, backing down with a tow is not recommended. It may be attempted if a collision with another ship is imminent.

If backing down is necessary, take great care not to foul the towline in the propeller. Tow position and speed of advance must be considered to avoid collision.

For information on anchoring with a tow, refer to Section 5-7.5.

6-4 Routine Procedures While at Sea

This section deals with procedures which are performed at sea on a routine basis but deal specifically with towing. Each tow is unique, of course, and will present unique problems and challenges, but some general guidelines apply.

6-4.1 Setting Course

When adequate sea room is achieved, maneuver to set course and begin streaming the tow. Do not stream to full scope until sufficient water depth is available to keep the towline catenary from dragging.

6-4.2 Towing Speed

Safe towing speeds are determined by many factors, including material condition of the tow, currents, sea states, towing direction relative to the surface waves, wind velocity and direction, hull type of the tow, tug horsepower, capacity of the towline system, and available powering assistance from other tugs or the tow's power plant.

The towing speed should be chosen to minimize the probability of damage to the tug and tow. When towing damaged vessels and flat-bottomed craft, try to avoid excessive seakeeping motions and pounding. When necessary, towing course and speed should be chosen relative to the sea state and wind direction to keep towed vessel motions within safe limits.

Barges generally should not be towed faster than 8 knots under mild sea conditions. Small service craft and some dry docks should be limited to 6 knots. Deterioration of weather conditions requires appropriate speed reduction to ensure continued safe towline loading. When towing larger surface ships, the speed limitation usually is a function of the tug's capabilities. Sometimes, however, the dynamic loads induced by the ship motions of a tug and tow in a seaway will be the controlling factor in determining a safe towing speed (as opposed to the safe towing speed of the towed vessel or the capabilities of the tug).

6-4.3 Towline Scope

To estimate the towline scope required, follow these steps:

1. Choose a candidate scope
2. Estimate steady towline tension (see Section 3-4.1)
3. Compute catenary (see Section 3-4.2)
4. Estimate maximum and minimum towline tensions
5. Ensure that catenary will not exceed water depth at minimum tension (A maximum scope for the water depths expected should also be calculated.)
6. Adjust the scope as necessary and repeat steps 1 through 5.

The scope should be adjusted to provide an adequate catenary for absorbing changes in towline tension without exceeding water depth. Dragging a towline on the sea floor will damage the two hawser through abrasion and could lead to fouling on a sea floor obstruction. Also, once the hawser is in contact with the bottom, the tug no longer has control of the tow and is in danger of being overtaken.

If the surface wave pattern has a predominant wavelength, attempt to adjust the towline scope so that tug and tow ride on crests of the predominant wave components at the same time. Adjusting the towline this way may keep tug and tow "in step," thus reducing changes in towline tension caused by seakeeping motions (see Section 3-4.1.4).

6-4.4 Towing Watch

With the tow streamed, the towing watch must be set to observe the tow, towing loads, towing machine, towline, and the tow's seakeeping performance. The tow watch must routinely advise the tow master of conditions observed. On board newer tugs, much of the information is automatically displayed in the pilot house and control stations.

6-4.5 Periodic Inspection of Tow

Elements of the tow's material condition should be visually inspected and continuously monitored, even at night. They include:

- Flooding and fire alarms, navigation lights, draft marks, and trim
- Sheer angle and seakeeping
- Timing of roll period for stability.

To supplement the flooding alarms, tug watch personnel should be alert to signs of flooding such as list, excessive drag (increase in towline tension without a change in conditions), change in roll period, or unexpected trim in the tow. The towline should also be inspected frequently for chafing and damage during a tow.

It is common practice to "freshen the nip" or "nip the tow" to avoid chafing. This is the practice of changing the scope of the towline so no single point is continuously in contact with the tug's caprail.

6-4.5.1 **Boarding the Tow for Inspection**

When carrying a riding crew, the crew performs most of the inspection functions. Long distance and valuable tows without a riding crew should be periodically boarded and inspected, preferably by the same personnel on each inspection. Because this operation is often difficult and hampered by weather and sea conditions, inspection preparations should be well planned and promptly and efficiently executed. The following suggestions may aid this process:

- When possible, consider seeking the lee of a land mass to make the operation safer, easier, and more controlled.
- Shorten up the tow, this provides an opportunity to inspect the towline and any part of the tow rig that can be brought aboard safely.

6-4.5.2 **Inspection Guidelines**

WARNING
Carefully adhere to safety requirements when entering closed spaces. See Naval Ship's Technical Manual (NSTM) S9086-CH-STM-030, Chapter 074, Gas Free Engineering (Appendix M -, Ref. K).

A written account should be kept of each inspection, to be used as a reference for following inspections. The tow inspection party should perform the following:

- Check the tow connections and bridle for integrity and unusual wear.
- Check propeller shaft locking system.
- Check rudder locking system.
- Check navigational lights and batteries.
- Check flooding and fire alarm system.
- Visually check open habitable compartments and topside areas.
- Sound any suspicious or questionable voids, double bottoms, and liquid tanks.
- If indicated, visually check structural framing and hull plating in the bow.
- Operationally check fire fighting and dewatering equipment weekly, or more often if conditions warrant.
- Upon completing the inspection, close and make watertight all hull access openings. Any additional checks appropriate to the peculiarities of the tow should be incorporated as needed into the inspection checklist.

6-4.6 Towing in Heavy Weather

Long ocean passages rarely offer the opportunity to plan for favorable weather during the entire tow. Seasonal storms and sudden, unexpected weather can cause difficulty for both the tug and the tow. Hurricanes and typhoons are the most dangerous and destructive of all storms. Advice on actions to take in the event of such storms is contained in Chapter 18 of Knight's Modern Seamanship (Ref. L).

Upon receiving a hurricane warning, take these steps:

- Determine the location and track of the hurricane to plan a course avoiding the dangerous semicircle.

CAUTION
Running before the sea and wind can cause difficulty in steering and in keeping the tow in the desired position. The tow may become awash or start to overtake the tug. If the tow begins to close on the tug, the tension in the towline will be reduced and cause an increase in the catenary, which may also cause the towline to snag on the bottom or bring the tug and tow to collision. The recommended course of action is to head into the weather and maintain steerageway, increase hawser scope and, as long as there is enough sea room, tolerate a negative speed over the ground. There is no reason to slip the tow unless the towing ship is in danger of grounding.

- If necessary, change course to avoid or ride out the storm. It is far better to depart from the projected track, ride out the storm, and accept delays than to endanger the ship and tow by remaining on a dangerous course and speed.

NOTE
If water depth permits, increase the towline scope and use the automatic feature of the towing machine in heavy weather. This enhances shock load reduction for the towline system. Every vessel rides differently in severe storms. Tug captains should use good seamanship to determine how their tugs and tows ride best. They should use the best combination of towline scope, speed, and heading. Generally, heading into the weather allows better control of the tow.

Estimate size and direction of the waves. Determine whether extreme tension indicators can be eased by slight changes in course away from towing directly into the wind.

- Recognize the tug and tow will likely make negative speed over the ground. Sail for a position which minimizes navigational hazards on a downwind track.
- Rig the tug's fantail for heavy weather. Stern rollers and Norman pins should be down and other obstructions to the towline cleared.
- Increase hawser scope, if possible.
- Set the towing machine on automatic if it has an automatic feature. Otherwise, tow on the brake, rather than on the dog, to ensure rapid reaction to changing circumstances.
- Arrange for quick disconnection of the towline. Methods for slipping the towline are discussed in Section 6-7.3.2.

6-4.7 Replenishment at Sea

Long ocean tows or emergency circumstances may require the tug to replenish at sea. Replenishment at sea is a well-established routine, with procedures documented in Naval Warfare Publication (NWP) MSC Handbook for Refueling at Sea, NWP 14-2 (Appendix M -, Ref. M). The methods outlined there are suitable for passing fuel, water, and other logistic necessities to a tug with a tow. The method selected is influenced mostly by sea and weather conditions, bearing in mind other factors that affect safe and efficient ship handling. Due to reduced maneuverability of a tug with a tow, consideration should be given to having the supply ship maintain station on the tug, vice the receiving ship maintaining station. It may be advantageous to replenish from astern of the replenishment ship due to speed and maneuvering limitations.

6-4.7.1 Transferring Personnel and Freight

Simple light line procedures are used for transferring small freight. During these transfers it may be advantageous, as in fueling, for a transferring ship to keep station on the tug.

Personnel and mail should be transferred by boat or helicopter. In unusual circumstances, personnel can be transferred by rigging a high line, or, if necessary, a Stokes stretcher. Conditions permitting, a small boat should be used to avoid the maneuvering restrictions of underway replenishment.

6-4.7.2 Emergency Replenishment

Emergency conditions, wartime operations, or heavy weather may require great ingenuity to replenish the tug or tow. Water and fuel can be received from the tow, if available, by shortening the towline and streaming hoses from the tug. In calm seas, the tug may go alongside the tow to effect necessary replenishment. This requires disconnecting the tow, but in calm seas reconnecting should pose no problem.

6-4.7.3 Rigging and Use of Fueling Rigs

Surging, often experienced in towing, may require that the replenishment ship keep station on the tug. The greater maneuverability of the oiler and the lack of complete control by the tug recommend this procedure. The tug designates the fueling station, receives the hose, and proceeds to take on fuel while employing standard precautions of proper stability, safety on deck, adequate communication, and proper navigation. Astern refueling can also be considered.

6-4.7.4 Astern Refueling from Another Tug

Being refueled astern from another tug while towing has become a common procedure due to the limited number of replenishment ships. This process is somewhat different than that described in NWP 14 and can be accomplished with or without the sending ship taking the receiving tug in tow. Due to the slow pumping rates available, however, taking the receiving tug in tow does simplify station keeping in what is sometimes a 24 to 36 hour operation.

6-4.7.5 **Replenishment Near a Port**

The tow ship can arrange a temporary transfer of the tow to a local tug or tugs (see Section 6-5.5). Then the ocean tug enters port to replenish, while the tow is maintained offshore by a temporary replacement tug, or offshore mooring. When replenishment is finished, the tow ship returns, reestablishes the tow, and proceeds on its journey.

If a long replenishment is anticipated, it may be more economical to seek temporary docking for the tow.

6-5 Terminating the Tow

Terminating the tow at its destination requires as much planning as any other phase in towing. If the schedule and the condition of the tow permit, it is generally best to adjust speed to arrive at the destination during daylight hours. Darkness can easily complicate a routine evolution – making it into a more difficult and dangerous situation. Based on the nature of the tow, pilot assistance and/or harbor tug assistance may be required.

6-5.1 Requesting Assistance

The tow master decides when to use a pilot, unless an order from senior authority supersedes. Some pilots, however, may be unfamiliar with towing and with the characteristics of the tug. If a pilot is not familiar with towing, it may be preferable to employ him as an advisor to the tow master rather than giving him the conn. The tow master shall be alert to the difficulty and relieve the pilot if he deems necessary.

Harbor tug assistance may also be necessary. Sea conditions may not permit harbor tugs to make up alongside. In this case, the only significant assistance that can be rendered is for the harbor tug to put a head line to the tow's stern to assist in steering the tow. Once within sheltered waters, harbor tug assistance can be used as required. If an additional tug is available, it and the original tug can be made up, each on a quarter, to effectively keep the tow heading fair to the channel. If the tow is large and unwieldy, additional tugs may provide both steering assistance and propulsion power. When using multiple tugs, it is advisable to have pilots on board both the tug and the tow to coordinate control of the assisting tugs.

6-5.2 Shortening the Towline

When approaching restricted waters, a shorter scope and slower speed will make the tow easier to handle. It may be necessary to bring a tow to short stay to prevent the towline from fouling on the bottom. Bringing a tow to short stay avoids being overtaken and fouling the towline. A delicate balance must be maintained between scope and speed. In this situation, an automatic towing machine is invaluable. Because there will be little or no catenary, automatic control of the towline or the use of a synthetic spring (see Section 4-6.5) are the only means of surge control available. An automatic towing machine can shorten the scope in either automatic or manual modes. Often where there is a long distance from sea buoy to berth, the ocean tug may continue to tow, at short stay, to a convenient and safe location well inside the harbor.

6-5.3 Disconnecting the Tow

Before actually disconnecting the tow, lay out necessary equipment, energize potentially involved machinery, and brief all personnel on procedures. A well-drilled, disciplined team will perform the routine smartly and will also be responsive to any unexpected occurrences.

Disconnecting procedures start by reducing speed to bare steerageway and bringing the tow up short with the towing winch. With assistance from whatever harbor tugs are in attendance, the towline is shortened until the connection fittings are on deck. A stopper is passed onto the pendant, the connection is broken and with all personnel clear, the stopper is released.

CAUTION
Do not permit the disconnected pendant or bridle to drag on the bottom — it can cause considerable additional resistance and seriously disrupt maneuvering.

When a tow bridle is long enough, the pendant can be brought fully aboard the tug and disconnected at the bridle apex. This may keep the pendant from dragging the bottom. The bridle and pendant may also be retrieved on the tow by using a previously rigged retrieving line at the bridles apex. (see **Towing rig**).

When slowing, the towline scope may need to be reduced to prevent dragging the bottom. A decrease in speed will cause a decrease in towline tension when the tow closes on the tug. As the tug and tow separate again, an increase in tension will occur. Deceleration, like acceleration, must also be done in a controlled and judicious manner. (See Section 6-7.5 for information on anchoring with a tow.)

6-5.4 Towing Delivery Receipt and Reports

If a harbor tug master is authorized to receive the tow formally, he should be asked to do so. This allows physical and legal transfer in the stream without having to dock or anchor. If the harbor tug master is not authorized, it may be necessary to send personnel ashore to obtain necessary signatures on the letter of acceptance. Sample forms for receipt of tow and towing reports can be found in Appendix H.

6-5.5 Transferring the Tow at Sea

Casualty, operational orders, weather, or other unusual circumstances may require transferring the tow to another tug. Preparing for transfer and understanding the transfer procedure will ensure success and minimize any difficulties. If possible, personnel from both vessels should review and agree on a plan prior to any action. Emergency conditions may not allow this.

The following procedure may be used for disconnecting the towline and passing the tow (see Figure 6-7).

a) Set a course into the seas and reduce speed.
b) Heave in until the pendant is on deck.
c) Signal the receiving tug to come close aboard on the designated side on a parallel course.
d) Secure tow bridle or pendant on deck with a chain stopper; allow sufficient length to lay on deck to facilitate disconnection from the hawser.
e) Break the tow hawser from the pendant.
f) Receiving tug passes a messenger connected to the bitter end of its hawser or to a messenger strong enough to control the tow.
g) Bring the receiving tug's hawser or heavy messenger on deck and bend it into the tow pendant.

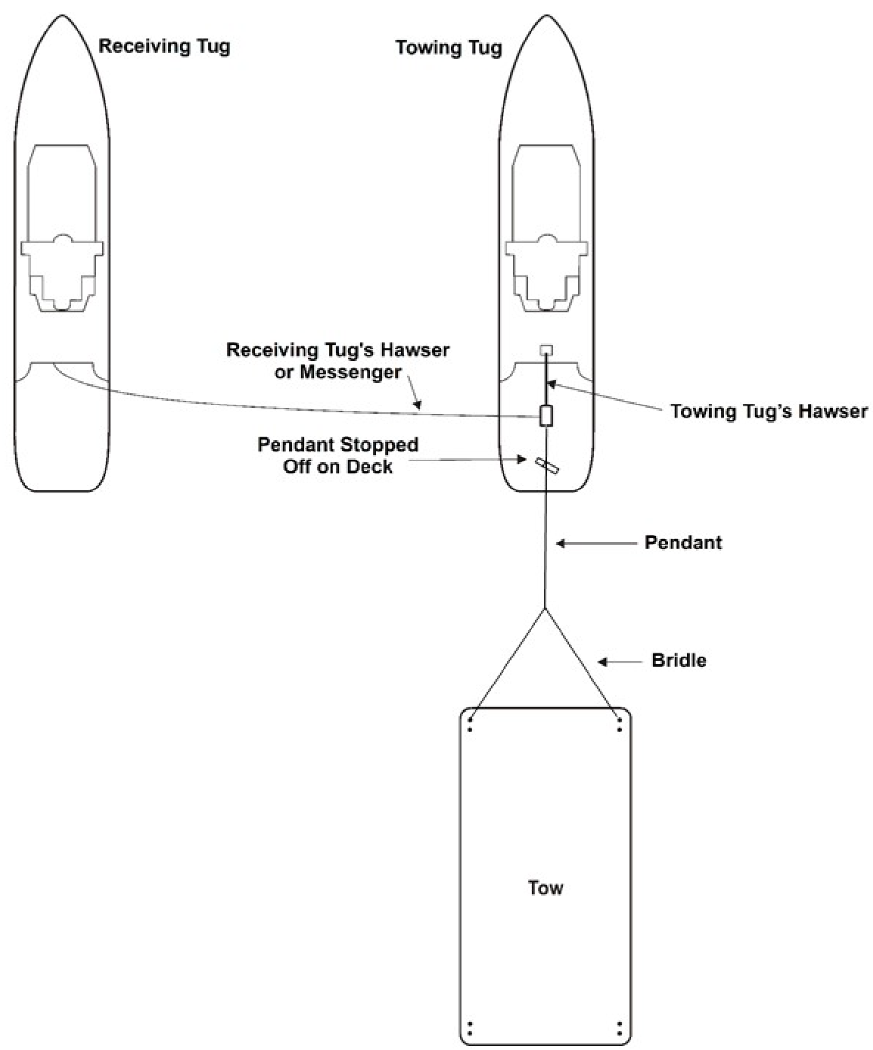


Figure 6-7. Passing a Tow at Sea.

h) With all lines and personnel clear, trip the stopper and transfer the tow to the receiving tug.
i) If a messenger was used, the receiving tug makes the final connection to the tow pendant on its own stern.
j) All special equipment and personnel associated with the tow are then transferred and appropriate documentation completed.

6-6 Tow and Be Towed by Naval Vessels

All U.S. Navy ships (except submarines and aircraft carriers) are capable of towing, using their own emergency towing hawsers. When two Navy ships are involved in a “tow and be towed” operation, each provides its own emergency towing hawser to form half of the total towing system (see Figure 6-8).

Some Navy ships may be equipped with old, little-used hawsers. These ships may not be aware of the recently understood problems with deterioration of nylon rope over time. All should be alerted to current directives concerning replacement of emergency towing hawsers. Double-braided polyester hawsers (MIL-R-24677) are required.

6-6.1 Towing Systems

Navy combatant surface ships have a towing pad and stern chock aft and a chain stopper pad (towing pad) and bow chock forward. Sometimes, because of equipment interference, the stern chock and towing pad are located on the quarter.

In addition to these deck fittings, Navy surface ships carry a towing hawser, chafing chain, pelican hooks, shackles and other appendages needed for emergency towing operations.

Each ship in the Navy is provided with a tow drawing showing how to rig the ship for being towed or for towing another ship. This drawing also shows such details as tow hawser size, chafing chain, and other appendages. For surface ships and some submarines, the Ship’s Information Book (SIB) has details on their tow gear and also contains diagrams illustrating how to rig for being towed or for towing another ship.

Aircraft carriers are only equipped to be towed. They do not have a padeye or other towing equipment located aft for towing another ship. Carriers are equipped with a 2-1/2 inch diameter 6 x 37 galvanized wire rope, 900-foot towing hawser. The towing hawser is stored in the anchor handling compartment on a horizontal storage reel.

Some submarines carry a tow bridle on board, but in some cases (SSBN 726 Class), the tow gear is stored ashore. In this case, this equipment shall be provided by the tow ship. Submarines are built with the necessary towing pads, cleats and chocks for being towed. When not in use, the cleats and chocks are arranged to retract and are housed inside the faired lines of the hull. See Appendix J for more detail concerning submarine towing.

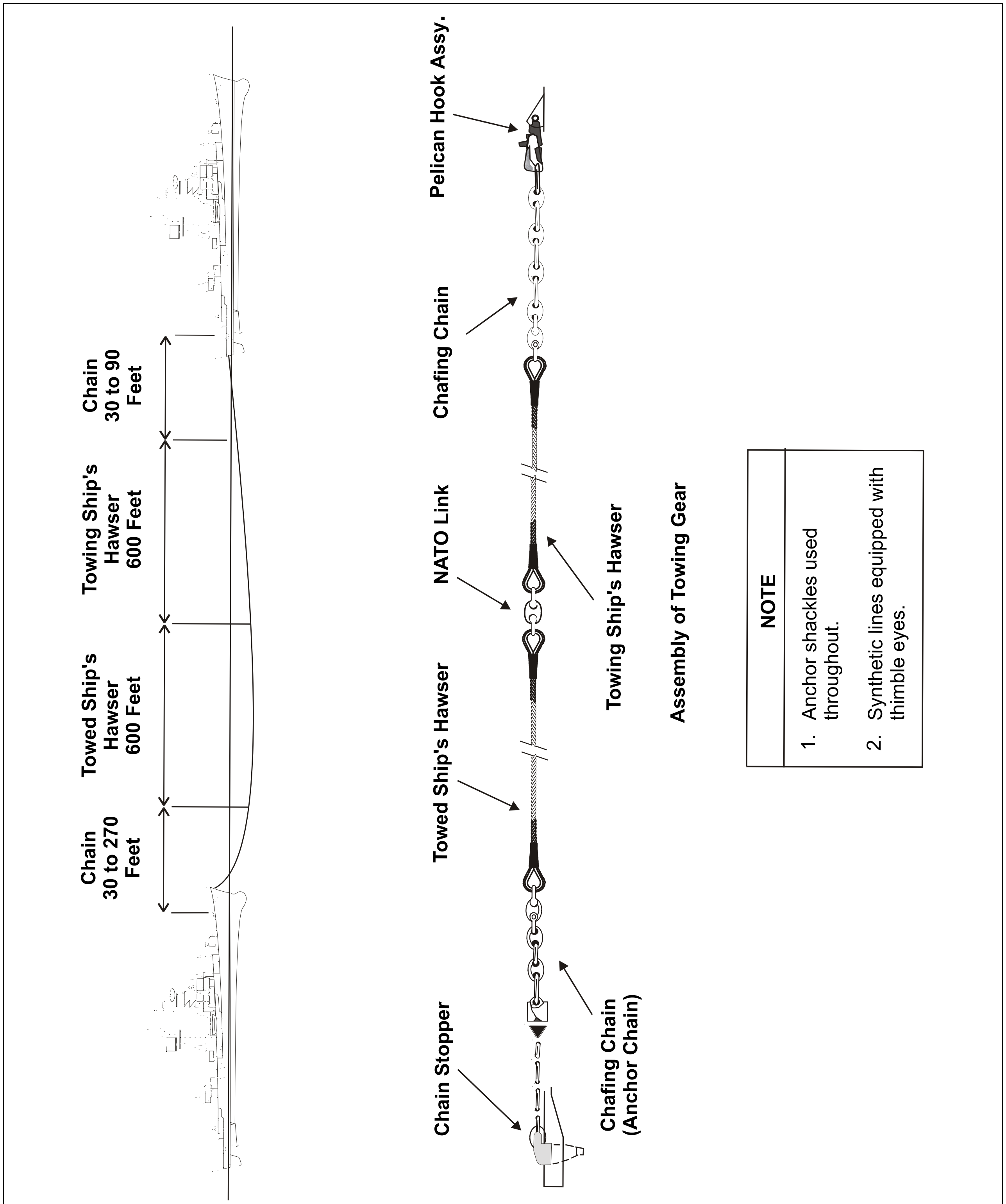


Figure 6-8. Tow-and-Be-Towed.

6-6.2 Tow Procedures

The information presented here is taken from NSTM CH-582 (Ref. A), which is the governing document for emergency ship-to-ship towing. Where this manual and NSTM CH-582 differ on this topic, NSTM CH-582 shall take precedence. Consult the reference directly for greater detail.

6-6.2.1 Procedure for the Towing Ship

1. Connect the pelican hook to the after-towing pad with a shackle.
2. Connect the chafing chain with an end link to the pelican hook. Lead the chafing chain through the stern chock.
3. Connect the tow hawser end fitting to the chafing chain with a detachable link.
4. Fake down the tow hawser clear for running fore and aft. Stop off each bight of the tow hawser to a jack stay with 21-thread. Place shoring under the stops for ease in cutting.
5. Connect the NATO tow link to the free end of the tow hawser. If a NATO tow link is not available use an appropriate size long link or shackle. This fitting should be capable of being connected to the hawser of the towed ship.
6. Connect a messenger, composed of approximately 100 fathoms (600 feet) of three-inch circumference line and 50 fathoms (300 feet) of 1-1/2 inch circumference line (For a 10-inch circumference or larger hawser, use four-inch line instead of three-inch), to the outboard end of the tow hawser. Lead the free end of the messenger through the stern chock.
7. Pass the messenger to the towed ship using a heaving line. Preparing extra heaving lines prior to hook up will allow several attempts to complete this pass during maneuvering. Control the pay out of the tow line messenger and hawser by cutting the stops. The tow line messenger and hawser should be payed out gradually to ease handling of the tow line by the towed ship and to avoid fouling the towing ships propellers.

6-6.2.2 Procedure for the Towed Ship

1. Stop off the anchor (port or starboard) of the anchor chain to be used. Set up on the anchor windlass brake. Pass a pinch bar through the chain, letting the bar rest on the lip of the chain pipe, or pass a preventer to prevent the chain from backing down into the chain locker and a preventer on the anchor to back up the stopper. Break the anchor chain at the detachable link inboard of the swivel. If power is available, haul out the desired length of chain using the anchor windlass. If power is not available, the chain will have to be hauled out manually.
2. Shackle the towing chain stopper to the designated (towing) padeye on the forecastle, for stopping off the anchor chain after the tow is properly adjusted.
3. Fake out the towed ship's hawser on deck, fore and aft, on the forecastle for clear running, prior to connecting it to the anchor chain. Use the tow ship's messenger to haul the towing hawser from the tow ship on board through the bullnose. Connect it to the towed ship's hawser secured to the end of the anchor chain. If the towed ship's hawser is not to be used, connect it to the anchor chain.
4. Pay out sufficient anchor chain (5 to 45 fathoms [30 to 270 feet]) to provide a substantial tow catenary when the tow hawser has been payed out. Synthetic line, by itself, will provide very little catenary.

5. Set the brake on the wildcat and pass and equalize the chain stoppers one outboard and one inboard of a detachable link, to take the strain on the towed ship's anchor chain. Disengage the wildcat.

6-6.2.3 **Quick Release of Towed Ship**

1. Pay out the anchor chain connected to the tow line on board the towed ship so that a detachable link is just forward of the anchor windlass.
2. To prevent the chain from returning to the chain locker when detached, pass chain stoppers on the anchor chain and lash the anchor chain just abaft of the detachable link or apply the chain compressor where fitted.
3. Disconnect the anchor chain between the anchor windlass and the chain stoppers so that only the chain stoppers are holding both the anchor chain and tow line. This arrangement allows quick release of the towing hawser and chain.

CAUTION
In case of emergency, for quick release, tripping the pelican hook on the towing ship is faster than the above procedure.

6-6.3 Getting Underway with Tow

Implement the following steps when the tow hawsers are connected and both ships are ready to start the tow:

1. The tow ship should come ahead as slowly as possible as the hawser begins to take strain. Increase turns slowly until the inertia of the tow is overcome and both ships are moving with a steady tension in the hawser. Increase speed slowly until the desired speed is reached. At no time should the tow speed be such that the tow hawser lifts completely out of the water. The course of the tow may be changed gradually, as necessary. Getting underway with a tow will likely result in the largest tensions and requires the most care.
2. Pay out or haul in (assuming power is available to the anchor windlass) anchor chain as desired to keep both ships in step (that is, taking wave crests at the same time). When a comfortable distance is found, the chain stoppers are passed on the anchor chain and the strain is equalized between stopper and wildcat. Locking plates are installed and set on both the chain stoppers. Remember the rule of three which addresses equalizing the load to all attachment point as discussed in Section 4-6.6.

3.

6-7 Emergency Towing Procedures

CAUTION
Riding crews normally consist of a minimum crew and can be expected to perform only limited emergency functions on board.

This section presents general guidelines for handling emergency situations unique to towing. As in all emergencies, prudent seamanship and adherence to safety guidelines are primary concerns in bringing a situation safely under control.

6-7.1 Fire

Fire on board is a well-known hazard; fire prevention and methods of fighting fires should be drilled with the riding crew. There should be little danger of fire on board an unmanned tow. One exception is the possibility a shaft locking device might fail and cause an engine room fire.

When a riding crew is on board, the fire potential should be evaluated. If equipment is being operated for propulsion, auxiliary power, pumps, or allied systems, the danger of fire can be significant. Prudent and adequate placement of pumps, hoses, fire extinguishers, axes, foam, and fire fighting equipment is required to help the riding crew fight fires. If necessary, personnel may be transferred from the tug to the tow to perform fire fighting and damage control. The tug, if it can be brought alongside, can deliver large quantities of water for use on board the tow; associated power, foam, hoses, and personnel from the tug can be of valuable assistance. A charged 2½-inch fire hose can be streamed aft on salvage balloons if alongside fire fighting is not practical.

6-7.2 Tug and Tow Collision

CAUTION
When towing under unfavorable conditions, inclement weather, or at short stay, danger exists of being overridden. In such a situation, particular care is advised in setting an underway material condition so that watertight doors, hatches, and other openings are secured.

The tug and tow may collide when maneuvering in restricted waters with the tow at short stay, or under other operationally complex circumstances. A collision may also occur when:

- There is a loss of propulsion power or sudden reduction of the tug's speed. With sufficient way on, the tow may override the tug, and in extreme circumstances sink it. The possibility is greater if a tow is at short stay. If propulsion power is lost on the tug, put the rudder hard over to the weather and slack the towline. With sufficient way on, the tug may fall clear of the advancing tow. If power loss is imminent but the tug can still make turns, consider going alongside or otherwise clearing the tow.
- Tug and tow will experience different set and drift from seas, currents, winds, or towline drag. To avoid collision, reduce speed and increase the towline scope. If possible, the tug should turn into the predominant sea, if the tow has a larger sail area. This will cause the tow to drift away from the tug. Follow the opposite course if the tow's sail area is smaller than that of the tug, as in the case of a submarine.
- A tug and tow are dead in the water, allowing towline cantenary to draw them together. The same situation can occur between two tandem tows. In an emergency in shallow waters, it may be possible to anchor both tug and tow by letting the towline come into contact with the bottom. (Routine use of this practice is discouraged because of possible towline damage.)

If a collision appears unavoidable, deploying fenders may serve to reduce or eliminate damage to both vessels.

6-7.3 Sinking Tow

Planning to sink a tow also requires special consideration and preparation. Often, special permission must be obtained and adherence to environmental regulations can be complex. Caution should be used when accepting a tow with the intention of sinking. This may be the case following a salvage operation.

Flooding, structural damage, shifting of ballast or cargo, or other events may degrade the tow's stability. When stability decreases, the tow may be in danger of sinking. Excessive force placed on the tug as the tow sinks can damage and seriously endanger the tug before the towline parts. Prompt action is necessary to save the tow and to ensure the safety of the tug.

It is vital to monitor the condition of the tow during transit. Trim, list, roll period, seakeeping, and draft are monitored from the tug or by a riding crew. Upon noting an irregularity, a boarding party should be dispatched, if possible, to investigate and correct any deficiency on board the tow. If the material condition of the tow is so deteriorated that sinking is likely, the tug should consider the following courses of action.

6-7.3.1 **Beaching a Sinking Tow**

When towing a casualty or a vessel that is likely to sink, beaching may be the best way to save the tow. The decision to beach a tow is an operational decision and should be based on an assessment pf all pertinent conditions. Weather conditions, rate of deterioration of the tow, damage control equipment available, and distance to safe port should all be considered when deciding whether to beach a tow. Permission to beach should be obtained from the cognizant authority when feasible. Authorization to beach a tow should be made by immediate message or voice communications when feasible. Significant time may be required to steam to a suitable site. It may be impossible to locate a smooth beach in time. If pumps are on board the tow and damage control procedures are employed, the tow may be kept afloat for days before beaching, but indecision has resulted in tows sinking.

When beaching a tow, follow these guidelines:

- When possible, select a beach with a smooth, gradually sloping bottom. Avoid rocky shores with breaking surf. Potential loss of the tow and danger to the tug exist in shallow, rocky waters.
- Ground the tow with the bow toward the beach. The tug's assistance may be required to put the tow on the beach bow first. If water depth is sufficient, the tug can tie up alongside in the lee of the tow and take the tow in. The alternative practice of allowing a tow to drift onto the beach should be avoided. This can increase the likelihood of broaching and cause increased damage to the tow as well as make recovery more difficult. Assistance from a small, shallow draft harbor tug is very valuable when beaching a tow.
- Disconnect the pendant and bridle before beaching, when possible, to prevent the tow from stopping short of the beach.
- Prevent the tow from broaching and sustaining additional structural damage due to excessive hull loading. Flooding the tow can prevent it from broaching or going further aground. The ship should be set down hard enough so that it will not be too light and, consequently, broach at high tide. It should be assumed that in time the tow will be pulled off; however, this does not eliminate the need for securing it properly and preserving it until it is extracted from the beach. If the tow has a stern anchor, it should be deployed to help prevent broaching.
- Ballast the tow as soon as possible after grounding to hold it securely in position. Even in completely sheltered waters, the range of tides and consequent currents can be powerful enough to alter the position of a beached ship.

6-7.3.2 **Slipping the Tow Hawser**

CAUTION
Releasing the hawser under tension, or even its own weight, can be hazardous, due to retained energy in the hawser.

In emergencies, wartime conditions, or heavy weather, it may be necessary to slip the tow hawser to remove the tug from a hazardous condition. This condition could be a sinking tow, danger to the tug from weather, or a grounded tow.

Options for slipping the hawser include:

- Paying out the hawser and allowing it to run off the towing machine (freewheeling).
- Cutting the hawser with a torch, explosive cable cutter, or plasma cutter. Synthetic hawsers under no tension can be cut with an axe.
- Rigging carpenter stoppers and cutting the cable inboard of the stopper.

- If a ship with power is being towed, it can sometimes cast off the towing pendant on the tow's bow.

If time allows, attach a buoy to the bitter end of the towline before slipping the hawser, otherwise, it will be difficult (if not impossible) to recover. Use a messenger that is at least 200 feet longer than the water depth and strong enough to lift the hawser. One end of the messenger is connected to the hawser and the other to a recovery buoy line. The buoy line must be long enough to reach the bottom and strong enough to lift the messenger, but it need not be strong enough to lift the hawser itself. The buoy should be adequately marked with a bright color, radar reflector, staff, or flag so it can be easily located.

6-7.4 Disabled Towing Machine

The main resource for recovering and storing a towline is the tow machine. If this machine fails, the tow ship should reduce speed and attempt to make repairs. The machine's mechanical brake should be set to prevent an accidental spooling off of the tow wire. If the machine cannot be fixed, it will likely be necessary to disconnect the tow, transfer the tow and recover the towline by a more difficult method. Since Navy tugs employ a 2 1/4-inch to 3-inch wire rope, these evolutions can be very difficult.

6-7.4.1 **Disconnecting the Tow**

If the tow machine fails while the tow is still connected, it will be necessary to break this connection at some point along the towline. If a retrieving wire has been rigged, this may not be so difficult. If there is power on the tow, it should haul on the retrieving wire until the connection point is on deck. A chain stopper (or other appropriate stopper) should be passed on the towline with sufficient slack to break the connection without tension on the line. It may be necessary to rig a stopper around the tow ship's towline to allow a connection to be broken. It may be sufficient to haul in slightly on the main chain pendant, and break the connection at the main towing padeye. Only stoppers with quick release capability should be used.

WARNING
When stopping the tow line for breaking, only stoppers with quick release capability should be used.

The exact disconnect method and stopper to be used is an operational decision and depends on many factors. If the tow is at its point of destination, and the main tow rig can be destroyed, explosive cutters or torches may be an appropriate method of disconnecting. The use of divers may be possible but, because of the inherent danger, shall only be used when there is no other solution. Ship-handling and working with heavy gear in a seaway are complicated evolutions that are made more so when there are people in the water.

If a retrieving pendant has not been rigged, the procedure is far more complicated and divers may be the only solution. Sliding a working line down a chain pendant has been done with varied success. The loop may snag on the way down or slide off during retrieval. It may be better to attempt to run a shackle along the tow wire, but this may also meet with varying success. Certainly, divers can make these evolutions more successful by providing assistance to keep the line unfouled. A better solution may be to use divers to rig a retrieval line. Depending on the length of the pendant divers may be able to attach a line to the bitter end of the chain; at the connection point. This is unlikely, though, since there will probably be a pendant longer than 90 feet. If divers are working in SCUBA, bottom times will limit the amount of work that can be done. However, divers may be able to rig a retrieving line of sufficient length to haul the main pendant on deck. By lacing small wire through links of chain 40 or 50 feet below the surface, the chain can be brought on the deck of tow ship (or an assisting vessel), once it has maneuvered alongside. The tow ship's deck machinery can be used to haul the heavy gear on board once dive operations are completed.

Dive Supervisors must be provided with an accurate and detailed sketch of the entire tow rig. This will enable them to develop a safe and efficient plan and ensure they are prepared with the proper tools to accomplish the mission.

6-7.4.2 **Recovering the Towline**

Once a tow has been disconnected, it is still necessary to recover the towline without the assistance of the main towing engine. The tow ship is faced with two problems. The first, how to recover the wire and second, is where to put it once its on deck. The weight of a 2 1/4-inch to 3-inch IWRC wire is almost 10 pounds per foot. A typical towline scope is 1500 feet or more. This is a total weight of almost 15,000 pounds. It cannot be handled easily without machinery.

Recovering a towline can be accomplished in several ways. One way is to slip the hawser off the drum and recover it when repairs have been made. A marker buoy and suitable messenger should be rigged to the bitter end so it can be found later. A messenger should be strong enough to be able to lift the hawser on deck for the depth of water. It need not be strong enough to lift the entire hawser, but if it breaks, divers will be required to rig another messenger, and it is very likely that the hawser will not be found without the marker buoy. Moderately deep water will make this alternative impractical. Additionally, it is probably unwise for the tow ship to try to bring the hawser to shallow water. Assuming the hawser is at a scope of 1500 feet or more, the hawser will drag the bottom for some time before sufficiently shallow water is reached. This may damage the hawser or cause maneuvering problems for the tow ship.

Another way to recover towline is to use deck machinery and carpenter stoppers. This method requires a great deal of time and a large amount of manpower. Assistance from shore crews may be required. This method does not solve the problem of stowage. A large deck area will be needed to fake out (figure-eight) this size of wire. It may be possible to hang the wire from the side of the tow ship and stop it off in bights, similar to the method used when preparing a main tow pendant on a tow, or a leg of beach gear. This process will also be laborious and time consuming.

A third method which may be used is to turn the towing drum manually. A wire can be secured to a point on the side of the towing drum and looped around the drum in the direction of reeling. A crane can pick up the bitter end and be used to lift this line and consequently turn the drum. Careful coordination between the crane operator and a crewman manning the drum brake is required to prevent accidental un-spooling of the wire. If a crane is unavailable, deck machinery can be used if sufficient blocks can be rigged to reeve the hauling wire in the right direction.

These are by no means the only methods of retrieving a tow wire, but are a few examples. Any of these methods require substantial manpower and large amounts of time. This process, like all towing procedures, should be performed with close attention to safety of personnel.

6-7.5 Anchoring with a Tow

In general, anchoring should always be considered less desirable than remaining underway. Steaming with a tow may prevent many difficulties encountered at anchor. Provided there are no limiting operational factors and there is sufficient sea room, steaming is usually the better choice. When anchoring with a tow is necessary, the following alternatives should be considered.

- Reduce speed to bare steerageway, head into the predominant set, allow the tow to remain well astern, and then reduce speed and allow the tug and tow to come dead in the water at the anchor drop point. Let the tug's anchor go and pay out the necessary scope of chain. The tow will follow as affected by set.
- Reduce speed and approach several hundred yards to port or starboard of the desired anchorage. With the anchorage position broad on the bow and approaching abeam, put the tug's rudder hard over and reduce speed; maneuver to hold at the anchoring point, letting the tow pass by. When the tow clears the tug, drop anchor.
- The tow can be taken alongside in favorable sea and wind conditions. With the tow alongside, the tug can maneuver in restricted waters, back down as necessary, and drop anchor.

CAUTION
The mooring loads of the tug and tow may be greater than the holding power or strength of the tug's ground tackle. A dragging anchor or failure of the ground tackle is possible, resulting in loss of control of the tug and tow.

In some circumstances, such as shallow water, the towline itself may be used for light holding of the tow and tug when the towline comes in contact with the bottom. Routine use of this practice is discouraged because of possible damage to the towline.

If there is little wind or current, the tug must be alert to the probability of the hawser's weight pulling the tow toward the tug, until the hawser rests on the bottom.

6-7.6 Quick Disconnect System

Most routine point-to-point tows are securely rigged with no provision for quick release, other than slipping the tow wire from the towing ship. When towing damaged ships, however, it may be desirable to provide for a quick release of the tow pendant or bridle to facilitate breakup of the tow.

Even if the tow hawser has already been disconnected, the weight of the chafing pendant or bridle legs will be significant, and must be considered in selecting the means of disconnecting.

WARNING
The tow wire or bridle will likely be under tension when released, creating an extremely hazardous situation. All nonessential personnel must evacuate the area to prevent serious injury.

CAUTION
The towing ship should reduce the tension on the towing assembly by either slowing down or stopping prior to cutting or otherwise releasing the tow rig.

In the case of a damaged ship, the tow pendant or bridle legs, if chain, should be securely held by multiple chain stoppers, each bearing equal tension. If the pendant or bridle legs are wire, then provision should be made for cutting with an oxyacetylene torch, a cable cutter, or any similar device. As cutting is extremely hazardous, precautions should be taken to prevent whipping, and the wire should be seized on both sides of the intended cut. When an emergency quick disconnect is provided, make sure that all jewelry will fit through all fairleads.

6-7.7 Man Overboard

Standard man overboard maneuvers may not be feasible in towing situations, primarily because of the time involved and the tug's limited maneuverability.

- If maneuvering is limited, the tug should stop, or at least reduce speed to bare steerageway, and recover the man overboard using a small boat. If the tug is stopped, take precautions to keep the tow from overriding the tug and to keep the towline clear of the propellers. Communications should be available between the boat and the tug so that the tug can direct the boat to the man.
- If the recovery requires maneuvering the ship back to the man, seamen should be stationed with heaving lines. Swimmers should be outfitted with immersion or wet suits and safety lines ready to swim out to the man.

6-7.8 Using an Orville Hook to Recover a Lost Tow

Using an Orville Hook to recover a lost tow with a chain bridle may be a viable option if a secondary towline is not available or it is not possible to recover the secondary towline.

6-7.8.1 Origin of the Orville Hook

The Orville Hook was initially designed and patented by SAUSE BROS TOWING, Inc. to recover lost tows which had a chain bridle. While the patent for this device has expired it still remains a useful tool for emergency recovery of broken or lost tows. This device was successfully used to recover the dry dock SUSTAIN when recovery of the secondary towline was not possible due to fouling.

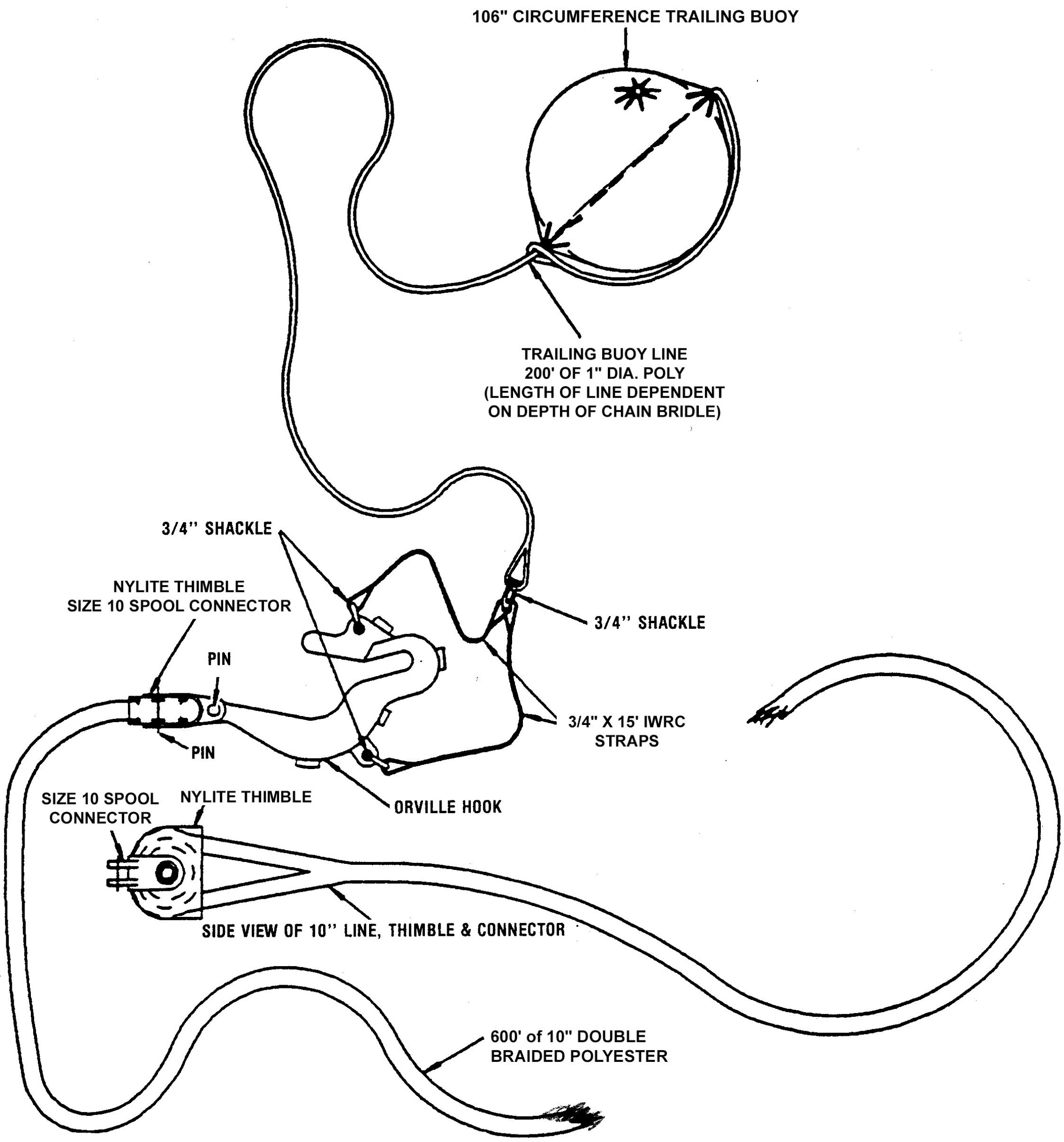
6-7.8.2 Use of an Orville Hook

Orville hooks are only recommended for recovering tows which have a chain bridle. They are not recommended for recovery of wire or synthetic tow pendants.

Figure 6-9 and Figure 6-10 depict the general configuration of the Orville Hook and its various components. Figure 6-11. depicts deployment of the Orville Hook.

The Orville Hook is suspended in the horizontal plane by a trailing buoy and is towed parallel to the tow by the recovery tug. Once the recovery tug has overtaken the tow by a sufficient distance dictated by the length of the towline, the recovery tug swings across the bow of the tow thereby snagging the mouth of the Orville hook on the chain bridle. The Orville hook is sized to fit between the individual links of the chain. In most cases the Orville hook will remain in place as long as tension is kept on the synthetic pendant. The synthetic pendant can then be retrieved along with the chain bridle so a more permanent connection can be made between the tow wire and the chain bridle.

ORVILLE HOOK RETRIEVAL ASSEMBLY



ORVILLE HOOK (1)

NO. 10 SPOOL CONNECTING LINK (2)

PIN FOR CONNECTING LINK TO HOOK (1)

PIN FOR CONNECTING LINK TO SPOOL (1)

NYLITE SPOOL AND SHIELD ASSEMBLY (2)

42" CROWN BUOY

Figure 6-9. Orville Hook Retrieval Assembly

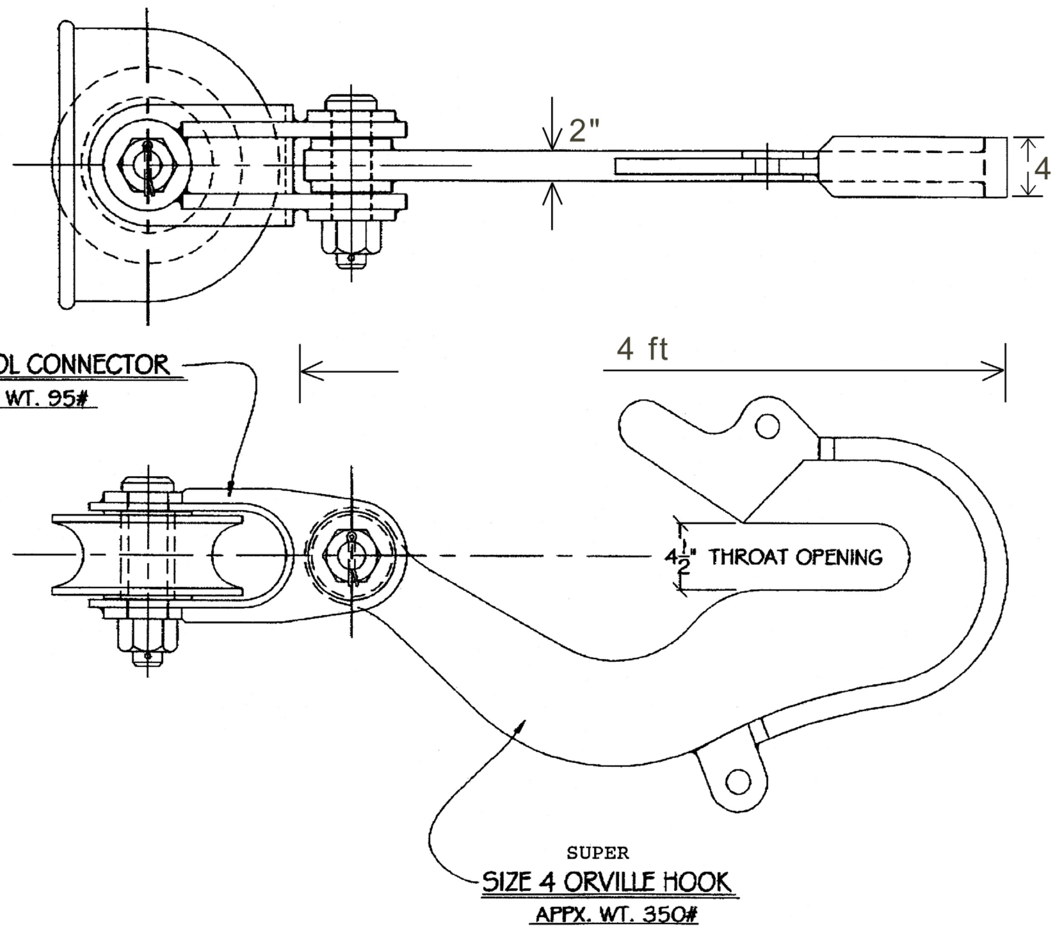


Figure 6-10. Orville Hook Configuration

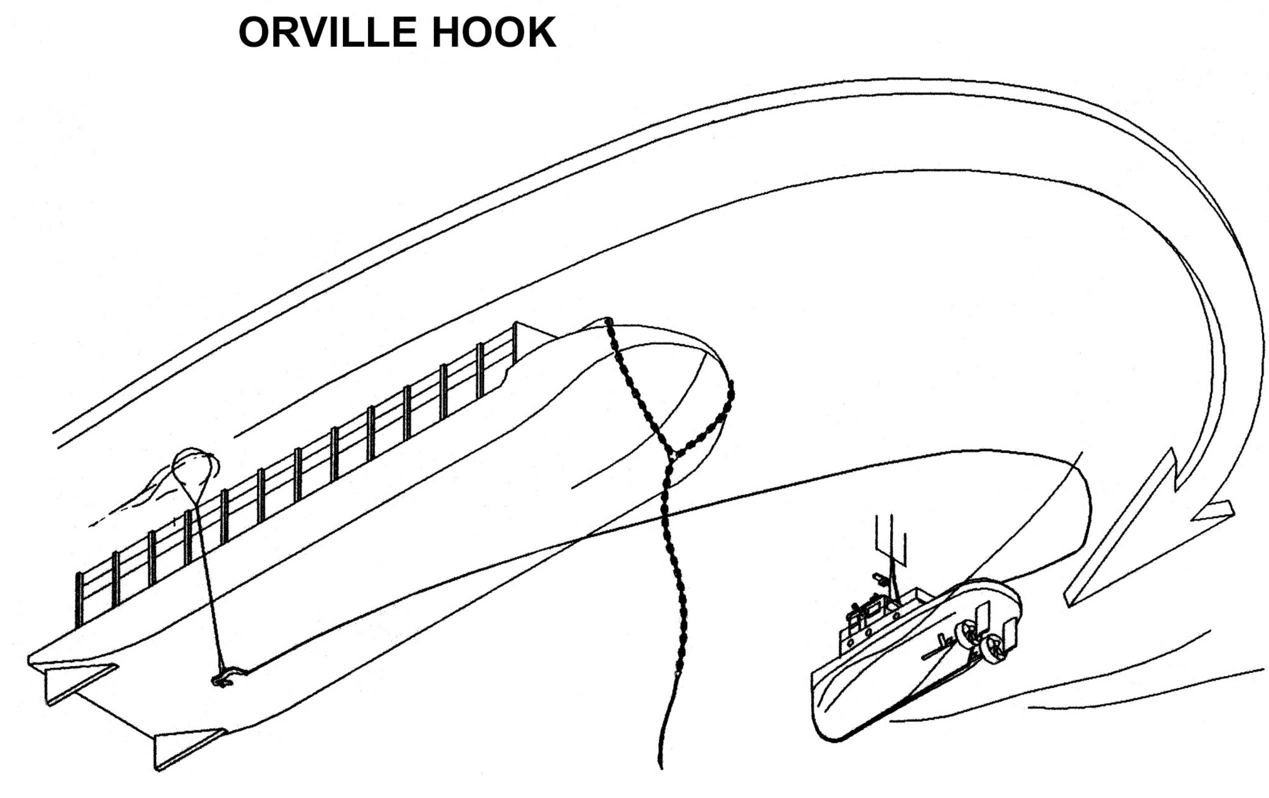


Figure 6-11. Deployment of the Orville Hook

CAUTION
Under more strenuous sea conditions, dynamic hawser tensions can be significantly higher when towing downwind than when heading into wind and seas at the same speed and power. Turning into the wind and seas and slowing to maintain steerageway are appropriate actions under such conditions.

Chapter 7 - SPECIAL TOWS

7-1 Introduction

This chapter addresses tows of unusual configuration that occur infrequently or are of a highly specialized nature. Topics include towing in ice and towing targets, submarines, merchant ships, and NATO ships in peril. Emphasis has been placed on rigging and procedural differences between these types of tows and towing operations previously discussed.

As their recurrence is unpredictable, these types of tows are not treated in depth in this manual. Instead, these topics are presented to make planners and operators aware that such operations have been successfully completed in the past. When faced with similar situations, they should refer to reports of actual operations.

7-2 Target Towing

The primary functions of ships such as the T-ATF, and ARS classes are salvage and ocean towing; target towing is a secondary function routinely assigned to them. Most combatant ships can tow target sleds with their standard shipboard equipment.

7-2.1 Williams Target Sled

Currently the catamaran-hulled Williams Target Sled is the target used most for gunnery exercises (see Figure 7-1). The Navy also uses sonar buoys, arrays, drones, and remotely operated boats as targets. Targets are towed, escorted, or carried as deck cargo to the operations area.

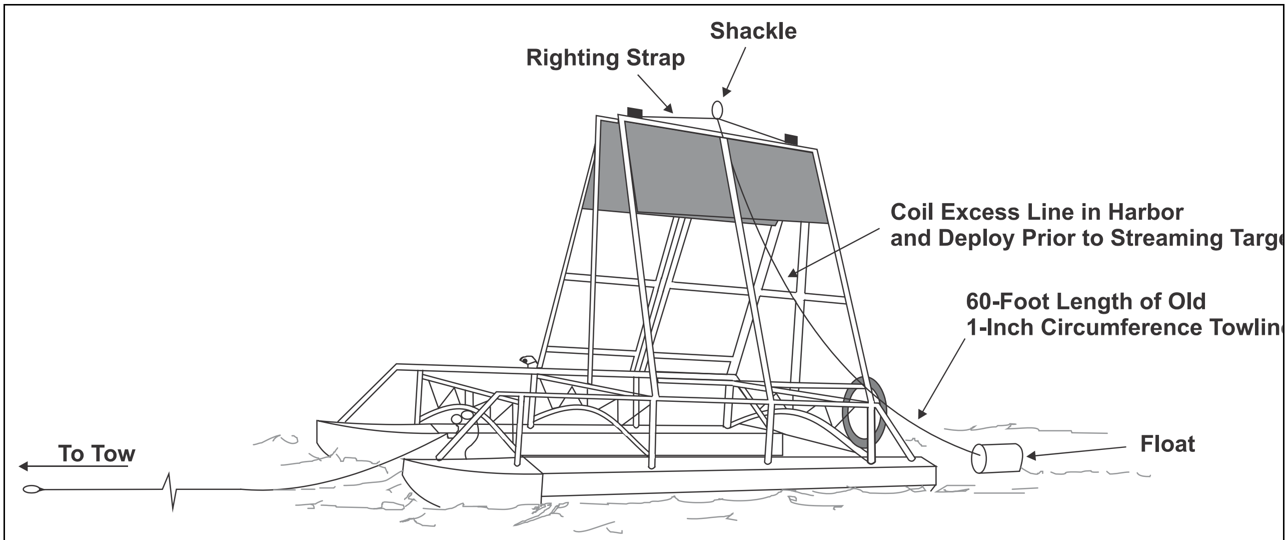


Figure 7-1. Williams Target Sled Rigged for Tow with Righting Line Streamed.

7-2.2 Towing Equipment

The Williams Target Sled is towed from a synthetic line bridle shackled to the inboard sides of the catamaran hulls. The two bridle legs are joined by a triangular flounder plate; a 30-foot pendant of synthetic line is also shackled to the flounder plate. The pendant is shackled to the main synthetic towline.

The towline is a 3-inch circumference, double braided synthetic line, 4500 feet long. On occasion, when a longer line is required, two lines are bent together. It is important that a non-rotating line be used in this application. If a three-strand line were to be used, the torque generated might cause the target to list or a damaged sled to capsize.

7-2.3 Routine Procedures

7-2.3.1 Transporting the Target to the Exercise

CAUTION
If the target is made up bow-to-stern, it should reverse direction and swing into position when slipped. Too much way on, however, will cause the target to be towed stern first. In a stern-first position, the target has a tendency to stream aft without reversing itself and can end up straddling the towline.

The tug can either pick up the target at its berth or have the target brought out of the harbor by a delivery ship, usually a work boat. If a delivery ship is used to bring the target out of the harbor to the towing ship, slow down and maintain steerageway so that the delivery ship can easily approach the stern.

For tows that begin at the target's berth, the target can be made up to the towing ship bow-to-stern alongside (with the towline shackled to the target's bridle pendant), bow-to-bow alongside, or bow-to-stern aft of the towing ship. The target can also be made up on the fantail of the towing ship. (It may be similarly made up on the fantail during protracted delays between exercises or in the event of impending heavy weather.) If the target is made up on the fantail, use the ship's crane or boom to set the target overboard upon arrival at the operations area.

If the tow is made up in the water, slip the target mooring lines when clear of the pier. Tow target at short stay until clearing congested waters. Steaming at short stay does not affect maneuverability or speed. When clear of the harbor and congested waters, about 600 feet of towline is usually streamed. If the towline is not on the drum of a winch, it may be paid out using a gypsy head or capstan to maintain control. Ships with towing bitts can control the payout of towline by taking turns around the bitts. When enough line has been paid out, the towline is stopped off to the towing bitts with the towline passing over the stern roller. Speed is then built up slowly until the target is towing steadily. If towing at night, make sure that the target's stern and side lights are lit.

7-2.3.2 **Streaming the Target**

The towing ship times its arrival at the firing range long enough before the exercise begins to allow time to stream the target. Slowing to about 4 knots and paying line out at 150 feet per minute is a safe way to stream.

7-2.3.3 **Making Turns with the Target**

Depending on the weather, turns can be made in one increment by using a small amount of rudder so as to have about a 1,000-yard diameter turning circle. When making turns, keep the target aft of the towing ship's beam, preferably broad on the quarter.

When proceeding on a circular course, the target's tendency to capsize is determined by the speed of the tow, length and depth of towline, and the sea state and heading relative to the wind. Turns to windward are different from turns to leeward. When turning into the wind, the target screen area acts as a mainsail and holds the target away from the turn, requiring an increased rudder angle and giving a smaller transfer with a slightly greater advance. When turning leeward, the screen acts as a sail effect and propels the target toward the inner part of the turn, requiring less rudder and performing a greater transfer with less advance.

In all turns the target acts as a sea anchor, making a small tactical diameter while the ship turns around the target with a larger tactical diameter. Turns with the current increase transfer; turns against the current reduce transfer. The advance in all turns is small.

To keep the towline tension low and to avoid capsizing the tow, keep the rudder angle as low as is practical. A mean rudder angle of 12 or 13 degrees is satisfactory. A good practice is to make the turn in small increments, steadying up until the target is directly astern before going to each new increment.

7-2.3.4 **Recovering the Target**

When the exercise is over, the towline is heaved in to a shorter stay for the tow home or brought up short so the target can be lifted aboard. Combatant ships use their capstans to heave the towline, MSOs use one drum of the sweep-wire winch, and salvage ships use their capstans or traction winches. Significant time must be allowed to bring the hawser in at even maximum capstan speed. Hawser recovery typically proceeds at 40 to 60 feet per minute. As soon as the towline is on board, it should be faked on deck or spooled on a reel.

Upon entering port, the tow can be brought alongside, brought to short stay, or lifted aboard. The use of riding lines that have been stopped off on the tow hawser during streaming contributes to the ease of bringing the sled alongside (see 6-2.3). For leaving and entering port, some ships prefer two-blocking the bow of the sled against their stern. When the sled is firmly snugged into position and riding lines are added, this method allows good maneuvering.

7-2.4 Special Procedures

7-2.4.1 Passing the Target to a Combatant Ship

WARNING
When tows are passed, most casualties occur because the ships do not maintain a steady course or speed or because the towing ship releases the tow before the other ship is ready to accept the strain.

It is sometimes necessary to pass a target from one ship to another on the open sea. The towing ship selects the side and speed for passing and signals this information to the receiving ship well in advance of passing the tow. Stop off the hawser along one side of the towing ship. The receiving ship steams into the wind alongside the towing ship.

The receiving ship signals and sends a messenger when it is ready to receive the tow. The towing ship receives the messenger and secures it to the hawser. The receiving ship hauls the messenger through its towing chock. The towing ship frees the hawser and the receiving ship hauls it away (see Figure 6-7).

WARNING
Always remain with a target sled until it is recovered or righted and towed to port; it will become a navigational hazard if left to drift.

7-2.4.2 Recovering a Capsized Target

A capsized target must be righted immediately because it cannot be towed at any speed. Safety precautions must be strictly observed because of the hazards of recovery work.

If the target capsizes, the towing ship should heave in slowly. The ship may be required to back slowly while heaving in, being careful not to foul the towline in the propellers or rudder. Another method is to reverse course and place the ship alongside the target. Weather conditions will determine the best method to use for approaching the target.

Before getting underway, the target should have been prepared for righting. A recovery pendant can be made from 60 feet of line and a float. Attach one end of the line to the middle of the pipe framework at the apex of the target. Coil the remainder of the line and secure it with small stuff to one of the pipe frames near the trailing edge of one of the catamaran floats (see Figure 7-1). Tie the bitter end of the line with a bowline onto the float. Before streaming the target, release the line and float to stream aft of the tow. If the sled capsizes, maneuver the ship alongside the sled and bring the float and recovery line aboard the ship. By leading the recovery line over the caprail to a capstan and heaving in, the sled can be made to rotate to an upright position in a motion that carries the target away from the hull of the ship. Once upright, inspect the target to make sure that it is not damaged and is fit for tow.

7-2.5 Target Towing Precautions

Take the following precautions when towing a target:

- Avoid surges
- Maintain a steady course, avoiding tight turns
- Ensure that the target's stern and side lights are lit at night
- Do not tow the Williams Target Sled at speeds in excess of those authorized by Fleet directives
- Do not tow a capsized Williams Target Sled
- Alter course gradually with a target under tow in order not to capsize the sled
- Approach the target with caution. The shallow draft of the target sled causes considerable pitching and rolling at slow speeds or when drifting.

7-2.6 Other Targets

SEPTARs (Seaborne-Propelled Targets) are remote controlled, high speed surface targets that are transported to the operating area by a tug and then operated from the tug. Similarly, tugs can carry drone-type targets for antiaircraft and antimissile training exercises. They can also carry transducers and arrays for submarine and antisubmarine training exercises. Each of these services is unique and presents special problems not found with standard target sled towing. Some of the information necessary to support specialized target services is classified. Generally, range personnel will provide specific information regarding these special systems.

7-3 Towing Through the Panama Canal

Tows of unmanned vessels through the Panama Canal present some unique concerns and often require additional preparations. A canal tow may be the result of an East Coast decommissioning of a nuclear vessel that needs to go to the West Coast for final disposal. It may be the result of an asset being transferred from a West Coast activity to an East Coast activity. Either way, as more and more vessels are decommissioned, and assets become fewer in number, tows through the canal have become more frequent.

The Panama Canal is unique and has restrictions on size and requirements for special bitts and chocks to accommodate tow wires. While many vessels that are designed for service through the canal have the necessary installed fittings, other ships, particularly warships, may not meet all the specific requirements.

It is essential for a tow planner to fully understand the requirements when towing through the Panama Canal. Code of Federal Regulations (CFR) 35, Panama Canal (Appendix M -, Ref. N) contains this information and is an invaluable resource when planning a canal tow. It has also proven to be well worth the investment to fly a representative from the Panama Canal Commission to the preparing yard. A walk through of the vessel by knowledgeable personnel can identify any changes that need to be made while the ship is still in the preparing yard. If the tow arrives at the breakwater in Panama, and does not meet the requirements to go through, arrangements must be made to effect repairs and modifications. This can result in both substantial costs and delays. Advance preparation is essential.

7-4 Towing in Ice

Arctic operations may require towing through ice. Towing ships may also be required to recover ships with no steering or propulsion capabilities that have been stranded in ice conditions.

An icebreaker may be required for breaking through heavy ice, but Navy ocean tugs can tow through thin ice or broken ice. The Navy T-ATS, T-ARS and T-ATF Classes were built to modified ice strengthening rules, but those with Kort nozzles are less suitable for heavy ice operations.

The major considerations when towing in ice are:

- Protecting the hawser from ice damage. Long periods of exposure to ice will chafe and wear the hawser. To prevent the hawser from coming into contact with the ice, adjust the catenary so the chain bridle, or chain pendant enters the water at the towed vessel. It may also be desirable to rig additional chain to help make this easier. This is addressed in Allied Tactical Publication (ATP) 15, Arctic Towing Operations (Appendix M -).
- Selecting the appropriate towing method. When towing in ice, a tow should be close to the tug's stern to keep an ice passage open ahead of the tow. The tow may not have an ice-strengthened bow and could sustain impact damage from floating ice. Two approved towing methods for keeping the tow close are the short-scope method and the saddle method. The method used depends upon type of towing ship and the design of the ship being towed. The saddle method will ensure that the tow will not encounter ice, but, if not rigged properly, could cause damage to both the tug and the tow.

7-4.1 Short-Scope Method

Navy ocean tugs should use the short-scope method because they have no saddles. A hawser scope of 150 to 300 feet should be maintained. The tow's rudder can be used, if necessary, to keep the tow in the tug's wake. Occasional kicks from the tow's propeller may also be necessary to augment the rudder's force. The tug's propeller wash should keep the tow from riding up on the stern; if it does not, the propeller of the tow should be backed, if possible. Riding lines may be used for increased lateral stability (See Section 6-2.3). These lines will be very susceptible to chafing.

CAUTION
The tug should follow these recommendations and guidelines when towing at short scope: • The pull on the towline will be severe if the towed ship suddenly contacts heavy ice. • Take special precautions to prevent the chain bridle, chain pendants, and hawser from chafing. An automatic towing machine makes this easier. • Avoid towing on the bitts they may be torn out by the sudden increases in tension if ice is encountered when towing at short scope.

7-4.2 Saddle Method

The saddle method can be used by icebreakers and tugs with reinforced sterns and towing machines. The U.S. Coast Guard has operated some icebreakers equipped with towing machines or strengthened saddles. Even when a towing ship has a saddle, the saddle method may not be practical for tows with sharp prows, bulbous bows, or any other protuberances that can interfere with the tug's propellers and rudders. Normally, the tow can be brought up and held firmly in the saddle by the towing machine.

If the tug does not have a saddle and the short scope method of towing in ice is not feasible, a variation of the saddle method formerly used by icebreakers may be possible for tow ships having strong, broad sterns. The tow is brought up snug against the tug's stern, using extensive chafing gear, and heavy fenders. The towline is attached in the normal fashion; the towing machine should be in automatic mode to prevent the towline from parting if the ships pitch or surge. Two mooring lines can also be passed from the tug's quarter-bitts to the tow's forecastle bitts to help keep the tow following fair. The tow's engines can be used. If the tow begins to jackknife or sheer or yaw badly, however, it should slow at once until it is again under control. A fire hose should be kept ready at the saddle or stern because friction may cause fires in the chafing material.

7-4.3 Rigging for Tow

The recommended gear for towing in ice consists of:

- Wire rope towing hawser
- A 2 1/4-inch chain pendant and connection jewelry, or
- A 2 1/4-inch chain bridle with flounder plate and connection jewelry.

This heavy gear will provide protection against the increased potential for chafing and impact damage. Synthetic lines are not recommended as main towing gear.

In a convoy with no icebreaker, any ship may be expected to tow and should be prepared to both tow and be towed. Rigging the tow bridle in advance quickly lowers the chance of being caught in the ice. Gear should be prepared in advance; the crew should know how to complete the rigging quickly and safely.

Before entering the ice, the bridle or anchor chains should be rigged to receive a towline. Even when using a bridle, it is necessary to secure bow anchors to keep them from striking hummocks in the ice. This is especially important on low bowed ships.

7-5 Submarine Towing

This section provides an overview of emergency (unplanned) towing of submarines. Appendix J provides specific data that will be useful in rigging submarines for emergency tow. For planned tows and for tows of deactivated submarines, consult NAVSEAINST 4740.9E Towing of Unmanned Defueled Nuclear Submarines (Appendix M -, Ref. P). This instruction, which takes precedence over this manual, may be useful also in planning and executing an emergency submarine tow.

Submarines are challenging tows. Even though they may be equipped for towing, the towing arrangements are not as strong as on typical surface ships, their configurations present serious topside personnel hazards, and they can be very poor at tracking behind the tow ship.

7-5.1 Towing Arrangements

7-5.1.1 Retractable Deck Fittings

Modern submarines are built with essentially no flat surfaces on the main deck. All submarine deck fittings are either retractable or recessed. They are normally constructed so that they can be retracted to form a flush deck, and rotated into position where they can be used. In most cases, deck fittings can be expected to be safe for working up to the breaking strength of the line with which they are normally used.

Most submarines have small hydraulic capstans, fore and aft, that can be useful in handling lines. They typically have a limited capacity of 3,000 pounds line pull at a maximum 40 fpm and a maximum pull of 4,500 pounds at creep speed. These capstans are severely limited in assisting with the connection of a towing hawser. The tug, accordingly, should plan its connecting procedure to minimize reliance on the submarine's capstans.

The controls for the retractable capstan are usually designed so that the capstan can be operated from topside. The machinery, however, is activated from inside the submarine and is dependent on the submarine's having hydraulic power.

7-5.1.2 Tow Attachment Points

CAUTION
The submarine's designed towing rig was intended for intra-harbor towing and is not generally acceptable for open-ocean towing.

The design of submarines is such that considerable ingenuity may be required to find suitable towing attachment points. See Appendix A - of this manual for details on towing arrangements for specific submarines.

CAUTION
Few deck fittings on submarines are designed for loads that are commonly considered in the design of surface ships. Care must be exercised to ensure that the safe load capacity of fittings, such as the bullnose fairlead, cleats, and padeyes is not exceeded. Particular attention must be paid to the loads that may develop when the submarine yaws.

On several classes of submarines, a tow pad is installed on the forward portion of the sail, where it is faired into the main deck. This is a hard point with an SWL of about 47,000 pounds, depending on submarine class. On some other classes, the tow pad is installed forward of the forward escape trunk and is also rated at 47,000 pounds. The latest submarines are intended to be towed using a bridle-flounder plate arrangement secured to a pair of 70,000-pound (SWL) mooring cleats.

On some submarines, the intended tow point may have been removed. In such cases, an emergency tow may well involve use of some of the installed cleats or other deck fittings such as capstans.

As a last resort, towing by the stern planes, the propeller, or the sail may be the only alternatives. In such an event, all parties must be aware of the damage that will likely result.

7-5.2 Personnel Safety Issues

The main deck of a submarine is frequently inaccessible and dangerous to board in a seaway. There is very little freeboard, and if there is any sea running, the decks will most likely be awash. Great care is required when moving about on the deck; a tether or safety line should be used. A safety track is provided for attachment of personnel-restraining safety lines. The necessary fittings and harnesses are carried on the submarine for use with this track.

7-5.2.1 **Protection for Work on the Deck**

When connecting to a submarine in the open sea, all personnel working on the deck should wear full wet suits, survival suits, or other such dress that will provide both thermal and physical protection if they are washed overboard. No one should be permitted to work without proper life preservers or other appropriate safety equipment.

7-5.2.2 **Boarding the Submarine**

An inflatable boat may be the only successful means for boarding a submarine. It is helpful if the submarine is able to rig a Jacob's ladder alongside for boarding purposes.

7-5.2.3 **Personnel Experience**

Submarine deck hazards are frequently compounded by limited personnel experience. Because submarines normally conduct independent operations, their personnel have few opportunities to become familiar with many of the deck seamanship procedures that are common to personnel on surface ships. At the same time, personnel on the tug may have little or no experience with submarines and may lack familiarity with the particular fittings, equipment, and limitations of the submarine. Good communications between the submarine and tug crews are especially important.

Guidance from the submarine crew is particularly valuable in the area of safety. They are far more experienced in the problems of working topside on the submarine than non-submarine personnel. The submarine can also provide additional assistance if required. The submarine, however, should follow the guidance provided by the tug. The tug is responsible after the tow connection is made.

7-5.2.4 **Submarine Atmosphere Problems Resulting from Fire**

If the submarine has had a fire or has discharged its extinguishing system, the atmosphere inside may not be of breathing quality. If entering the submarine is necessary, proper breathing equipment should be used. The atmosphere in the submarine is difficult to clear unless it is possible to run some of the equipment on the submarine. Running the low-pressure blower or the emergency diesel engine will quickly provide a change of atmosphere.

7-5.3 Tendency to Yaw and Sheer

Some model tests of the towing characteristics of the various classes of submarines have been conducted. These tests confirm the observed tendency for submarines to yaw and sheer far off the towing track. This can be improved if the submarine is trimmed by the stern. This can be done by sealing ballast tanks and deballasting the sonar dome. These actions will also provide more freeboard forward for rigging the tow wire, thus facilitating the tow operation. In deep water, deploying the stern anchor of the submarine may also help (assuming that hydraulic power is available). If rudders and planes are not being used to control the submarine, they should be secured.

7-5.4 Rigging for the Tow

Innovation is often required when rigging a submarine for towing. Creative thinking is needed both when making up a connection and when selecting the hardware to use. In an emergency, it is better to rig something as strong as possible the first time, accepting some possible damage, than to risk loss of the tow at a more inopportune time in the future.

See Appendix A - for information on rigging specific submarines.

7-5.4.1 **Hardware**

There is no assurance that towing hardware will be carried by the submarine. Occasionally the submarine will carry special shackles or other hull fittings to connect the towline to the tow point. In most cases, however, a Navy tug should have sufficient gear to make up a towing connection superior to that included in the submarine design.

The ship conducting a tow must determine what special jewelry is available or required, from either the submarine crew or the appropriate Squadron or Type Commander. If required jewelry is stored ashore, it may be possible for the tug to pick it up before getting underway or to have it delivered to the scene of the casualty. Modifications to submarine's designed towing jewelry may be necessary as circumstances warrant. When jewelry is not available, it may be necessary to manufacture it. The necessity of providing for both adequate strength and chafing capability for whatever jewelry is employed must be kept in mind.

It is advisable to use a length of chain as a chafing pendant where the tow connection passes through the fairlead chock. It may be necessary to include a wire between the connection point and a short length of chain to reduce the length (and weight) of chain used. The chain needs to be just long enough to take the chafing at the fairlead. Assistance may be available from the submarine's hydraulic deck capstan, if it can be rigged and operated. Keep in mind the limited capacity and speed of the capstan. For submarines using a bridle attached to a set of mooring cleats (chiefly SSN 688 and SSBN Classes), no fairlead is used and a wire chafing pendant is sufficient.

7-5.4.2 **Underwater Projections**

CAUTION
Every retractable item forward of the tow fairlead (or flounder plate, if used) must be retracted by the submarine crew to preclude damage to the submarine and the tow hawser.

The submarine crew can provide information on the location of all underwater projections. These projections must be rigged in to avoid problems. Submarine personnel may not appreciate the deep angle of the tow hawser resulting from an adequate catenary. In addition, most submarines can take wide swings from the direction of the tow, meaning that any projections forward of its tow fairlead, including items on the keel, can damage or be damaged by a tow hawser or pendant. If there is any doubt, a diving survey should be made to assure the hull exterior is clear.

All tugs must also be aware that U.S. submarines have keel anchors, often located aft. If such a submarine is anchored, it will head downstream. See Appendix J for identification of anchor location by submarine class.

7-5.4.3 **Towing by the Stern**

NOTE
Use of the submarine's anchor chain for towing may be feasible if its windlass is operable.

A submarine that has been damaged by a grounding or collision may require a stern tow. For submarines whose anchor is located aft, the anchor chain is the first choice for a stern tow. Careful coordination is critical. By using divers, the tow ship may be able to connect to the submarine's anchor chain, with or without the anchor removed. It also may be possible to dip a wire around the anchor chain. If the stern planes or the propeller must be used for a tow point, take great care to ensure that the attachment chain, strap, and so forth, are wrapped close to the hull. When using stern planes or rudder, the strong operating shaft extends only a short distance into the control surface. It is important that the attachment point be held against the hull and not at the outboard side of the rudder or plane.

7-5.4.4 **Use of the Sail as a Tow Connection**

For connection to a sail, consider chain, wire, or a wide heavy strap that is fabricated from plate or from a wide synthetic lifting strap. Chafing gear may be required to distribute the load because the sails after edge may be brought to a relatively sharp edge. Suitable chafing gear can be fabricated from a short section of split pipe and plate. Rigging such a device, however, is not a simple task at sea.

7-5.4.5 **Welding to the Hull**

CAUTION
Contact NAVSEA to obtain technical advice before any welding is done to a submarine's pressure hull.

If welding is required, make sure that towing pads are fastened to the pressure hull (as opposed to the non-pressure hull) and that the welding is done in accordance with the specifications for the material of the hull.

7-5.4.6 **Passing a Messenger**

In establishing the initial connection, it is easier for the submarine to pass an initial line to the tug than vice versa. Limited deck space on the submarine makes it difficult to catch a heaving line or the line from a line throwing gun. It may be easier to rig a double messenger around the tow connection and use the tug's power to heave around on the hawser. A sufficiently long messenger should be prepared in this case.

7-5.5 Towing Operations

CAUTION
Due to their severe sheering tendencies, submarines should employ active steering (if available) as directed by the towing vessel.

Once a suitable tow connection is achieved, come up to speed very carefully. A constant watch should be kept on the position and attitude of the submarine. At night, it may be necessary to require the submarine to continually report its relative position until a stable condition is achieved. If they cannot be steered, many submarines will tend to sheer off and hold a position as much as 70 degrees relative to the tow ship's stern. Sometimes the submarine will hold this extreme position for hours, only to veer suddenly to the other side without warning. The tug's Conning Officer must be advised immediately. In such a case, the Conning Officer may have to reduce power to prevent the tug from surging ahead and compounding transient stresses developed when a submarine fetches up on the other side. This sheering characteristic, coupled with a lack of strong fittings, is a major reason for insisting upon relatively modest tensions in towing submarines.

7-5.5.1 Towing on the Automatic Towing Machine

Every effort should be made to tow with an automatic towing machine. Controls should be adjusted for a maximum tension setting not to exceed the safe working loads of the components used for the tow rigging and fittings on board the submarine. Deploying a synthetic spring will also help to reduce peak tensions. More information about the use of springs is contained in Section 4-6.5 and NAVSEAINST 4740.9E (Appendix M -, Ref. P).

7-5.5.2 Towline Tension and Towing Speeds

Attainable towing speeds will be dependent upon weather, class of submarine, type of connection, equipment used, and the ability of the submarine to use its rudder. In general, towline tension should be limited to 25,000 pounds for all submarine classes built prior to the SSN 688/SSN21/SSBN 726 Class submarines. This will provide about five knots towing speed under favorable sea conditions. The 688/21/726 Class submarines should be limited to a maximum of 35,000 pounds tension, resulting in about four knots speed under favorable conditions. Normally, increasing tension/speed should not be attempted without first observing the tow's behavior and consulting with appropriate operational and technical authority.

As with all towing operations, it may be necessary to slow down and simply maintain steerage when the weather is severe.

7-5.5.3 **Drogue**

If the submarine rudder is out of commission, a drogue rigged behind the submarine may assist it to stay on course. In deep water, the stern anchor may be deployed. In narrow waterways or where interference from other traffic is anticipated, docking (harbor) tugs should be used alongside to properly control the submarine's movements.

7-6 Towing Distressed Merchant Ships

Occasionally, during routine operations and national emergencies, the Navy is called upon to engage in towing merchant-type ships in distress. These may be MSC ships, chartered ships, ships engaged in support of operations, or any other merchant ships requiring assistance. In emergencies and in remote areas, these services also may be required to save lives and valuable ships and cargo. If pollution is a concern, towing the ship to sea will likely reduce the impact of any spill. Be sure the distressed vessel is capable of surviving any increased seas.

Information on the events and circumstances surrounding the towing should be collected and documented as soon as practical, if not immediately. The following information may help the Navy in subsequent claims for reimbursement:

a. Note reasonable availability of adequate privately-owned or commercial towing assets at the time that the Navy towed the distressed merchant ship. Examples of such information are:
    - Location of the nearest privately-owned or commercial towing vessels.
    - How the existence of nearby towing companies or vessels was known. Are they locals whose presence was known from past incidents that resulted in the need for towing or salvage? Were they discovered as a result of communications at the time of the casualty that required the tow?

b. Nature and extent of services rendered.

c. Location of the nearest safe haven. If a merchant ship was towed elsewhere, the reason for towing to that farther point should be documented.

d. The citation of funds, cash deposit, "promise to pay", or other agreements arranged by the merchant ship prior to the commencement of any operation.

Supervisory control of the effort will ordinarily remain in the Navy. A situation may arise, however, in which it may be advisable to relinquish supervisory control to an owner or underwriter's designated representative, even though Navy facilities are required. Relinquishment of supervisory control may be effected upon authorization by the cognizant naval commander or higher authority. Prompt notification should be made of such action to CNO; the cognizant Fleet Commander in Chief; numbered Fleet Commanders; Naval Surface Force Commander; COMNAVSEASYSCOM; and other interested authorities, because this may well affect the status of the Navy's claim. Relinquishment of supervisory control shall in no case be construed to affect the responsibility of commanding officers for the safety of their ships.

NAVSEA 00C should be contacted (202) 781-1731; DSN 312-326-1731; or the Duty Officer (24 hours): (202) 781-3889; DSN 312 326-3889 to assist in assessing commercially available assets. Information can also be provided regarding towing procedures.

7-6.1 Information Sources

Various companies and trade groups have assembled information intended primarily to provide guidance to merchant tanker operators in contingency planning. This same information can be equally valuable to Navy personnel who may become involved in rescue responses to merchant ships in distress. Some particular publications are cited in International Maritime Organization (IMO) Resolution A.535(13), Recommendations on Emergency Towing Requirements for Tankers (Ref. Q) and International Chamber of Shipping Oil Companies International Marine Forum, Peril at Sea and Salvage: A Guide for Masters (Appendix M -, Ref. R).

7-6.2 Attachment Points

Ideally, a distressed ship would present an easily reached connection to the rescuer. This would be a complete system including the hawser, or at least everything necessary to connect the hawser to the ship. The Oil Companies International Marine Forum (OCIMF) recommendations have been superseded by similar IMO standards, but these have not been formally adopted. Nonetheless, many of the larger tanker operators have complied with the IMO recommendations.

Many ships employ a prearranged attachment point on the tow such as the Smit Towing Bracket (see Figure 4-10). Alternative points for attachment include the bitts, the anchor chain, and the foundations of deck machinery (see Section 4-5).

Many commercial vessels have an emergency tow hawser and connecting jewelry in a packaged arrangement on the bow or stern. These boxes usually require assistance from the crew or a boarding party. Light weight material is usually used and a connection can be made very quickly. This arrangement should be sufficient until a more permanent arrangement can be made.

7-7 Ships with Bow Ramp/Door

LST type tows are required to have hydraulic rams connected with bow ramp operating instructions posted in the hydraulic control room. Ensure that mud flaps at the bottom of the doors are secured and that all dogs, heavy weather shackles, ratchet-type turnbuckles, and strongbacks are tightly and securely in place so that they cannot work free. YFU/LCUs are inherently unseaworthy due to their wide beams and flat bottoms. A lift of opportunity should be used whenever possible. If it is absolutely necessary to tow these crafts, the following must be strictly adhered to:

- The bow ramp must be secured with a minimum of four angle straps on each side, welded on the outside of the ramp. Straps should be at least 4 inches by 3/8 inches and overlap the bow ramp and sides of the craft by a minimum of 10 inches.
- All normal securing devices (such as ramp chains, dogs, and turnbuckles) must be in place and in good mechanical condition.
- All hatches, scuttles, and doors must have good gaskets and all securing devices must be in proper operating condition.

7-8 Towing Distressed NATO Ships

The NATO navies are concerned with emergency towing as part of their military missions as well as normal maritime concerns for safety of life at sea and pollution prevention for all ships.

7-8.1 Standardized Procedures (ATP-43)

Standardized NATO emergency towing procedures are found in the unclassified ATP-43 (Appendix N -, Ref. B). It was written for the situation where one combatant tows another. In this type of operation, each ship typically provides its own towing hawser as half of an entire rig of reasonable length. As in the U.S. Navy, this activity is sometimes referred to as "tow and be towed." ATP-43 includes sections on:

- Principles of Operations
- Organization and Command (including Communications)
- General Consideration of Towing Operations
- Preparation, Approaching the Casualty, Passing and Connecting the Towing Rig
- Conduct of the Tow
- Emergency Release or Parting of the Rig
- Transferring the Tow

The Annex to ATP-43 contains data on the emergency towing hawser carried by each class of NATO warship and auxiliary ship, as well as the end fittings on the hawser. It also provides hawser strengths and dimensions and the static tests of the end fittings.

ATP-43 should be available on board every NATO warship and auxiliary vessel. The assigned tow ship might remind the disabled ship's Commanding Officer of the publication's existence, so that the disabled ship can better prepare for the arrival of the tow ship.

The operational data contained in ATP-43, while accurate, are quite elementary compared to the background of the experienced tug crew. Nonetheless, knowledge of the contents of ATP-43 will be useful to the naval tug or salvage ship since it describes what the crew of the casualty should know concerning being towed.

7-8.2 Making the Tow Connection

It may be prudent to use the casualty's own hawser and end fitting to expedite the removal of the casualty from immediate danger. In such a case, the casualty may have already rigged its own hawser ready to pass to the tug. The tug need only heave the casualty's hawser on board the tug to make the final connection to its own hawser, thus being ready to commence towing shortly after arriving at the scene. The towing system can be re-rigged with the tug's more robust gear after the casualty is removed from immediate danger.

This is not to suggest that the damaged ship's towing gear is preferred over a tug or salvage ship's gear. On the contrary, the tug's gear will be more robust than that of all but the largest warships, and will almost always be longer than the casualty's hawser. Furthermore, unless the emergency hawser is connected to the ship's anchor chain, there will be insufficient long-term chafing protection for the casualty's own hawser, and possibly insufficient catenary as well. Use of the tug or salvage ship's towing gear is preferred for towing a warship or naval auxiliary. Connecting to the casualty's hawser as an expedient means should be based on a careful balancing of the tactical circumstances, rapidity of commencing the tow, distance to be towed, and existing and forecast wind and sea conditions. If the tactical situation requires initial use of the casualty's hawser, re-rigging to the more conventional connection is recommended at the earliest possible opportunity.

When connecting to the casualty's own emergency towing hawser, the towing ship should consider inserting a shot of chain between the two hawsers to assist in maintaining a healthy catenary, provided that the water is deep enough. This may complicate recovery if the rig is to be changed at sea.

7-8.3 NATO Standard Towing Link

Change 1 to the publication (May 1987) also specifies a NATO Standard Towing Link, which should soon be found on NATO ships of over 1,000 tons displacement (see Figure 7-2).

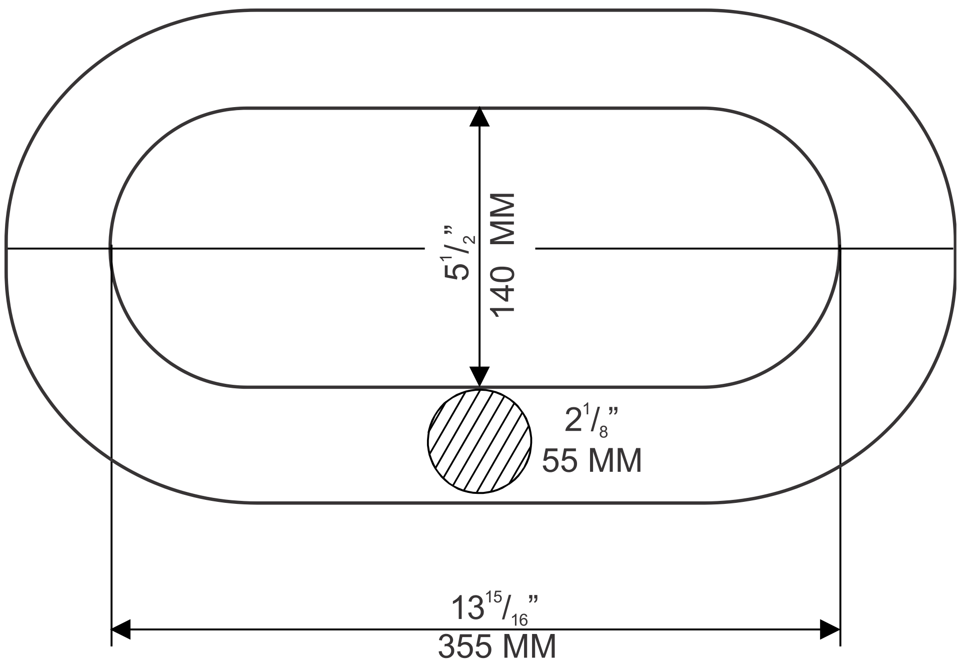


Figure 7-2. NATO Standard Towing Link.

The ATP-43 comments relevant to the NATO Standard Towing Link are:

a. The NATO Standard Towing link is to be used during ship-to-ship towing operations as an interface between the towing equipment of the towing ship and that of the ship towed, whichever of the two ships provides the equipment, in order to improve interoperability.

b. Ships of less than 1,000 metric tons displacement, other than tugs, are not obliged to have the Standard Towing Link.

c. The interface will be at the presented end of one or both ships' towing hawsers. (One of the ships will have to provide a joining shackle.)

d. The NATO Standard Towing Link shall conform to the dimensions shown.

e. The strength of the link is the responsibility of the providing nation.

The link is quite large, so the largest conceivable tow shackle (4 inches) can be dipped through it. Note that the strength of the link is left to the Providing Nation. In the absence of information to the contrary, assume that the link strength exceeds the breaking strength of the casualty's emergency tow hawser. Assume that the casualty's attachment points also exceed the strength of its hawser.

7-9 Unusual Tows

Conditions may require towing floating structures that are in unusual positions. Many such tows have been successfully completed in the past.

7-9.1 Dry Dock (Careened)

One example of an unusual tow is the towing of an AFDM through the Panama Canal. These dry docks are approximately 124 feet wide. Because the canal is only 109 feet wide, these docks must be careened for transit. This has become an established practice. When the transit operation has been completed, the careening procedure is reversed to restore the dock to its even keel condition for towing to its destination. An attempt should be made to adjust the trim to improve the behavior.

7-9.2 Damaged Ship (Stern First)

If a ship cannot be prepared properly for tow due to bow damage, the feasibility of towing by the stern may be considered. Some ships will tow fairly easily by the stern, but most can be expected to track very poorly.

7-9.3 Inland Barge Towing

Barge towing supports Navy logistic requirements. The basic techniques for inland barge towing are almost identical for harbor tugs and towing ships. The principles of alongside towing and handling become part of the open-ocean tow in making up, streaming, and entering the harbor. Naval Education and Training Command (NAVEDTRA) 10122-E, The Boatswain's Mate First Class and Chief Rate Training Manual (Appendix M -, Ref. S) provides a thorough discussion of inland barge towing in its most common configuration, alongside. Understanding the basic principles set forth in that manual will enable personnel on board the ocean going tug or salvage ship to approach inland towing in a professional manner.

7-9.4 Other Tows

Contact NAVSEA 00C for information concerning advice on unusual and unique tows including:

- NR-1, submerged tow
- Towing of gravity structures
- Non-self-propelled floating structures
- Minesweeping devices

- Submerged and surface towing of submersibles
- SINKEX
- Test bodies
- Platforms
- Pipe structures
- Cable-layers
- Acoustic arrays
- Semi-submersibles
- Ships of unusual hull forms (SWATHs, PHMs, and so forth).

7-9.5 Towing on the Hip

While it is common practice for harbor tugs to tow on the hip, it is somewhat unusual for an ocean tug to do so. However, if an ocean tug is involved in a salvage it may be necessary to engage in this type of towing. Caution should be taken if there is any sea state. Beam waves, may cause the vessels to roll out of sync and alternately separate and collide.

Chapter 8 - HEAVY LIFT TRANSPORT

8-1 Introduction

This chapter describes the personnel, procedures, preparations, and safety precautions required for float on/float off (FLO/FLO) heavy lift transports of Naval ships and craft. Heavy lift, as used in this chapter, is defined as the transportation of a ship, craft, or other assets aboard a larger semi-submersible ship or barge. FLO/FLO refers to the method of loading and unloading a heavy lift vessel. Heavy lift is an alternative to towing, developed for the movement of large drilling rigs and other offshore structures. The United States military used this method to transport smaller vessels, some of which were not suited for ocean transit and others, including larger ships, which were damaged vessels that could not transit safely under their own power.

The U.S. Navy used heavy lift to transport smaller assets such as mine warfare ships, patrol craft, landing craft and service craft to and from transoceanic forward deployment as pre-planned lifts. Examples of damaged vessels transported by heavy lift include the mine-damaged frigate, USS Samuel B. Roberts (FFG 58) in 1988 from the Persian Gulf, the bomb-damaged destroyer, USS Cole (DDG 67) from Aden, Yemen in 2000, the collision damaged USS John S. McCain (DDG 56) from Singapore in 2017, and the collision damaged USS Fitzgerald (DDG 62) from Yokosuka, Japan in 2017. Movement of assets including tugs, barges, and floating cranes have used the FLO/FLO process.

The U.S. Navy does not currently own any heavy lift FLO/FLO vessels and uses contracted vessels to perform these services. This chapter assumes that the heavy lift vessel is a contracted vessel and that the lifted ship, or asset, is a commissioned warship. The contracted vessel will most likely be owned by a foreign entity, which will require approval for the release of technical data associated with the ship to be heavy lifted, often referred to as asset or cargo. Military Sealift Command (MSC) and Naval Sea Systems Command (NAVSEA) are responsible for coordinating the data release and the heavy lift team is responsible for knowing what data can be released.

This manual serves as a technical guide and best practices document for the execution of heavy lift operations. While many of the FLO/FLO processes are similar to a typical floating dry-docking, there are several elements that make heavy lift unique. While U.S. Navy docking drawings provides detailed information for docking, and how to account for certain contingencies such as hurricane force winds and seismic events, the docking drawing does not provide how to account for dynamic forces during a sea transit. Also, the forces seen at sea are heavily dependent upon the specific heavy lift vessel utilized, the condition of the asset(s) being lifted, as well as, the predicted sea states during transit. Other factors that must be considered include, but are not limited to, accommodations for a riding crew, the status of the asset’s systems during transit and if any must remain operational, and security during transit. For these reasons, the application of good engineering practices and sound project management are key to a safe and successful heavy lift operation.

8-1.1 .Responsible Organizations

Naval Sea Systems Command (NAVSEA) Supervisor of Salvage and Diving (SUPSALV) or NAVSEA 00C –. NAVSEA 00C is the designated Technical Warrant Holder for Salvage with the authority, responsibility, and accountability to establish, monitor and approve technical standards, tools, and processes in conformance to higher authority policy, requirements, architectures and standards. NAVSEA 00C maintains standing worldwide commercial contracts for salvage, emergency towing, deep ocean search and recovery operations, and oil pollution abatement to respond to emergent situations. For heavy lift transport NAVSEA may act as the Contracting Officer for emergent heavy lift requirements.

Contracting Officers Representative (COR) – To execute a FLO/FLO operation, the heavy lift contractor and vessel must be put under contract by the U.S. Navy through a Contracting Office. The Contracting Officer will designate a COR to establish, execute and manage a heavy lift contract. The responsibilities of the COR include:

- Publishing a Request for Proposal (RFP).
- Selecting the members of the proposal technical review team.
- Leading the proposal review.
- Writing and awarding the heavylift contract.
- Monitoring the contract throughout the heavylift process.
- Advising on contractual issues that may arise during the heavy lift contract
- Contract closeout.

In most cases Military Sealift Command (MSC) is responsible for all contracting actions associated with heavy lift operations. In the event of an emergent requirement NAVSEA 00C also can leverage standing salvage contracts to execute heavy lift operations. For example, NAVSEA 00C utilized a standing salvage contract for the heavy lift transport of USS John. S. McCain. In either contract case, MSC or NAVSEA 00C will designate a COR.

The COR shall work with all other responsible organizations to ensure a successful heavy lift and ensure that all technical and administrative information is available to all members of the government's heavy lift team and to the heavy lift contractor.

NOTE
The remainder of this chapter assumes MSC contracted the heavy lift and is the COR although operational activities presented also apply to emergent heavy lift contracts.

Operational Command. – As the owner of the asset, the Operational Commander has cognizance of the operation and will typically determine the FLO/FLO requirement, asset availability dates, required delivery date, and designate the on-load and delivery locations. They will provide information on security concerns and details for access to the assets and base(s). They will also task ship's force with supporting the preparations for transport and identify any unique operational requirements that may impact transit.

Ship's Force - Ship's force will provide information regarding the asset's condition to MSC. Once the FLO/FLO operation is confirmed, ship's force shall support the Heavy Lift Project Team to prepare the asset for heavy lift transport. Ship's force responsibilities include:

- Securing the asset for sea and completion of all checklists for preparing for tow and heavy lift (tow checks are required for any tow operation from/to pier side and the FLO/FLO location)
- Ensure that the asset's condition does not change once the asset is deemed ready for heavy lift and notify the Heavy Lift Project Team of any actions that may affect the ship's condition.
- Provide line handlers during the FLO/FLO operations.
- Provide riding crew during the heavy lift transport from onload location to delivery location to include an officer-in-charge (OIC) and a team of ship's force personnel familiar with the asset and capable of regular safety and security checks and damage control response if necessary.

NAVSEA Heavylift Project Team – The Heavy Lift Project Team is the government's technical oversight and safety team consisting of members from NAVSEA 00C and the U.S. Navy Reserve Supervisor or Salvage (SUPSALV) and Heavy Lift units. This team executes the technical aspects of the heavy lift operation and works with other NAVSEA codes and Planning Yard to provide technical information (docking drawings, damage control books, etc.). When international travel is required for the team, NAVSEA 00C assists in processing country and theater clearances for travelling personnel.

The team is responsible for the execution of the heavy lift operation and will provide technical support for the following:

- RFP preparation
- Technical proposal review
- Heavy lift technical planning and calculations
- Asset preparation and checklist completion
- Onload and offload execution

SUPSALV 00C will provide naval architects, Subject Matter Experts in towing and heavy lift and additional personnel as needed for a specific operation.

The Reserve units train Engineering Duty Officers (EDOs) to conduct heavy lift operations and tracks qualification status and proficiency to maintain a cadre of qualified personnel ready and available to safely support NAVSEA 00C. Personnel provided for each operation include:

- Heavy Lift Project Officer (HLPO)
- Heavy Lift Docking Officer (HLDO)
- Blocking Expert
- Stability Expert
- Services Coordinator

Planning Yard (PY) – The Planning Yard will provide all necessary and available technical information to MSC and NAVSEA 00C associated with the specific asset and class to be heavy lifted, to include:

- Drawings (docking drawing, curves of form, etc.)
- Ship-Alt history
- Docking Reports
- Weight and stability documents
- Computer Aided Design (CAD) models if available
- Technical Point-of-Contact (POC) information (name, telephone number, e-mail and address) of the person(s) responsible for supporting the heavy lift. The POC is typically a platform manager and qualified to act as a ship repair officer in the event the heavy lift is used as a docking opportunity.

Heavylift Contractor – The COR will select the heavy lift contractor who will execute the asset onload, sea-going transportation and delivery of the asset to the offload location. The heavy lift contractor is responsible for the following:

- Providing a semi-submersible heavy lift vessel suitable for the size of asset(s).
- Obtaining support vessel(s), logistics, security, customs and any services necessary for the FLO/FLO operation and transit.
- Material and services to secure the asset for sea.
- Completing a Transport Manual to include all details regarding the FLO/FLO, sea fastening, onload and delivery locations, technical calculations, and voyage planning for the potential weather conditions.
- Provide a Loadmaster who is overall responsible for the heavy lift preparation and FLO/FLO operation.

8-2 Special Considerations

8-2.1 Dry Docking Comparison

FLO/FLO onload and offload procedures are similar to floating dry dock operations. Both involve block build, ballasting, positioning a floating asset over the blocks, deballasting and "landing" the floating asset on the blocks. Although these procedures are similar, FLO/FLO operations require other considerations:

- Drydocks have access to a large, organic workforce; FLO/FLO vessels have small crews and typically subcontract labor to complete the block build.
- When drydocking, all blocking is typically in place before landing; in FLO/FLO, often a portion of side blocks are added after on-load.
- Keel and side blocks may be placed in alternate locations than those provided in the Docking Drawing depending on hull damage, loading configuration, or strength characteristics of the heavy lift vessel.
- Time of year, sea state, route, etc. must be considered when planning a heavy lift with dynamic and static calculations completed to account for accelerations associated with transit.

- Seafastening must be installed to secure the asset to the cargo deck of the heavy lift vessel during transport.
- FLO/FLO operations in open water areas will be subject to maritime authority approval and environmental conditions.
- The asset must be secured internally for the sea transit (condition Zebra, refer to Appendix R of this manual).
- Some of the asset's systems may be required to be operational during transit, in which the heavy lift vessel will need to provide additional services (e.g., air conditioning, fire main water, sonar dome pressure, etc.) to ensure the safety of the asset being lifted.
- The asset being lifted may be in the final days of preparing for extended deployment. Therefore, it may be topped off with provisions, fuel, and water, if within stability and block pressure limits.

8-2.2 Commercial Heavy Lift Vessels

Some basic characteristics of the larger, commercial heavy lift vessels are presented in Table 8-1. These semi-submersible vessels are self-powered and have large open decks to support cargo. They contain enough ballast tank volume to allow them to ballast down sufficiently to prevent interference with the vessel during FLO/FLO. This allows assets to be floated over the deck and lifted by dewatering ballast tanks. This process is almost identical to floating dry docks except that it is often done in open water due to the depth of water required.

Smaller ships of this type also exist but are not used to perform lifts of larger vessels. Commercial submersible and semi-submersible barges may also meet the requirements of some heavy lifts. Barges have the added complexity of a tow arrangement and are considered less desirable due to stability concerns during loading and less protection for the cargo from heavy seas while underway.

Table 8-1. Commercial Submersible and Semi-Submersible Vessels						
Company Name	**Vessel Name**	**LOA (m)**	**Beam (m)**	**Deck Dimensions (m)**	**Draft Full Load (m)**	**DWT (tons)**
Boskalis	BOKA VANGUARD	275	78.75	275 x 70	10.94	116,175
Boskalis	BLUE MARLIN	224.8	78.75	178.2 x 63	10.24	76,292
Boskalis	WHITE MARLIN	216.7	63	177.6 x 63	10	72,146
Boskalis	BLACK MARLIN	217.8	63	178.2 x 42	10.08	57,021
Boskalis	TRIUMPH	216.79	42	130 x 44.5	10.44	54,000
Boskalis	TRUSTEE	216.79	44.5	130 x 44.5	10.44	54,000
Boskalis	TRANSPORTER	216.79	44.5	130 x 44.5	10.44	54,000
Boskalis	TARGET	216.79	44.5	130 x 44.5	10.44	54,000
Boskalis	FORTE	216.75	43	177.6 x 43	9.68	50,000
Boskalis	MIGHTY SERVANT 1	190.03	50	150 x 50	8.77	40,910
Boskalis	TRANSSHELF	173	40	132 x 40	8.8	34,030
Boskalis	MIGHTY SERVANT 3	181.23	40	140 x 40	9.48	27,720
GPO Heavy Lift	GRACE	225	48	183 x 48	10.64	63,581
GPO Heavy Lift	AMETHYST	225	48	183 x 48	10.64	63,581
GPO Heavy Lift	SAPPHIRE	225	48	183 x 48	10.64	63,581
GPO Heavy Lift	EMERALD	225	48	183 x 48	10.64	63,581
Eide Marine Engineering	TRANSPORTER	180.1	30	153 x 20	N/A	11,435
Eide Marine Engineering	TRADER	112.5	34.22	96.75 x 29.4	N/A	9,424

Figure 8-1 shows a typical heavy lift vessel where the assets can be loaded from the port or starboard sides or from astern. The vessel shown in Figure 8-2 is similar to a floating dry dock and the asset is loaded from astern. The large wing walls provide some added protection to the weather (particularly wind effects). Figure 8-3 shows a vessel with a deckhouse fore and aft and the asset must be floated on from the port or starboard sides.

Figure 8-1. ***Heavy Lift Vessel (typical)***

Figure 8-2. ***Heavy Lift Vessel (loads astern only)***

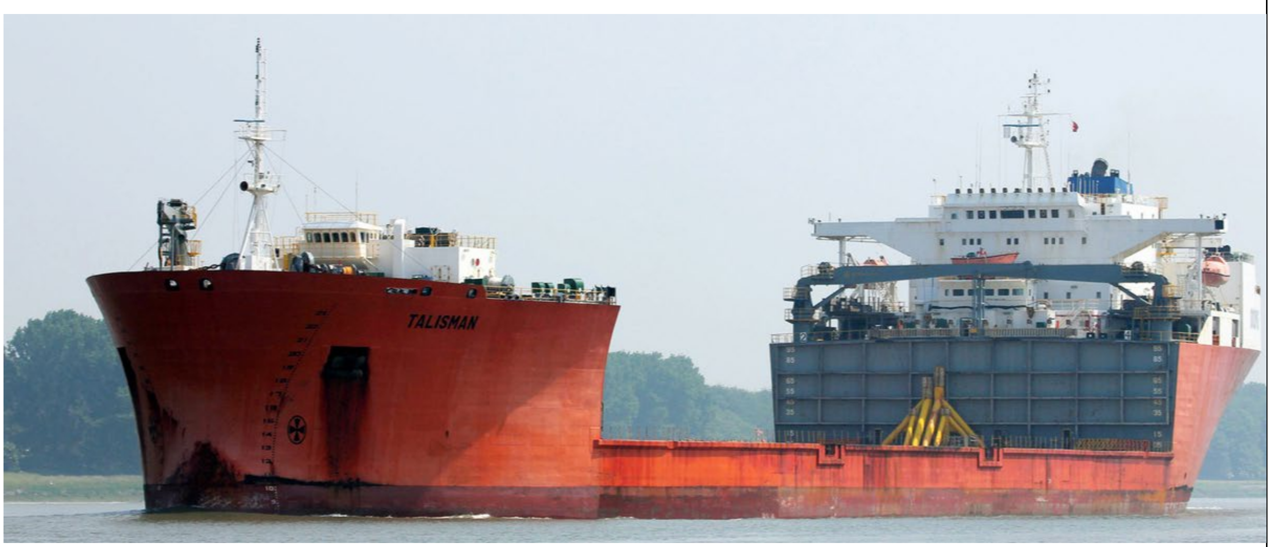


Figure 8-3. ***Heavy Lift Vessel (deckhouse fore and aft)***

8-2.3 Choosing a Heavy Lift Vessel

Several factors must be considered when deciding on which type of heavy lift vessel to use and will vary depending on the mission being supported. For instance, for a coastal or inland lift, a barge may be suitable, but for a trans-ocean voyage, the added seaworthiness of a heavy lift vessel will likely be worth the extra cost. Some of the factors for consideration are shown in Table 8-2.

Table 8-2. Heavy Lift Vessel vs Submersible Barge

Factors	Heavy Lift Vessel	Submersible Barge (with Tug)
Stability	Stable in all operational modes, sheltered in head seas	Relies on bottom contact for stability during lift, limited shelter in head seas
Access to Asset	Asset(s) on deck of vessel, access through brow or ladder	Access limited by weather and small boat capability
Support	Designed to support lift ops, usually good hotel services	Barge likely has no hotel services and tug may have limited additional hotel services
Cost	Specialized craft, more expensive, but generally shorter transit time	Tug/barge combo may have cheaper day rate, but longer rental time due to slower transit speed
Insurance/Risk	Generally, insurance is less due to larger, more controllable platform	Insurance rates can be higher
Speed	Open ocean design, good speed	Tow will be slower
Risk	One-unit, minimal risk with good seafastening plan	With two craft and towline, risk is inherently greater

8-3 FLO/FLO Planning and Preparations

Each FLO/FLO transport requires careful planning, preparation, and execution to minimize error and maximize safety. Few FLO/FLO operations are duplicates of earlier operations as there are always differences in season (weather), route, personnel, and configuration of the asset(s).

The cost of a heavy lift may make this option seem disadvantageous, but several situations may dictate that this method is the preferable way to relocate an asset. Moving small coastal vessels across the ocean under their own poser can be slow, costly and at significant risk to both personnel and the vessel. A vessel designed to operate in sheltered coastal waters is ill-suited to survive the elevated winds and sea states of winter storms and hurricanes. Towing the vessel is an option but a long ocean tow of a small vessel has a different set of risks to consider. A heavy lift is safer and more efficient that a tow for a multiple asset transfer. In the case of a damaged vessel, heavy lift may be the only option as towing may cause more damage and therefore not be feasible.

8-3.1 Notional Heavy Lift Schedule

Significant planning and preparation go into FLO/FLO operations with a focus on a safe and successful asset onload for transit departure and asset offload upon arrival at the delivery location. For a planned heavy lift contracted by MSC, Table 8-3 depicts a notional schedule for actions and milestones for planning the heavy lift onload and transit departure. This schedule allows sufficient time to perform all necessary document review, asset preparation, block build completion, and installation of seafastening.

Table 8-3. Notional Schedule for a Planned FLO/FLO	
Notional Timing	**Activity or Milestone**
D-180	Decision to contract heavy lift transport
D-90	Contract execution
D-60	Receive Transport Manual for review
D-45 to D-30	Transport Manual Review conference
D-25	Approve Transport Manual (Upon closure of all government comments by contractor)
D-20 to D-9	Appendix H and R asset preparations and coordination with ship's force
D-18 to D-15	Heavy Lift Project Team arrives on site
D-15	Coordinate with port and base authorities
D-15	Pre-Load Conference with all stakeholders
D-15 to D-12	Arrival of heavy lift vessel at onload port
D-15 to D-12	Commence block build
D-11	Tug inspection (if previously unassessed tugs are necessary for the operation)
D-10	Block build verification walkthrough
D-10	Diver walkthrough
D-9	Final confirmation of asset load conditions
D-9	Appendix H and Appendix R checklists complete and signed off
D-9	Go/No-Go Meeting
D-8	Float-on of asset
D-7	Post onload deck walkdown
D-6	Seafastening installation (this may take less than 6 days)
D-1	Seafastening verification and certification
D	Departure for transit
Seagoing transit from onload site to delivery site	
A-4	Arrival of Heavy Lift Project Team
A-3	Review seafastening removal plan, off-load procedure, pumping plan, and any required logistics
A-3	Coordinate with port and base authorities
A-2	Pre off-load conference with all stakeholders
A	Arrival of Assets; Post Voyage Walk-down
A+1	Appendix H and R Asset Preparations, Coordination with Ships Force, Asset Inspections
A+1	Commence seafastening removal
A+2	Conduct walkthrough with divers (if using)
A+2	Go/No-Go Meeting
A+3	Float off and delivery of asset

In the case of an emergency, or emergent heavy lift operation due to battle damage or collision, NAVSEA 00C may expedite planning and execution of the heavy lift. Table 8-4 depicts a notional schedule for actions and milestones for preparing an emergent heavy lift.

Table 8-4. Notional Schedule for Emergent FLO/FLO	
Notional Timing	**Activity or Milestone**
D-30	Decision to contract heavy lift transport
D-28	Emergent heavy lift contract execution
D-15	Receive Transport Manual for approval
D-12	Transport Manual Review conference
D-10	Approve Transport Manual (Upon closure of all government comments by contractor)
D-10	Appendix H and R asset preparations and coordination with ship's force
D-10	Heavy Lift Project Team arrives on site
D-9	Coordinate with port and base authorities
D-9	Pre-Load Conference with all stakeholders
D-9	Arrival of heavy lift vessel at onload port
D-9	Commence block build
D-7	Tug inspection (if previously unassessed tugs are necessary for the operation)
D-5	Block build verification walkthrough
D-5	Diver walkthrough
D-5	Final confirmation of asset load conditions
D-5	Appendix H and Appendix R checklists complete and signed off
D-5	Go/No-Go Meeting
D-4	Float-on of asset
D-4	Post onload deck walkdown
D-3	Seafastening installation
D-1	Seafastening verification and certification
D	Departure for transit
Seagoing transit from onload site to delivery site	
A-4	Arrival of Heavy Lift Project Team
A-3	Review seafastening removal plan, off-load procedure, pumping plan, and any required logistics
A-3	Coordinate with port and base authorities
A-2	Pre off-load conference with all stakeholders
A	Arrival of Assets; Post Voyage Walk-down
A+1	Appendix H and R Asset Preparations, Coordination with Ships Force, Asset Inspections
A+1	Commence seafastening removal
A+2	Conduct walkthrough with divers (if using)
A+2	Go/No-Go Meeting
A+3	Float off and delivery of asset

The remainder of this chapter assumes that MSC contracted the heavy lift and it is a planned heavy lift although emergent heavy lift operations require the same activities discussed in subsequent sections.

8-3.2 Request for Proposal (RFP)

Contracts for FLO/FLO operations typically originate through the MSC Headquarters Contracting Officer. MSC shall perform a market survey to identify suitable vessels for heavy lift. The market survey shall provide the following information regarding the heavy lift vessel; size, water depth capabilities, draft requirements of the heavy lift vessel, maximum dimensions and displacement of an asset being carried as cargo. The market survey shall be used to determine which heavy lift vessels have the capability of lifting a specific U.S. Navy ship given the particulars of the asset to be heavy lifted.

Following a market survey MSC issues an RFP or modifies an existing time charter to include the details of a particular operation. Information supplied by the operational command is included as requirements in the RFP or contract modification. Information required may include, but is not limited to:

- Asset(s) to be lifted (class/name)
- Dates and locations of load and discharge points
- Supporting activities and additional cargo to be transported
- Asset condition of readiness or loading condition
- Date of last dry docking
- Asset's plant service requirements (during the FLO/FLO operations and during sea transport)

MSC must also specify certain requirements be submitted by the contractor in response to the RFP. MSC may decide to allow the successful contractor to provide some or all this information as part of the Transport Manual after contract award. As a minimum MSC shall ensure that the contractor provides the following information:

- Proposed voyage route and expected worst case sea conditions.
- Proposed logistics to show fulfillment of required asset services and transport requirements such as security and bunkering.
- Surfaced and semi-submerged drafts of the heavy lift vessel during the offload and on-load.
- Lift capacity and pumping plan during onload and offload.
- Stability calculations of the heavy lift vessel throughout the on-load and offload. The contractor shall provide sufficient information regarding the stability of the heavy lift vessel so the Heavy Lift Project Team can review the contractor's calculations, and if necessary, independently calculate the stability of the asset and heavy lift vessel.
- Calculated stability at each point in the onload/offload and the point of minimum stability will be stated in the pumping plans, along with the timing at each point.
- Keel block, side block, and side support dimensions and loading calculations. Loading calculations shall include worst case static (onload and offload) and dynamic (transit) loads.
- Sea fastening geometry and loading. Loading calculations shall be worst case based on expected weather and sea state conditions during transit.
- Clearances with an emphasis on points of minimum clearance throughout the on-load and offload process.
- Ballasting demonstration. This demonstration is to verify the heavy lift vessel can obtain the necessary depth required to execute the lift. It should be conducted in advance to allow sufficient time to select another vessel if the necessary depth cannot be obtained. A waiver to this requirement may be granted if the vessel can provide proof from a recent FLO/FLO evolution that the vessel can ballast to the necessary depth.
- Line handling plan for on-load and offload.
- Available services for the asset or temporary requirements to provide necessary services.
- Access and egress to the asset from the heavy lift vessel.

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NOTE
Since the heavylift vessel is not a US Navy vessel it must be assumed that the government observers will not have sufficient information to verify these calculations (stability, blocking and sea fastening loading, clearances, etc) unless provided by the heavylift contractor via MSC.

NOTE
Since the heavylift vessel is not a US Navy vessel it must be assumed that the government observers will not have sufficient information to verify these calculations (stability, blocking and sea fastening loading, clearances, etc) unless provided by the heavylift contractor via MSC.

MSC shall provide all Government Furnished Information (GFI). While MSC will not generally be the owner of the GFI, as the contracting authority MSC shall be responsible for ensuring all GFI necessary for the safe execution of the heavy lift is provided promptly to the contractor and the Heavy Lift Project Team. MSC will provide the following GFI:

- All relevant drawings (Docking Drawing, Curves of Form, tank diagrams, etc.)
- Weight and stability documents
- Ship-Alt history relevant to stability and loading of the vessel to be heavy lifted
- Anticipated condition of the asset to be heavy lifted
- Computer Aided Design (CAD) models if available

Upon receipt of the proposals, MSC and other technical authorities (the operational command, a dry-docking authority, NAVSEA tech codes, NAVSEA 00C, etc.) will review the proposals for technical correctness and cost comparison. MSC will then award a contract or contract modification.

8-3.3 Preparations

Once a contract is awarded MSC will initiate the preparation activities in coordination with NAVSEA 00C. In this preparation phase, communication between the various organizations is critical to the heavy lift's successful and timely execution. The following activities should be accomplished before the vessel arrives at the onload site.

8-3.3.1 Choosing a Heavy Lift Team

The Heavy Lift Project Team functions much like a Supervisor of Shipbuilding command during bid, award, and oversight of a contractor dry-docking availability. The team reviews the contractor proposals and following award approves the Transport Manual and ensures the work is being performed in accordance with the contract and Transport Manual. Every effort should be made to choose personnel who can be present throughout the entire process (plan development, contract award, Transport Manual review, onloading, and offloading). If this is not possible, a process for turnover of information and responsibilities between incoming and outgoing personnel shall be implemented.

The following roles are fulfilled by the Heavy Lift Project Team. In some operations each role may be filled by one person and in other operations one person may fill several roles concurrently.

Heavy Lift Project Officer (HLPO) - The HLPO is a senior technical officer, preferably an Engineering Duty Officer and is the leader of the Heavy Lift Project Team. Once designated, they will be responsible for coordinating both technical and logistics support for the asset to be lifted, development of heavy lift requirements, and review of the Transport Manual. he HLPO is responsible for stakeholder management during planning and execution of FLO/FLO operations, including dissemination the daily situational report (SITREP), see Appendix S for a SITREP template, and schedule, see Appendix T for a schedule template.

Heavy Lift Docking Officer (HLDO) - The HLDO is responsible for the safe execution of the FLO/FLO operation and the seafastening installation before transport. The HLDO reviews and approves all contractor calculations required to conduct the FLO/FLO and seafastening operations by completing calculations independently from the contractor and resolves discrepancies between calculations. The HLDO must be familiar with the local ship repair service industry and the environmental conditions at the onload and offload sites. The HLDO is responsible for ensuring the asset and heavy lift vessel are ready for onload, monitors the onload operation for asset positioning and stability, reviews the final seafastening for transport, and similarly monitors the offload operation. The Blocking Expert and Stability Expert support the HLPO in fulfilling these responsibilities.

Blocking Expert - The Blocking Expert oversees the construction and installation of all necessary blocking and seafastening. They should be familiar with U.S. Navy docking drawings, the contractor's Transport Manual blocking and seafastening drawings, and the construction of various types of docking blocks. The Blocking Expert verifies that all blocks, seafasteners, roll bars or spur shores are structurally sound, of the right dimensions, and installed properly and in accordance with the approved Transport Manual

Stability Expert - The Stability Expert monitors the operation to ensure adequate stability of both the heavy lift vessel and the asset at all stages of the lift process. They should be familiar with the operation of a heavy lift vessel or floating dry dock and can verify that the ballast/deballast sequence is sound and performed in accordance with the Transport Manual. They should inspect the ballast/deballast system (including the tank and draft indicator system) to ensure that it operates properly and should monitor this system during on-loading and offloading operations. In support of the HLDP, the Stability Expert will perform all the vessel stability and docking calculations to include block loading to determine number of required blocks, operational clearances, draft at landing, draft at instability and required seafastening.

Services Coordinator - The Services Coordinator will coordinate with ships force to prepare the asset for heavy lift, ensuring all spaces are secured and ready for transport, as well as ensuring all requirements of Appendix R (and Appendix H when a tow is involved) of this manual have been meet, approved and signed off by the HLPO. They coordinate the installation of asset plant services such as electrical power, fire main and potable water. They also coordinate general vessel support during the FLO/FLO operation, such as sonar dome and tank level adjustments, divers when necessary, line handling, security watches, communications, access, scupper overboard discharges, etc. The Services Coordinator should be familiar with the asset in order to verify all support requirements and ensure they are properly planned for in the FLO/FLO planning phase.

NOTE
The Services Coordinator is responsible for the shipment, receipt, inventory, and return of the heavy lift fly-away kit which is made available to the Heavy Lift Project Team and shipped globally. The fly-away kit includes radios, key tools, equipment, personal protective equipment and life vests necessary for FLO/FLO operations.

NAVSEA 00C Representative - As the designated Technical Warrant Holder for Salvage, SUPSALV 00C personnel typically attend the onload and offload operations and work directly with the HLPO and team members. SUPSALV 00C representatives may include naval architects, subject matter experts in towing and heavy lift or other technical expertise.

The following roles are in addition to the Heavy Lift Project Team and are designated by the wider group of responsible organizations associated with the safe and successful FLO/FLO operation.

Riding Crew - The riding crew should be familiar with, or come from, the asset being lifted and include personnel from several rates. For multi-asset lifts, the riding crew should include at least one representative from each asset. The size and make-up of the riding crew is designated by the Operational Commander and determined by the asset or assets being lifted and the berthing and messing capabilities of the heavy lift vessel. The riding crew is responsible for security, damage control, maintenance, and other duties required for assets in a secured or partly secured status.

Independent Marine Surveyor (IMS) - An IMS qualified in FLO/FLO operations for heavy lift vessel and sea transports shall be present at all FLO/FLO operations for U.S. Navy assets. The IMS will be responsible for independently assessing the following items:

- Transport Manual
- Material condition of the heavy lift vessel
- Ship systems
- Blocking arrangement
- Seafastening
- Onloading/offloading procedures
- Voyage arrangements
- Preparation of the asset

The IMS is an independent third party to act as a mediator between the U.S. Navy and the contractor to provide independent analysis of the operation and to assist in settling discrepancies. The IMS selected shall be agreed upon by both the COR, with input from the Heavy Lift Project Team, and the heavy lift contractor.

Loadmaster - The Loadmaster is the heavy lift contractor's designated coordinator. The Loadmaster directs the heavy lift vessel's crew and subcontractors during the blocking build, the positioning of the asset over the submerged heavy lift vessel, ballasting/deballasting operations, the installation seafastening and approves the loading and securing of deck cargo before departure. Similarly, the Loadmaster coordinates the offloading procedure.

Contract Coordinator - The Contract Coordinator represents the COR and works with the members of the different parties represented during a FLO/FLO operation to resolve any contract disputes. They will often be a representative from the MSC. The Contract Coordinator will handle any modifications to the contract, the scope of work, or other contractual questions.

Ship Repair Officer - A Ship Repair Officer may be assigned at the onloading and offloading sites to coordinate any emergent/emergency repair work necessary, using the heavy lift as a docking of opportunity, if the maintenance activities do not interfere with the heavy lift. The Ship Repair Officer must maintain the hulls' watertight integrity because this is a transport operation (i.e., the asset must be ready for sea transit). The Ship Repair Officer should be familiar with local ship repair and other services necessary to complete repair work. Any repair work shall be checked and authorized by the COR to ensure it does not impact the heavy lift contract.

8-3.3.2 Contractor Preparations

Once awarded the contract, the heavy lift contractor must provide information regarding the FLO/FLO operation. They must choose onloading and offloading sites and develop drawings and procedures for the entire transfer including blocking, line handling sequences, onloading, seafastening for transit, and offloading.

The primary document detailing the preparations and procedures is the Transport Manual. The contractor prepares and provides this document in advance (exact dates will be specified in the contract but is required with sufficient time prior to the Transport Manual Review Conference for Government review and comment) of the transport ship's arrival at the load site or the blocking build operations begin, whichever occurs first. It is recommended that the Heavy Lift Project Team be in contact with the contractor during the development of the Transport Manual to avoid delays if corrections or adjustments are necessary. The Heavy Lift Project Team, COR and IMS should review the Transport Manual and documents to:

- Ensure adherence to technical requirements.
- Confirm that the proper information, including drawings, is provided.
- Corroborate references and their use.
- Verify all engineering calculations and technical topics are addressed.
- Verify voyage, logistical, milestones, and schedule proposals meet transport RFP requirements

Upon approval, this document will serve as the technical guide during the FLO/FLO operations.

8-3.3.3 Transport Manual

The contractor shall provide a Transport (Load) Manual that details the technical requirements of the lift. The manual includes, but is not limited to, the following:

- Description of the heavy lift vessel, including critical dimensions and clearances.
- Particulars of the asset (and any additional deck cargo) used by the contractor in the development of the Transport Manual.
- Particulars on which services and parameters the heavy lift vessel can provide, such as electrical power, potable water, firefighting (including physical connection requirements).

- Proposed voyage route and probable sea states.
- Motion analysis of the heavy lift vessel loaded with the asset, for determination of roll and pitch angles, periods and accelerations for use in developing blocking and seafastening arrangements.
- Critical motion curve or table depicting the motions (angle and periods of roll, pitch, heave, and surge) to which the blocking and seafastenings are designed and which must not be exceeded during transport.
- The contractor must perform a slamming study if an asset overhangs the edge of the heavy lift vessel's deck (either over the side or over the stern) to determine the number of occurrences and accelerations to which the asset may be subjected. The study should ensure the asset can be safely transported without sustaining damage.
- Stability analysis of the heavy lift vessel as loaded, including calculating onloading conditions and intact stability assessment including righting moment curves and wind heeling moment, as defined in Paragraph 5.1.3.b of MIL-STD-1625D (Ref T) as specified in Section 8-5.4.
- Stability analysis (GM curve) during the ballast/deballast sequence as defined in Paragraph 5.1.3.3.b(1) of MIL-STD-1625D (Ref T), except that the minimum GM must not be less than specified in Section 8-5.2.2 unless specifically approved by NAVSEA at the request of the DDA.
- Cargo deck arrangement plan/drawing with relevant longitudinal and transverse cargo, asset, blocking and seafastening locations, including clear indications of any blocks to be added after onload.
- Structural analysis of longitudinal bending stress imposed on the heavy lift vessel by the proposed loading. Include a cargo deck load diagram, plating thickness, and arrangement and size of transverse and longitudinal stiffeners with acceptable cargo deck load capacity or drawing(s).
- Structural data for the heavy lift ship:
    - Maximum allowable bending moment calculation.
    - Transverse strength calculation sustaining the maximum allowable pontoon deck loading in long tons per linear foot.
    - Longitudinal deflection calculation.
    - Maximum keel block, side block, and hauling block loading calculations.
    - Maximum pontoon deck loading at keel block and side block locations and other areas of the pontoon deck if different than that of the blocking area.
    - Structural arrangement and scantlings.
    - Longitudinal and transverse watertight bulkhead design calculations.
    - Maximum allowable differential head between tanks and exterior tank draft.
- Cribbing and blocking plan/drawings, including table of keel and side block offsets as specified in the docking drawings and calculation of loads including analysis of worst-case block loading when the heavy lift vessel is at extreme trim angle during ballasting/deballasting.
- Pumping plan with stability calculations. These can be the same onload/offload pumping plans provided in the RFP if appropriate (see Section 8.3.2).

NOTE
Experience with past FLO/FLO operations demonstrate that locating side blocks in the locations as specified on the U.S. Navy docking drawing offers the best chance to have proper offset heights. The U.S. Navy standard docking drawing is a Selected Record Drawing (SRD) and takes precedence over all other drawings in determining offsets for height of the side blocks. For this reason, side block locations from the U.S. Navy docking drawing will be used for the onload of the asset whenever possible. Once the asset has been onloaded, the remaining side blocks will be located at the intersection of a transverse frame and a longitudinal girder whenever possible. This will ensure that the blocking dimensions are accurate for onload and that the post-onload blocks are located on vessel's strength points. The blocking plan is discussed in further detail in section 8-6.1, Preparing the Heavy Lift Docking Plan.

- Descriptions of the docking blocks showing the physical characteristics of the blocks, including material, dimensions. Calculations to verify that the blocks will be stable and structurally adequate to withstand the loading used in heavy lifting capacity calculations and the side blocks (and shores) are adequate in number to provide sufficient bearing area to resist overturning moments specified herein.
- Seafastening plan/drawings, including design forces.
- Onloading/offloading sequence plan/drawings, showing position of tugs and lines during various phases of evolution.
- The amount of damage the heavy lift vessel can withstand and survive without dropping the asset off the blocking and seafastening.

8-3.3.4 **Choosing an Onload Site**

The contract will specify the points of departure and destination for the assets; however, the contractor will select the actual onload site, subject to HLPO and IMS approval. Environmental conditions will be the major factor in determining the choice of onload site. The location should be as protected as possible from wind and swell, although open water locations offshore have been used successfully. A poor choice of location for conducting FLO/FLO preparations can lead to major problems, delays, or canceled operations. If the operation is to be conducted offshore, consider that the preferred anchoring/mooring method may be to swing on a single anchor allowing natural adjustment to prevailing weather conditions.

The site must have enough water depth to accommodate the heavy lift vessel's required draft for onload plus a minimum of one-meter clearance below the keel. The water depth must account for the asset's draft, the height of the blocking installed, and a minimum of one-foot clearance from the asset's deepest protrusion and the height of the block build during onload.

NOTE
Semi-submersible barges may require that one end of the barge rest on the bottom for stability during onloading.

The contractor may choose to do their preparations at a location other than the site of onloading. They can make the preparations at any full-service, easily accessible location and then move to a staging area when ready for onload and final installation onboard the heavy lift vessel before onload at the designated location.

The onload location shall be mutually agreed upon by all parties involved in the loading process, including the IMS. Persons tasked with evaluating potential onload sites need to be knowledgeable in heavy lift operations and factors that affect evolution safety (wave periods, weather requirements, currents, etc.).

NOTE
If the heavy lift vessel must transit from the onload site to a site where additional blocking and seafastening will be accomplished, the contractor must make calculations (static and dynamic) available before onload to ensure a safe transit.

8-3.3.5 **Preparing the Deck**

It is the contractor's responsibility to prepare the deck of the heavy lift vessel according to the approved Transport Manual and arrange for any necessary subcontractors. MSC should provide the contractor with the most recent docking drawings and docking report available for the asset to be lifted to assist in deck preparation. The Planning Yard, or NAVSEA 00C, should ensure that information and drawings provided to MSC for use by the contractor are accurate and current. The building drawings presented in the Transport Manual should be reviewed and approved before the contractor starts the build. During the review of the Transport Manual, the team should ensure that the referenced docking drawing is the latest markup from the asset's last dry docking, and that blocking locations and heights are in accordance with the docking drawing or asset's lines plan if using alternate blocking locations. The minimum number of keel and side blocks is discussed in Section 8-6.

NOTE
Final block build should be installed and inspected a minimum of 24 hours before commencement of the heavy lifting operation to accommodate any final adjustments to conform to the approved block plan per the Transport Manual.

An important consideration in preparing the deck is ensuring, to the maximum extent practicable, 100% contact between the asset being transported and the heavy lift vessel deck. Blocking and other structural support bases are typically completely flat, while the heavy lift vessel's deck may not be resulting in local areas of concentrated stress that may damage the asset being transported. This is of particular concern if the asset is fastened to horizontal rigid steel supports before being attached to the more flexible/irregular decking of the heavy lift vessel. The contractor should shim any gaps between the vessel's deck, blocking, and the asset to minimize this effect.

With multiple assets (or additional deck cargo), placement of the assets on the cargo deck may be dependent on of the required working area between and around the assets. Deck space permitting, forklifts can be used to move material around the assets on deck and crane lifts for installation of seafastening or post-load blocking. Workspace may be limited and spacing may dictate the workflow. A minimum spacing between assets of 2800 mm (9.2 ft) should be adequate for one directional workflow and walking space. However, twice the minimum spacing allows for two directional workflow and forklift access between the spur shore thrust blocks. A minimum of 2500 mm (8.2 ft) clearance between the assets and the edge of the cargo deck should be adequate for blocking, working and access requirements. If possible, additional spacing should be allowed so that forklifts can still pass between the assets after the seafastening spur shores (roll bars) are installed.

8-3.4 Pre-Load Conference

A conference shall be held before loading, where all parties involved are represented and chaired by the heavy lift contractor, preferably the Loadmaster. The pre-load conference must cover all aspects of the procedure to familiarize all parties with their respective roles and interface points during the operation. Important topics to cover at this meeting include personnel, schedules, procedures, and responsibilities. This is often the first opportunity for some parties to have contact with each other. The contractor, NAVSEA 00C, HLPO, IMS, operational commander, local port authorities and services need to conclude the conference with an aligned view of schedule and expectations with clear points of contact. If possible, the conference should be held near the onload site and/or the asset(s). This will allow site and asset inspections and may identify potential problems in advance of the evolution. This conference should be held far enough in advance to ensure that any changes or adjustments to the plan can be completed without adversely impacting the schedule. It should also be near enough to the onloading date to allow for as many details as possible to be finalized. Any changes need to be incorporated into the Transport Manual or a revision issued.

Each stakeholder leader or a representative with decision making authority must attend the pre-load conference to ensure they thoroughly understand their role in the process. Stakeholders attending the pre-load Conference are expected to be present at the evolution to ensure the plan is executed as agreed at the conference. Separate meetings should be held, or scheduled, as part of the conference to discuss specific operational details with line handlers, divers, block builders, tug masters, pilots, etc. Relevant pre-operational meetings may be held close to the actual on-load operation such as a line handling safety brief or a diver walkthrough of heavy lift deck following block build completion.

NOTE
Attendance of all operational stakeholders to include port operations, tug masters, and pilots are of particular importance at these meetings.

8-3.5 Load Site

Before the start of the float-on operation, all assets and support craft must be on scene and all preparations and inspections (including of support craft) must be completed. The heavy lift vessel must complete the blocking build (see Section 8-6) and any preparatory efforts. These may be completed at the actual load site or at another facility. The Heavy Lift Project Team must inspect all work to ensure compliance with the Transport Manual.

For the identified onload site, the heavy lift contractor shall identify the maximum environmental limits to include wind, wave, swell, current and visibility. If any of the environmental limits are exceeded or are forecasted to be exceed during the operational window, then the operation should be postponed. An alternative location may also be identified as back-up. Based on the location, the effects of passing traffic may need to be accounted for in the limits or operational planning.

8-3.5.1 **Visual Survey**

At the onload site (or preparation site), the blocking placement, arrangement, and build on the heavy lift vessel's deck are inspected to ensure compliance with the drawings referenced or included in the Transport Manual. The materials used to build the blocks should be in serviceable condition. Any blocks with rotted wood shall be replaced by the contractor. At a minimum, a visual survey of the heavy lift vessel and its systems must be conducted, including the ballast/deballast system. This survey must be completed satisfactorily before the heavy lift vessel is accepted (described in Section 8-9.2). A survey of the asset(s) must also be conducted. The survey should include an inspection of the asset's floating condition including drafts, trim, and list. An internal survey to document the asset's loading including a final liquid load report and any onboard weights should also be completed.

A complete checklist for both the heavy lift vessel and the asset is included in Appendix R.

8-3.5.2 **Support Tugs/Divers**

Support tugs and divers may be used to assist in the positioning of the assets over the blocks. It is important to keep in mind that the onloading area will likely not be as well sheltered as a dry dock. Therefore, when selecting the number and size of tugs, assume the maximum allowable condition for safe onload of asset(s). Tugs should be of sufficient size to hold the asset(s) within the environmental limits for the operation's onload location. If multiple tugs are used, it is important to keep lines of communication clear. Before the operation one person should be designated, usually the harbor pilot or Loadmaster, to direct the positioning and operation of all tugs.

Divers shall be used to check the final alignment of the assets on the blocks. During diver checks there is increased risk for divers since the operation is taking place in open water vice in a dry dock. Blocking heights are generally minimized, allowing little clearance between the asset and the cargo deck. Appropriate safety measures must be taken and only divers with experience in checking docking blocks should be used.

WARNING
All parties must be informed when divers are being used, and clear communications signals must be used when they are in the water. Extreme caution must be used to ensure the safety of these individuals. No deballasting or other ship movements should occur while divers are working in the vicinity of the asset. Consideration should be given to securing sea suctions in the area divers are working.

Tug masters and divers shall be briefed about the operation and be present at the pre-load conference. Divers shall be thoroughly briefed on the blocking arrangements, build and marking to include a walk around of the blocking build before submerging the cargo deck.

8-3.6 Preparing the Asset

An asset must be specially prepared to be lifted and transported. Many preparations are similar to preparations for a long deployment, docking, tow, or other special event. However, as a vessel on a heavy lift ship will experience substantially higher accelerations than in normal operation special attention must be paid to adequately securing all potential lose items and equipment. Appendix R provides a thorough list of all items that should be checked before arrival at the onload site, which must be completed and signed off by the HLPO.

The preparing activity should ensure that the asset has complete watertight integrity. It is unnecessary to go through the rigors of preparing a vessel for tow (locking propellers, double-valve protection, etc.), but every effort should be made to make the hull as watertight as possible, especially when longer tows may be expected to the on-load site. Ship's force should accomplish all of these items as early as practicable, leaving only essential tasks until the day of onload:

- Condition Zebra shall be set throughout the ship.
- All compartments and bilges should be free from oil and water.
- All sea valves shall be secured and tagged out following normal tag out procedures. This may need to be done while the vessel is being lifted or shortly after float-on. If connections from the heavy lift vessel are to be used for items like cooling water, these valves should not be secured until the connection is made. A list of sea valves should be prepared and made available to watchstanders and the Heavy Lift Project Team.
- All sounding tubes shall be capped. A list of sounding tubes and their condition shall be prepared and made available to watchstanders.
- All between tank sluice valves shall be closed.
- All watertight boundaries shall be sealed. Gaskets exhibiting signs of wear or deterioration must be replaced with new gaskets.
- Rudders shall be secured against any vessel motions. This may be accomplished after the asset has landed firmly on the blocks or before this if no steering is required for docking.
- All loose equipment shall be secured.
- If necessary, to ensure proper clearance propellers will be placed in docking position.
- If necessary, propellers may need to be removed altogether to ensure adequate clearance or tolerable block loading.

8-3.6.1 **Arrival Conditions**

When the asset is delivered to the on-load site, it should be in the condition (loading, drafts, trim, list, etc.) in which it will be transported. If multiple assets are being transported, they should be in a similar condition of draft, trim, and list. The assets should arrive early enough to allow for inspection by the Heavy Lift Project Team, the IMS, and the Loadmaster.

The trim should be less than one foot, and the list should be less than 0.25 degrees. It may not be possible to bring the asset into proper trim and list by simply adjusting tank levels. All tanks should be topped off or emptied to minimize the free surface effect. The final configuration and details of loading shall be completed and made available as early as possible, preferably at the pre-load conference. This will ensure adequate time to prepare the vessel and plan the heavy lift.

Weights may be added to help achieve the right configuration. If weights are placed on the asset to adjust draft, trim, or list, the asset’s structural adequacy to support the weights during the transport shall be considered. It must also be considered that the facilities at the offload site may preclude removal of the weights. The HLDO shall be notified when adding weights as they may affect the blocking build. Assets of the same design positioned alongside one another and in the same longitudinal orientation should be at a similar draft and trim.

8-3.6.2 **Transport of Damaged Vessels**

The transportation of a damaged asset requires careful assessment. Stability must be assured but trim and list more than those values indicated above may be accommodated by adjusting the heavy lift vessel’s draft, trim, list, or freeboard. For example, USS Cole (DDG 67) was lifted with 4 feet of trim by the bow and 1½ degree list to starboard. This condition was the maximum that the heavy lift vessel could accommodate by the freeboard on the aft starboard caisson.

8-4 On-loading Operations

This section will discuss the operations at the on-load site. Note that many heavy lift vessels require deep water to operate, which may preclude these vessels from performing FLO/FLO operations in protected waters. All preparations must be completed before the day of the onload. Favorable weather windows may be small, and unnecessary delays may jeopardize the operational safety or cause immense cost increases.

8-4.1 Positioning of the Asset(s)

When the heavy lift vessel is in position and ballasted to the proper draft, the Loadmaster will assume control of the asset(s) for final positioning. The exact point of turnover must be decided and agreed upon by all parties during the pre-load conference. Good communications between the heavy lift vessel/crews, supporting tugs, and riding crew must be established to ensure all operations proceed smoothly. Often, alignment columns (guideposts) will be constructed to assist in the athwartships alignment of the asset(s) (Figure 8-4). Sufficient fendering or other systems must be employed on the alignment columns to prevent damage to the asset. Use of alignment columns will depend on the number and size of the assets being lifted. Support tugs and lines will position the asset(s) over the blocks and against the alignment columns or other guide mechanisms if used for the operation. The Loadmaster will verify both fore and aft position. Divers may also be used to verify positions (see Section 8-3.5.2).

NOTE
When using alignment columns, the heavy lift contractor must account for tumblehome hulls in which the portion of the hull resting on the alignment column is below the main deck.

NOTE
To aid in the positioning of the vessel on the blocks, a brightly colored line painted on the center of the keel blocks wider than the vessel's keel line can aid the divers in verifying the vessel's position on the blocks.

Care should be taken to ensure that there is sufficient clearance for all underwater projections such as sonars, propellers, bilge keels, and pit swords. During positioning, a minimum of 1 foot of all-around clearance should be maintained between the blocks (both keel and side) and the asset (including underwater projections). This minimum clearance is to provide for relative motion between the ships, so, if deviations greater than 1 foot may be anticipated, more clearance must be accounted for. Protrusions from the heavy lift ship must also be considered, if present. Features such as ramp sills, fish plates, exposed piping or vents, or other projections, are all subject to the 1 foot clearance requirement. The 1 foot clearance requirement between the asset and the heavy lift ship is a minimum clearance requirement and may require upward adjustment depending upon load site conditions. Every effort to maximize clearance should be taken if practical.

When planning Float-On / Float-Off (FLO/FLO) operations, a minimum clearance of 3 feet is required in both athwart and longitudinal directions. This requirement is to be applied to any vertical structure on the heavy lift transport vessel such as wing walls, superstructure, ballast/stabilizing tanks, or other large structures that extend above the load deck. Additionally, in the case of multiple ship lifts, the 3 foot clearance is also to be applied between the individual vessels being lifted.

Any departures from these clearance requirements require SEA 00C approval prior to final plans and implementation.

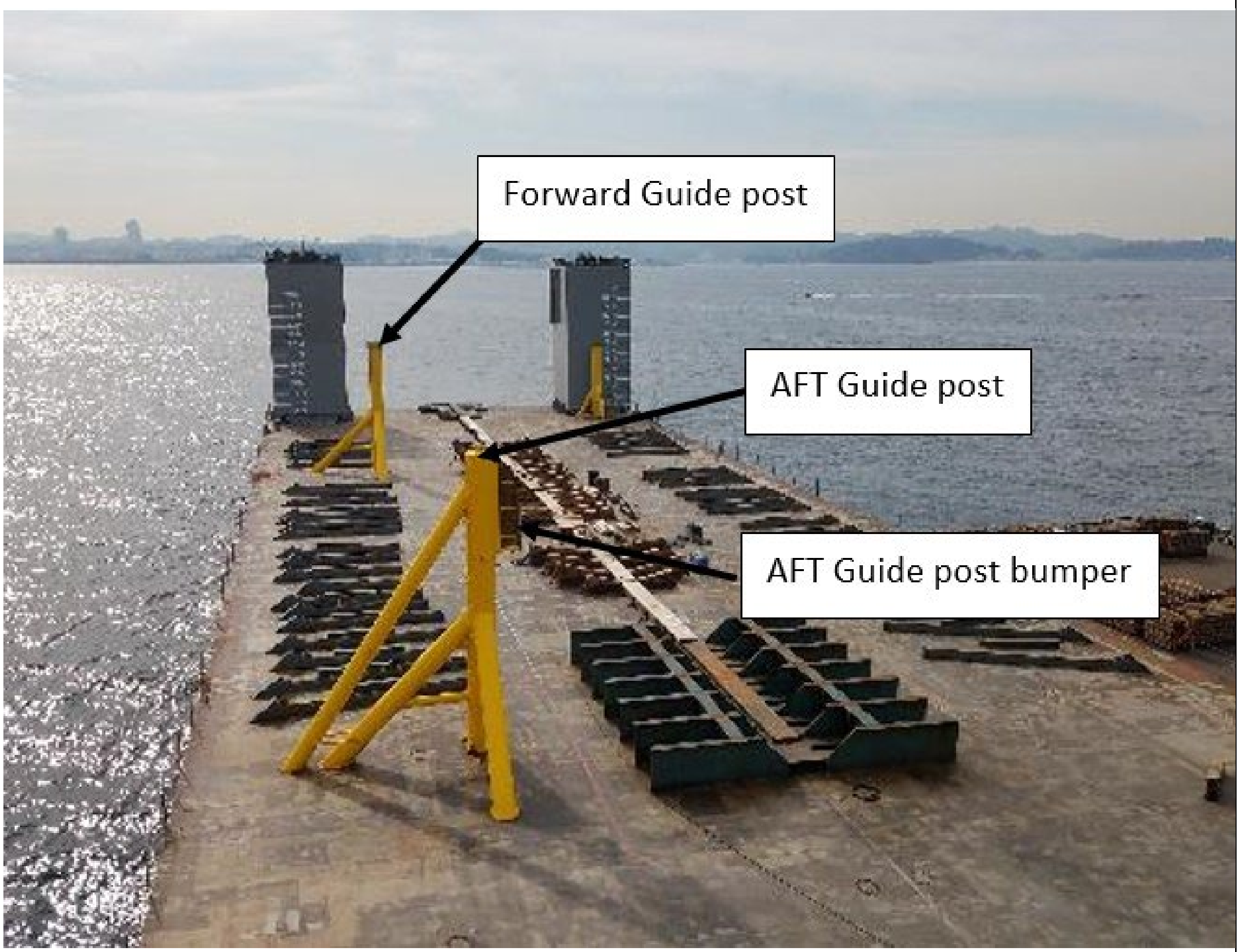


Figure 8-4. Onload Block Build with Guideposts highlighted

8-4.1 Fendering

Support tugs and alignment columns may be used to assist in positioning the asset(s) over the pre-built blocking arrangement. The riding crew should be prepared to provide fendering from the asset if insufficient fendering exists elsewhere. These fenders should be tended and moved as appropriate throughout the deballasting operation until the vessel comes to its final resting position. 4 feet x 4 feet sheets of plywood may prove to be useful fender material to prevent damage as the asset is moved into its final position.

8-4.2 Riding Crew Accommodations during Loading

A riding crew is required on board each asset for handling lines and tending hand fenders during onloading and offloading. This operation may require extended worktime but the riding crew size should be kept to a minimum. Since the asset may be in a reduced operating status and have no power during on-loading, sanitary facilities, and if necessary, box meals should be provided for all personnel aboard the asset during the procedure.

8-4.3 Deballasting

Once the asset(s) is positioned to the Loadmaster's satisfaction, the heavy lift vessel will begin deballasting procedures and the asset(s) should be observed carefully for any abnormal motion or any indications of damage or stress. The Heavy Lift Project Team shall have members positioned strategically to observe the asset(s) movement into the final position, landing and final deballasting. The Heavy Lift Project Team shall be cognizant of all key points of the deballasting operation (i.e. hold point for diver alignment check, draft at landing, draft at instability, etc.) to ensure that the deballasting process is progressing as planned. The Heavy Lift Project Team will notify the Load Master and IMS of deviations that could cause safety issues and call a halt to the deballasting process, if necessary, to discuss and correct the deviation. The riding crew shall tend the fenders to ensure that no damage occurs to the asset(s). See Section 8-5.2.2 for more information concerning stability during this critical phase.

8-4.4 Connection of Services

CAUTION
Hook-up of critical services, such as firefighting, should be given priority over other connections. Firefighting services must be available throughout the process. Care shall be taken to ensure that the asset is electrically grounded before its hull comes entirely out of the water.

CAUTION
Once the asset is lifted, overboard discharges from the asset should be avoided, if this is not possible, they must be routed via a scupper over the side of the heavy lift vessel.

CAUTION
When a U.S. Navy ship is the asset on board the heavy lift vessel, a U.S. Navy manned security watch shall be established at the gangway of the heavy lift vessel once pierside.

During the transit, the asset(s) may depend on the heavy lift vessel for all necessary services. Connection of these services should not begin until the asset is in position and the heavy lift vessel starts deballasting. In planned operations, it is common for the riding crew to live aboard the heavy lift vessel. However, certain services for the safety and security of the asset(s) should be made available, even if no one is aboard the asset(s) during the transit.

Firefighting and cooling water services should be connected as soon as possible after the asset is secured and in position. These connections must be completed before their respective sea suctions emerge from the water. The asset must be electrically grounded to the heavy lift vessel prior to fully emerging form the water. Special attention should be paid to the physical connection points between the heavy lift vessel and asset(s) to ensure compatibility. Power cables and firefighting hoses should be pre-staged for use when required.

NOTE
Available commercial maritime industry connections and systems for power and fire main may be different from U.S. Navy shipboard equipment and systems.

Additional services may be required if the riding crew remains aboard the asset during the transit. These extra services should be considered a secondary priority compared to deballasting. If a problem occurs with one of these non-critical service connections, deballasting should continue without delay.

A temporary means of access to, and egress from, the asset should be provided as soon as possible after the heavy lift vessel's cargo deck is dry. Primary, all-weather access may be provided later, but must be installed before departure.

After deballasting, the asset quarterdeck watch should be moved to the cargo deck, or other designated location, of the heavy lift vessel near the gangway. The asset may be expecting technical representatives or other visitors who must be directed to the safest means of access/egress. Because these operations are unique and interesting, visitors not directly involved in the evolution may be present; safety and security considerations should be planned and implemented for any visitors. In general, visitors not involved in the operation should be minimized. Any visitors required to be present during the onload should be directed to designated locations that do not interfere with personnel responsible for various aspects of the operation.

8-4.5 Blocking and Seafastening Installation

CAUTION
Welding and industrial facility safety precautions must be followed closely during blocking and seafastening operations, including all personnel wearing the appropriate personal protective gear.

CAUTION
Nonessential personnel must be restricted from the heavy lift vessel deck during work periods associated with seafastening, and those monitoring work shall wear appropriate personal protective gear.

Once the heavy lift vessel is deballasted, additional blocking, shoring, and seafastener installations should begin. Depending upon the number and size of the asset(s), and the complexity of blocking and seafastening necessary to accommodate the shape of each hull form, these operations may require several days of around-the-clock operations. A Heavy Lift Project Team representative, normally the HLDO or Blocking Expert, should be present to inspect these operations in coordination with contractor personnel at all times. Personnel not associated with the blocking and seafastening installation should avoid the area as much as possible because of the extensive amount of industrial activity on the cargo deck. All personnel working in or traversing the areas where blocking and seafastening installations are being made should exercise caution to avoid injury from welding, cutting, overhead lifting and/or movement of heavy equipment. Hard hats, steel toe boots and eye protection are the minimum personal protective equipment to be worn and other personal protective equipment may be required based on the nature of the hazardous work areas. Designated access routes should be created to minimize any interference from traffic. Overboard discharges from the asset(s) should be secured, if possible, or re-directed during the seafastening procedures.

8-4.6 Heavy Lift Calculations

Heavy lift calculations must be accomplished to ensure that the blocking and seafastening designs can withstand all static and dynamic loading that is expected during the onload and along the route of transit, as well as, to anticipate expected conditions during the operation, such as draft of the asset when landing on the block build. The calculations are affected by numerous factors such as the size and design of the heavy lift vessel, the specific asset or multiple assets to be lifted, any damage to the asset, and the planned sea voyage route. Because of the complexity factors, there is not a single set of calculations however there a generalized approach that can be applied to most FLO/FLO operations coupled with good engineering practices.

8-4.6.1 **Introduction to Example Heavy Lift Configurations**

Sections 8.5 – 8.7 outline the calculation approach and Appendix P provides worked calculation examples of four heavy lift configurations. The examples highlight how calculations can be adjusted to address unique heavy lift operational requirements and accommodate some of the factors above. These sections shall be the basis for planning a U.S Navy heavy lift operation.

NOTE
There is no substitute for sound engineering judgement. This chapter is intended to provide a basis to understand the process of safely conducting a heavy lift operation. Every heavy lift is going to have its own unique challenges that cannot be individually addressed in this manual.

8-4.6.2 **Configuration 1 – Standard Single Asset**

The first configuration is the standard heavy lift configuration. The following conditions define this configuration: the asset to be heavy lifted is undamaged; the asset to be lifted can be aligned both longitudinally and transversely with the heavy lift vessel's longitudinal and transverse axes within 5 degrees (this may mean the asset is not on centered on the heavy lift vessel); and there is only one asset to be heavy lifted by the same heavy lift vessel.

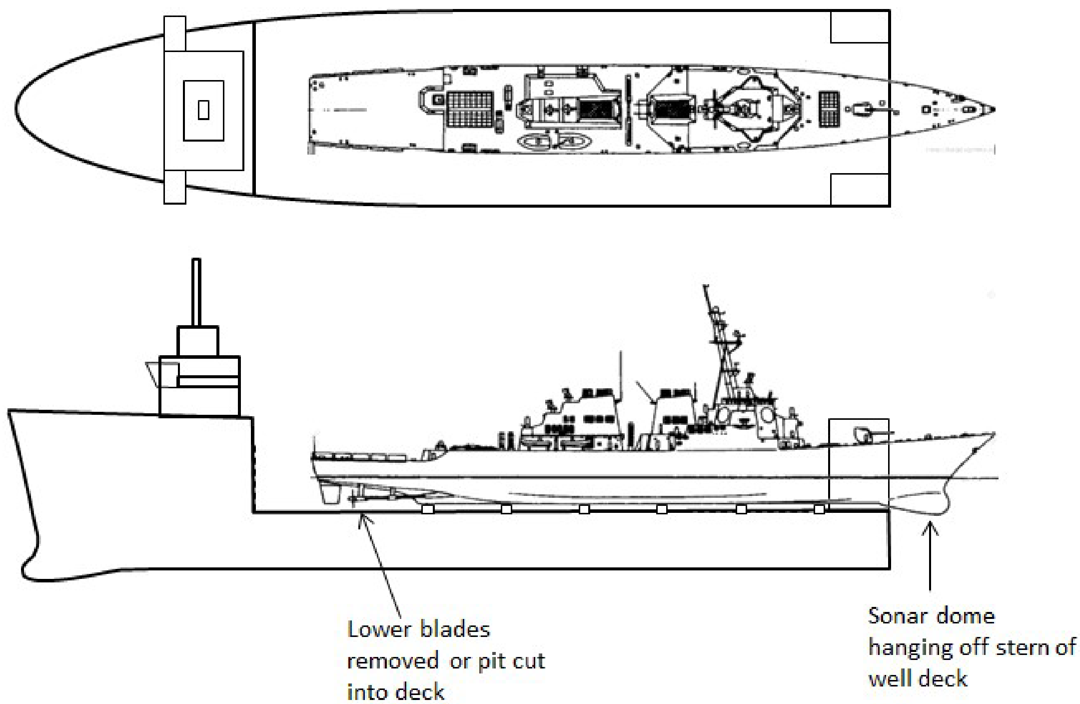


Figure 8-5. USS Fitzgerald (DDG 62) Alignment on M/V Transhelf

Figure 8-5 shows the alignment of the USS Fitzgerald (DDG 62) on the M/V Transhelf heavy lift vessel. For the example calculations in Appendix Q, it is assumed that DDG 62 is undamaged and the unmodified docking drawing was used to develop the onload blocking plan. Since DDG 62 is aligned longitudinally and transversely with M/V Transhelf, the heavy lift vessel's motions will translate directly to DDG 62 (i.e., pitch, roll, and yaw will be identical for both vessels). In this example the asset is centered on the heavy lift vessel and subsequent configurations provide examples of deviations from this standard configuration.

NOTE
Undamaged is defined as any patched damage to the asset that prevents water from entering or discharging from the patched areas. This will prevent any significant change in displacement, change in the center of gravity, or changes in calculated drafts at instability and landing.

8-4.6.3 **Configuration 2 – Multiple Assets**

The second configuration as shown in Figure 8-6 with three patrol craft loaded on a heavy lift vessel is similar to the first configuration with the added complexity of multiple assets for transport on a single heavy lift vessel. Like the first configuration the calculations are similar per asset with the main change being that keel block heights are different for each asset. Different keel block heights ensure the assets land on their respective block build one at a time rather that simultaneously. The varying keel block height will affect the both static and dynamic calculations for each asset.

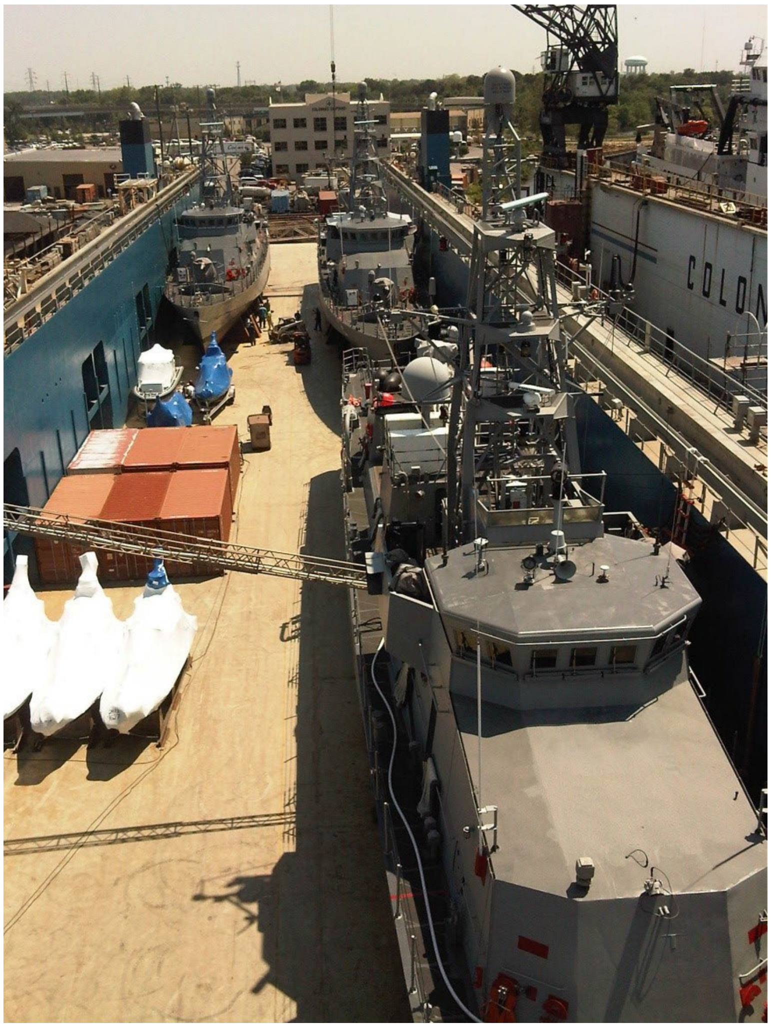


Figure 8-6. Three Patrol Craft loaded on M/V Eide Transporter

8-4.6.4 **Configuration 3 – Canted Asset**

The third configuration in Appendix P is when the asset is canted more than 5 degrees with respect to the heavy lift vessel. In this example calculation it was assumed that the asset was undamaged but does not line up longitudinally and transversely with the heavy lift vessel.

NOTE
Undamaged is defined as any patched damage to the asset that prevents water from entering or discharging from the patched areas. This will prevent any significant change in displacement, change in the center of gravity, or changes in calculated drafts at instability and landing.

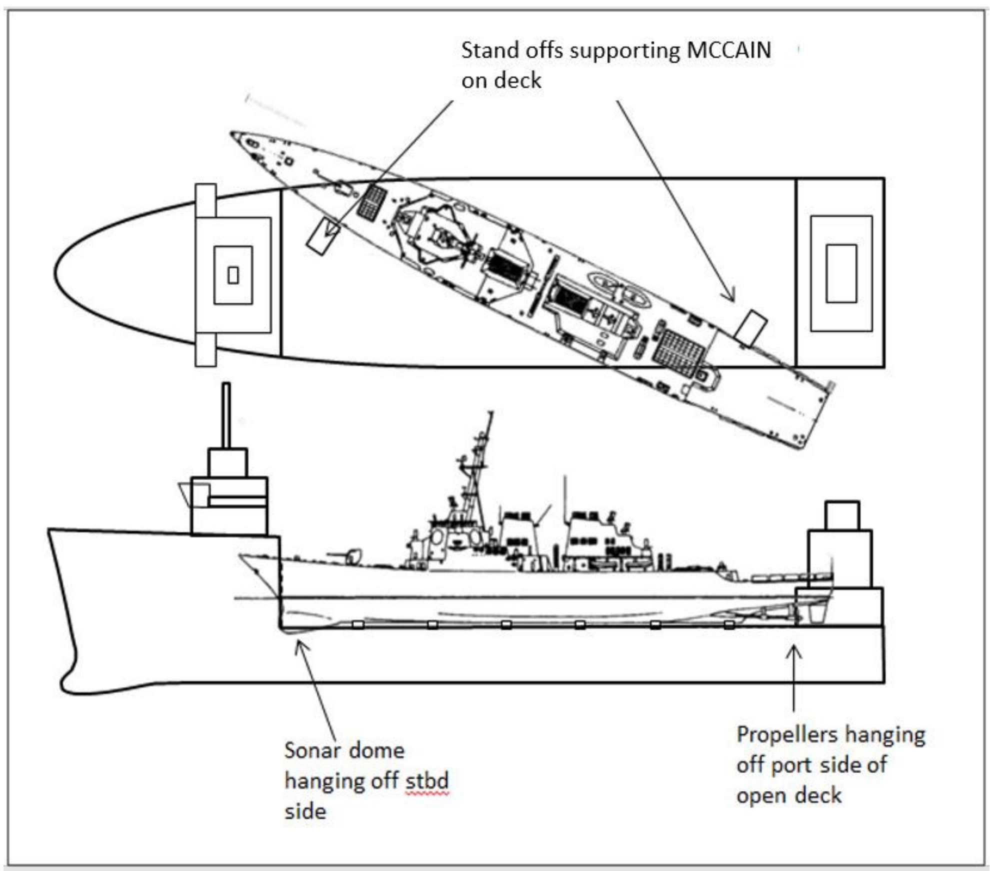


Figure 8-7. USS John S. McCain (DDG 56) alignment on the M/V Treasure

Figure 8-7 shows USS John S. McCain (DDG 56) onload configuration with the heavy lift vessel M/V Treasure. The key difference between this configuration and the standard configuration shown first is the angle of the asset which prevents the heavy lift vessel's motion from direct translation to the asset's motion. The roll component of the heavy lift vessel will translate to both a pitch and roll components for the asset. Likewise, the pitch component will translate to both a pitch and roll components for the asset. If the canted angle is greater than 5 degrees, then the differences in the roll and pitch between the heavy lift vessel and the asset will be significant and must be considered when designing the blocking and sea fastening.

8-4.6.5 **Configuration 4 – Damaged Asset**

The fourth configuration is when the asset is damaged and will not be repaired or patched before FLO/FLO operations. This configuration is the most complex because the docking drawing for developing the onload block build will need modification to account for the damaged area that is open to the sea. Due to the free movement of sea water in and out of the damaged section, this is likely to cause a dynamic change in the asset's weight and stability characteristics which must be accounted for in the onload planning.

Figure 8-8. Bomb-damaged USS Cole (DDG 67) being towed to onload location

Figure 8-8 and Figure 8-9 shows the bomb-damaged USS Cole (DDG 67) with an unpatched area on the port side of the hull extending below the waterline. During the onload a significant amount of water discharged back into the sea causing changes in the displacement and center of gravity. Multiple before and after discharge calculations were completed to ensure stability would be maintained throughout the onload and in support of the offload as water re-entered the damaged section.

Figure 8-9. ***Bomb-damaged USS Cole (DDG 67) loaded onto Blue Marlin***

8-4.6.6 **Software Tools (POSSE)**

The software platform *Program of Ship Salvage Engineering (POSSE)* was enhanced to serve as an analysis tool, providing functionality for evaluating a heavy lift operation. Static conditions such as hydrostatics, stability, weight distribution, and strength properties of both the heavy lift vessel and the asset can be evaluated for all phases of the heavy lift operation. The interaction of the two ships during the lift can also be analyzed including loads on individual blocks and seafastenings as well as the resultant forces and stresses applied to both ships. This includes the application of accelerations in all six degrees of freedom to the combined two-ship unit. This tool can be used to ensure that adequate stability is maintained throughout the lift and stresses applied to the two ships and the blocks are kept within prescribed limits. While POSSE is a powerful salvage analysis tool, its use as a specific heavy lift analysis tool is under development. **The Heavy Lift Docking Observer shall verify all calculations and stability analysis using the methods outlined in Chapter 8, Appendix P and Appendix Q of the U.S. Navy Tow Manual.**

8-5 Seakeeping and Stability

This section discusses some of the concerns associated with the stability of the asset, the heavy lift vessel, the combination of the two during ballast/deballast operations, and when the asset is secured to the heavy lift vessel deck. Some calculations are presented to describe the physical situation adequately; however, a qualified stability expert is required to complete the necessary stability analysis and ensure the safety of all vessels involved.

CAUTION
If in doubt, consult a qualified Naval architect

During a FLO/FLO operation, several distinct stability considerations must be addressed:

- Stability of the asset
- Stability of the heavy lift vessel
- Stability of the asset/heavy lift vessel as a combined system during the ballast/deballast operation
- Stability of the heavy lift vessel with the asset secured aboard during transit

The various phases of stability are depicted in Figure Figure 8-10 starting with phase 1 with the heavy lift vessel ballasted down and the asset positioned over the blockbuild. Before reaching phase 2 the divers (if using) should swim the blocks to check alignment and verify clearance with any hull protrusions. Phase 2 and phase 3 include landing the asset and starting to deballast the heavy lift vessel to bring the cargo deck out of the water, during this time the asset will pass through its 'draft at instability' which is the most critical point in the operation for the asset's stability (Section 8-5.2.3). As the heavy lift's cargo deck clears the water in phase 4 it passes through its most critical point for stability in the operation until the cargo deck is clear of water. The final phase is when the heavy lift vessel is at its transit draft, the asset is secured for sea, and both are ready for departure.

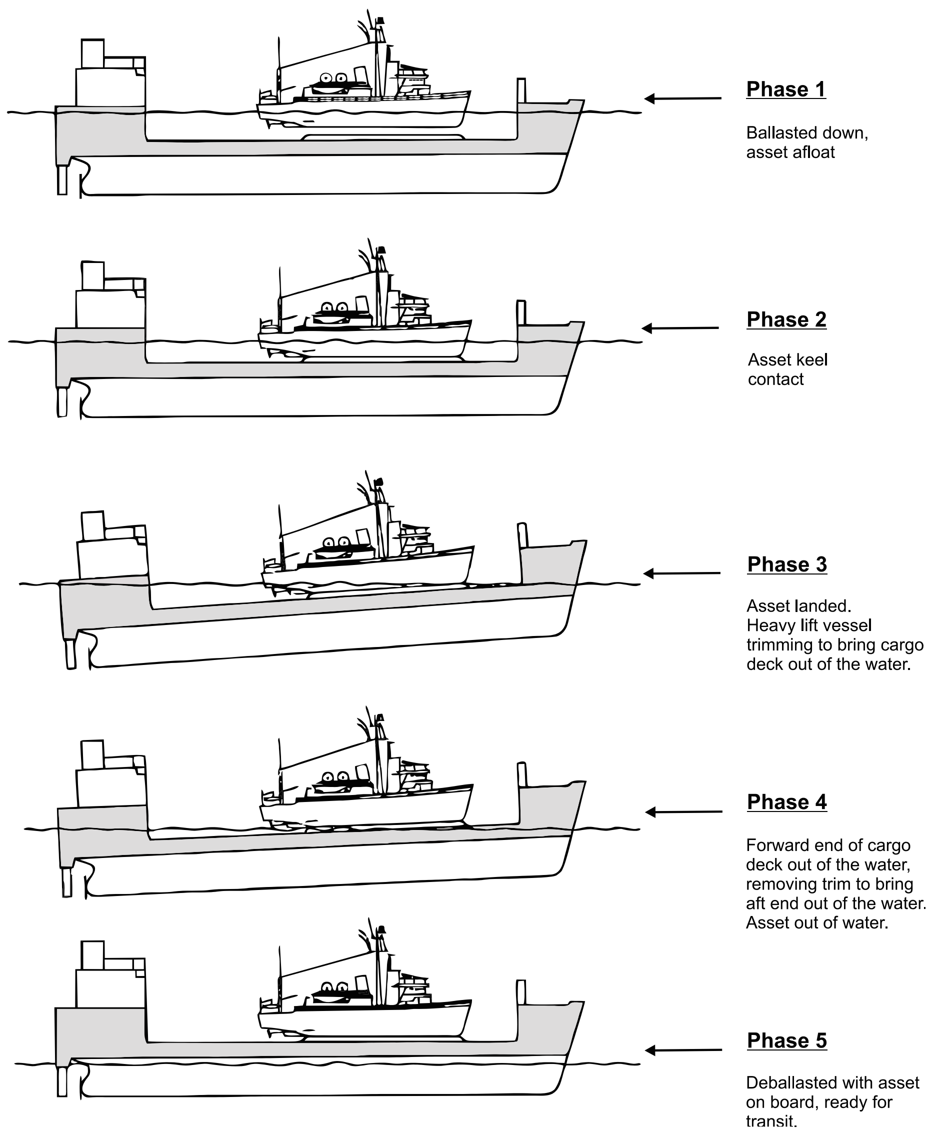


Figure 8-10. Phases of Stability.

8-5.1 Ship Motions

CAUTION
All personnel must strictly adhere to the operational plan and safety guidelines.

A FLO/FLO onload can be a very dynamic operation. Each asset and the heavy lift vessel move independently when the asset(s) are positioned on the heavy lift vessel's cargo deck. This difficult situation is further complicated if the operation takes place in unprotected waters or the open ocean. Once the asset(s) are on the cargo deck, they act as one, similar to an asset docking or undocking in a floating dry dock. The dry dock, however, is in protected waters and not normally moved. In a normal dry-docking evolution, little is done to secure the asset (internally or within the dry dock) except to provide blocking for an earthquake or hurricane-force winds. When preparing for a heavy lift transport, the asset(s) must be made fit for sea (secured internally) and then secured aboard the heavy lift vessel's cargo deck for transit using blocking and seafastening. The intent is to hold the asset in position on the cargo deck and cradle the asset to keep it from sliding, either transversely, longitudinally, or rolling over.

As the heavy lift vessel proceeds through the seas, it will flex (hog and sag). If the asset is rigidly tied down on the heavy lift vessel, this flexing will be imparted to the asset and may cause structural damage to either or both the asset and heavy lift vessel. Therefore, it is necessary to design a strong enough to resist the vessel's motions, yet flexible enough not to cause damage to the asset or heavy lift vessel. Understanding of the dynamics of the heavy lift vessel and the asset(s) is necessary to create such a structure. Methods and considerations used to analyze the effects of ship motions are covered in Sections 8-6 and 8-7.

8-5.1.1 **Wind Heel Criteria**

WARNING
Onloading and offloading shall not be conducted in winds above 20 knots or in a sea condition of sea state 3 or higher.

FLO/FLO operations are best conducted in sheltered waters; however, currents or channel depths may make this impossible. Wherever the operation is conducted, the dominant weather patterns should be studied and accounted for in calculations. Stability calculations for onload and offload should use a minimum wind of 60 knots with a gust factor of 1.21.

Weather routing during transit requires a separate analysis and information concerning expected sea states and winds should be acquired for planning purposes. If no data is available the commercial standard of 86.8 knots (100 mph) shall be used. **In no case shall a wind of less than 60 knots be used.**

8-5.2 Stability of the Asset

The asset must meet stability requirements for all potential environments of the FLO/FLO evolution. Four different environments should be examined; on-loading, offloading, transit, and any transitional periods (i.e., towing the asset from on-loading site to block building and seafastening site). Transitional periods may occur when the heavy lift vessel transits immediately after on-load to another location for seafastening activities.

In the case of an unmodified or undamaged U.S. Navy commissioned ship, the stability of the asset can be determined by reviewing the data in Chapter II(a) of the ship's Damage Control Book and a recent Inclining Experiment Report. Contact the Naval Architecture or Stability/Weight codes at the Planning Yard for reports/updated stability information due to alterations to the ship since the last inclining experiment. Similar information for commercial ships should be available in the ship's Trim and Stability Booklet and the Deadweight Survey. Ships from other services (U.S. Coast Guard, U.S. Army, etc.) should also have a consolidated source for this information. These documents will provide a good source of information for planning purposes and contain specific measures to improve stability. These books also contain stability characteristics for various loading conditions that meet the U.S. Navy's stability criteria.

For small craft and barges that do not have Damage Control Books, follow these general guidelines when attempting to improve stability:

- Completely fill any slack tanks to reduce the free surface effect
- Lower and secure or off-load high weights
- Secure any large hanging weights and add ballast
- Ballast by completely filling low tanks

Completely filling tanks or adding ballast will decrease freeboard but will generally improve stability.

Do not shift, add, or remove any weight from the asset, including liquids such as fuel or water, once certified and ready to be loaded, and when it is on the heavy lift vessel, unless authorized by the Loadmaster. When permission is given to shift weights, an accurate record of the amount and location of the weight change must be kept. Maintain a weight log to account for weight changes to enable accurate calculations which will ensure the asset lifts from the blocks without losing stability or taking an undue list or trim.

In the event of significant flooding due to damage, the condition of the asset must be the same for both onload and offload. If the damage was patched and the asset onloaded with flood water, then the asset must be offloaded with the same amount of flood water to ensure a safe offload. If this is not possible calculations shall be completed to ensure acceptable draft at instability, draft at landing, proper clearances, and acceptable trim (less than one foot) and list (less than 0.25 degrees) throughout the offload.

8-5.2.1 **Stability Afloat**

An assessment of the asset's stability should be performed before starting the FLO/FLO process to use in heavy lift calculations. This includes draft readings, tank soundings, and determination of the displacement (weight) and center of gravity. However, such a detailed analysis may not be possible if wartime or emergency conditions mandate quick action. Regardless of the circumstances, the best available information should be used to estimate of the asset's stability.

If there is no stability data for the asset, the stability may be roughly estimated by timing the its roll period. This method is further explained in Section 8-5.2.3 and Table 8-8.

CAUTION
Roll periods are not used as a substitute for thorough stability analysis and weight determination. It only provides an estimate of a asset's stability and is only used to check stability in emergent conditions.

CAUTION
Equally important is frequent verification that the asset's roll period has not changed. Even if overall criteria are satisfactory, any significant time increase in the period of roll should be promptly investigated, since this suggests flooding or additional free surface effect.

8-5.2.2 **Stability during On-loading**

The condition of the asset for onloading should be made available to all parties so it can be evaluated and the heavy lift vessel can make final preparations. All assets of the same design that are to be loaded in fore and aft orientation should arrive in a similar condition of list (no more than 0.25 degrees), trim (no more than one foot) and draft. It may not be possible to meet these limits with damaged assets.

The heavy lift vessel can adjust trim and list to match that of the asset, although additional considerations may limit the trim and draft of some vessels.

- When deballasting the heavy lift vessel, consideration must be given to knuckle loading on the forward or after most blocks.
- Channel drafts may preclude excessive trim angles by the heavy lift vessel.
- Freeboard requirements and limiting submerged draft may preclude excessive trim angles.
- During ballast/deballast operations, the trim of the heavy lift vessel must be limited so that the asset does not float off or slide on the blocking.

NOTE
The heavy lift vessel must remain at least one meter above the seabed when fully ballasted.

The deballasting operation will put the asset in an unusual stability condition. The docking block's reaction on the asset is equivalent to removing weight from the asset's keel. This weight removal will effectively raise the asset's center of gravity and reduce its metacentric height (GM), and thus reduce its stability (Figure 8-7). As more water is removed from the heavy lift vessel, the asset will be raised further out of the water, the reaction on the docking blocks will increase, and the reduction in stability will be increased. The amount of reaction from the docking blocks is equal to the difference between the asset's floating displacement and the displacement at the waterline under consideration in the landed condition. Eventually, the block's reaction will be large enough to cause the center of gravity to rise to a point where the GM, and thereby the stability, is zero. This is a hazardous, and the asset will almost surely capsize unless side blocks are in place. The asset's draft at this condition is called the "draft-at-instability."

Another way of explaining the effect on stability when an asset is lifted from the water is the buoyancy moment is reduced yet the gravitational moment stays constant. Once the draft at instability is reached, the buoyancy moment is insufficient to counter the gravitational moment, and the vessel will topple without side blocks as illustrated in Figure 8-11.

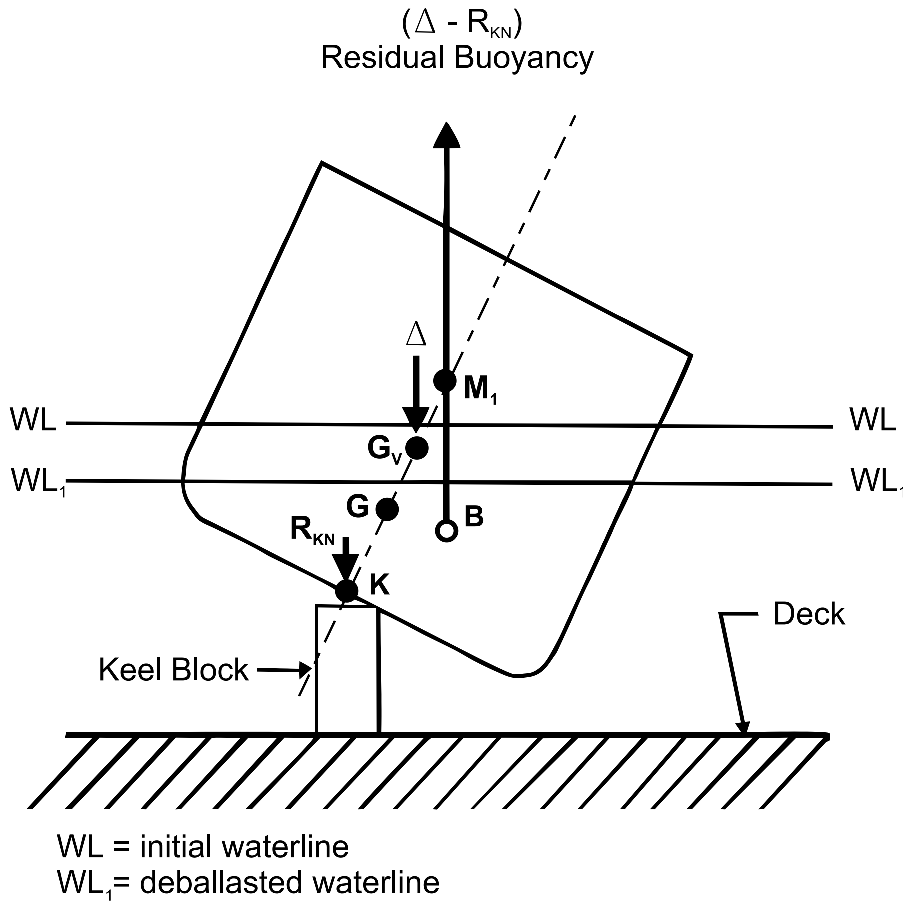


Figure 8-11. Draft at Instability.

The asset must land firmly on the keel (fore and aft) and side blocks before this point is reached. It is necessary to calculate both the draft-at-instability and the draft-at-landing fore and aft to ensure that the vessel will not capsize during deballasting. These calculations should be provided by the heavy lift contractor in the Transport Manual. There shall be a minimum of one foot of difference between the draft-at-instability and the draft-at-landing fore and aft.

If the draft-at-landing is greater than one foot difference from draft-at-instability, the asset is expected to have acceptable stability and on-load safely. For example, if the asset has a draft-at-instability of 13 feet and a draft-at-landing of 15 feet, the asset should remain stable until it lands on the side blocks, in calm water. Additional consideration must be given to the local sea state conditions. For example, if the weather criteria to perform this operation allows for the asset to pitch such that it may lift off the blocks after the initial landing, a difference between draft-at-landing and draft-at-instability of one foot may not be adequate for the asset to reland on the block build safely. If the draft values cannot be changed, the minimal difference may dictate reduced operational weather criteria to minimize asset pitch during on-load.

8-5.2.3 **Draft-at-Instability**

A good measure of a vessel's initial stability is the vessel's metacentric height (GM). It measures the ship's ability to recover from disturbances that cause small angles of heel. If GM is positive, the ship will be stable and return to its original heel angle when the disturbing force (wind, waves, etc.) is removed. If GM is negative, the vessel will be unstable. This means that if the vessel is disturbed, it will not recover and will continue to roll in the direction that it moved at the disturbing force's onset and likely capsize.

GM can be determined from known or predictable quantities, KM and KG. The metacenter (M) for a ship is the theoretical point around which a ship rolls and through which buoyancy acts for small heel angles. This point is based on a ship's geometry. The height of the metacenter (KM) is generally plotted on a ship's draft diagram or curves of form. A ship's vertical center of gravity (G) is the point that represents the centroid of all the weights of a ship. The height of the center of gravity (KG) is derived from the asset's current condition of loading. Both of these quantities are measured from the keel and can be determined with some degree of certainty. GM is simply the distance between these two points or:

$$GM = KM - KG$$

As stated previously, a positive value for GM is required for the ship to be stable. By looking at this equation, KM must be greater than KG to have a stable asset. As the heavy lift vessel deballasts, and the asset lands on the blocks, the asset's draft will begin to decrease. As draft goes down, the buoyant force on the asset (or residual buoyancy) will decrease and the height of the metacacenter will change. Simultaneously, the amount of the asset supported by the keel blocks (or reaction of the keel blocks) will increase.

The reaction of the keel blocks acts as weight removal at the asset's keel. This negative weight at the keel causes the same effect as an added weight high in the ship. Both will cause an increase in KG. Since the asset's weight did not actually change, this rise in KG is called a virtual rise. This virtual increase will effectively cause a reduction in GM and reduce the stability of the asset. As the draft continues to decrease, this effect will become more pronounced and the asset will become unstable. This point of instability occurs in every docking. The asset must land on the keel and side blocks before this point is reached or it may capsize.

To determine the draft-at-instability, it is necessary to determine the virtual reduction in metacentric height caused by the virtual rise in KG. The draft at which this virtual metacentric height (GM_v) equals zero, will be the draft where the asset is unstable. The virtual GM can be found by subtracting the virtual center of gravity (KG_v) from the height of the metacenter (KM) at the draft in question.

The virtual center of gravity can be found by using the weight moments of the asset:

$$(KG_o \cdot \Delta) - (R_{kn} \cdot 0) = KG_v(\Delta - R_{kn})$$

or:

$$KG_v = \frac{\Delta \cdot KG_o}{(\Delta - R_{kn})}$$

Where:

KGv	=	Virtual center of gravity (ft)
Δ	=	Ship's displacement (tons)
KGo	=	Afloat center of gravity (ft)
Rkn	=	Reaction at the keel blocks (tons)
(Δ - Rkn)	=	Residual buoyancy at a reduced draft (tons)

When the asset lands on the blocks and the draft begins to decrease, the asset is supported by two forces, the reaction of the keel blocks (Rkn) and buoyancy. The total of these two forces equals the displacement (weight) of the asset. In other words, the difference between the displacement and the reaction of the keel blocks is equal to the buoyancy at the reduced draft. This quantity (Δ - Rkn) is also called the residual buoyancy. The residual buoyancy can be determined for a given draft from the asset's curves of form or draft diagram. Knowing these values, the equation for GMv can be solved.

$$GM_v = KM - KG_v$$

$$GM_v = KM - \frac{\Delta \cdot KG_o}{(\Delta - R_{kn})}$$

Where:

GMv	=	Virtual metacentric height (ft)
KM	=	Height of the metacenter (ft) from ship's curves of form or draft diagram
KGv	=	Height of the virtual center of gravity (ft)
Δ	=	Ship's displacement (tons) from ship's curves of form or draft diagram
KGo	=	Afloat center of gravity (ft)
Rkn	=	Reaction at the keel blocks (tons)

NOTE
The term (Δ - Rkn) is the displacement at a reduced draft, i.e., the residual buoyancy after keel contact. This equation can be solved for several drafts until a draft is found where GMv equals zero

A shorter way to determine this value is to set the equation equal to zero and solve it graphically. By setting GMv equal to zero we see that:

$$0 = KM - \frac{(\Delta \cdot KG_o)}{(\Delta - R_{kn})}$$

or:

$$KM(\Delta - R_{kn}) = (\Delta \cdot KG_o)$$

Both KM and the residual buoyancy (Δ - R_{kn}) are found on the asset's curves of form or draft diagram. To solve this graphically:

- Determine a range of drafts, starting at the floating draft and decreasing in increments of one foot.
- For each draft, determine the asset's residual buoyancy and KM.
- For each draft, calculate the residual buoyancy moment $(KM(\Delta - R_{kn}))$.
- Calculate the displacement moment $(\Delta \cdot KG_o)$.

NOTE
This quantity is determined at the assets floating draft

- Plot the residual buoyancy moment and the displacement moment for the range of drafts.

NOTE
The displacement moment should be a vertical line

- Where these two curves intersect will be the draft-at-instability.

A sample of this graph is presented in Figure 8-8 and Appendix Q.

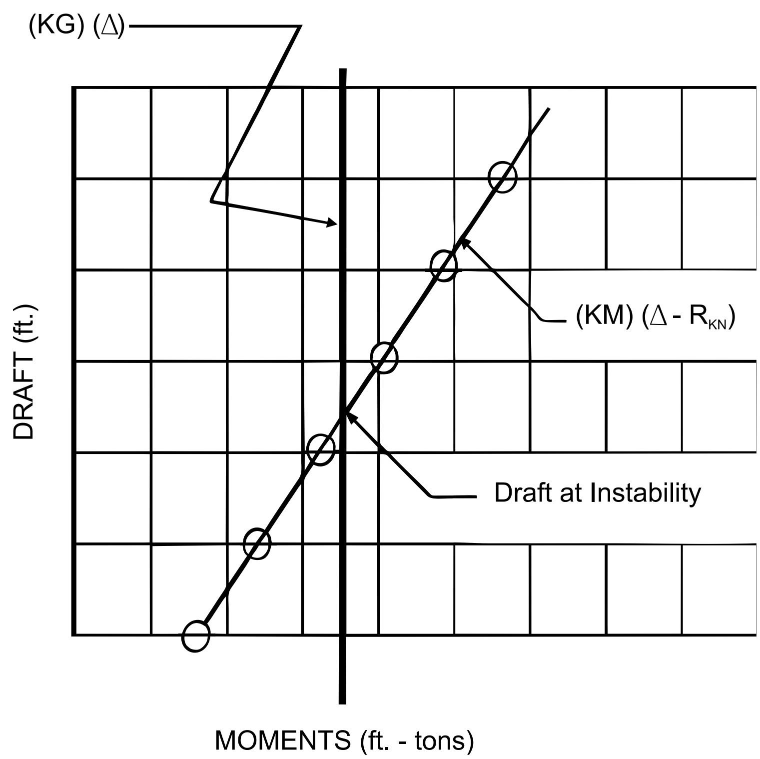


Figure 8-12. Limit of Stability.

If information is not known, such as during an emergency or rescue docking, an estimate of the asset's condition can be made. By measuring the asset's roll period (see Table 8-8.), an estimate of the GM and hence KG can be made using the formula:.

$$GM = \frac{C_c^2 \cdot B^2}{T^2}$$

Where:

GM	=	Metacentric height (ft)
C_c	=	A constant (sample values given in Table 8-5)
B	=	Beam of ship (ft)
T	=	Period of roll for complete cycle, from a maximum on one side to a maximum on the other and back (sec)

Thus, from the value of GM, KG may be obtained from the equation:

where:

KG	=	Height of the center of gravity of the ship above keel when waterborne (ft)

KM	=	Height of metacenter above the ship's keel (ft) from ship's curves of form.
GM	=	Metacentric height (ft)

NOTE
It is emphasized that the C_c value is only an approximation and enters the equation as the square of its value. The GM value obtained is, therefore, an approximation. This approximation method is not a substitute for thorough weight analysis.

When the asset lands on the blocks and the draft begins to decrease, the asset is supported by two forces, the reaction of the keel blocks (R_{kn}) and buoyancy. The total of these two forces equals the displacement (weight) of the asset. In other words, the difference between the displacement and the reaction of the keel blocks is equal to the buoyancy at the reduced draft. This quantity ($\Delta - R_{kn}$) is also called the residual buoyancy. The residual buoyancy can be determined for a given draft from the asset's curves of form or draft diagram. Knowing these values, the equation for GM_v can be solved.

$$GM_v = KM - KG_v$$

$$GM_v = KM - \Delta \cdot \frac{KG_o}{(\Delta - R_{kn})}$$

Where:

GM_V	=	Virtual metacentric height (ft)
KM	=	Height of the metacenter (ft) from ship's curves of afloat draft
KG_V	=	Height of the virtual center of gravity (ft)
Δ	=	Ship's displacement (tons) from ship's curves of afloat draft
KG_o	=	Afloat center of gravity (ft)
R_{kn}	=	Reaction at the keel blocks (tons)

Note: The term $(\Delta - R_{kn})$ is the displacement at a reduced draft, i.e. the residual buoyancy after keel contact. This equation can be solved for a number of drafts, until a draft is found where GM_V equals zero. A shorter way to determine this value is to set the equation equal to zero and solve graphically. By setting GM_V equal to zero we see that:

$$0 = KM - \frac{(\Delta \cdot KGo)}{\Delta - R_{kn}}$$

or:

$$KM \cdot (\Delta - R_{kn}) = \Delta \cdot KG_o$$

(Note: This quantity is determined at the assets floating draft and is not affected by the change in draft)

- Plot the residual buoyancy moment and the displacement moment for the range of drafts.

(Note: The displacement moment should be a vertical line)

- Where these two curves intersect will be the draft-at-instability.

A sample of this graph is presented in Figure 8-8. and in Appendix Q. If information is not known, such as during an emergency or rescue docking, an estimate of the vessel's condition can be made. By measuring the asset's roll period (see Table 8-8.), an estimate of the GM and hence KG can be made. Using the formula:

$$GM = \frac{{C_C}^2 B^2}{T^2}$$

where:

GM	=	metacentric height (ft)
C_c	=	a constant (sample values given in Table 8-5)
B	=	beam of ship (ft)
T	=	period of roll for complete cycle, from a maximum on one side to a maximum the other and back (sec)

Thus, from the value of GM, KG may be obtained from equation:

$$KG = KM - GM$$

where:

KG	=	height of center of gravity of ship above keel when waterborne (ft)
KM	=	height of metacenter above the ship's keel (ft)
GM	=	metacentric height (ft)

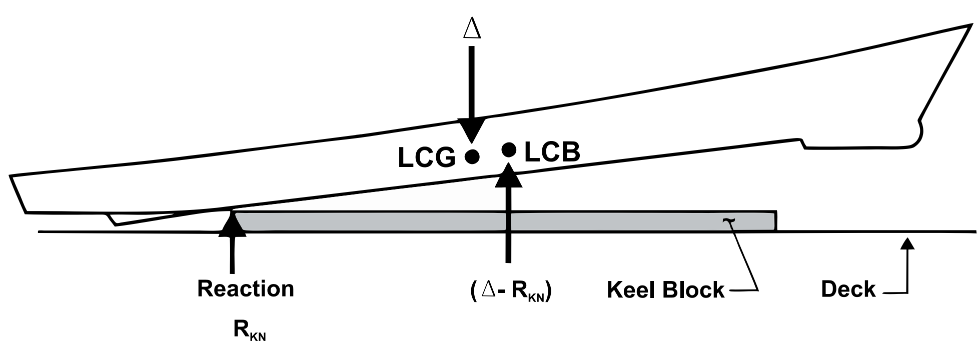
The value of KM is obtainable from the curves of form.

NOTE
It is emphasized that the Cc value is only an approximation and enters the equation as the square of its value. The GM value thus obtained is, therefore, an approximation. This approximation method should not be a substitute for a thorough weight analysis.

Table 8-5. Sample C_C Values	
Ship Types	**C_C**
Auxilliaries	0.44
Aircraft Carriers	0.58
Cruisers	0.43
DD692 (short hull)	0.42
Destroyers (other)	0.44
Destroyer Escorts	0.45
Landing Ships	0.46
Patrol Craft	0.47
Submarines Body of Revolution hull Other (fleet type)	 0.41 0.36
Tugs	0.40

8-5.2.4 Draft at Landing Fore and Aft

A similar method can be used to determine the draft-at-landing fore and aft. Again, it will be a balance of the residual buoyancy moments and the moment created by the asset's displacement and the keel blocks reaction (Figure 8-13). If the asset lands on the aftermost block (the method is similar for bow landings), it will begin to pivot about this point as the draft changes. The asset will land fore and aft when the moment created by the buoyancy equals the displacement moment (each is acting about the aftermost keel block). To determine the draft when this occurs, the following procedure is provided:



Note: Trim is exaggerated for demonstration

Figure 8-13. Draft at Landing Fore and Aft.

- Establish the displacement, the longitudinal center of gravity (LCG), buoyancy, and the longitudinal center of buoyancy (LCB) for the floating asset.
- Ascertain buoyancy and LCB for selected drafts below the floating waterline.
- (If the asset or heavy lift vessel has considerable trim at the time of landing, horizontal waterlines may not provide an accurate estimate. In most cases, however, differences will be negligible).
- Determine the distance between the knuckle block and the LCG.
- Determine the distance between the knuckle block and the LCB.
- Calculate moments of residual buoyancy and moments of displacement about the aftermost keel block, (KM(Δ−Rkn) and (Δ−KGo), respectively.
- (Differences caused by the reaction point moving due to compression of the keel block can be ignored unless the stability is marginal and a more precise calculation is needed).
- Plot these moments versus draft. The displacement moment will be a vertical line.
- The point where the line of buoyancy moment crosses the line of displacement moment, will be the draft at landing aft. This same procedure may be used to determine the forward landing draft.

A sample of this graph and these calculations is provided in Appendix Q.

8-5.3 Stability of the Heavy Lift Vessel

Any commercial heavy lift vessel considered for use as a transport platform for U.S. Navy assets shall be classified by one of the commercial regulatory bodies (ABS, DNV-GL, Lloyd's Register, etc.) and the contractor must provide documentation showing current certification. The regulatory body may be contacted to verify that the vessel has met the latest requirements. Most regulatory bodies have websites where this information is public domain and some flag states post similar data. When transporting assets, heavy lift vessels must be at or below specified load line drafts, which are intended to ensure adequate freeboard.

8-5.3.1 Intact Stability Requirements

The calculated stability and buoyancy characteristics of the heavy lift vessel (including displacements and centers of gravity with and without the asset on board) must be provided. Since the U.S. Navy does not own a heavy lift vessel, the heavy lift vessel will be contracted to a foreign entity. Thus, it is unlikely that detailed technical data required to independently calculate the stability of the heavy lift vessel throughout the heavy lift process (on-load, transit, and offload) will be available unless provided by the heavy lift contractor. Therefore, the Heavy Lift Project Team must work with the heavy lift contractor to ensure the contractor has provided their calculations in a timely manner for evaluation and concurrence.

The intact stability must be determined for all modes of operation, including the five phases shown in Figure 8-6. Longitudinal stability must be included for phases 3 and 4 of Figure 8-6. Draft at instability, draft at landing, and free surface effects must be determined and included in the heavy lift vessel calculations.Stability During Ballasting/Deballasting

8-5.3.2 Stability during Ballasting/Deballasting

The ballast/deballast operation presents some unique stability concerns and must be evaluated thoroughly. Stability is largely impacted by the amount of waterplane area of the heavy lift vessel. As the heavy lift vessel's cargo deck goes into or out of the water, the vessel's stability changes rapidly and substantially. If the deck is completely submerged, only the waterplane of the raised hull structure, which extends above the cargo deck, will provide stability to the vessel. Additionally, during this phase, the ballast tanks' water level is changing and may not be in either an empty or pressed up condition. This may produce a free surface effect which will also reduce stability. The result is that the heavy lift vessel passes through a phase of minimum stability (minimum GM) while the cargo deck is under water. To avoid a large, abrupt change in the waterplane area, heavy lift vessels generally go through this phase with some list and trim.

CAUTION
Submersible barges used for FLO/FLO lifts may rely on bottom contact of one end of the barge to ensure sufficient stability until the cargo has landed on the blocks and stability can be increased through added waterplane. Problems with exact positioning and high knuckle block loading add to an already difficult procedure. When one end of the cargo has landed, the barge must rely on the cargo staying in position and contributing the barge/cargo system's stability until more of the barge's cargo deck comes out of the water

A thorough study of the heavy lift vessel's changing conditions must be completed for the entire onloading and offloading process. The point of minimum stability of the heavy lift vessel should be known and compared to the minimum stability conditions already calculated for the asset. Review the stability of the heavy lift vessel to ensure that it is not at the point of minimum stability while the asset assumes its draft-at-instability. If this condition occurs, the asset and the heavy lift vessel may roll out of phase, causing landing problems, or, even worse, causing the asset or the lift vessel to become unstable, resulting in a large list or capsize.

During operations involving heavy lifting of U.S. Navy assets, the heavy lift vessel shall maintain a GM (including free surface correction) of no less than 3.28 feet (one meter). Trim of the heavy lift vessel of up to three degrees may be included to meet the minimum GM. More trim than this may cause the asset to float off the blocks on one end or slide on the blocks. The effect of this trim should be investigated to ensure it is satisfactory. Normally, in protected or calm waters if this trim on the heavy lift vessel's cargo deck does not cause the asset's draft at one end to be zero while the draft on the other end is less than two to five feet of the afloat draft, the asset should not slide or float off (Figure 8-6, phase 3). To waive the one meter minimum GM, the asset must be hard on the blocking before the phase of minimum stability of the heavy lift vessel, and the minimum GM (not accounting for the list) must meet or exceed regulatory body requirements of 0.5 feet (0.15 meters) in all phases of the operation, including the free surface effect. This is the minimum GM typically required by the different regulatory agencies. A detailed stability analysis for all operations must be included with the waiver request. In no case should a GM below 0.5 feet be accepted and every effort should be made to meet the U.S. Navy requirements.

8-5.4 Stability of the Heavy Lift Ship with the Asset Secured Aboard during Transit

The heavy lift vessel with the asset aboard must withstand beam winds as described in Section 8-5.1.1. The contractor must present a stability analysis (righting arm curve) meeting the criteria in the Transport Manual.

The dynamic stability under the righting arm curve at a given angle of heel is a measure of the amount of energy that has to be put into the ship to give it that angle of heel. This heeling or overturning energy can be supplied by wind, waves, or a combination of these and other forces. This quantity can be measured by making a plot of the righting arm (GZ) (Figure 8-10). The area under the GZ curve from zero degrees (or where the curve first crosses the x-axis) to the angle in question, multiplied by the displacement, is equal to the amount of energy that is available to return the ship to the original static heel angle (usually zero degrees).

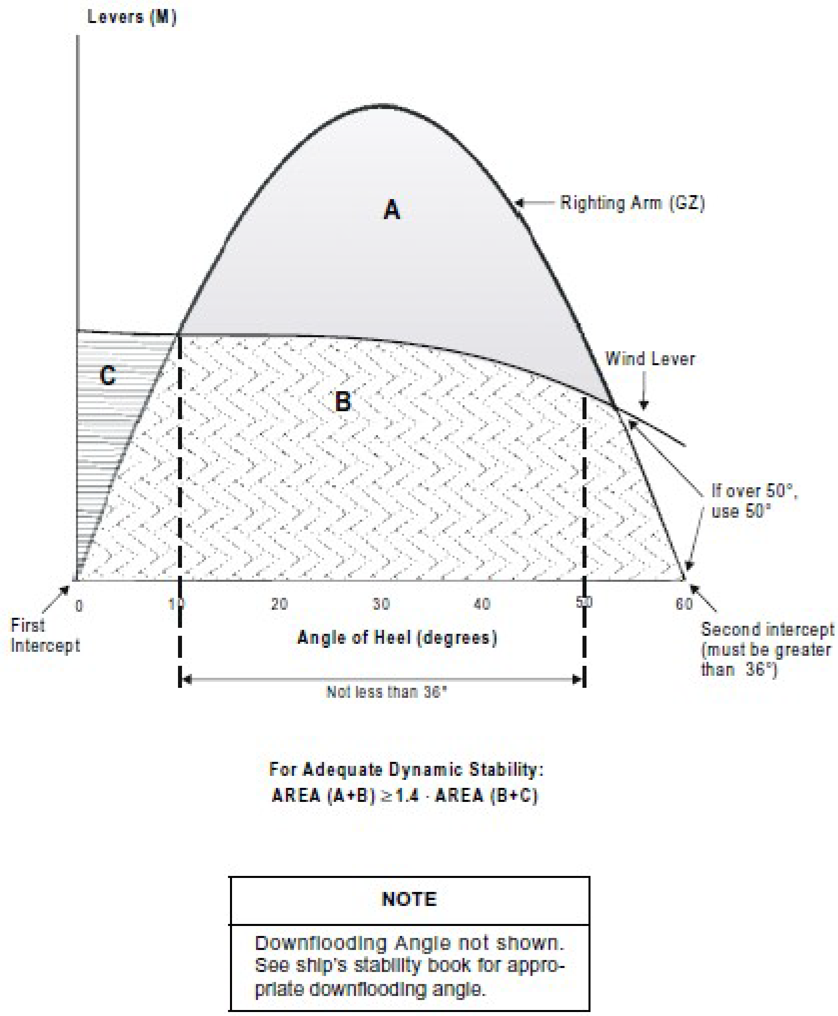


Figure 8-14. GZ Curve.

The righting arm curve should also display the wind lever curve (Figure 8-14). This curve represents the heeling energy imparted by the wind acting on the sail area of the vessel (with the asset aboard). The area will change as the vessel heels, which gives this curve its downward arc. The curve is dependent on wind velocity and represents only one particular speed. For analysis purposes, the maximum wind, including gusts expected during transit, shall be used.

The American Bureau of Shipping (ABS) uses this GZ curve to establish their dynamic stability requirements. The area under these two curves is then compared to determine adequate dynamic stability. The GZ curve area is computed from the first intercept (where it first crosses the x-axis) to the second intercept or the downflooding angle, whichever is less (see ship's stability book for downflooding angle). If both the downflooding angle and the second intercept are greater than 50 degrees, then 50 degrees is used. The area under the wind lever curve is taken from 0 degrees to the same limiting angle. The range of dynamic stability, from the intersection of the wind lever and righting arm curves to the point of zero righting moment and must not be less than 36 degrees (Figure 8-14). Additionally, the second intercept point must be greater than 36 degrees.

ABS requires that the area under the righting arm curve at or before the second intercept or downflooding angle (whichever is less), is not less than 40 percent above the area under the wind lever curve to the same limiting angle. Figure 8-14 demonstrates this graphically.

The angle of heel at which the cargo deck edge is submerged must also be indicated.

In general, Chapter 8 calculations do not lend themselves to the calculation of a GZ curve. The heavy lift vessel contractor and NAVSEA's POSSE software both can calculate a GZ curve. The heavy lift vessel contractor shall provide a GZ curve to the Heavy Lift Project Team to confirm dynamic stability of the heavy lift vessel. If POSSE is being used for the operation, the Heavy Lift Project Team should compare the results to the heavy lift contractor's. Any discrepancies between curves shall be adjudicated between the HLPO, the contractor, and the IMS.

8-6 Blocking

Unlike normal dry docking operations, heavy lifted assets are subjected to significant motions caused by exposure to an ocean environment. This section will discuss the blocking design, which will be the support system for the asset. This structure will carry the entire weight of the asset and protect the asset from potential damage from the motions of the heavy lift vessel. The proper design of this system will help to ensure safe transit for the asset.

8-6.1 Preparing the Heavy Lift Docking Plan

Check with the Planning Yard to ensure the latest revision of the docking drawing is being utilized. This drawing, along with any previous FLO/FLO or docking plans for the asset, should be provided to the heavy lift contractor early in the process and, if possible, in the RFP.

Most vessels, and certainly all active U.S. Navy vessels, have docking drawings. These drawings contain information that show the correct placement and dimensions of docking blocks to provide a proper fit to the asset hull, positioning on the asset hull structural strength members to prevent damage to the hull and underwater projections, and proper distribution of the docking loads. The latest revision of the docking drawing serves as a base document from which a first estimate can prepare a heavy lift docking plan for a FLO/FLO operation. Preparation of the docking and seafastening plan requires consideration of additional factors along with those normally considered in a dry docking.

The docking drawing shall be used for block placement for onload. Care shall be taken to ensure that the onload blocking will be sufficient to safely land and support the asset and provide a sufficient righting moment. The use of docking drawing blocks will ensure that the block have the proper height pitch and shape. Once the onload is complete additional blocking may be added at locations that are at the intersection frames and longitudinals whenever possible to ensure maximum strength and safety during transit.

A FLO/FLO is not an ordinary dry docking in terms of operations and loading. Docking drawing block positions are designed for maintenance, not transport, so there is flexibility in selecting block positions. These positions may vary due to the asset's loading position, hull damage, or alignment with heavy lift vessel structural strength positions and characteristics. Therefore, block position selections from the docking drawing are not limited entirely to docking positions A, B, or C; a combination of these positions can be used. In certain situations, block positions may be used that are not defined in the docking drawings due to the aforementioned conditions.

For a FLO/FLO operation, the keel block height must be minimized. The keel block height will affect the stability of the heavy lift vessel and dictate the required depth of water and depth of submergence, which are used to determine acceptable onloading sites. Tall keel blocks will require even taller side blocks and seafastening. These blocks may be subject to loads caused by currents, waves or motions of the asset when submerged for onloading. Therefore, precautions must be taken to ensure these blocks do not tip over during onloading. Transporting across the ocean subjects the docking blocks to higher dynamic loading and, at the same time, requires the docking blocks to absorb the flexing of the heavy lift vessel under the asset.

A docking plan shall be prepared for every operation. Previous plans can be used as a guide, but each FLO/FLO presents unique concerns. The asset's onloading condition, weather, and expected sea conditions will likely be different and must be accounted for in the plan. Careful preparation is essential for a successful operation. The docking plan must ensure sufficient blocking to support the weight of the asset with static loadings, maximum expected dynamic loads during transit, including at the maximum angle of inclination, and the effects of wind loading. The contractor should provide the proposed docking plan in the Transport Manual

8-6.2 Docking Blocks

The contractor's docking plan should contain descriptions of all the docking blocks, such as location on the heavy lift vessel's cargo deck, the physical characteristics of the blocks, including material and dimensions. Keel block height should be kept to a minimum to reduce the required depth for FLO/FLO. As such, the use of concrete base blocks, common in dry docking, should be avoided.

The Transport Manual should also provide calculations to verify that the blocks are stable and structurally adequate to withstand the loading used in heavy lifting capacity calculations and that the number of side blocks (and shores) is adequate to provide sufficient bearing area to resist overturning. Due to the operation's dynamic nature, all blocks and shores should be secured to the cargo deck of the heavy lift vessel. Before onloading, these blocks should be inspected to ensure they are the required dimensions, in the proper location, and in the same material condition reported by the Transport Manual.

The keel blocks are subject to both the static weight of the asset and the dynamic loads in the vertical direction imposed by the action of the sea. The side blocks and sea fasteners will bear some of the assets weight while being subjected to dynamic loading in both the vertical and transverse directions. Figure 8-15 illustrates the keel block, side block and spur shore typical location and direction force. To find the total force on the blocks it is necessary to calculate the effects of dynamic motion.

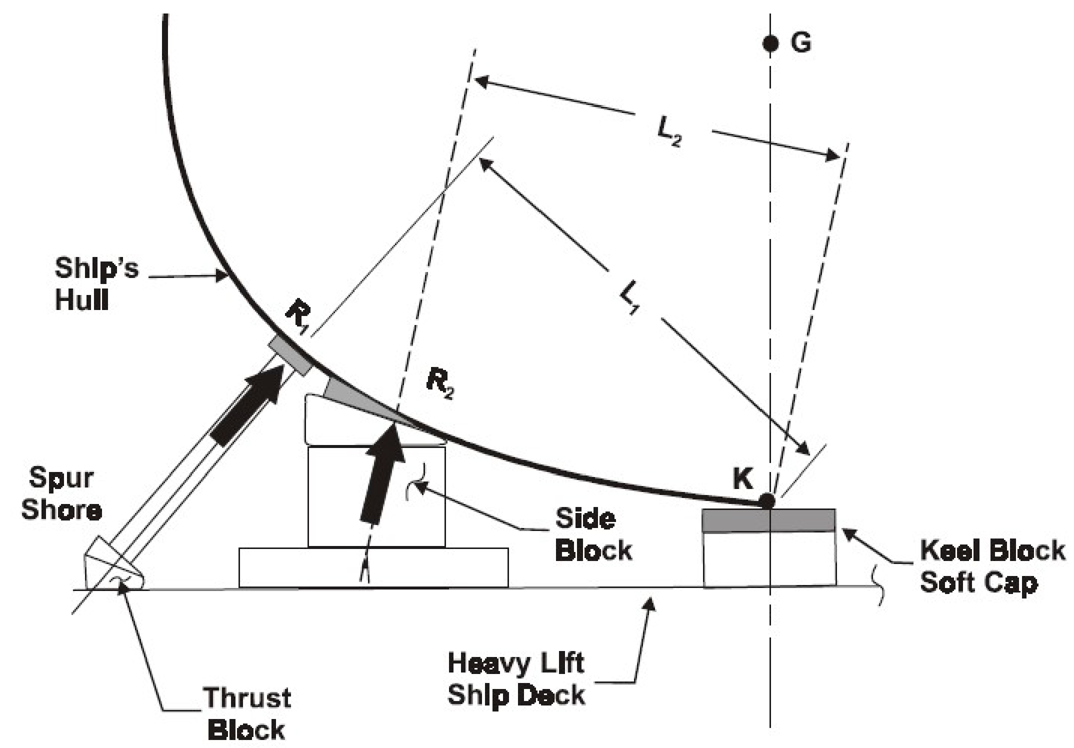


Figure 8-15. Heavy Lift Blocks.

8-6.2.1 **Dynamic Loading**

The commercial industry designs sea fasteners using load forces based on a motion for roll and pitch. The U.S. Navy developed their own series of equations for determining these dynamic forces. An explanation of these equations is in DOD-STD-1399-301A, Interface Standard for Shipboard Systems Section (Ref. V). The U.S. Navy equations combine the effects of dynamic motion and static force due to weight into a load factor. The equations use assumed values for maximum roll and pitch. The U.S. Navy approach is demonstrated here.

NOTE
See Principles of Naval Architecture (PNA) The Society of Naval Architects and Marine Engineers (Ref. U) for more information about the commercial approach.

NOTE
DOD-STD-1399-301A is written for calculating the accelerations on equipment installed on a U.S. Navy ship. Applying DOD-STD-1399-301A to calculating the accelerations associated with an asset sitting atop a heavy lift vessel is acceptable in most cases. If there is a concern associated with the accuracy of the DOD-STD-1399-301A calculations the asset to be heavy lifted can be broken into multiple segments where the displacement and locations of the individual centers of gravity can be calculated for each segment using the DOD-STD-1399-301A calculations accomplished for each segment.

Dynamic loading and accelerations are calculated for specific sea states as defined in Table 8-6. Detailed voyage planning shall be performed to identify the highest probable sea state to be encountered with dynamic analyses performed for the next sea state higher to account for short term periods of higher than predicted waves. Sea State 7 is an appropriate early panning factor but not a substitute for voyage planning and weather routing.

Table 8-6. Sea State Wave Heights for Dynamic Loading

Sea State Number	Significant Wave Height	
	Meters	**Feet**
0-1	0.0 - 0.1	0.0 - 0.3
2	0.1 - 0.5	0.3 - 1.6
3	0.5 - 1.25	1.6 - 4.1
4	1.25 - 2.5	4.1 - 8.2
5	2.5 - 4.0	8.2 - 13.1
6	4.0 - 6.0	13.1 – 19.7
7	6.0 – 9.0	19.7 – 29.5
8	9.0 – 14.0	29.5 – 45.5
>8	>14.0	>45.5

The DOD-STD-1399 equations that are relevant to the calculation of heavy lift dynamic loading are as follows.

NOTE
For the following formulas the center of gravity of the heavy lift vessel includes the weight of the asset once fully loaded.

$$a_z = 1 + h + \frac{0.0214Px}{{T_p}^2} + \frac{0.0214Ry}{{T_r}^2}$$

where:

a_Z	=	vertical acceleration factor (g)
h	=	heave acceleration (g) (Table 8-7)
P	=	Maximum angle of pitch (degrees) (Table 8-8.)
x	=	distance of center of gravity of asset forward or aft from center gravity of heavy lift vessel (ft)
R	=	Maximum angle of roll (degrees) (Table 8-9)
y	=	distance of asset off centerline of heavy lift vessel (ft)
Tp	=	Period of pitch (sec) (Table 8-8)
Tr	=	Period of roll in (sec) (Table 8-9)

The athwartships acceleration factor is calculated by:

$$a_y = sinR + \frac{0.0107Px}{T_p^2} + \frac{0.0004R^2y}{T_r^2} + \frac{0.0214Rz}{T_r^2}$$

where:

a_y	=	Athwartships acceleration factor (g)
R	=	Maximum angle of roll (deg)
P	=	Maximum angle of pitch (deg)
x	=	Distance of center of gravity of asset forward or aft from center of gravity of the heavy lift vessel (ft)
y	=	Distance asset's centerline is off centerline of the heavy lift vessel (ft)
z	=	Distance the asset's center of gravity is above the center of gravity of the heavy lift vessel (ft)
T_p	=	Period of pitch (sec)
T_r	=	Period of roll (sec)

The longitudinal acceleration factor is calculated by:

$$a_x = \sin P + S + \frac{0.0004P^2x}{T_p^2} + \frac{0.0214Pz}{T_p^2}$$

where:

a_x	=	Longitudinal acceleration factor (g)
P	=	Maximum angle of pitch (degrees) (Table 8-8.)
S	=	Surge acceleration (g) (Table 8-7)
x	=	Distance of center of gravity of asset forward or aft from center of gravity of the heavy lift vessel (ft)
z	=	Distance the asset's center of gravity is above the center of gravity of the heavy lift vessel
T_p	=	Period of pitch (sec) (Table 8-8.)

Table 8-7. Heave and Surge Motion Parameters for Calculation of Loading Factors for Conventional Surface Ships.

Sea State	LBP meters (ft)	Heave acceleration (g)	Surge acceleration (g)
4	Less than 46 (150)	0.10	0.06
	46-76 (150-250)	0.10	0.05
	76-107 (250-350)	0.10	0.05
	107-152 (350-500)	0.08	0.04
	152-213 (500-700)	0.06	0.04
	Greater than 213 (700)	0.04	0.02
5	Less than 46 (150)	0.17	0.10
	46-76 (150-250)	0.17	0.10
	76-107 (250-350)	0.17	0.10
	107-152 (350-500)	0.14	0.05
	152-213 (500-700)	0.10	0.05
	Greater than 213 (700)	0.07	0.05
6	Less than 46 (150)	0.27	0.15
	46-76 (150-250)	0.27	0.15
	76-107 (250-350)	0.27	0.15
	107-152 (350-500)	0.21	0.10
	152-213 (500-700)	0.16	0.10
	Greater than 213 (700)	0.11	0.05
7	Less than 46 (150)	0.40	0.25
	46-76 (150-250)	0.40	0.20
	76-107 (250-350)	0.40	0.20
	107-152 (350-500)	0.30	0.15
	152-213 (500-700)	0.20	0.15
	Greater than 213 (700)	0.20	0.10
8	Less than 46 (150)	0.60	0.35
	46-76 (150-250)	0.60	0.30
	76-107 (250-350)	0.60	0.30
	107-152 (350-500)	0.50	0.25
	152-213 (500-700)	0.40	0.25
	Greater than 213 (700)	0.20	0.10

Table 8-8. Pitch Motion Parameters for Calculation of Loading Factors for Conventional Surface Ships.			
Sea State	**LBP meters (ft)**	**Pitch angle * (degrees)**	**Pitch Period (seconds)**
4	Less than 46 (150)	2.0	3.5
	46-76 (150-250)	2.0	4.0
	76-107 (250-350)	1.0	5.0
	107-152 (350-500)	1.0	6.0
	152-213 (500-700)	1.0	7.0
	Greater than 213 (700)	1.0	8.0
5	Less than 46 (150)	3.0	3.5
	46-76 (150-250)	3.0	4.0
	76-107 (250-350)	2.0	5.0
	107-152 (350-500)	2.0	6.0
	152-213 (500-700)	2.0	7.0
	Greater than 213 (700)	1.0	8.0
6	Less than 46 (150)	5.0	3.5
	46-76 (150-250)	4.0	4.0
	76-107 (250-350)	4.0	5.0
	107-152 (350-500)	3.0	6.0
	152-213 (500-700)	3.0	7.0
	Greater than 213 (700)	2.0	8.0
7	Less than 46 (150)	7.0	3.5
	46-76 (150-250)	6.0	4.0
	76-107 (250-350)	6.0	5.0
	107-152 (350-500)	5.0	6.0
	152-213 (500-700)	4.0	7.0
	Greater than 213 (700)	3.0	8.0
8	Less than 46 (150)	11.0	3.5
	46-76 (150-250)	10.0	4.0
	76-107 (250-350)	9.0	5.0
	107-152 (350-500)	7.0	6.0
	152-213 (500-700)	6.0	7.0
	Greater than 213 (700)	5.0	8.0
*NOTE: Pitch angle is measured from horizontal to bow, up or down.			

Table 8-9. Roll Motion Parameters for Calculation of Loading Factors for Conventional Surface Ships.[1]

Sea State	Beam Meters (ft)	Roll angle[2] (degrees)	Roll period[3]
4	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	7 6 6 5	See note for determination of roll period
5	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	12 10 10 9	
6	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	19 16 15 13	
7	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	28 24 22 20	
8	Less than 15 (50) 15-23 (50-75) 23-32 (75-105) Greater than 32 (105)	42 37 34 31	

[1] Excludes multi-hulls, surface effect ships and all craft supported principally by hydrodynamic lift.
[2] Roll angle is measured from vertical to starboard or port.
[3] Natural roll period is to be calculated from:

$$T_r = (C_c \times B)/(\overline{GM})^{1/2}$$

where:

T_r = Natural roll period (sec)
C_c = Roll constant based upon experimental results from similar ships - typical ranges are 0.38 to 0.49 (sec/√ft) or (0.69 to 0.89 (sec/√m)). For heavy lift vessels, use C_c of 0.40 unless a better estimate is provided (it may be as high as 0.44). See Table 8-5 for examples of other surface ships.
B = Maximum beam at or below the water line (m or ft)
$\overline{GM}$ = Maximum metacentric height (m or ft)

The keel blocks will bear most of the asset's weight with the side blocks and seafasteners taking only a partial load. To be conservative, the keel blocks will be designed to support the entire weight of the asset. The weight of the asset is equal to its displacement at the time of loading. As discussed earlier, an account of the dynamic loading must also be included for accelerations in the vertical direction.

To determine the design loads (forces) that must be resisted to hold the asset on the cargo deck of the heavy lift vessel, multiply the weight of the asset (w) by an acceleration factor (a) determined from the motions of the heavy lift vessel, considering the location of the asset on the cargo deck.

The pitch and roll numbers are those of the heavy lift vessel which will be similar to those of the asset if both ships (the heavy lift vessel and the asset) are aligned longitudinally and transversely.

When this is not the case, such as the heavy lift of the USS John S. McCain (DDG 56) with a 22-degree angle from alignment (Figure 8-16), then estimating roll and pitch requires trigonometric mapping.

Figure 8-16. USS John McCain (DDG-56) on board the M/V Treasure

The pitch on M/V Treasure will impart both a pitch and roll component on the DDG-56. Given the aforementioned 22-degree offset between M/V Treasure and DDG-56 the following roll and pitch calculations apply to DDG-56:

P(DDG-56) = P(M/V Treasure) X COS(22 degrees) + R(M/V Treasure) X SIN(22 degrees)

R(DDG-56) = R(M/V Treasure) X COS(22 degrees) + P(M/V Treasure) X SIN(22 degrees)

Pitch estimate from P(DDG-56) and roll estimate from R(DDG-56) must be used in the DOD-STD-1399 Section 301A dynamic calculations to ensure accurate block and seafastening load calculations. If the alignment between the heavy lift vessel and the asset is equal to or less than five degrees, then the sine terms in the above formulas are extremely small and can be eliminated making the roll and pitch of both vessels equal.

NOTE
It is always preferable to select a heavy lift vessel that does not require a significant longitudinal / transverse offset (i.e., >5 degrees) but if this is not possible, then it is necessary to perform the trigonometric mapping.

Information concerning acceleration factors and the angles of roll, pitch, heave, and surge should be presented in the Transport Manual.

8-6.2.2 Loading of Keel Blocks

To find the total force on the blocks, multiply the acceleration factor a_Z by the weight of the asset.

$$DL_k = wa_z$$

where:

DL_k	=	total dead load on the keel blocks (tons)
w	=	weight of the asset (tons)
a_z	=	vertical acceleration factor (g)

NOTE
The vertical acceleration factor, a_z, represents an increase in the downward force. It is essentially a multiplier to increase the effect of gravitational acceleration and the units used, g, reflect this.

8-6.2.3 **Keel Block Loading Distribution**

Using the U.S. Navy docking drawing as a guide in the placement of keel and side blocks will assure alignment with the asset's structure, omissions for hull penetrations and appendages, and a proper fit to the curvature of the hull. Specifics of the proposed blocking arrangement must be provided to ensure the asset's hull is properly supported. The asset's load distribution on the blocks must be calculated to ensure the structural load requirements are not exceeded. The distribution of the asset's weight, as shown on the longitudinal strength drawing (20 station weight breakdown), indicates how the asset's weight is distributed on the asset's hull structure and thereby onto the blocks as shown in the U.S. Navy docking drawing.

The asset's weight and the locations of the asset's centers of gravity (vertical, transverse, and longitudinal) must be accurately predicted to avoid overloading the blocks. Keel bearing should be uniform and continuous. If keel bearing is non-uniform, as in the case for an asset with a partial bar keel, long overhangs, highly concentrated weights or excessive hull projections, then special considerations must be given to further spread the load over individual keel blocks. For loadings that are not continuous and uniform, a more rigorous method may be required to determine the necessary load distribution. For example, mine countermeasure (MCM) ships require additional shores to be placed under the stern due to a long overhang.

8-6.2.4 **Distribution of Asset's Weight**

Once the keel blocks' total force is known (DLk from 8-6.2.2), an assessment of the loading distribution should be conducted to ensure the blocking is not overloaded. The calculated loading distribution should be compared to the docking drawing used as a first estimate of the required blocking. To perform a loading distribution analysis:

- Examine asset's data for the latest information. Sources include docking drawings, curves of form, and full load weight distribution.
- Survey the asset to find information on all variable weight and abnormalities (trim weights added, hull damage, cargo, etc.).
- Record asset's drafts.
- Calculate the assets expected drafts at the time of docking.
- Calculate the asset's displacement and centers of gravity.
- Compare the expected values with the recorded values and resolve any discrepancies

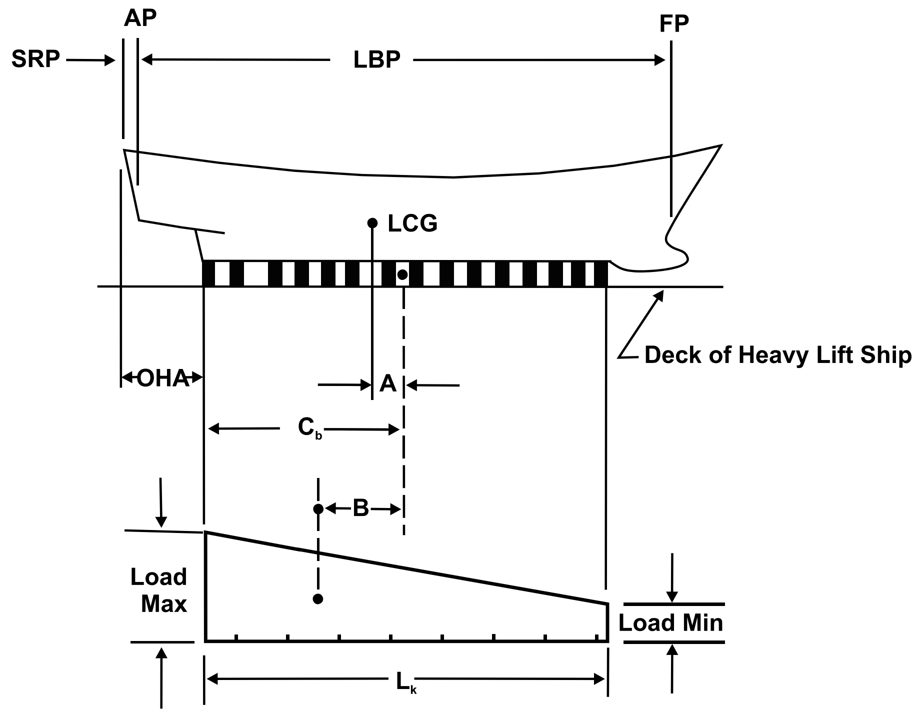
NOTE
When lifting a damaged asset the displacement at the time of lift may differ from the displacement to be transported. This is due to the entrained water in the damaged area that will run out during and after the heavy lifting operation.

In the event of lifting a damaged asset the displacement at the time of lift may differ from the displacement to be transported. This is due to the entrained water in the damaged area that will run out during and after the lifting operation.

8-6.2.5 Block Loading Calculation - Trapezoidal Method

It is important to estimate the load on the blocks to ensure that they are not over-stressed. Begin by examining the required blocking shown on the docking drawing. This will provide the first estimate of the asset's longitudinal location with respect to the blocking and its center of gravity with regards to the center of blocking (Figure 8-17).

It is important to use the asset's weight distribution at the time of its loading onto the heavy lift vessel. For the current loading condition, the displacement and centers of gravity are calculated using the current draft readings and the weight distribution as described above. In the case where the blocking can be assumed to be continuous and uniform (Figure 8-18), the loading distribution may be approximated by using a trapezoidal approximation.



FP = Forward Perpendicular
AP = After Perpendicular
LBP = Length between perpendiculars of asset
SRP = Distance from AP to Point from which distance to keel blocks is measured
LCG = Asset's longitudinal center of gravity
OHA = Distance from SRP to keel block
Lk = Length of keel blocking
$Cb = \frac{L_k}{2}$ = Center of blocking
$B = \frac{L_k}{6}$ = Approximate Center of Trapezoid
A = Distance from asset's LCG (center of Gravity) to C (center of Blocking)
= CB -[LBP+SRP-LCG-OHA] (Note that if A is a negative number the trapezoid is reversed in the above diagram so the Load max is greatest at the forward end of the asset

Figure 8-17. Load Distribution.

If the asset's longitudinal center of gravity (LCG) aligns vertically with the center of the block build (C_b), the forward and after blocks will share the load fairly equally. In practice, this is rarely the case. When the asset's LCG is forward or aft of the C_b, we can assume the load distribution is roughly trapezoidal. Again, this assumes no significant anomalies in either the ship's load distribution or in the block build. If the LCG is aft of C_b, the after blocks will carry more of the load.

The amount of load supported by the after blocks will depend on the distance that LCG is from C_b, A as shown in Figure 8-17. The greater the distance between LCG and C_b, the more uneven the distribution of loads. In fact, if the LCG is outside of the center third of the block arrangement, the load distribution will be triangular and the difference between maximum load and minimum load may be significant. See Figure 8-17 for an illustration of the relationship between LCG and the center of the assumed trapezoid, B. For a trapezoidal load distribution, B will be approximately one-third of the keel blocks' length (L_k) from the after end, or one-sixth of L_k from C_b (based purely on geometry). This is a good initial estimate to determine the maximum and minimum load.

To determine the maximum and minimum loads, use the following equations:

If A < B, load distribution is trapezoidal:

$$Load\ Max = \frac{DL_k}{L_k}\left(1 + \frac{A}{B}\right)$$

$$Load\ Min = \frac{DL_k}{L_k}\left(1 - \frac{A}{B}\right)$$

If A > B, load distribution is triangular:

$$Load\ Max = \frac{4DL_k}{3(L_k - 2A)}$$

$$Load\ Min = \frac{Load\ Max}{L_e}$$

where:

Load Max	=	Maximum expected blocking load (tons)
Load Min	=	Minimum expected blocking load (tons)
DL_k	=	Loading due to weight and dynamic effects (8-6.2.2) (tons)
A	=	Distance from asset's center of gravity to center of blocking (ft)
B	=	Distance from center of trapezoid to center of blocking (L_k/6) (ft)
L_k	=	Length of keel blocking (ft)
L_e	=	Length of effective keel blocking (ft) = 1.5(L_k) - 3A

As defined by Load Max and Load Min, the load distribution is used to determine if the blocking (and, in some cases, the cargo deck) is adequate to support the asset. Check the maximum loading against the loading assumed for the ship's docking drawing. The keel blocks should be checked to ensure that they are not overstressed. Assume that the last block in the line will see Load Max. To find the stress on this block use:

$$S = \frac{Load\ Max}{A_e} \times \left(\frac{2240\ lb}{ton}\right)$$

where:

S	=	Stress on block (psi)
Load Max	=	Maximum expected blocking load (tons)
A_e	=	Effective area of keel block (in^2)

CAUTION
These calculations assume a continuous row of keel blocks. If this is not the case, increases in loading should be made accordingly.

This stress should be lower than the proportional limit for the material used. See Table 8-10 and paragraph 8-6.2.7 for the allowable stress on blocks. If it is not, consider using more keel blocks, keel blocks with better contact area or redistributing the asset's load more evenly.

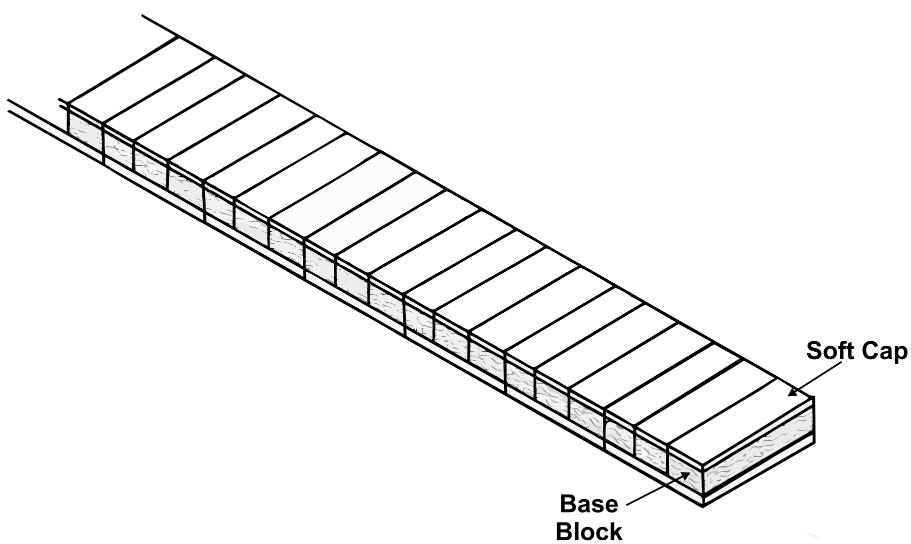


Figure 8-18. Keel Blocks

Table 8-10. Allowable Block Stress (Assuming Douglas Fir).	
Keel Width, ft	**Allowable Unit Stress for Blocking (S), lb/in^2**
≥3.00	370
2.50	323
2.00	277
1.75	254
1.50	230
1.25	207
1.00	184

8-6.2.6 **Block Loading Calculations - Moment Area Method**

The Trapezoidal Method for calculating block loading has known limitations. The **(Heger Paper) states t**he trapezoidal method is an easy and accurate way of calculating keel block loading unless the following is present.

- The longitudinal strength of the asset is impaired due to damage or cutting.

NOTE
: In this case the asset is not considered a rigid body and should be divided into individual segments that can be considered rigid. The keel block loading shall be calculated separately for each segment.

- The blocks are not all constructed similarly or the block spacing is not uniform.

NOTE
Keel blocks should be constructed similarly/uniformly whenever possible. Damage to the asset or obstructions may require that the keel blocks be non-uniform in size or shape.

- The bearing area varies on top of the block (bar keel at one end, etc.).
- The asset over hangs the keel blocks by more than twice its molded depth.
- The asset has a large initial hog or sag and the keel line is built straight.
- A floating dock is not dewatered according to the trapezoidal results.

The Moment Area Method is more accurate when the asset(s) does not have a singular line of uniformly spaced and sized keel blocks. The blocks may be of different sizes, irregularly spaced and/or multiple lines of keel blocks such as for the Independence Class Littoral Combat Ship (LCS) (see Figure 8-19 Figure 8-20).

Figure 8-19. USS Independence in Drydock

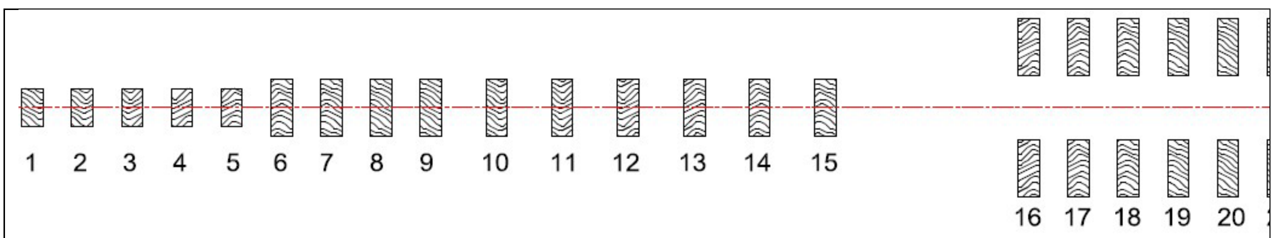


Figure 8-20. Non-Uniform Keel Line

Naval Ship's Technical Manual (NSTM) S9086-7F-STM-010, Chapter 997, ACN XX, Docking Instructions and Routine Work in Dry Dock (Ref. W) provides a methodology for computing the keel block loading via the Moment Area method.

8-6.2.7 **Knuckle Loading**

Special consideration must be given to the end of the keel blocking arrangement as an asset makes initial contact with the blocking. The individual block at each end of the keel block row is referred to as the knuckle block and may be subject to high compressive stress as the asset first lands. Initial contact will be highly localized and may cause high stresses and deformation of the block, especially for assets with narrow keels. For an asset with trim by the stern, the reactions at the aftermost block should be analyzed. Even when an asset is at an even keel condition, the heavy lift vessel will likely deballast in such a way as to expose deck area as quickly as possible to maintain maximum stability and minimize the free surface effect. This trimmed condition may also cause localized loading on the knuckle block.

As the heavy lift vessel continues to rise, the knuckle block will load and the asset will reduce trim. Additional support will be provided by blocks forward of the knuckle block as contact with the asset increases. At the same time, more of the asset's weight will be supported by the blocking. The stress seen at the knuckle block will likely rise at first and then decrease, reaching a maximum somewhere between initial and full contact. This maximum stress should be analyzed to ensure the strength limits of the material are not exceeded. Naval Ship's Technical Manual (NSTM) S9086-7F-STM-010, Chapter 997, Docking Instructions and Routine Work in Dry Dock (Ref. W) provides a methodology for computing the knuckle block stress. .

8-6.2.8 **Safe Allowable Compressive Stress of Blocking**

CAUTION
Douglas fir is the U.S. Navy standard blocking material but actual material may differ. Use the strength characteristics of the actual blocking material.

The allowable timber compressive stress for distributed loading on keel blocks, taken as the fiber stress at the proportional limit for Douglas fir, is 370 psi. This assumes a uniform pressure on a 42 by 48-inch docking block resulting in a total load of approximately 330 tons. When computing the stress for the actual condition, the asset's weight and the area in contact with the blocks should be used to determine loading.

Table 8-10 lists allowable timber compressive stresses for the blocking based on the proportional limit for Douglas fir. The computed stress is dependent upon the area of the keel in contact with the knuckle. For assets with keels that are narrower than three feet, the allowable stress has been reduced. This is necessary because of the compression of the block during on-loading. There will be less contact area with the blocks concentrating the load for narrower keels, supporting less load. Appendix D of NSTM, CH-997 (Ref. W) presents a detailed explanation of total load as a function of compressive stress.

When docking assets with narrow keels, it is advisable to use hardwood or steel capping at the knuckle block (Figure 8-21). The hardwood capping will be able to carry stress concentrations that would cause severe crushing of soft capping. Hard caps shall be used in conjunction with a soft wood stratum below to give the same overall compressive characteristics to the block. For certain vessels with bar keels (e.g., tugs), using caps bound with steel angles will prevent the keel from cutting into the cap.

Figure 8-21. ***USS John S. McCain (DDG 56) Build with Steel Cap over soft wood***

8-6.3 Block Inspection Criteria

Blocks are required to be inspected before constructing the block build for each asset. If the block has no obvious defects, it will be considered satisfactory and will not need to be inspected in detail.

NOTE
Douglas fir is the U.S. Navy standard blocking material but actual material may differ. Use the strength characteristics of the actual blocking material.

In general, unsatisfactory components are defined by:

- Steel: sections or blocks show excessive corrosion of the steel beams or structures; welds have fatigue cracks, or the structure has permanent deformation or buckling due to loading beyond the elastic limit.

- Timber: display very advanced deterioration. They are localized to widespread areas where timbers are missing; more widespread failures are possible.
- Fasteners: show severe deterioration and loss in cross-section to the point that the fasteners no longer fulfill their intended use.
- Soft cap timber: sections display advanced deterioration; there are sections where the timber is missing or deformed or soft caps made of inconsistent materials and not layered but joined by butting next to each other.

The inspection criteria is outlined in Appendix K of MIL-STD 1625D (Ref. T). If the timber, fasteners, or steel are determined to be unsatisfactory according to the appendix's criteria, the component shall be replaced, or a qualified engineer shall provide an evaluation to demonstrate the component is satisfactory for its intended purpose. The qualified engineer shall be a U.S. Navy representative designated by the HLPO.

Blocks are also required to be inspected after the build is complete prior to beginning operations to ensure they are built as per the approved Transport Manual.

8-7 Seafastening Plan

The seafastening plan is a composite arrangement of side blocks, spur shores and seafasteners (Figure 8-22, Figure 8-23 and Figure 8-24). Side blocks will supply some of the necessary support associated with the vertical loading for the initial docking phase. They provide resistance of any overturning moment resulting from the asset's motions and heel angles. Spur shores, or roll bars, are installed to provide further resistance to the dynamic overturning moments in a seaway. Seafasteners (stopper blocks) are installed to prevent fore, aft, and athwartships sliding action as the heavy lift vessel pitches and rolls. Each of these will be addressed separately in this section.

Figure 8-22. ***Spur Shores***

8-7.1 Side Blocking

Side blocking must be able to withstand some portion of the asset's deadweight as well as dynamic loading. As the heavy lift ship rolls or pitches, the contribution of the side blocking in supporting the deadweight will increase. There is also an increase in dynamic loading due to the effect of rolling and pitching. The static and dynamic effects will be examined separately.

Figure 8-23. ***Wedged Side Blocks***

Side blocks are used for handling the loading up to the angle to which the heavy lift ship will heel over or a heel of 15°, whichever is greater. Roll bars or spur shores (see Figure 8-22) should be used for angles from 15° - 45°.

To be effective, side blocks should have relatively planar surfaces (minimum curvature). Blocks will form to the shape of the hull under significant compressive loading. Attempting to shape the blocks to exactly fit the surface of the hull will add considerable effort and may not significantly improve their contact area or overall performance. It will be difficult to land the ship precisely in the intended location and small variations may prove to make the shaping of the blocks a wasted effort. Contact can be improved by using wedging material. This may be easier to accomplish if the block surfaces are planar.

The blocks should be placed under the asset's major structural members such as main transverse bulkheads and secondary frames. They should also have enough effective surface area (width) to span two frames. The asset's docking drawing will provide recommended locations.

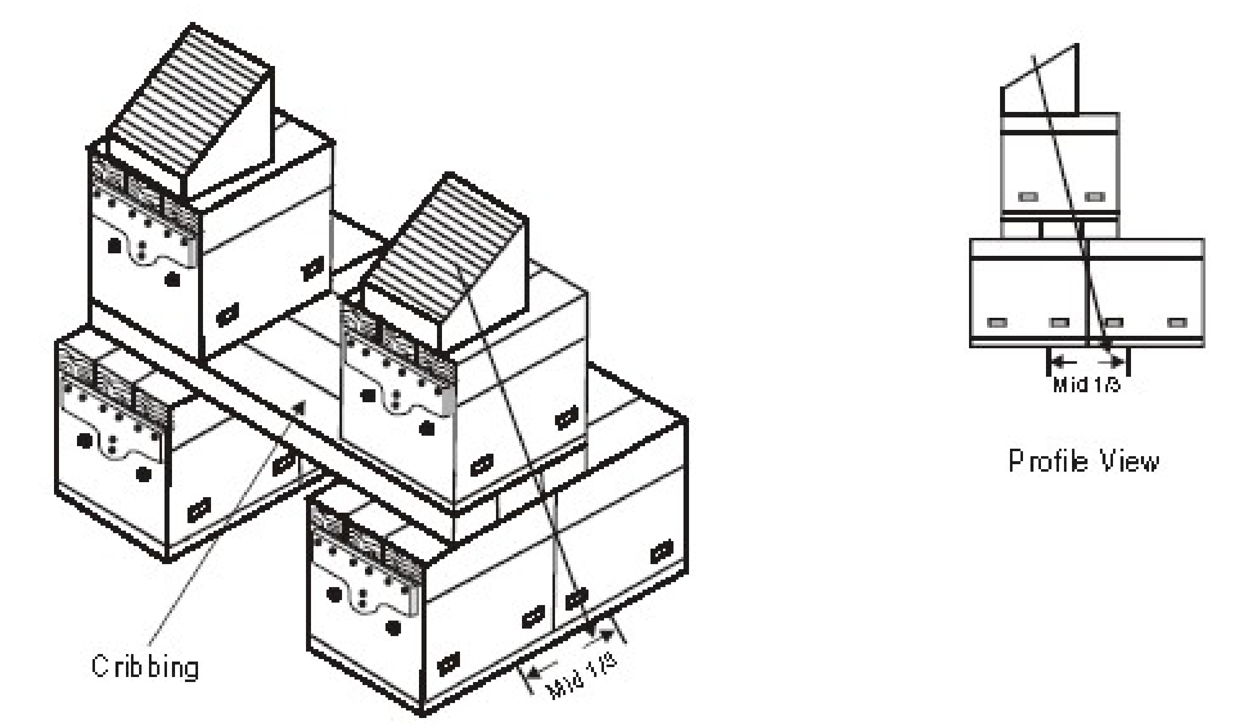


Figure 8-24. ***Cribbed Blocks***

The transverse stability of individual side blocks is essential and depends on overall block height and hull shape. The side blocks must be of a construction and located such that the resultant force (normal to the shell at point of tangency) falls within the middle one-third of all horizontal layers of blocking. Using a two-tiered block with a double wide base will help ensure this stability in both the transverse and longitudinal direction (see Figure 8-24). The side block caps should be of a soft material such as Douglas Fir or Southern Yellow Pine. The discussion concerning the use of hard woods as capping material for keel blocks does not apply to side blocking. Side blocks must have similar stiffness as keel blocks with sufficient soft wood caps to compress and form to the curvature of the hull, thus avoiding local high stress loading conditions. Side blocks must be securely fastened to the deck of the heavy lift ship to resist overturning and sliding.

8-7.1.1 **Stability of High Blocks**

Heavy lifting U.S. Navy assets with large sonar domes or other underwater projections may require the use of excessively tall blocks. In these cases, the block's stability is a concern and special precautions must be taken. These blocks may require additional cribbing to ensure they do not tip over. Use the following guidelines when considering the stability of the blocks.

- All keel blocks over 8.5 feet in height require cribbing
- Keel blocks over six feet, but less than 8.5 feet, should be cribbed when located in the after one-third or forward one-third of the block line
- Side blocks over six feet in height (measured from the deck to the highest corner of the soft cap) shall be tied together longitudinally (steel tie rods, cribbing, etc.)

- Loading force should act in the middle one-third of all tiers of blocks (Figure 8-24)

8-7.2 Loading on Side Blocking

The side blocking will support both static and dynamic loads. The side blocking supports some of the weight of the asset in the zero heel condition. This support increases as the vessel heels. Side blocking is also needed to resist dynamic loads that may be caused by ship motions and wind which are dependent on environmental conditions during loading and transit.

8-7.2.1 Assessing the Loading on Side Blocking

Several conditions need to be examined in determining when to install, and the amount of, side blocking required for a transport. The most strenuous condition is when the asset is loaded onto the heavy lift vessel while in an open seaway. In this condition, the most extreme wind and motions will be experienced. A second, reduced condition of loading exists during float on. The condition of the loading associated with the float-on operation should be evaluated. It may be advantageous not to complete the side blocking construction until after the asset is onloaded. This is normally advised to reduce the side blocking height so that less submergence of the cargo deck is required during the onloading operation. If proposed to use fewer side blocks for the float-on operation, this condition must be analyzed separately (Section 8-7.3). It is assumed that float-on is conducted in a relatively sheltered location where operational loads are expected to be lower, similar to those experienced in a dry docking.

A third condition arises when the load and build sites are not the same. The heavy lift vessel will need to transit after the onloading to build site but before completion of the seafastening plan. The environmental conditions associated with the transit should be analyzed as a separate evolution for the loaded asset without seafastening. This may occur if an asset is in extremis or the port where onloading occurs does not have the required water depth for onload near the industrial services necessary for seafastening activities. Therefore, calculating the side loading of the blocking is a multi-step process.

The approach outlined here breaks down the loading under static (deadweight) and dynamic (rolling and wind) conditions. Each of these components can be considered separately and then combined to determine a suitable blocking arrangement. As a minimum, an analysis of the open ocean seafastening plan should be conducted. Winds and ship motions associated with this transit should be evaluated to determine the total number of side blocks and spur shores..

8-7.2.2 Calculating Side Block Loading

The side blocks will support a portion of the deadweight of the asset, both in a heeled and an upright condition. For the zero-heel condition, the side blocks are assumed to take 15 percent of the assets displacement (w) and that this load is evenly distributed between port and starboard. Therefore, the load on the side blocking for port or starboard is calculated by:

$$DL_s = \frac{(0.15)w}{2} = 0.075w$$

where:

DL_S	=	Vertical load on side blocks for one side (tons)
W	=	Displacement of asset at time of loading (tons)

The number of side blocks required on one side for supporting displacement (Nd) without considering dynamic and wind effects can be calculated by:

$$N_d = \frac{DL_s}{S_p A_e}$$

$$= \frac{0.075w}{S_p A_e \left(\frac{1\ ton}{2240\ lbs}\right)}$$

$$= \frac{168w}{S_p A_e}$$

where:

N_d	=	Minimum number of side blocks on one side to support displacement
DL_s	=	Vertical load on side blocks for one side (tons)
S_p	=	Strength at the proportional limit of the block material (lb/in^2)
	=	370 psi for Douglas fir
A_e	=	Effective surface area of side block in contact with asset (in^2)
w	=	Displacement of asset at time of loading (tons)

NOTE
These equations are static and thus are independent of the offset angle, if any, between the heavy lift vessel and the vessel to be heavy lifted. A trigonometric mapping is not appropriate for the static calculations.

8-7.2.3 **Dynamic Loads during Transport**

Side blocks and spur shores are also needed to resist dynamic loading due to wind and vessel motions. The method for calculating the moments associated with these forces are presented. In performing an analysis, it is important to examine all likely conditions the vessel will experience. During transit the predicted sea state may be as high as sea state 7, while the conditions during on-loading shall be limited to sea state 4 or below. Each of these scenarios must be evaluated to ensure that the blocking arrangement is sufficient. The dynamic loads will be dependent on the environmental conditions encountered during the transport.

8-7.2.4 Dynamic Loads from Ship Motions

Calculating overturning moments caused by sea state dynamic forces is similar to calculating seismic overturning moments for a normal dry-docking operation (NSTM 997). These calculations are modified to include the acceleration loads associated with rolling and pitching of the heavy lift vessel. The maximum ship motion and roll angle is found by examining the expected weather during transit. For example, if the routing indicates that the maximum condition is sea state 7, use pitch and roll angles from Table 8-8. Table 8-9, respectively. This is the limit to which the heavy lift vessel is assumed to heel during the transit. Note that this load is supported by only one side of the blocks.

To calculate the overturning moment, Mr, associated with athwartships motion, the asset's weight is multiplied by the height of the center of gravity above the asset's keel. This is then multiplied by the athwartships acceleration factor calculated in 8-6.2.1.

$$M_r = (w)(a_y)(KG)(2{,}240 \text{ lbs/ton})$$

where:

M_r	=	Overturning moment due to rolling (ft-lbs)
w	=	Displacement of vessel at time of on-loading (tons)
a_y	=	Acceleration factor for athwartships motion (g)
KG	=	Center of gravity of the asset above its keel (ft)

The side blocks can provide the effort to resist this overturning moment. Still, the number of side blocks needed is dependent on the size of the blocks, their distance from the centerline (Figure 8-19 offers an extreme example), and available space on the cargo deck around the asset. Therefore, the number of additional side blocks on one side required to resist the dynamic loads due to rolling is:

$$N_r = \frac{M_r}{A_e S_p L_2}$$

where:

N_r	=	Number of additional blocks for rolling
M_r	=	Overturning moment due to rolling (ft-lbs)
A_e	=	Effective surface area of side block in contact with asset (in^2)
S_p	=	Strength at the proportional limit of the block material (lb/in^2)
	=	370 psi for Douglas fir
L_2	=	Average moment arm of side block reaction force (ft)

8-7.2.5 **Dynamic Loads from Winds**

Additional side blocking is necessary to resist the overturning moment associated with the wind forces encountered during transport. Calculating overturning moments caused by wind is similar to calculating hurricane loading in a normal dry docking situation. This is also a two-step process, one for the wind force during loading (< 25 knots) and the second for the wind loading during the transit. To determine the expected wind during transit, use the guidelines listed in Section 8-5.1.1.

The following equations can estimate the overturning moment associated with the wind forces:

$$M_w = 0.004(A_s)(L_3)(V)^2$$

where:

M_w	=	Overturning moment due to wind forces (ft-lbs)
A_s	=	Projected sail area of the asset (ft^2) (Figure 8-16)
L_3	=	Lever arm from the cargo deck to the center of the sail area of the asset (ft) (Figure 8-16)
V	=	Wind speed (knots)

NOTE
The 0.004 factor in this equation provides for the density of air and unit conversions.

The number of additional side blocks required on one side to resist the forces due to wind is:

$$N_w = \frac{M_w}{A_e S_p L_2}$$

where :

N_w	=	Number of additional blocks for wind
M_w	=	Overturning moment due to wind forces (ft-lbs)
A_e	=	Effective surface area of side block in contact with asset (in2)
S_p	=	Strength at the proportional limit of the block material (lb/in2)
	=	800 psi for Douglas fir
L_2	=	Average moment arm of side block reaction force (ft)

NOTE
Wind calculations should assume a worst-case situation whereby the wind is perpendicular to both the heavy lift vessel and the asset even when the heavy lift vessel and asset are not longitudinally and transversely aligned.

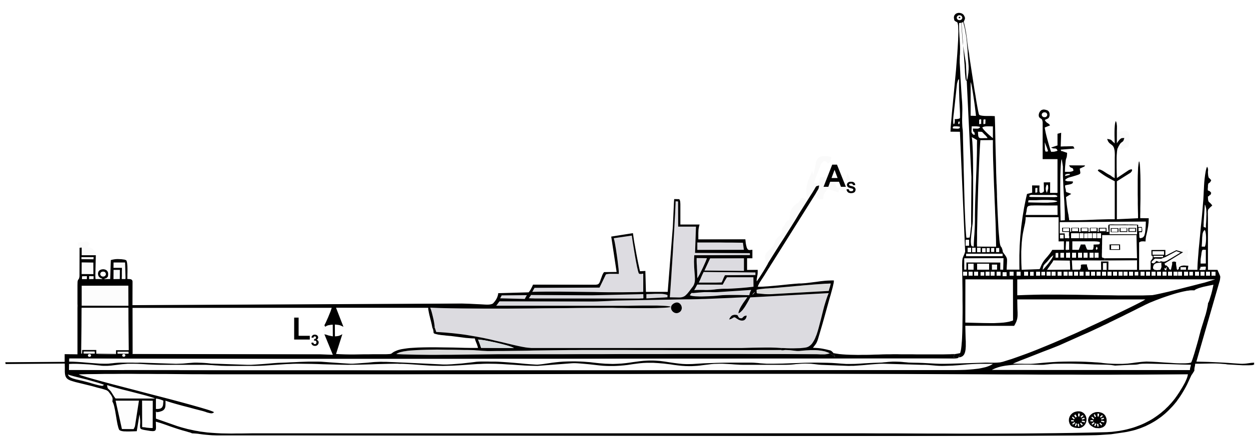


Figure 8-25. Overturning Moment Due to Wind Forces.

8-7.2.6 Determining the Total Number of Side Blocks Required

The total number of side blocks required is the total calculated for dead weight loading (section 8-7.2.2), dynamic loading (Section 8-7.2.4) and wind loading (Section 8-7.2.5):

$$N_T = N_d + N_r + N_w$$

where :

N_T	=	Total number of side blocks
N_d	=	Number of side blocks for deadweight loading
N_r	=	Number of side blocks for dynamic loading
N_w	=	Number of side blocks for wind loading

A better solution may be a combination of side blocks and spur shores. Side blocks provide better support to static type loading because of their higher compressive strength. Spur shores may be better placed farther out and higher against the asset's hull to resist dynamic loading.

8-7.2.7 **Maximum Load on Side Blocks to Prevent Hull Damage**

As in section 8-6.2.5 or 8-6.2.6, the safe allowable compressive stress of blocking must be considered as not to crush the side blocks. Static and dynamic loads on the side blocks should be analyzed as outlined above to ensure the loads do not exceed safety limits, and do not damage the asset's hull.

A higher load can be placed on the side blocks when they are placed under the asset's transverse frames, in which case the block loads can safely support up to 370 psi. This coincides with the maximum safe allowable compressive stress of Douglas fir wood blocking.

Certain situations may preclude positioning the side blocks under major structural members and transverse frames, such as in an off longitudinal center diagonal loading position of the asset, hull damage, or when aligning to the heavy lift vessel strength positions and characteristics.

A lower maximum load, up to 170 psi, is to be used if side blocks are not placed under a transverse frame.

NOTE
These maximum load limits apply to keel structured steel hull ships only (not aluminum-hulled littoral combat ships (LCS), patrol craft, or wooden-hulled Mine Counter Measure ships).

8-7.3 Additional Side Block Considerations

In some cases, the heavy lift contractor may desire to install a minimum number of blocks during float on and build the remainder of the blocks after the asset is onloaded. This is normally done to reduce the required depth of submergence during onloading. This is acceptable given that the environmental conditions during loading and transit to the buildout site are evaluated. The calculations used from the equations above should be repeated using the maximum expected weather conditions during onloading and building. Generally, a sea state 4 condition is acceptable and therefore used for the onloading and transit to the buildout site calculations. In no case should the minimum number of side blocks be less than the number necessary to support the static load and the expected roll angle. A minimum of five degrees of roll should be used. If the asset has an initial list, e.g., USS Cole had a 2.5 degree list before on-loading, that value should be added to the five degrees to determine the number of initial side blocks for on-loading. The static load is calculated using the equations in Section 8-7.2 and adjusting the roll angle. In no case should the minimum number of side blocks be less than four (two port and two starboard).

In the past, obtaining an accurate fit of side blocks has been a recurring problem. Contributing factors include inadequate drawings, bad offsets, damage to the asset's hull, or landing the asset slightly out of position due to the dynamic environment. Placing side blocks in positions shown on the U.S. Navy docking drawing offers the best possibility of a correct fit, but wedging material may still be needed. Air bags have been used on top of the side blocks and inflated by divers after the asset landed, which was effective in stabilizing the asset for the onload. However, with wedging or air bags, the blocks have an unknown compressive flexibility due to dynamic loading. If a significant change in the contact area or the compressive flexibility is observed, the number of side blocks required should be recalculated after the asset is on-loaded, taking into account the dynamic loading, maximum roll angles, and actual location and effective area of the side blocks. Installation of additional side blocks or shores may be necessary before the transit.

When determining how many side blocks are in place before landing versus installed after landing consideration should be made that blocks in place for landing will take both static and dynamic loads. Blocks installed after landing will only take the dynamic load. This will result in higher maximum loads on side blocks in place before landing that must be evaluated against the maximum allowable side block loads identified in Section 8-7.2.7. To improve the load distribution to side blocks installed after landing the heavy lift vessel is to ballast to a 1 degree list, install the blocks on the high side, and then ballast to reverse the list prior to installing the remaining blocks. A similar method is used improve the loading of spur shores.

The side blocks should be positioned as shown on the U.S. Navy docking drawing because the side block build is based on hull offsets in these locations and will ensure the best possible fit. This will also help to guarantee stable blocks up to angles of 15 degrees. The approach is conservative as the spur shores will share some of the deadweight

8-7.4 Spur Shores

The number of side blocks needed to resist all the loads experienced during transport will likely be too large to fit the given space and the number of side blocks placed in a given area will be less than what is needed, particularly if more than one asset is transported. To counter this shortcoming, along with the added benefits of resisting not only the dynamic forces associated with roll angles greater than 15 degrees but the overturning moments which are due to the dynamic motions of the heavy lift vessel and high winds (Mr + Mw), spur shores (roll bars) in combination with side blocks can be utilized.

Spur shores are tall, column-like structures placed further outboard on the hull than side blocks (Figure 8-22). They do not contribute significantly to supporting the asset's weight, but they can make a significant contribution to resisting overturning. The number of side blocks can be reduced if spur shores are used to help resist the dynamic moments associated with transit. Consider the following points when deciding to use spur shores:

- Spur shores are generally easy to install and take up less deck space.
- Roll angles above 24 degrees have been observed during this type of lift/transport. Therefore, supports should be placed at various angles to encompass the total range of the heavy lift vessel's stability. Spur shores are more suitable than side blocks for this duty.
- Spur shores are easily angled to resist the highest roll the vessel is likely to encounter.
- Thrust blocks (base plates) must be provided at the base of all spur shores and be firmly secured to the cargo deck of the heavy lift vessel.

- The shores must be suitably secured to prevent the shores on one side from falling out when those on the other side are compressed. This limits the bearing load per shore to the compressive load of the soft cap.
- A higher number of shores will likely be required to resist the same moment as fewer side blocks.
- Sufficient space will be required between multiple assets to install spur shores.
- Shores must be secured in the fore and aft, as well as the athwartships direction.
- Because of their point loading on the hull of the asset, the local structural limit must be evaluated in determining the number of spur shores to be used and designed with a top spreader which will spread the load to the asset's hull structure.
- Spur shores should be located on frames.

Heavy lift vessels shall be listed one degree opposite to the side that the spur shores are being installed to ensure maximum contact.

CAUTION
Exceeding one degree of heel could cause the asset to move on the blocking a cause a safety hazard.

8-7.4.1 **Loading on Spur Shores**

The number of shores required is dependent on several factors. Because the shores are slender, they will fail as columns before they fail in direct compression. This is the opposite of the failure mode for side blocks. It is necessary to determine the maximum column stress that the shore can withstand to ensure that the shores do not buckle under a compressive load. The actual load that each spur shore experiences will be dependent on the number of side blocks used and the local structural load limit on the side of the asset. If space limitations require only a few side blocks, a larger number of spur shores will be needed.

NOTE
In no case shall the number of side blocks be reduced below the minimum number required for loading, as determined in Sections 8-7.2.2 – 8-7.2.6

The equations below, based on the actual number of side blocks used, will determine the number of spur shores needed. The docking drawing and structural details should be checked to determine suitable locations and places where spur shores are more appropriate. The analysis begins with a series of equations to determine the maximum column stress for the shores based on their geometry and material. The maximum stress for each shore is found by:

$$S_c = C\left(1 - \left(\frac{1}{3}\right)\left(\frac{L_s}{d \times K}\right)^4\right)$$

where:

S_c	=	Maximum column stress (lb/in^2)
C	=	Proportional limit (psi)
	=	3,000 psi for Douglas fir parallel to grain
L_s	=	Length of shore (ft)
d	=	Minimum dimension of shore cross section (ft)
K	=	Relationship between elasticity and proportional limit

The relationships between elasticity and the proportional limit is a constant (K) and can be calculated by:

$$K = 1.11\sqrt{\frac{E}{C}}$$

where:

K	=	Relationship between elasticity and proportional limit
E	=	Modulus of elasticity of shore (lb/in^2)
	=	(1.6 x 10^6 psi for Douglas fir)
C	=	Proportional limit (lb/in^2)
	=	3,000 psi for Douglas fir parallel to grain

To prevent the shore from buckling, the shore reaction (Rs) must be equal to or less than:

$$R_s \leq S_c A_s$$

where:

Rs	=	Maximum shore reaction (lb)
Sc	=	Maximum column stress (lb/in2)
As	=	Cross sectional area of the shore (in2)

NOTE
The R_s of an individual shore must be less than the local structural limit of the asset’s hull structure.

8-7.4.2 **Determining the Number of Spur Shores**

It is necessary to evaluate the entire build to determine the number of shores required for a given number of side blocks. Information about the spring constants of both the blocks and shores is needed as well as their locations. To calculate the spring constant of a spur shore, use the following:

$$K_s = \frac{A_s E}{12 L_s}$$

where:

Ks	=	Spring constant of spur shores (lb/in)
As	=	Cross sectional area of shore (in2)
E	=	Modulus of elasticity of shore (lb/in2)
	=	(1.6 x 106 psi for Douglas fir)
Ls	=	Length of the shore (ft)

To test the suitability of a build (column stability of the shore and compression of the side block) the average reactions of the shores, R_s and side blocks R_b can be calculated using:

$$R_s = \frac{(M_w + M_r)(K_s L_1)}{{L_1}^2 N_s K_s + {L_2}^2 N_b K_b}$$

$$R_b = \frac{(M_w + M_r)(K_b L_2)}{{L_1}^2 N_s K_s + {L_2}^2 N_b K_b}$$

Because the maximum reaction that a particular shore can handle is known from previous analysis, the equations can be manipulated to solve for the minimum number of shores required. The equation then becomes:

$$N_s = \frac{(M_w + M_r)(K_s L_1) - R_s {L_1}^2 N_b K_b}{R_s {L_1}^2 K_s}$$

where:

N_s	=	Number of shores required <u>on one side</u>
N_b	=	Number of side blocks required <u>on one side</u> of the ship
M_w	=	Moment caused by wind for transit (ft-lbs)
M_r	=	Moment caused by rolling for transit (ft-lbs)
K_s	=	Spring constant of spur shores (lb/in)
K_b	=	Spring constant of side blocks (assume 200,000 lb/in)
L_1	=	Average lever arm of the spur shore's reaction forces (ft) (Figure 8-15)
L_2	=	Average lever arm of the side blocking reaction forces (ft) (Figure 8-15)
R_s	=	Max allowable reaction of shores (lb)

NOTE
For larger assets, or to reduce the number of spur shores required, consider using steel shores.

8-7.4.3 Distribution of Spur Shores

NOTE
The locations for spur shores are estimated by hull shape and structural drawings. The actual positioning of each shore is dependent on location and limits of the local structure on the ship.

The procedure presented above determines the minimum number of spur shores necessary. This procedure assumes the number of side blocks used is regulated by available spacing and direct support of the asset when subjected to the maximum expected roll angle. Side blocks will generally be placed to resist rolls of at least 15 degrees, but preferably to the maximum roll angle. The spur shores must resist rolls beyond this angle. To help resist these rolls, the shores should be distributed throughout the range of angles.

Since spur shores need to support the load down the shore's axis and tend to trip out, positioning the spur shores in increments of approximately five degrees should provide acceptable load sharing. They should be set up in pairs, fore and aft, to resist twisting. They need to be positioned perpendicular to the hull on the local structure, high enough on the hull to resist the overturning moment and constructed to remain stable throughout their design load limit. While effective length dictates a higher angle, in general, angles of 45 degrees or less should be utilized unless the compensation for the overturning moment dictates placing the shores higher on the hull.

The use of this method may produce a different number of spur shores than previously determined. The larger number should be used, to be conservative, and a minimum of two shores (one fore and one aft) should be installed at each angle. The shores should be secured to the deck at the foot of the shore to ensure that they do not slide when loaded. They should also be placed normal (perpendicular) to the curvature of the hull.

Final verification of the compensation of the overturning moment (Mo) is accomplished by ensuring the overturning moment about the attachment point of the spur shores is less than the righting moment (Mr) produced by the spur shores, that is:

$$M_o < M_r$$

Mo is created by the transverse dynamic force working through the ship's center of gravity and its separation from the attachment point of the spur shore.

$$M_o = (w)(a_y)(L_o)(2{,}240 \text{ lbs/ton})$$

where:

M_o	=	over turning moment (ft-lbs)
w	=	Displacement of vessel at time of on-loading (tons)
a_y	=	Acceleration factor for athwartships motion (g)
L_o	=	distance between the line of action of the dynamic force working transversely through the asset's center of gravity and the position of the shores on the hull in the vertical direction (ft)

NOTE
Refer to Appendix P, Appendix Figure P-5 for an illustrative example of the geometry.

Mr is created by the resultant force that spur shores can create in the transverse direction against the hull and its separation from the line of action of the weight of the asset passing through the asset's center of gravity.

$$Mr = (w)(2 - az)(Lr)(cos\ R)(2{,}240\ lbs/ton)$$

where:

M_r	=	righting moment produced by the spur shores (ft-lbs)
w	=	Displacement of vessel at time of on-loading (tons)
a_z	=	dynamic load factor in the vertical direction, increasing the blocking load when the heavy lift vessel pitches up, and decreasing the blocking load when the heavy lift vessel pitches down or $(2\text{-}a_z)$(g)
R	=	maximum roll angle (degrees)
L_r	=	distance between the line of action of the downward force through the asset's center of gravity and the shore's position on the hull in the transverse direction (ft)

NOTE
Refer to Appendix P, Appendix Figure P-5 for an illustrative example of the geometry.

NOTE
The factor cosR is to adjust the line of action of the weight from the vertical to account for the maximum angle of roll.

In practice, the Transport Manual will recommend a seafastening plan that will include, among other things, a plan for positioning spur shores. The contractor will likely perform a detailed analysis to determine maximum loading for each spur shore through various roll angles. This distribution should be similar to the distribution determined by the method presented above.

8-7.5 Seafasteners

Seafasteners must be designed to restrain the asset from movement at high angles of pitch and roll anticipated during transits. Some resistance to these forces is provided by the friction between the keel and the blocks. Seafasteners must be installed at the forward and aft ends of the keel or some other reasonably accessible location of the asset to resist longitudinal movements due to the heavy lift vessel's maximum angle of pitch. They should also be installed on the port and starboard sides of the keel to help resist athwartships movement of the asset during rolling of the vessel. It is prudent to install seafasteners at both the fore and aft ends of the keel to prevent twisting. A minimum of two seafasteners should be installed at each end (one port and one starboard) (Figure 8-26). However, each seafastener should be capable of resisting the entire sliding force.

8-7.5.1 Dynamic Force

The dynamic force that must be restrained in each direction is equal to the weight of the asset multiplied the dynamic load factor. This is similar to the procedure used to calculate the dynamic loading on the blocking (Section 8-7.2.4). Here, the main concern is the asset sliding off the blocking. However, for the transverse direction, the dynamic load factor, ay, will be the same. Therefore, the dynamic load in the transverse direction will be:

$$DL_t = \Delta a_y$$

where:

DL_t	=	Dynamic load in the transverse direction determined by the maximum angle of roll to be expected in route (tons)
Δ	=	Displacement (tons)
a_y	=	Athwartship acceleration factor (g) (Section 8-7.2.4)

Similarly, the dynamic load in the longitudinal direction will be:

$$DL_1 = \Delta\, a_x$$

where:

DL_1	=	Dynamic load in the longitudinal direction determined by the maximum angle of pitch to be expected in route (tons)
Δ	=	Displacement (tons)
a_x	=	longitudinal acceleration factor (g),

NOTE
The above equation assumes transverse and longitudinal alignment between the heavy lift vessel and the vessel to be heavy lifted.

8-7.5.2 **Friction Resistance**

In practice, it has been observed that a ship slides transversely when the heel exceeds roughly 15-degrees and longitudinally when the pitch exceeds roughly 3-degrees. The dynamic frictional resistance of steel on wet or greased wood is approximately 22%, equating to an angle of approximately 12-degrees before sliding will occur (depending on the ship's weight and center of gravity when on docking blocks). These numbers work well for relatively flat bottom vessels as long as the vessel does not lift off the blocking due to being submerged.

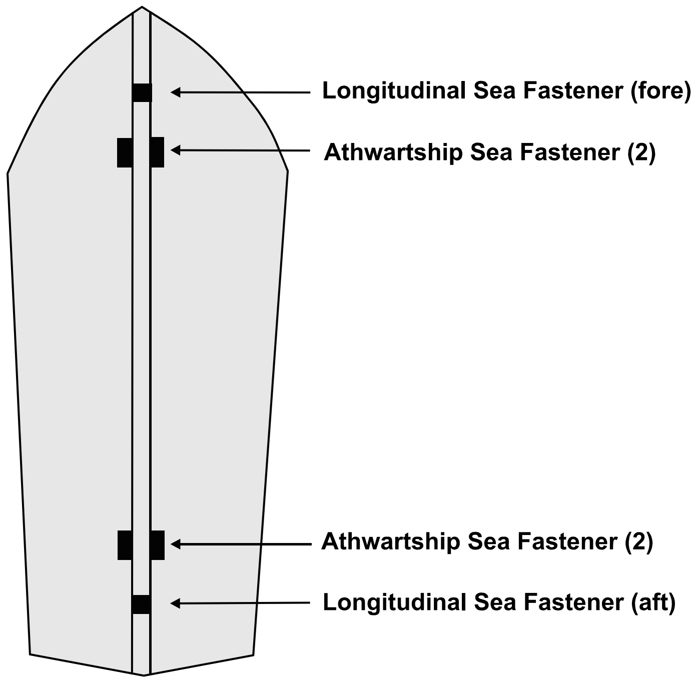


Figure 8-26. Sea Fasteners.

Figure 8-27. Longitudinal Sea Fastener (Bow Stop).

Figure 8-28. Athwartship Sea fastener (Stop).

Figure 8-29. Longitudinal Sea fastener (Stern Stop).

The friction factor used for longitudinal sliding is less in value because there is a greater possibility of the vessel lifting off the blocks due to submergence or slamming. When a 500 foot heavy lift vessel pitches three degrees then the trim increases by 26-feet. Other factors contributing to these conclusions include variations in materials, variations in hull shape, column stability of the blocks, and the asset's possible overhang. These approximations should provide reasonable estimates for sizing seafasteners. To calculate the load that is resisted by friction, multiply the asset's weight by the frictional factor using the following:

$$FR_t = 0.15\Delta \textit{ and } FR_l = 0.05\Delta$$

where:

FR_t = Frictional resistance in the transverse direction (tons)
Δ = Displacement (tons)
FR_l = Frictional resistance in the longitudinal direction (tons)

8-7.5.3 **Seafasteners Resistance**

The seafasteners must resist the force that is not carried by friction. Therefore, the force carried by the seafastener is equivalent to:

$$SF = DL – FR$$

In the transverse direction, this becomes:

$$SF_t = DL_t - FR_t$$

where:

SF_t = Transverse seafastener force (tons)
DL_t = Dynamic load in the transverse direction (tons)
FR_t = Transverse frictional resistance (tons)

In the longitudinal direction, this becomes:

$$SF1 = DL1 – FR1$$

where:

SF_l = Longitudinal seafastener force (tons)
DL_l = Dynamic load in the longitudinal direction (tons)
FR_l = Longitudinal frictional resistance (tons)

NOTE
When the heavy lift vessel and the asset are not aligned longitudinally and transversely the heavy lift vessel's roll will translate to a significant pitch of the asset. This increase in the asset's pitch must be accounted for when designing the bow and stern stoppers to ensure they can provide a sufficient resistance.

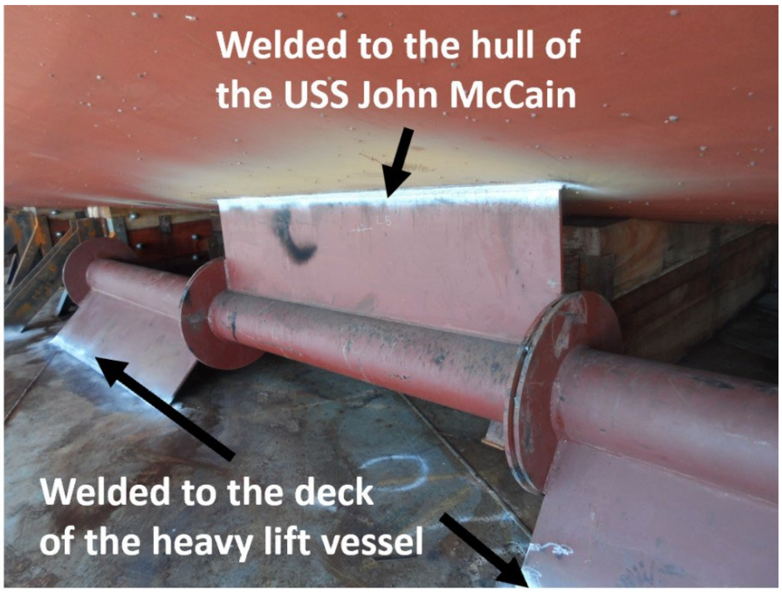


Figure 8-30. Strong Box used to prevent longitudinal movement of the DDG-56.

Figure 8-31. Bent Plate used to prevent longitudinal movement of the DDG-62.

In the case of the USS John S. McCain (DDG 56) both the bow and stern hung over the side of the heavy lift vessel. In the cases of the USS Fitzgerald (DDG 62) and USS Cole (DDG 67) the bows were hung over the stern of the heavy lift vessel. In each case, either strong boxes (Figure 8-30) or bent plates (Figure 8-31) were used for longitudinal fastening.

8-8 Surveys

Several surveys must be conducted to ensure that the vessel and its systems can adequately perform the FLO/FLO operation. These surveys will determine that all material and procedures are in accordance with the Transport Manual and conform to the requirements of this manual. When possible, photographs or videos should accompany critical aspects of the surveys.

8-8.1 Hydrographic Survey

NOTE
Heavy lift vessels, in general, are not designated to make contact with the sea floor. Adequate depth of water must be provided so that the heavy lift vessel does not contact the sea floor bottom.

The hydrographic survey must be conducted at the proposed onloading and offloading sites and in the approach channel by an adequate number of soundings referenced to Mean Low Water. These surveys are part of the decision making on choosing the onloading and offloading sites and dictate the operating procedures for each. A sounding chart must be included in the survey results. Complete tidal ranges, approach channel width and depth configuration, dredging frequency, and any irregularities must also be noted. Where a history of hydrographic data is available, rates of siltation must be noted.

8-8.2 Acceptance Survey / On Hire Survey

An acceptance/on hire survey should be conducted by the COR (generally the MSC area representative). This is a general survey that shows that the vessel and its systems are the same as those described in the Transport Manual. If possible, the COR should observe a ballast/deballast sequence. If not, they should, at a minimum, review the time required for a complete sequence (this information should come from an actual evolution and not just from published capabilities). The inspection should also include a general walk through of the vessel to verify sea worthiness and proper adherence to class society regulations. The heavy lift vessel must classed and present the latest certificate of class and material condition survey. It is often prudent to have the HLPO (or HLDO), IMS, and Loadmaster participate in these surveys as well.

NOTE
This survey should be conducted as close to the scheduled onload as possible; preferably before the heavy lift vessel departs the last off-load before arriving for onload of the U.S. Navy asset. Doing so ensures sufficient time for tank cleaning and decontamination if problems are identified.

The heavy lift contractor needs to prove to the COR that they have been at the required depth for the FLO/FLO within the last 6-12 months. Failing to do so, the contractor must demonstrate they can reach the depth.

After the vessel is accepted, several detailed surveys should be completed to ensure all systems are in good working order. The surveys of the heavy lift vessel, asset(s) and blocking described below are conducted by the Heavy Lift Project Team, IMS, and Loadmaster.

8-8.3 Structural Surveys

A thorough inspection of the heavy lift vessel’s primary structure should be completed. The plating, strength members, joints, foundations, sea chests, entire cargo deck where blocking may be installed, and structures associated with mooring must be checked. Indications of excessive corrosion or local failure should be analyzed accordingly. In addition to this general walk around inspection, the latest material condition survey, records of repair, and design data should also be examined. These may alert the inspectors to any areas that might warrant a more thorough inspection. The information collected by the visual inspection should be analyzed and compared with the information contained in past surveys to determine whether detail surveys and/or repairs are required in any area.

8-8.4 Indicators and Controls

An inspection of the heavy lift vessel's ballast/deballast control system shall be accomplished. This system is critical to completing a safe operation and should be in good working order before the start of the FLO/FLO procedure. In general:

- Draft indicators must be provided that shows the heavy lift vessel's draft at all four corners of the vessel and cargo deck. Backup systems, such as visual observation, should be addressed.
- Must have indicators that continuously display the heavy lift vessel's trim and heel during FLO/FLO ballast/deballast operations.
- Ballast tank level indicators must be able to control ballasting/deballasting. These indicators' accuracy must be sufficient to prevent accidental overstressing of tank bulkheads by excessive differential heads and accidental overstressing of the overall ship structure in shear and bending.
- Provide ballasting system valve indicators that show the position of the valves.

Ballasting/Deballasting Systems and Gauges. Confirm the following during the ballast/deballast inspection

- Actual ballasting and deballasting times. If these times are different from ballasting and deballasting times for which the system was originally designed, reasons for this variation must be explained in the survey results.
- Adequacy of the power supply, determined by operating all applicable pumps (and the fire pump, if installed on dock) at the same time.
- Effectiveness of all pumps, motors, valves, and generators by remote control and local control.
- The accuracy and reliability of water level indicators compared with actual sounding of the water level in each tank.
- Tightness of air-cushioned boundaries, if they are required, in the tanks.

Controls. Confirm the following during the ballast/deballast inspection:

- Control panel: Check wiring, relays, bulbs and lenses for dust collection and abrasion of wires.
- Motor controls: Check contractors, relays of electrical and mechanical interlocks and manual overhauls.
- Limit switches: Check panel limit switches and switch activator mechanisms.

8-8.5 Pre-loading Block Check

Before submerging the heavy lift vessel, blocking should be inspected to ensure it is in accordance with the arrangements in the approved Transport Manual. As a minimum, the inspection should concentrate on the following areas:

- The heavy lift contractor shall define a datum(s) from which all block (keel, side, etc.) locations are determined.
- Location of first keel block (after most on the asset).

- Location of the alignment marks or columns for port and starboard alignment to the center of keel blocking.
- Location of fore-and-aft centering markers.
- Side clearance of the asset.
- Rudder, propeller, and other hull projections clearances above the cargo deck and blocking.
- Offsets from the center line or from set keel blocks and side blocks.
- Keel blocks levels to ensure there are no excessively high blocks.
- Heights of side blocks and keel blocks, if not flat.
- Special blocking arrangements for hull projections, hull openings, or special support blocks.
- Removal of unnecessary blocks.
- Visual deck markings for diver alignment of keel and confirmation of protrusion clearances.
- Blocking layout verified according to Transport Manual plan.

NOTE
As-built block heights must be with +/-0.25 inches of the approved Transport Manual.

8-8.5.1 Wooden Blocks

Inspect wooden blocks for deterioration resulting from excessive crushing, warping, cracking, checking, rotting, or damage from dogging. Check for loss of contact at edges resulting from checking and unequal shrinkage.

8-8.5.2 Block Securing Method

All blocks must be secured in place. Securings, supports, nuts, bolt heads, and other fasteners should be sounded. If the blocking does not land on transverse strength members of the cargo deck, investigate to ensure that adequate grillage is used to distribute loading to adjacent strength members. Inspect the securing and bolt connections through the wood where blocks are bolted to clip angles or plates welded to the cargo deck. When blocks are set on steel frame supports, inspect the bolts and supports as well. If welding is used for securing block brackets or grillage, determine if non-destructive testing is necessary to confirm weld integrity.

8-8.6 Additional Systems Checks

Structure and ballasting are two systems that make FLO/FLO vessels different from other ships. In addition to these systems, the survey should also include inspection of traditional ship's systems on the heavy lift vessel. The survey should include a review of the following:

Communication Systems and Alarms

The communication systems and alarms must be checked thoroughly and tested for proper operation to maintain communications between all operating stations.

Fire Protection Systems

The fire protection systems intended for fighting fire on the cargo deck or asset must be thoroughly checked and tested for conformance to all requirements of paragraph 5.1.3.13 of MIL-STD-1625D (Ref T). The capacity available to serve the asset's Firemain (either permanent or temporary) shall also serve the fire stations on the cargo deck, but in no case shall be less than 1,000 gallons per minute. The supply pressure shall provide a minimum nozzle pressure of 60 psi when supplying fire nozzles at the most remote and highest elevation hose connections.

Block Handling Systems

The block handling system must be observed in operation and must be inspected.

Mooring and Anchoring Systems

The mooring and anchoring systems must be inspected thoroughly for adequacy and for signs of local buckling and excessive loading.

Electric Power Systems

Both the primary and alternate electric power systems must be inspected. Power switches, converting panels, and cables for providing power to the asset must be inspected for material condition, proper fit, and size.

Ship Positioning Gear

Bitts, bollards, winches and cleats must be inspected for fatigue, looseness or other signs of excessive loading.

Ship Services

Compatibility of all connections (Firemain, electrical, cooling water, etc.) should be verified as specified in the Transport Manual and identified at the pre-loading conference.

Safety Equipment

All safety equipment necessary to comply with the governing regulatory agency should be inspected. While some safety equipment from the asset can be used, most will not be suited for this purpose. To avoid delays, be sure that it is clear who is responsible for providing safety equipment for the riding crew.

8-8.7 Asset Inspection

The Heavy Lift Project Team should complete a walkthrough of all compartments with ship's force to ensure the asset(s) is rigged for sea. This survey should include an inspection of the hull's watertight integrity and ensuring that Condition Zebra is set. The final condition of the asset's loading should be inspected and recorded just before its departure and copies made available to all parties. All tanks and voids must be accurately sounded and photographs should be taken of the topsides of all assets. These photographs will accurately identify the nature and position of any items that may have been added topside. They will be used to verify that the assets condition has not changed when it is time for offloading. No weights, including liquids such as fuel or water, should be shifted, added, or removed from the asset unless authorized by the Loadmaster and HLPO, and during transit as authorized by the heavy lift vessel's Master and the riding crew's OIC. The HLPO approves the asset(s) ready for heavy lift via the checklist provided in Appendix R.

8-8.8 Post Float-On Inspection

When the asset lands on the blocks as deballasting begins, the landing condition should be examined. Divers should be used to ensure that no blocks have tipped, the asset is in the predicted location, and there are no interferences. Appropriate safety precautions must be taken as these operations will be taking place in open water instead of within a dry dock.

CAUTION
All parties must be informed when divers are being used and clear communications signals when they are in the water. Extreme caution must be used to ensure the safety of these individuals. All sea suctions for the asset and the heavy lift vessel near the area the divers will operate should be secured during diver operations. No deballasting or other vessel movements should occur while divers are working under the asset.

When the divers have reported that the asset(s) have landed satisfactorily on the blocks, the deballasting operation should continue until the cargo deck emerges from the water.

Once the cargo deck is clear of the water and safe for access, as determined by the Loadmaster, a thorough examination of the landing condition should be completed by the Loadmaster, HLPO, and the IMS. A decision whether to continue deballasting or to refloat the asset(s) should be made. Any irregularities found should be noted and corrected, and any necessary wedging and/or shoring must be placed. If the decision is made to continue with the deballast procedure, this effort should be completed immediately and the remainder of the build and seafastening should commence.

8-8.9 Examination of the Seafastening

All final seafastening will be completed after the asset's onload and before transit to the delivery site and shall be in accordance with the heavy lift contractor's Transport Manual.

8-8.9.1 **Pre-Transit**

Following the build-out completion, all components, keel blocks, side blocks, and spur shores should be surveyed by the Loadmaster, HLPO, and IMS. They should inspect the spur shores and seafastening before departure to verify they are satisfactorily installed and per the Transport Manual. Any agreement to changes should be noted and recorded. Additionally, the OIC must understand the final seafastening arrangement as briefed by the HLDO to monitor during transit.

8-8.9.2 **During Transit**

The seafastening and blocking should be inspected daily by the OIC of the asset and the heavy lift vessel's Master, or more frequently if rough weather is encountered during transit.

8-8.9.3 **Upon Arrival**

Upon arrival, the Heavy Lift Project Team team should inspect blocking, spur shores, and seafastening, noting any movement and/or damage that may have occurred along the hull or connection/touch points of the asset(s). Any movement or damage should be photographed and documented before the removal of seafastening, and if necessary, repairs made before offload.

8-9 Offloading Operations

The final phase of the operation is the offload of the asset(s). While this is less complicated than the onloading procedures, it is still a critical phase of the operation and demands careful planning. The selection of an appropriate offloading site will allow the operation to proceed without incident. Also critical to identifying the offloading site is available water depth for ballasting and float off, and prevailing weather conditions allowing for a sufficient weather window long enough to complete the operation without unexpected delays due to weather

.

NOTE
A risk associated with offload is the unanticipated movement or change in weight after onload. The Heavy Lift Project Team and the heavy lift contractor shall make every effort to ensure that no weight changes occur after the asset(s) is loaded. If weight changes after onload are unavoidable, the Heavy Lift Project Team and heavy lift contractor will ensure that a safe offload is still possible.

8-9.1 Pre-Arrival at Destination

All parties involved in the offload procedures should be available at the discharge location at least two days before the heavy lift vessel's arrival. A pre-arrival conference with all parties represented should be held to review offloading details. This meeting is held in advance of the heavy lift vessel's arrival in order to confirm the offloading details, including the offloading site, number of assist tugs, and a rough timeline. The heavy lift contractor will arrange the meeting location, agenda and chair the meeting. Key members of the Heavy Lift Project Team, MSC, the IMS and relevant stakeholder such as local port authorities, pilots, tug service providers, and the operational commander's available members are also expected to attend.

All necessary arrangements shall be made to accommodate the pier space for the asset(s) after they are offloaded. These arrangements should be in place before the arrival of the heavy lift vessel.

For example, if the asset(s) are to transit under their own power, sufficient manning must be arranged including personnel boats to the heavy lift vessel, or if the asset(s) need to be towed, sufficient tug assets must be arranged, and inspected if necessary.

8-9.2 Arrival Activities at Off Loading Site

When the heavy lift vessel arrives at anchor or pierside, each asset and all cargo shall be inspected by the Heavy Lift Project Team, the Loadmaster and IMS. Any voyage related damage shall be recorded in a post transit report and made available to all parties. The asset(s) should be returned to the float on conditions before float off. All tanks and cargos should be in the same condition as before float on. The OIC of the riding crew should prepare an updated loading condition report. If the same conditions of onload are not possible, as in the case of a damaged asset (USS Cole (DDG 67)), a deadweight survey of the asset should be conducted.

The Loadmaster should prepare to remove the seafasteners and any "Lift-On/Lift-Off" deck cargo in addition to preparing the heavy lift vessel and asset(s) for offloading. The final seafasteners should not be removed until the heavy lift vessel is at the final offload site.

A final offloading conference should be held within 24 hours of the offload operation as the final review of activities such as line handling and tug makeup, schedule and weather conditions. All parties involved in the offloading operation, including any local tug captains and pilots, shall attend this meeting. A detailed review of the offloading procedure should be made and agreed to by all parties.

8-9.3 Off Loading

Before offload, the asset(s) and heavy lift vessel stability analysis should be revisited. Any changes to the condition of any ship should be documented and taken into consideration. The Loadmaster, HLDO, and IMS should agree on the asset(s)' expected float off draft and the heavy lift vessel's final ballast depth for asset float out.

The offloading operation proceeds in the reverse order of onloading, with all the individuals performing the same tasks as at the on-load. Representatives from all parties should agree on any deviation from the approved Transport Manual.

NOTE
There is one procedural difference in the offload compared to that of the onload. Watertight hull integrity checks need to be performed, typically by ships force.

As the heavy lift vessel ballasts down to one foot before the asset(s) lifting off the blocks, ballasting stops to allow for hull integrity checks. Stationed watch standers rove the hull's inner spaces to look for any signs of leaks and are prepared to take corrective actions. Close attention is placed on through hull valves, submerged discharge ports, and sea chests. If hull integrity is reported satisfactory with no significant leaks, ballasting can continue to offload the asset(s). If significant leaks are reported, the heavy lift vessel will de-ballast to lift the asset(s) out of the water and corrective actions are taken to fix the leaks. Offload, in this case, may be delayed or postponed to a later time. If no leaks are reported the watch standers will continue to rove and monitor for signs of leakage until ballasting is complete, the asset(s) is afloat, and the asset(s) is ready to be maneuvered off the heavy lift vessel.

If the asset(s) is to be towed to their final destination, towing preparations on the asset(s) and coordination with the tug contractor or port operations must take place. Appendix H provides a checklist for preparing and rigging an asset for tow. Sufficient tugs to complete the unloading and transport of the asset(s) needs to be provided. Having an excess of tugs may be a cheaper alternative to delaying the offloading procedure.

8-9.4 Post-Offloading Inspection

Following the successful float off and departure of the asset(s) the heavy lift vessel will deballast to expected transit draft. The Heavy Lift Project Team team will remain onboard until the cargo deck is dry and available for walk-through with the Loadmaster and IMS. The inspection is intended to identify any movement of blocks or blocks that may be missing. Moved blocks can indicate interface with a protrusion or service vessel, and missing blocks may have adhered to the asset(s) hull and the operational commander must be notified.

8-10 FLO/FLO Operation Closeout

Upon completing the post-offload inspection, the HLPO will issue the final SITREP to close out the operation as the team departs the offload site. Additionally, they are responsible for collating the project file for turnover to NAVSEA 00C. The project file shall include, although not limited to, the following documents and information:

- Onload Procedure (signed out by the HLPO)
- Offload Procedure (signed out by the HLPO)
- Transport Manual and any revisions or documented modifications
- Appendix R and H, as utilized in the onload and offload operations
- Independent docking calculations to verify sufficient blocking, draft of instability, draft at landing, draft at float-off, and required water depth for float-on and floatoff
- Copies of witnessed cargo verification forms the HLPO may co-sign with the IMS
- Key photos or videos of inspections and operational execution
- Full set of daily SITREPS
- Any additional relevant documents, reports or briefs (e.g. Onload or Offload Conference briefing slides)

This project file is turned over to NAVSEA 00C electronically for filing and record keeping.

As part of the departure activities the Services Coordinator will inventory the Heavy Lift Project Team's fly-away kit and return to ESSM at:

Virginia ESSM Facility
Naval Weapons Station Cheatham Annex

P.O. BOX JK
Williamsburg, VA 23187

Appendix A - SAFETY CONSIDERATIONS IN TOWING

A-1 Introduction

The purpose of this appendix is to supplement the specific safety precautions for towing operations discussed in this manual with the general safety precautions published in OPNAVINST 5100.19C, N45, 0579LD057 1210, Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat (Ref. X).

A-2 Scope and Applicability

The safety information contained in this manual shall apply to all afloat Naval Commands that are involved in towing operations. It shall also apply to United States Naval Ships (USNS) of the Military Sealift Command (MSC) and its activities and the Marine Corps, when embarked in the aforementioned vessels and to the extent otherwise determined by the Commandant of the Marine Corps. This information, in combination with the OPNAVINST 5100.19 series, comprises the Navy Occupational Safety and Health (NAVOSH) standards for towing operations as required by the OPNAVINST 5100.23C, *Navy Occupational Safety and Health (NAVOSH) Program* (Appendix M - , Ref. Y). For additional salvage safety information, consult the US Navy Salvage Safety Manual 0910-LP-107-7600 (Appendix M -, Ref. Z).

A-3 Basic Safety Philosophy

Many safety studies have indicated that human error is a common cause of mishaps. Even though the failure of some item of equipment may be listed as the "cause" of a mishap, the equipment often has failed because of an earlier human error or oversight in design, manufacture, maintenance, or use of the equipment.

Therefore, all personnel must be trained in the use of, and have ready access to, appropriate Navy technical manuals and other publications to guide them in their operations. Consequently, the approach to achieving safety in towing operations is to:

- Comply with existing Navy parent documents, such as the OPNAVINST 5100.19 series for general policy and procedural guidelines, and refer to the pertinent technical manuals and Planned Maintenance System (PMS) cards for specific information on operation and maintenance of commonly used gear and equipment.
- Comply with Navy technical manuals, such as this volume on towing, and manufacturers' operating manuals for more detailed information on specialized operations. Use PMS cards and data for information on gear and equipment that are primarily or peculiarly associated with such specialized operations.
- Encourage the use of systems safety analyses, in which the overall system or activity of concern is planned and reviewed from the standpoint of safety. Factors such as the specific environment in which an operation is to be conducted should be considered and accounted for in planning. Consequently, fewer omissions should occur and safety awareness among all personnel who may be involved should increase. See Section 34.1.5 and Table 32 for a discussion of factors of safety in the selection of towing components.

No list of safety precautions in towing can be comprehensive without the principles of good seamanship. The precautions stated here and in the OPNAVINST 5100.19 series are basic and must be followed.

Personnel involved in towing operations must be thoroughly trained, disciplined, and equipped not only to perform routine duties, but also to react appropriately to unusual or nonroutine situations. The officers and crew of vessels involved in towing operations should continuously conduct safety indoctrination lectures and exercises aimed at reducing unsafe conditions or practices and at reacting appropriately to unusual circumstances through professional knowledge of their duties and towing procedures.

A-4 Specific Safety Precautions

In addition to the safety precautions in the OPNAVINST 5100.19 series, many paragraphs within this manual also contain specific notes of safety related information. Rather than repeating notes from these two sources, the following paragraphs discuss only the approaches that are recommended specifically for towing operations.

A-4.1 Specific Approaches

A-4.1.1 General Specifications

The *General Specifications for Ships of the United States Navy* (Ref. D) mandates that any ship that is likely to require towing, especially emergency towing, should be equipped to "tow or be towed." The equipment inventory should be such that in an emergency nothing is required to be brought on board the tow or fabricated on the tow. Each ship must be capable of receiving or rigging an emergency towing rig designed so that the ship can tow or be towed.

A-4.1.2 Non-Emergency Towing

For non-emergency situations (and for emergencies, to the extent that time permits) the preparation procedures outlined in this manual and in appropriate Type Command Directives or Instructions must be completed. Even for missions that are repetitions of previous tows, the preparation phase must be repeated to ensure that nothing is overlooked. In both the preparation and operational phases of any tow, it is essential that full and open communication exists between the preparing activity and the towing vessel.

A-4.1.3 Safety

Safety is paramount in the preparation of individual Command Instructions and Towing Bills, as well as in the preparations for individual towing tasks.

Appendix H includes checklists to help in the operational planning and preparations for tows. All hands must fully understand that good planning and preparation for emergency situations are just as important for safe towing as correct ship handling and good seamanship. Planning is not a simple paperwork drill. The preparation phase of a towing operation demands the same knowledge and seamanship skill as the actual at sea phase.

Past experience has amply demonstrated that, from the very onset of the tow tasking, it is imperative that the plan for preparing the tow for the transit be thoroughly conducted and reviewed before implementation. In some instances, such as ocean tows of complex units like dry docks, the plans and the tow may be prepared by a civilian marine contractor and supervised by the Supervisor of Shipbuilding and Repair at an appropriate Navy facility.

In a peacetime Navy (or in the early stages of war) the availability and quality of "inhouse" expertise in the field of towing and tow preparations can vary widely. The towing unit must therefore monitor the efforts of the activity preparing the tow. The towing unit must make continuous inspections and take positive action immediately to correct identified deficiencies. The towing unit Commanding Officer or a representative should attend any meeting held by the cognizant activity for the tow and the preparing activity and should make any comments or recommendations necessary.

A-4.1.4 **Planning**

Although this manual presents planning procedures in considerable detail, extreme care and judgment must be exercised. Blind dependence upon the results of routine calculation methods, especially computerized procedures, without careful cross-checking can lead to major errors and possibly extreme operational difficulties.

Even a poor choice of location for conducting pre-tow preparations can lead to major problems. If available, the tow should be prepared at a full service, easily accessible location and then moved to a staging area once fully prepared and made ready for sea.

Few Navy tows will be exact duplicates of earlier tows. Even though some tows may appear to be duplicates, there will be differences in weather, route, and configuration of the towed vessel. Thus, the pre-tow planning and preparations must be conducted each time a towing task is undertaken to ensure a minimum of oversights and mishaps.

A-4.2 Contingency Planning

Contingency planning is very similar to operational planning, except that it concentrates on the aspects of being prepared to respond to emergency conditions. Being prepared includes both knowing what to do and having the appropriate supplies and equipment available to do it. The Navy "tow-and-be-towed" instructions, including individual ships' bills and equipment, are one example of contingency planning.

Appendix B - WIRE ROPE TOWLINES

B-1 Introduction

The towing hawser is the key element in the tug-tow connection. For Navy towing ships, the hawser is usually wire rope. It is especially important to keep a wire rope hawser in excellent condition, to protect it against excessive wear, and to inspect and lubricate it regularly.

To maintain a written reference of a wire rope towline's history, the Naval Sea Systems Command requires that all U.S. Navy and MSC vessels regularly engaged in towing operations keep a Towing Hawser Log. Appendix F includes instructions for keeping this log.

B-2 Traceability

The ability to trace a rope's history is an important element in accident investigation, as well as in general product improvement efforts. Some of this information is maintained in the Towing Hawser Log (see Appendix F). American made wire rope and some brands of foreign made rope can be identified by special core marker materials used as a part of, or layered around, the core of the wire rope, as well as by the metal tags and other information on the reel upon which the rope is delivered. Identification of manufacturing source through core markers is particularly useful in cases where the color coding has not been applied to a strand. Additional information on a specific domestic wire rope producer's core color marking practices is available on request from the manufacturer.

B-3 Strength

Steel wire rope currently provides the strongest towing hawser for a given diameter and is usually specified by the Navy as the preferred hawser for towing.

CAUTION
Aramid fiber lines (Kevlar, Spectra) have a similar strength to diameter ratio as wire rope and offer a considerable weight savings, but this light line provides no catenary and aramid fibers do not possess the stretch characteristics of polyester. Therefore, these lines are not well suited for ocean towing.

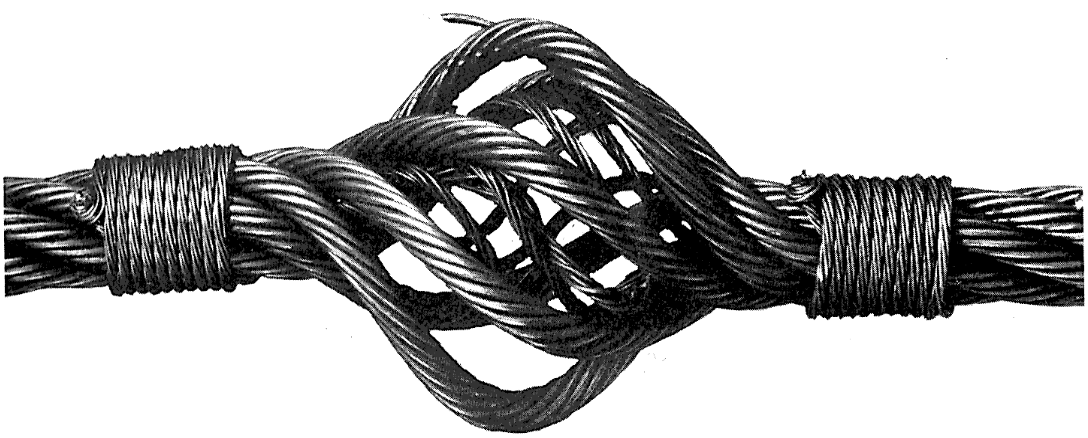
Target sleds are virtually the only tows for which a synthetic fiber line hawser is currently specified.

Wire rope strength varies with the type of construction and material as well as with size. Consequently, it is important to be certain that all wire ropes used in towing are of the proper construction, core, and required material.

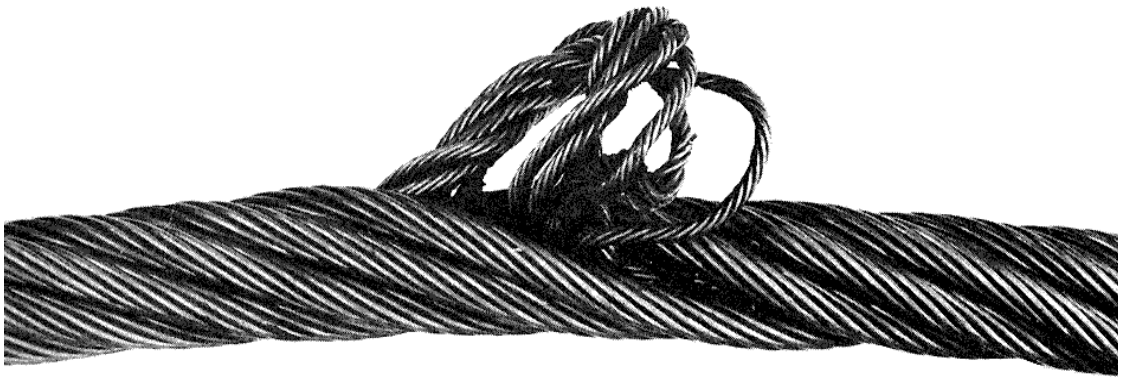
WARNING
Wire rope stretches under load far less than most natural and synthetic fiber. Lines and thus presents less danger to bystanders from loose ends "snapping back". If it fails under high loads, the elongation under load is sufficient nonetheless, to be dangerous. The recoil can be extremely violent and all personnel should stay well away from any potential recoil path.

B-3.1 Elongation (Stretch)

In addition to the above noted danger, the sudden release of tension can sometimes cause a popped core or a "birdcage" in the rope when a failure in the towline or its connections allows



Appendix Figure B-1. Bird Caging Bird Caging



Appendix Figure B-2. Popped Core

the rope to rebound from an overload. These conditions also can result from operating a wire rope through an undersized sheave groove (see Appendix Figures B1 and B2).

B-4 Maintenance, Cleaning, and Lubrication

Wire rope, like a machine, is made up of many moving parts. The individual steel wires slide independently and must be kept clean and protected against the effects of movement and pressure by adequate lubrication.

Corrosion damage is also a danger. The exact loss of strength resulting from corrosion of wire rope cannot be estimated. Washing the tow hawser down with fresh water and lubricating it during retrieval after each use can help retard corrosion. This, however, is not a “cure-all” since the core remains saturated with salt water.

Properly specified and procured wire rope is lubricated during manufacture. Since the time in storage may not be known, the towing ship should clean and relubricate a new towing hawser upon receipt. Relubrication will be required, based on frequent inspection, and may be required as often as after each use of the hawser. Procedures for inspecting and lubricating wires are detailed in NSTM CH-613 (Ref. F).

A pressure lubricator has been developed for wire rope and is the preferred method of lubrication. Grease (MIL-G-18458) is currently specified. This product contains a corrosion preventive and can be thinned with solvents such as JP5 or turbine oil 2190 (MIL-L-17331) for cold application.

Take care that all sections, including dead layers on the drum, are kept lubricated. These inner layers can be lubricated at such opportune times as:

- Overhauls
- When the hawser is reversed, end-for-end, on the drum
- When towing in good weather, at which time extra line may be run out to expose the inner layers for lubrication.

The Navy procedures for wire rope lubrication are currently being modified. The most recent guidance is contained in NAVSEA Interim MRC for ARS 50 Class Running Rigging (Ref. AA).

B-5 New Hawsers

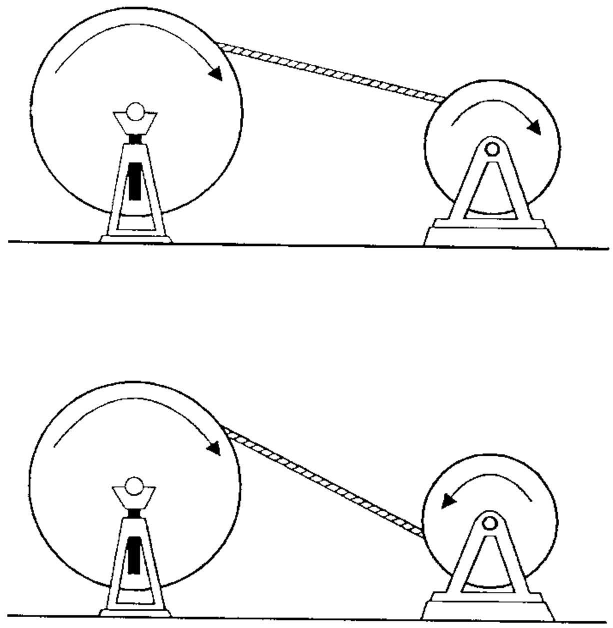
Wire rope for towing hawser is shipped in cut lengths on reels.

B-5.1 Unreeling

CAUTION
Remove rope from the shipping package very carefully. Improper unreeling can cause permanent damage, such as kinks and hockles (Figure B3).

Unreeling wire rope requires careful and proper procedures. Mount the reel on a horizontal shaft supported high enough for the reel to clear the deck so the reel is free to rotate. To begin the unreeling process, hold the rope end and walk away from the reel as it unwinds. Use a braking device to keep the rope taut and prevent the reel from overrunning the rope. This is particularly necessary with powered reeling equipment.

Appendix Figure B-3. Kinks and Hockles.



Appendix Figure B-4. Re-reeling.

B-5.2 Reeling

When reeling a wire rope hawser from a reel to a towing machine drum, it is best for the rope to travel from the top of the reel to the top of the drum, (see Appendix Figure B4). This method avoids putting a reverse bend into the rope as it is being installed. A reverse bend can make a rope less stable and, consequently, more difficult to handle.

B-5.3 Installing New Wire Rope

CAUTION
Rapid acceleration can cause significant stress on a wire rope. Avoid such stress on the rope by accelerating gradually.

Wire rope should be installed on a towing machine drum under a tension of at least five percent of its breaking strength. Each wrap must be positioned tightly against the neighboring wrap. A tight fit will help prevent the wire rope from becoming buried between wraps when used under heavy loading. Burying the wire between wraps is likely to result in serious damage. Loose or poorly spaced wires may cause movement in underlying layers during towing. In practice, the wire rope is initially installed on the towing machine drum under as high a tension as practical.

NOTE
For both smooth and grooved drums, the towing hawser must be wound on the drum under fairly high tension, approximately 5 percent of the breaking strength.

Using stoppers to load the wire bight by bight is one way to maintain tension, but it is cumbersome and time consuming. During the construction of the first four ARS-50 Class ships, a cable brake called a Wallis Brake was used to help install the wire rope towing hawsers (see Appendix Figure B5). This cable brake is designed for the continuous loading of the wire rope under tension.

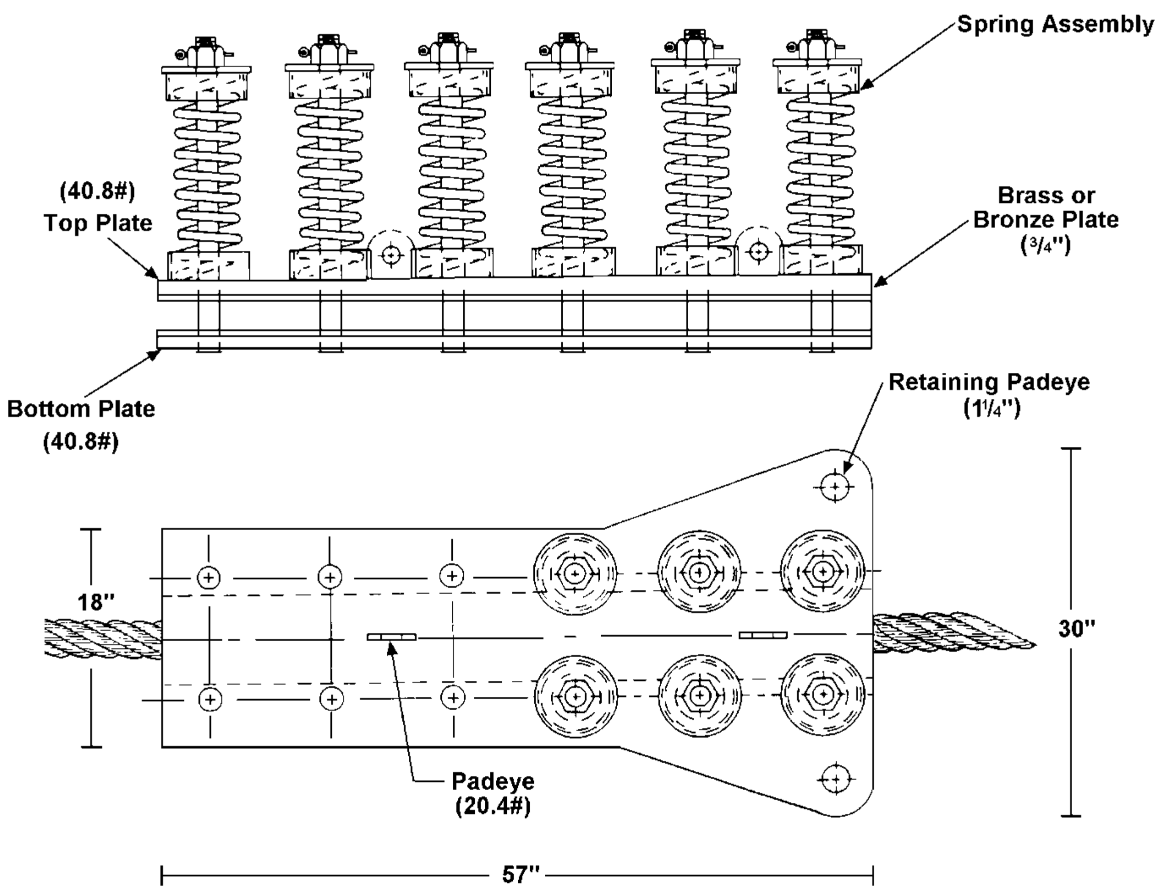
NAVSEA 00C has detailed plans for construction of a Wallis Brake. The Wallis Brake is first tied down to a strong point aft of the drum. In the case of a towing machine or winch, there is usually a strong point on the fantail such as an H-bitt or a heavylift roller. These devices are not intended to be pulled on in the forward direction, but they are built for much heavier loads than they will be required to withstand while supporting a cable brake.

To install the wire, pass the bitter end through the brake and onto the winch or open the brake by removing the spring assemblies and the top plate. Place the wire to be loaded on the bottom plate of the brake and reinstall the top plate and spring assemblies. Next, tighten the spring assemblies with the clamp nuts until the proper tension is reached. Once the cable brake has been properly adjusted, wind the rope onto the winch in a continuous manner until all the wire is on the winch drum.

Take care to keep the wraps tightly together. Wind the first layer slowly, using a heavy maul or hammer to obtain a tight fit. Protect the wire as necessary during any hammering by using soft-faced hammers or wooden blocks. Once the first layer is installed it should be retained as the foundation for subsequent layers and not disturbed during towing operations.

If a Wallis Brake is not available, or if the wire rope could not be initially installed under sufficient tension even with the brake, it can be shackled to a bollard or a mooring buoy, payed off the drum, and then hauled in under the correct tension.

When new wire ropes are put in service as towing hawsers or pendants, record their identification (see Section B-2 for Identification Markings) in the Towing Hawser Log (See Appendix F).



NOTE

Wallis Brake Sized for a family of wire rope sizes. The approximate dimensions for a 2-inch Wallis Brake are shown. NAVSEA 00C has details for construction.

Appendix Figure B-5. Wallis Brake

B-6 Stowing

When the towing hawser is removed from the drum, wind it neatly on a reel and store it in an acid free, dry, protected location. Whenever a wire rope towing hawser is to be stored, lubricate it first with MIL-G-18458 grease (preferably with a pressure lubricator) and then keep the outer layer lubricated with the same grease throughout the storage period.

B-7 Inspection

CAUTION
In general, wear gloves when handling wire rope, except when it is moving under load. In this case, the gloves can get snagged and can drag the hands into danger. Wire rope should not be handled when it is moving under load.

B-7.1 General Criteria

Inspect the rope thoroughly as it is being wound after each use. Refer to Appendix Figure B-6 for nomenclature of wire rope and Appendix Figure B-7 for measuring guidelines.

The inspection criteria for general usage running rope are as follows:

- Reduction of nominal rope diameter due to loss of core support, internal or external corrosion, or wear of individual outside wires.
- Number of broken outside wires and degree of distribution or concentration of broken wires.
- Corroded, pitted, or broken wires at end connection.
- Corroded, cracked, bent, worn, or improperly applied end connections.
- Severe kinking, crushing, or distortion of rope structure.
- Evidence of heat.

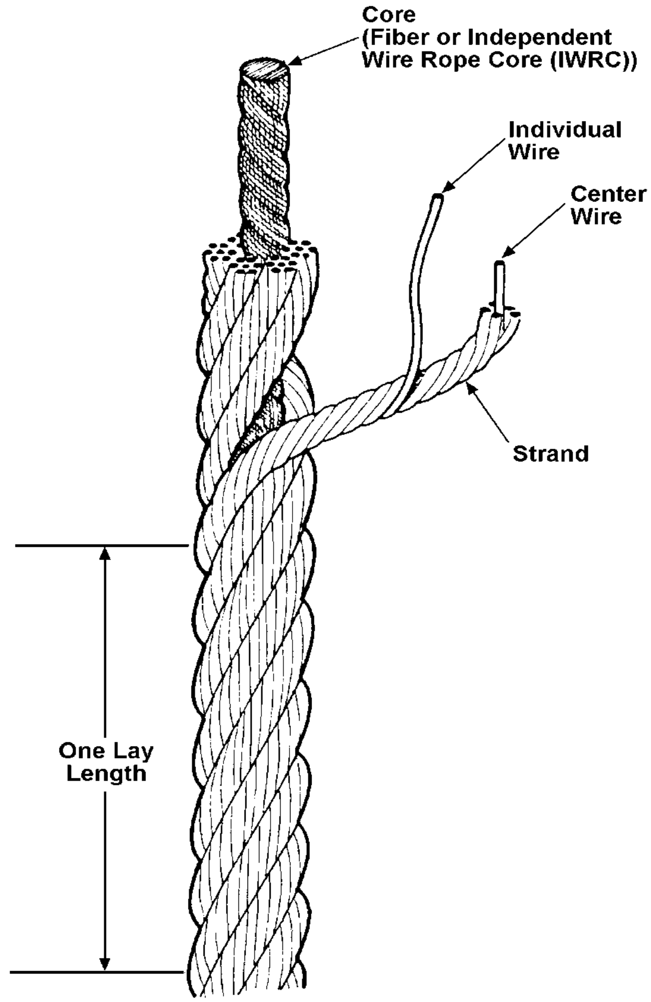
B-7.2 Specific Steps

Detailed steps for inspection and maintenance of wire rope are specified in NSTM 613. The principal steps in wire rope inspection are:

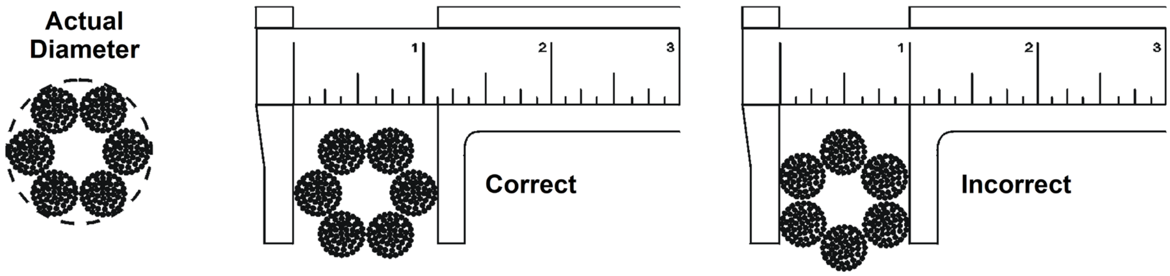
a) Clean the rope by wire brushing and wiping with rags.
b) Inspect wire rope for rust, deterioration, corrosion, wear or flattening, broken strands, and weakened splices.
c) Count number of broken or protruding wires in each wire rope lay length.
d) Measure wire rope diameter with vernier calipers.

Replace wire rope when one or more of the following conditions exists:

- The nominal rope diameter is reduced by more than the amount shown in Appendix Figure B-7 for the applicable size rope for measuring rope diameter.
- Six wires are broken in one rope lay length or three wires are broken in one strand lay length.
- One wire is broken within one rope lay length of any end fitting (cut wire and replace with new fitting).
- The original diameter of outside individual wires is reduced by one-third.
- Pitting due to corrosion is evident.
- Heat damage is evident.
- Kinking, crushing, or any other damage resulting in distortion of the rope structure is evident.



Appendix Figure B-6. Nomenclature of Wire Rope



Rope Diameter (Inches)	Maximum Allowable Nominal Diameter Reduction (Inches)
5/16 and smaller	1/64
3/8 to 1/2	1/32
9/16 to 3/4	3/64
7/8 to 11/8	1/16
11/4 to 11/2	3/32
19/16 to 2	1/8
2 to 2-1/2	5/32

Appendix Figure B-7. Measuring Wire Rope

Table B-1. Wire Hawsers Carried by U.S. Navy Towing Ships.

Ship Class	Wire Rope Hawser Diameter by Length
T-ATF 166*	2¼” x 2500’ 6 X 37
ARS 50	2¼” x 3000’ 6 X 37

* T-ATFs are being refitted with wire core rope when hawsers are due for replacement.

B-8 Special Precautions

WARNING
Proper maintenance is extremely important for wire rope used in critical or potentially dangerous applications such as towing.

Wire rope must be properly maintained when used in critical or potentially dangerous situations. It should not be subjected to any of the following common abuses:

- Chafing
- Impact loads or rapidly changing loads
- Incorrect size of groove on drum or sheave
- Drum or sheave grooves that have become rough or corrugated through wear
- Inadequate diameter of drum or sheave
- Improper winding on drum
- Improper or insufficient lubrication
- Exposure to corrosive fluids
- Exposure to excess heat or electric arcing
- Lack of protection against moisture and salt water
- Kinks or hockles.
- If wire rope is struck by lightning, inspect it and consider replacing it

It is important to maintain minimum and evenly distributed wear. Pay special attention to possible chafing points where the wire rope passes over chocks, bitts, stern rollers, and so forth. Even though no particular wear may be noticed, it is advisable to freshen the nip at least once per watch to change the location of possible wear.

B-9 Wire Rope Hawsers for Navy Tow Ships

Navy towing hawsers are of two types:

- 21/4-inch diameter, fiber core
- 21/4-inch diameter, Independent Wire Rope Core (IWRC).

Table B-1 lists the wire hawsers carried by each Navy towing ship class. T-ATF-166 class vessels are replacing fiber core wire with IWRC wire during normal replacement cycles. Table B-2 provides the strength and weight per foot of 6 x 37 class IPS marine ropes.

B-10 Wire Rope Terminations

Wire rope towing hawsers are terminated with a closed, poured socket. The dimensions and weights of four common sizes of open and closed Spelter sockets are shown in Figure B-8 The strength of these sockets, when properly made, exceeds the strength of the wire rope for which they are designed. The dimensions are given in detail to assist in selecting the appropriate mating jewelry.

WARNING
When using a termination of less than 100 percent efficiency, the base strength to which the factors of safety are applied must be adjusted accordingly.

Table B-2. Nominal <u>Breaking Strength</u> of Wire Rope 6x37 Class, Hot-Dipped Galvanized.

Fiber Core[2]		Nominal Diameter (inches)	Independent Wire Rope Core[3]		
Weight in Air (lbs/ft)*	**Improved Plow Steel (lbs)****		**Weight in Air (lbs/ft)**	**Improved Plow Steel (lbs)****	**Extra Improved Plow Steel (lbs)****
0.11	4,932	1/4	0.12	5,292	6,100
0.16	7,668	5/16	0.18	8,240	9,500
0.24	10,980	3/8	0.26	11,800	13,600
0.32	14,886	7/16	0.35	16,000	18,400
0.42	19,260	1/2	0.46	20,700	24,000
0.53	24,300	9/16	0.59	26,100	30,250
0.66	30,060	5/8	0.72	32,200	37,100
0.95	42,840	3/4	1.04	48,100	53,000
1.29	57,960	7/8	1.42	62,300	71,100
1.68	75,240	1	1.85	80,800	93,000
2.13	94,680	1 1/8	2.34	101,700	117,000
2.63	116,280	1 1/4	2.89	125,000	144,000
3.18	139,860	1 3/8	3.50	150,300	172,800
3.78	165,600	1 1/2	4.16	178,000	205,200
4.44	192,600	1 5/8	4.86	207,000	237,600
5.15	223,200	1 3/4	5.67	239,400	275,400
5.91	253,800	1 7/8	6.50	273,600	313,200
6.72	288,000	2	7.39	309,600	356,400
7.59	322,000	2 1/8	8.35	345,600	397,800
8.51	360,000	2 1/4	9.36	387,000	444,600
9.48	339,600	2 3/8	10.4	430,200	493,200
10.5	439,200	2 1/2	11.6	471,600	543,600
11.6	482,400	2 5/8	12.8	518,400	595,800
12.7	525,600	2 3/4	14.0	565,200	649,800
13.9	570,600	2 7/8	15.3	613,800	705,600
15.1	619,200	3	16.6	666,000	765,000
16.4	687,800	3 3/8	18.0	718,200	824,400
17.7	718,200	3 1/4	19.5	772,200	885,600
		3 1/8	21.0	826,200	952,200
		3 1/2	22.7	883,200	1,015,206
		3 5/8	24.3	941,400	1,083,600
		3 3/4	26.0	1,002,600	1,153,800

* Weights are given in air. To obtain net weight in water, multiply air weights by 0.87.

** Nominal <u>breaking strength</u> in pounds.

NOTES:

1. All data shown is for hot-dipped galvanized wire. Bright (uncoated) wire strengths are 10% higher and are listed in the same tables in Notes (2) and (3). Drawn galvanized wire rope has the same strength as bright wire.
2. Data for fiber core wire rope is taken from RR-W-410D, Table X.
3. Data for Improved Plow Steel <u>IWRC</u> wire rope is taken from RR-W-410D, Table XI. Data for Extra Improved Plow Steel IWRC galvanized wire rope is taken from RR-W-410D, Table XII.

See Table B-3 and NSTM 613 for efficiency of wire rope terminations.

Poured socket wire terminations are not tested because they are presumed to be stronger than the safe working strength of the wire. Instead, reliance is placed on the skill of the operator, who is initially qualified and maintains that qualification as described in NSTM 613. Factors of safety listed in Table 32 are applicable to the nominal breaking strength of new wire. If, under an emergency towing situation, a termination other than a poured socket is used, the reduced efficiency of the termination must be included in the allowable load calculations. Furthermore, if the reason for alternate termination is to replace a failed termination or a parted wire, it must be assumed that the balance of the hawser has been overstressed as well. If it is necessary to continue using the questionable hawser, doubling the factor of safety against the lowered system strength would be appropriate.

B-11 Wire Rope Procurement Requirements

This section discusses the applicable specifications for the purposes of procuring wire hawsers for ARS 50 and T-ATF 166 class vessels. For detailed information, consult the below list of documents.

Federal Specifications

RRW410 Wire Rope and Strand

RS550 Sockets, Wire Rope

Manuals

Naval Ship's Technical Manual S9086-UU-STM-010, Chapter 613, "Wire and Fiber Rope and Rigging," S9086-UU-STM-010/CH613, Second Revision, 1 May 1995.(Ref. F)

Copies of Military and Federal Specifications and Standards may be obtained from the following facility:

Commanding Officer

Naval Publications and Forms Center (NPFC)

5801 Tabor Avenue Philadelphia, PA 19120

Tel: (215) 697-2179

B-12 Requirements

B-12.1 Wire Rope Characteristics

Independent wire rope core may be substituted for fiber core and Extra Improved Plow Steel (EIPS) for Improved Plow Steel (IPS) in any of the cases below if deemed prudent by the purchasing activity. The information below may reflect the original configuration, but availability at the time of replacement may dictate an IWRC.

B-12.2Wire Towing Hawsers for T-ATF 166 Class Ships

Wire rope shall be 2 1/4-inch diameter cut to 2500-foot lengths (see 34.1.3 for tolerances in lengths), IPS (or EIPS), drawn galvanized, preformed, regular (R.H.) lay, polypropylene fiber core (or Independent Wire Rope Core (IWRC)), Type I, Class 3, Construction 6, 6 x 37 (Warrington Seale) IAW Specification RRW410. Documentation of all test results (as required by RRW410) from each Master Reel used in fabrication of wire lengths shall be submitted for the production assemblies (one data set included with the report in Section 4-2.2)

Table B-3. Efficiency of Wire Rope Terminations.

Type Terminations	Efficiency*
Poured Spelter Socket	100 percent
Wire Rope Clips (See Table 41 for number)	80 percent
Swaged Socket**	100 percent
Eye splice (hand-spliced) 2 ¼" and larger wire 1 5/8" to 2" wire 1 1/8" to 1½" wire 7/8" to 1" wire	 70 percent 75 percent 80 percent 80 percent
Flemish Eye (" Molly Hogan") (with sleeve and thimble)	90 percent

* Efficiency is the strength of the termination divided by the nominal breaking strength of the wire.

** Not recommended for fiber core ropes.

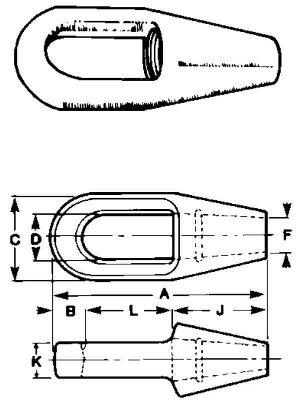
Each of the 2500-foot lengths of 2-1/4-inch wire rope shall have a closed zinc-poured socket on one end and a permanent seizing on the other end (See Section B13).

Wire rope shall be wound on reels, closed socket first. Reel drums shall be modified as required to allow the closed socket to be inserted into the drum and held so wire can be uniformly wound and tightly secured. Presence of the closed socket must be verifiable by visual examination without disturbing the stowage of wire on the reel. Marking for shipment and storage shall be in accordance with best commercial practices. Each reel shall be clearly marked on each side with the diameter and length of wire in a three-inch size letters as follows: "2 1/4-in x 2500-ft w/closed socket termination."

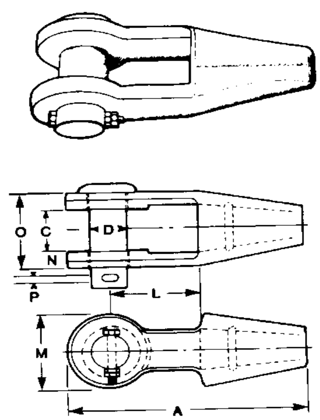
B-12.32-1/4-Inch Towing Hawsers for ARS-50 Class Ships

Wire rope shall be 2 1/4-inch diameter cut into a 3000-foot length, EIPS, drawn galvanized, preformed, regular (R.H.) lay, IWRC, Type I, Class 3, Construction 6, 6 x 37 (Warrington Seale) procured IAW Specification RRW410. Documentation of all test results (as required by RRW410) from each Master Reel used in fabrication of wire lengths shall be submitted for the production assemblies (one data set included with the report in Section 4-2.2)

Each of the 3000-foot lengths of 2 1/4-inch wire rope shall have a closed zinc-poured socket on one end and a permanent seizing on the other end (See Section B-13).



WIRE ROPE DIAM INCHES	DIMENSION IN INCHES								WEIGHT POUNDS EACH
	A	B	C	D	F	J	K	L	
1- 5/8	15-1/8	2-1/8	5-3/4	3-1/4	1-3/4	6-1/2	2-3/4	6-1/2	36
2 - 2 1/8	19-1/2	2-7/8	7-5/8	3-25/32	2-1/4	8-1/2	4-1/4	8-9/16	80
2 1/4 - 2 3/8	21-1/8	2-5/8	8-1/2	4-9/32	2-1/2	9	3-5/8	9-1/2	105
2 1/2 - 2 5/8	23-1/2	3-1/8	9-1/2	5-1/2	2-7/8	9-3/4	4	10-5/8	140



WIRE ROPE DIAM INCHES	DIMENSION IN INCHES								WEIGHT POUNDS EACH
	A	C	D	L	M	N	O	P	
1- 5/8	16-1/4	3	3	6-1/2	5-3/4	1-5/16	6-5/8	1/2	55
2 - 2 1/8	21-1/2	4	3-3/4	9	7	1-13/16	8-3/4	½	125
2 1/4 - 2 3/8	23-1/2	4-1/2	4-1/4	10	7-3/4	2-1/8	10	1/2	165
2 1/2 - 2 5/8	25-1/2	5	4-3/4	10-3/4	8-1/2	2-3/8	11	1/2	252

Appendix Figure B-8. Poured Sockets FED Spec. RR-S-550D Amendment 1.

Wire rope shall be wound on reels, closed socket first. Reel drums shall be modified as required to allow the closed socket to be inserted into the drum and held so wire can be uniformly wound and tightly secured. Presence of the closed socket must be verifiable by visual examination without disturbing the stowage of wire on the reel. Marking for shipment and storage shall be in accordance with best commercial practices. Each reel shall be clearly marked on each side with the diameter and length of wire in three-inch size letters as follows: “2 1/4-in x 3000-ft w/closed socket termination.”

B-13 Sockets

Each towing hawser shall have a closed zinc-poured socket on one end and a permanent seizing on the other end. Closed sockets shall be Type B, procured IAW Specification RRS550. Documentation of results of tests required by RRS550 shall be delivered with each wire rope assembly. Closed zinc-poured sockets shall be attached to the wire in accordance with the NSTM, CH-613 (Ref. F). Testing and proof of personnel qualifications shall be as required by the Naval Ships Technical Manual. A report of tests and personnel qualification documents shall be provided with the wire rope assembly.

Tolerances on 2 1/4-inch wire rope lengths after sockets have been attached shall be plus or minus five feet from the center of socket eye to the bare end of the wire rope.

B-14 Lubrication

All wire towing hawsers shall be lubricated with MIL-G-18458 grease in accordance with the NSTM CH-613 (Ref. F) prior to being placed on the towing machine drum. The use of a pressure lubricator is preferable when one is available.

Appendix C - SYNTHETIC FIBER LINE TOWLINES

C-1 Introduction

The material presented in this appendix does not supersede any Fleet or NAVSEA directives on the operational use or care of synthetic towlines. The use of singe- and double-braided polyester is approved for all routine and emergency towing applications. Nylon line is only approved for operations with craft less than 600 tons displacement, or other unique or special tows as approved by NAVSEA on a case-by-case basis.

Existing nylon line should be replaced on a size for size basis with single- or double-braided polyester. This includes emergency tow and be towed hawsers.

Fiber lines, either natural or synthetic, can be employed in two different functions within towline systems. In some systems, the entire main towing hawser is made of fiber line. In other systems, the hawser is wire rope and a shorter fiber line is used as a spring to provide relief from shock and other dynamic tension variables. In both cases, the fiber line must be kept in excellent condition, protected against wear, and inspected regularly.

When fiber line is used as the main towing hawser or as a spring, a written record of its history is required by NAVSEA in the form of the Towing Hawser Log (see Appendix F).Traceability

C-2 Traceability and Identification

There are many types of fiber line within use in the marine industry, with each suited to a specific purpose. Using fiber lines for a task it is not suited for will often provide unacceptable performance. The five most common material categories of synthetic fiber lines are:

• Polyester (PES, PET) – Trade names may include Dacron (duPont) or Terylene (ICI; England) and some manufactured products include Jetkore and Ultraline (Samson), Supermix (Marlow), Karat (Scan Ropes), and Deltaflex (Bexco). Polyester is frequently used as a protective outer layer of a manufactured line because of its good resistance to abrasion and ultraviolet degradation. It is also seen interwoven with other materials. Polyester is the preferred material for synthetic towlines, however, care must be taken that the actual product selected is suitable for the purpose.

- Nylon or Polyamide (PA) – Some manufactured items may be called Perlon (Bayer; Germany), Atlas (Bexco), and Caprolan 2000 (Performance Fibers). While dry, Nylon has excellent performance. However, when it becomes saturated in water, it loses a significant amount of strength. Some products are manufactured with a hydrophobic coating to resist moisture, but this should not be considered an effective barrier against long-term submersion, such as is the case with a towing evolution. **Nylon is not recommended for towing if another material is available,** and it is recommended to replace any in-service Nylon lines with polyester.
- Polyethylene (PE, also seen as high modulus polyethylene or HMPE) – Trade names for polyethylene include Spectra (Allied/Honeywell), Novabraid, Dyneema (DSM), Amsteel Blue (Samson) and others. Polyethylene tends to have very high strength-to-weight and is well-suited for things like winches, sail rigging, and other block-guided, load-bearing applications. Most manufactured products are not suitable for towing. However, it is

strong, UV resistant, and many polyethylene products float, so it has a wide range of applications. Within the past decade, much of the commercial towing industry has begun using specially engineered polyethylene lines for towing. There are many new products within this category which have not yet been fully evaluated for Navy use as towing hawsers. As of the printing of this manual, **they are NOT yet approved for use in towing**.

- Polypropylene (PP) – May be seen under a great deal of trade names, including Nelson (Marlow). Polypropylene has the worst strength and the lowest performance of all available synthetic materials. However, it is inexpensive, and it floats. It is suitable only for general cordage uses and never for critical loads. **Polypropylene lines are NOT approved for towing.**
- Aramid (PPTA) – Seen as Kevlar, Nomex (duPont) and many other trade names. These lines are extremely strong and stiff, which provides inadequate stretch and catenary when used as a towline. However, the extremely high strength and temperature and abrasion resistance may make these materials suitable for some other applications. Aramid lines are NOT approved as towing hawsers.

Even if a material was originally suitable, it is important that it be properly maintained if it is to remain in good condition. The ability to trace a line's history is an important element in accident investigation, product/process improvement, and to provide confidence in future performance. Information should be maintained in the Towing Hawser Log.

American-made fiber line and many brands of foreign-made rope can be identified by special marker tapes inserted into the lay, color-coded fibers and/or metal tags, and other data which may be printed upon a reel/spool upon which the line is delivered. Identification of manufacturing source through the marker coding is particularly useful in cases where the reel markings have been lost. Additional information on a specific manufacturer's identification marking practices may be obtained by request to the Cordage Institute, 994 Old Eagle School Rd, Suite 1019, Wayne, PA 19087. Telephone 610-971-4854. Email: info@ropecord.com

If there is uncertainty about the age, service history, or pedigree of a line, **do NOT use it** as a towing hawser.

C-3 Strength and Lifetime

WARNING
The failure of synthetic fiber lines under high tension loads can be extremely dangerous. Synthetic lines, particularly polyester and nylon, retain high amounts of energy when under tension. These lines will have severe snapback if they fail under load. Personnel should stay clear of areas through which the end of a failed line may whip.

C-3.1 General

Most synthetic fiber lines are stronger than natural fiber (manila) lines, and they usually have longer lifetimes because of their resistance to rot and other forms of environmental deterioration.

C-3.2 Specific

The primary material for synthetic towlines used by the Navy is polyester. The use of Nylon in towing applications is currently restricted, and is not recommended if other materials are available. Polypropylene should NEVER be used. Table C-1 presents a relative valuation of the performance characteristics of these three line types.

One notable takeaway from Table C-1 is that Nylon undergoes dramatic changes to its physical properties when wet. When dry, it is one of the best lines available to us, and when wet its performance becomes intermediate. Consequently, the Navy has phased out the use of Nylon in towlines in favor of polyester.

Aramid and polyethylene lines do not appear on the table. These products often have widely varying properties, so a generalization would be of little use. When considering these products, keep in mind that they are engineered to perform in a specific way, and often for specific applications. In any case, do NOT use Aramid fibers as a towline, and obtain explicit approval before selecting a polyethylene product.

Table C-1. Fiber Comparisons.

Fiber Type	Strength[1]	Cyclic[2] Fatigues	Bending[2] Fatigue	Abrasion	Heat Resistance	Creep
Nylon (dry)	VG	VG	G	E	G	G
Nylon (wet)	G	F	F	F	—	G
Polyester (dry)	VG	VG	VG	VG	G	VG
Polyester (wet)	VG	VG	G	G	—	VG
Polypropylene (dry)	F	F	P	P	P	F
Polypropylene (wet)	F	F	P	F	—	F

E = Excellent, VG = Very Good, G = Good, F = Fair, P = Poor

NOTES:

1. Tensioned between two limits without bending.
2. Usually running over pulleys. Some line wears out before failing from fatigue because of abrasion.

As one may note from Table C-1. Fiber Comparisons, nylon's water-absorption characteristic changes its comparative rating from best to intermediate in nearly every category. Consequently, the Navy has phased out the use of nylon in favor of polyester. Where springs are required in towline systems, polyester fiber will be used. Polypropylene will also continue to be used for certain purposes because it is the only one of the three fiber lines that floats.

The Navy also employs synthetic lines in some of its lifting operations. These applications demand lightweight, high strength, small diameter lines in very long lengths. Aramid fibers such as Kevlar, Spectra, and Vectran are well suited for this need. These types of fiber are not approved for Navy towing, however. They have extremely low elongation and, because of their light weight, do not provide the catenary of wire rope. These fibers, therefore, do not provide the same extreme tension mitigation as the other hawser types.

C-4 Elongation

The elongation or stretch of fiber line under tension has both advantages and disadvantages. Elongation tends to greatly reduce dynamic loads in the towline such as shock loads and wave-induced loads. Unfortunately, elongation also stores a great deal of energy in ropes under tension and the release of this energy when a rope fails causes a very dangerous whipping or "snap back" of the line. The stored energy, and potential danger, is much greater in the case of synthetic lines than for wire rope under the same load. For this reason, extreme caution is required when working near fiber lines that are under load. Under heavy tension loads, nylon line can snap back at speeds up to 700 feet per second (500 m.p.h.). Braided fiber lines tend to stretch about one-half to two-thirds as much as plaited or stranded ropes of the same size.

C-5 Maintenance and Cleaning

Although fiber lines are not subject to corrosion as wire ropes are, they still require careful maintenance and cleaning. If the line becomes oily or greasy, scrub it with fresh water and a paste-like mixture of granulated soap. For heavy accumulations of oil and grease, scrub the line with a solvent such as mineral spirits, then rinse it with a solution of soap and fresh water.

The five different synthetic fibers show different responses to various chemicals. In brief:

- Nylon weakens if exposed to acids, particularly mineral acids. Its resistance to alkalis is good at normal temperatures.
- Polyester line will deteriorate with exposure to hot, strong alkali solutions. It is particularly vulnerable to very strong acid solutions; therefore, even diluted acid solutions should not be allowed to dry on the rope.
- Polypropylene is resistant to both acids and alkalis at normal temperatures, but is affected by some organic solvents such as xylene and metacresol and by coal tar and paint-stripping compounds. These types of chemicals are most likely to be found in the paint locker in thinners and cleaning compounds.
- Polyethylene has good resistance to both acids and alkalis, but weakens when exposed to halogen-containing compounds. Keep away from chlorine (bleach), iodine, benzene, MEK, as well as petroleum solvents and lubricants which are likely to contain additives which can degrade polyethylene. Pure acetone is a safe cleaning agent if you must use a solvent.
- Aramids vary from type to type, but are generally resistant to nearly all chemical compounds. There are some exceptions, however, and most types are vulnerable to formic acid (possibly found on ship in some drain-clearing products), benzene, and some amines.

All synthetics are weakened by exposure to strong sunlight and should therefore be stored out of the sun. Polyester has the best resistance to ultraviolet rays.

To extend the life of synthetic line, maintain minimum and evenly distributed wear. Pay special attention to possible chafing points where the line passes over chocks, bitts, stern rollers, and so forth. Even though no particular wear may be noticed, it is advisable to freshen the nip at least once per watch to change the location of possible internal wear.

Do not subject fiber lines to any of these other common abuses:

- Incorrect size of groove on drum or sheave
- Drum or sheave grooves that have become rough or corrugated through wear
- Inadequate radius on fairlead or stern roller
- Rough or abrasive surfaces on fairlead or stern roller
- Improper winding on drum
- Exposure to excessive heat
- Kinks or hockles.

C-6 Stowing

Stow synthetic line away from strong sunlight, heat, and strong chemicals, and cover it with tarpaulins. If the line becomes iced over, thaw it carefully and drain it before stowing. If feasible, store the line on appropriately treated wooden dunnage. Nylon is susceptible to a rapid reduction in strength when exposed to rust; make sure that it is not exposed to rust-prone bare steel surfaces.

C-7 Uncoiling or Unreeling New Hawsers

Synthetic line is shipped in pre-made, cut lengths, either in coils or on wooden reels. It must be uncoiled or unreeled carefully to avoid both permanent kinks and abrasion damage. Never pull line over the deck, through a tight bend, or over the end plate of the reel.

CAUTION
The common method of uncoiling wire rope by rolling the coil along the deck is NOT recommended for synthetic line because of the potential for abrading the line on the rough deck surface.

If line is delivered in a coil, it is recommended to place the entire shipping pallet onto a turntable. As the line is wound onto the reel, the turntable will spin freely to prevent kinking. If this method is not available, the line may be streamed from the tug into the sea until the bitter end is reached. The tug is then brought to all stop to prevent prop wash from affecting the line. The line is then reeled in, and any kinks allowed to run out the trailing end.

If the line is delivered on a spool, the preferred method is to hoist the spool horizontally above the deck, supported by a mandrel made from suitably sized pipe inserted through the eyes of the spool. The line should then be drawn from the lower reel surface with the spool allowed to spin as needed. Do not peel coils of line over the end of a spool, as this will create numerous kinks that will be difficult to remove.

If possible, it is recommended that new line be faked out on deck and allowed to relax for 24 hours to remove residual set from the spool. When faking out line, be careful not to drag it along the deck and cause abrasion damage. Twisted fiber lines should be faked out in single passes, whereas double braided lines should be placed in a figure-eight to avoid twists.

C-8 Breaking in New Hawsers

CAUTION
New synthetic hawsers must not be subjected to heavy stress until they have been properly broken in.

When a synthetic line is newly manufactured, the strands of the line are not equally spaced and tensioned. The line must be load-cycled with some care to even out the strands so that the line holds stress evenly. Note that during this process, the strands often produce a sharp crackling sound. This noise is generally not cause for alarm.

After the line has been unspooled, had any excess turns run out of it (see C-7), and been allowed to sit unstressed for a period of time, it should be placed onto the drum or winch or otherwise be made ready for loading. The load path may use rollers, chocks, pins, or other fairleads as needed, so long as any tight bends or friction hot spots are avoided.

The line must then be cycled up to its rated working load, or to within 20% of breaking strength, whichever is less. After five cycles, the permanent stretch in the line will reach its maximum and the line will perform at its strongest. When breaking in a new line, you MUST use a load indicator. Judging the load by measuring line stretch is not reliable, as the temporary stretch characteristics of each product can vary significantly.

All synthetic materials behave differently, but in general, the permanent stretch will be less than seven percent of the original length. Nylon and polyester products will normally be in the 5% to 7% range, whereas polyethylene and Aramids will exhibit much less stretch.

If post-stressed line length is important for any reason, it is vital that you know the specific characteristics of the material you are ordering and account for this permanent stretch.

Many manufacturers and waterfront facilities may also be able to break-in a line using specialized equipment. The ESSM warehouse system can also provide this service.

For more information, consult NSTM CH-613 (Appendix M – Ref F). Inspection

Regular inspection is essential to ensure that synthetic lines remain serviceable and safe.

Keep in mind that no matter what has weakened the line, the effect of the same injury will be more serious on a small line than a large line. Therefore, always consider the relationship of the surface area of the line to its cross section.

Examining the line about one foot at a time is usually practical. Turn the line to reveal all sides before continuing. At the same intervals, untwist the rope slightly to examine between the strands of three-strand and plaited rope.

Synthetic lines should be inspected after each use. Look for broken fibers in the outer layer and for discoloration or appearances of melting. When examining between the strands, look for these same evidences of wear and look also for any appearance of a powdery substance between the strands. Broken outer fibers may indicate that the line has been dragged over sharp or rough surfaces. Discoloration or melting may indicate excessive frictional heat from either dynamic loads or from rubbing over smooth surfaces. Internal wear, sometimes indicated as a fuzzed or fused condition between strands, may indicate fatigue damage from repeated or cyclic loads and overloading.

If the examination raises any doubts about the safety of the line, discard it. Again, keep in mind that the effects of wear and mechanical damage are relatively greater on smaller lines which, therefore, require more stringent standards of acceptance.

The following section on types of wear should be helpful during the inspection of synthetic lines.

C-9 Types of Wear or Damage

The usual types of wear exhibited by synthetic lines are as follows:

- ***General external wear.*** External wear due to dragging over rough surfaces causes surface chafing. In the extreme, the strands become so worn that their outer faces are flattened and the outer yarns are severed. In ordinary use some disarrangement or breakage of the fibers on the outside of the line is unavoidable and harmless if not extensive. Generally, nylon and polyester filament lines have very good abrasion resistance.
- ***Local abrasion.*** Local abrasion, as distinct from general wear, is caused by the passage of the line over sharp edges while under tension and may cause serious loss of strength, especially if accompanied by fused areas signifying high heat generated by rope surges under heavy load. Slight damage to the outer fibers and an occasional torn yarn may be considered harmless, but serious reduction in the cross-sectional area of one strand or somewhat less serious damage to more than one strand should warrant rejection. When such damage is noticed, preventive measures should be taken. Typical protective steps are to smooth and round off all rough or sharp areas on the surface that are chafing the line and apply chafing gear such as rubber or plastic sleeves or cloth material secured by small stuff around the line.
- ***Cuts and contusions***. Cuts and contusions are caused by rough or sharp surfaces. Such careless use may cause internal as well as external damage. This may be indicated by local rupturing or loosening of the yarns or strands.
- ***Internal wear***. Internal wear may be indicated by excessive looseness of the strands and yarns or the presence of fuzzed or fused internal areas. It is caused by repeated flexing of the line and by particles of grit that have been picked up. Ice crystals can also cause internal wear. This condition results from towing in very cold weather and will most likely occur at the stern of the tug and at the tow where the hawser is occasionally wetted, but generally exposed to the cold air.

WARNING
Surging of synthetic line under tension can cause sufficient frictional heat at the contact surfaces to melt the surface of the line. The melting point of polypropylene line, for instance, is 320F to 340F, while the softening point is around 300F. Comparable temperatures for polyester are only moderately higher. These temperatures are quite quickly produced when a line is surged on a winch or capstan.

- ***Repeated loading.*** Although polyester filament line resists damage from repeated loading, permanent elongation will occur over time in heavily loaded ropes. If the original length of the rope is known exactly, remeasuring under exactly the same conditions indicates the total extension of the rope. This method, however, may not reveal severe local permanent elongation that may cause breaking on subsequent loading. Measuring the distance between regularly spaced indelible markers on the rope can help reveal this problem.
- ***Heat.*** Heat may, in extreme cases, result in melting. Any signs of melting should obviously warrant rejection, but a line may be damaged by heat without any such obvious warning. The best safeguard is proper care and storage. A synthetic line should never be dried in front of a fire or stored near a stove or other source of heat.
- ***Strong sunlight.*** Strong sunlight causes weakening of synthetic fibers, but is unlikely to penetrate beneath the surface. Unnecessary exposure should be avoided, however. Solar degradation should be checked by rubbing the surface of the line with the thumb nail. If degradation has taken place, the surface material will come off as a powder. In addition, the surface of the line will feel dry, harsh and resinous.

C-10 Special Precautions

WARNING
Listed below are three precautions to be considered when using synthetic tow hawsers. They should be taken as warnings as they are critical to safety of personnel.

- When using heavily loaded synthetic lines, the major precaution to be taken is to be constantly alert to the potential danger of line “snap back” during failure. Personnel must remain clear of the areas through which the ends of a failed line may whip or snap.
- To avoid damage from rough surfaces, synthetic line should not be used in areas where chafing potential is high. Use of a wire rope or chain pendant is preferred. This is particularly important on the tow, as the conditions of the tow’s chocks, bitts, etc. may be unknown and contact with these may cause extensive chafing. Barges usually have very rough chocks caused by previous repetitive use of wire rope or chain. Special attention should be paid to where the hawser crosses the stern of the tug.

- Since their coefficient of friction is below that of manila, synthetic lines may slip when eased out under heavy loads, causing personal injury. Make sure that personnel are thoroughly instructed in these lines' peculiarities. Take two or three turns on a bitt before you "figure 8" the line; this provides closer control. Stand well clear of the bitts.
- Fiber Rope Characteristics

Table C-2 provides the strength and weight of several sizes and types of fiber ropes. See NTSM CH-613 (Ref. F) for additional data on fiber lines.

Table C-2. Synthetic and Natural Line Characteristics.

Size (Inches)	Dry Nylon Double-Braid (MIL-R-24050 D)		Polyester Double-Braid (MIL-R-24667 A)		Polyester Single Braided 12-Strand (MIL-R-24750)	
	BS (lbs)	WT/100 ft	BS (lbs)	WT/100 ft	BS (lbs)	WT/100 ft
3	27,825	24.3	29,480	31.9	25,600	30
5	78,110	67.6	74,000	84	67,200	78
6	109,675	97.1	105,000	128	96,000	112
7	149,800	132	133,600	161	131,200	153
8	192,600	173	180,000	220	172,000	200
9	243,000	219	232,000	287	215,200	253
10	284,840	270	277,000	337	264,800	312
11	351,000	327	335,000	419	319,200	378
12	415,800	389	396,150	510	376,800	449
13	475,200	450	446,500	576	440,800	527
14	548,640	524	500,650	646	508,800	612
BS = Breaking Strength			WT = Weight			
Strength shown for nylon is for new dry nylon. Nylon wet strength is about 15% less. Multiply figures listed by 0.85 to obtain the new breaking strength of wet nylon.						

Appendix D - CHAINS AND SAFETY SHACKLES

D-1 Introduction

Chain is an important component in the connection between the towed vessel and the tug. It usually appears in the form of pendants or bridles at the towed-vessel end of the towline. The chain components serve one or more of the following purposes:

- A chafing-resistant strong terminal connection to the towed vessel
- An equalizing device (bridle) to share the towing load between two strong points located port and starboard of the towed vessel's bow (or stern)
- A means of absorbing dynamic loads in the towline, by virtue of its weight, which increases catenary in the towline.

Chain, like other marine tension members, has evolved over the years. The Boston Naval Shipyard led U.S. Navy chain development and manufacture for many years. Two major developments and manufacturing responsibilities at the Shipyard were die lock chain and the Navy detachable link. With the deactivation of the Boston Naval Shipyard in 1972, this capability was lost to the Navy, although similar products were commercially manufactured until the mid-1980s. Nonetheless, large amounts of die lock chain remain throughout the Fleet and this type chain is perfectly acceptable for all uses for which it was designed. The Navy now purchases "flash butt welded stud link" chain that is similar in appearance to high quality, commercial anchor chain, usually referred to as "welded" or "stud link" chain. In this appendix, this new Navy chain will be called "stud link" chain for the sake of simplicity. Navy stud link chain is slightly stronger than standard Type 1 die lock chain; they may be used interchangeably.

Until recently, commercial "DiLok" chain was made by one manufacturer, Baldt. It is slightly stronger and heavier than Type 1 standard Navy die lock chain. Section D-11 discusses the strengths of the various chains that may be used in towing.

D-2 Traceability and Marking

D-2.1 Traceability

The ability to trace a chain's history is an important element in accident investigation as well as in general product-improvement efforts. For identification, a corrosion-resistant metal tag is attached to the end link at each end of each shot or length of Navy chain. Included among data plainly marked on the tag is a manufacturer's serial number, which permits tracing the chain back to its manufacturing source. The manufacturers also provide information with new chain regarding size, type, material, proof tests, certification, and so forth. This information should be maintained in the Towing Hawser Log (see Appendix F) and updated as necessary for chain that is used as an integral part of the towline connection.

D-2.2 Marking

Navy chain, whether die lock or stud link, is marked in accordance with MILC24633A Notice 1, Chain, Stud Link, Anchor, Low Alloy Steel, Flash Bolt Welded (Ref. AB).

Commercial chain used in marine service, including DiLok, is controlled and certified by various marine classification societies such as the American Bureau of Shipping (ABS), which certifies all U.S. flag vessels and many foreign ships. Marine stud link chain is made in three grades. Grade 2 is most prevalent. ABS requires chain to be marked on the end link of each shot, or every 15 fathoms if the chain is continuous (without connecting links). The markings include:

- Certificate number
- Chain size
- Classification society stamp (such as a Maltese Cross for ABS)
- Designation of the grade of chain, for example: AB/1, AB/2, or AB/3. The other classification societies have marking requirements and grading systems that are similar to those of ABS.

When towing a commercial ship, if it is intended to use the ship's anchor chain for a bridle or pendant, the chain should be carefully inspected in accordance with the requirements of Section D-8 If the classification society grade marking cannot be determined, the chain should be assumed to be Grade 1, which is roughly one-half as strong as standard Navy chain.

Chain from unknown or non-marine sources that is unmarked or cannot otherwise be identified should not be used in towing.

D-3 Strength and Lifetime

Chain, properly used, should be the strongest and longest-lived element in the towing system. Because of its construction and generally rugged configuration, chain is considerably stronger than wire or fiber rope of the same nominal size.

D-4 Elongation

The rugged, large-diameter, individual strength members of chain give it the least elongation, or stretch, under load of any towline component. This characteristic of chain is one of the prime reasons it is used as an element in the towline system. Because it does not stretch, working at chafing points, under constantly changing tension, is minimized. Additionally, the weight and flexibility of the chain promotes the towline catenary and mitigates the effects of dynamic loading on the rest of the towing system.

D-5 Maintenance and Cleaning

As with other elements of the towline, chain must be properly maintained and cleaned. Perhaps the most important element of chain maintenance is corrosion prevention. Corrosion leads directly to loss of chain strength by reducing the diameter of the load-carrying rods that form the links. In stud link chains, corrosion can also loosen the studs and eventually lead to their loss.

Corrosion prevention is best achieved by a fresh-water washdown of the chain after each use, coupled with visual inspection for initial signs of corrosion. During the required annual inspection, the chain should be carefully cleaned, inspected, and re-preserved as necessary; see Naval Ship's Technical Manual (NSTM) S9086-TV-STM-010, Chapter 581, Anchoring (Ref. AC).

Cleaning should be done by scaling, sandblasting, or wire brushing. Penetrating oil should not be used to loosen the rust because it is difficult to remove and may reduce the effectiveness of corrosion prevention coatings. After cleaning, a careful inspection should be made in accordance with Section D-8. All suspected links should be checked by non-destructive test methods, careful measurement, sounding, and so forth.

Preservation after cleaning and any necessary repairs should be performed in accordance with Section D-8 and with NSTM CH-074 (Ref. K). For most chain, the use of TTV51 paint (asphalt varnish) or MILP24380 paint (anchor chain gloss black solvent type paint) is satisfactory.

D-6 New Chain and Links

New or reissued chain or links that will be used as components of towline connections should be treated in the same manner as new towing hawsers. The chain and links should be inspected and pertinent data entered in the Towing Hawser Log (see Appendix F).

D-7 Stowing

No special stowing precautions are needed beyond attempts to prevent corrosion, such as trying to avoid moisture and salt. Again, oil and grease should be avoided.

D-8 Inspection

D-8.1 General

Annual inspection of chain components of a towline system should follow the Navy practices for anchor chain detailed in NSTM 581. After cleaning by scaling, wire-brushing, or sandblasting, each link should be checked by sounding with a hammer. Give particular attention to locating possible loose studs, bent links, excessive corrosion, and sharp gouges.

D-8.2 Specific

Proper reactions to various conditions noted in the inspection are indicated in the following notes, most of which apply to stud link chain:

- Missing stud: discard link.
- Out-of-plane bending of more than three degrees: discard link.
- Average of the two measured diameters at any point less than 95 percent of nominal diameter, or a diameter in any direction less than 90 percent of nominal diameter: discard link.
- Crack at the toe of the stud weld extending into the base material: discard link.
- Surface cracks or sharp gouges: attempt to eliminate by light grinding. If the chain diameter is reduced to less than 90 percent of the nominal diameter after grinding: discard link.
- Excessively loose stud: since it is difficult to quantify excessive looseness of chain studs, the decision to reject or accept a link with a loose stud depends on the experience and judgment of the inspector. Consider discarding a link if:
- The stud can move more than 1/8 inch (3 mm) axially or more than 3/16 inch (5 mm) laterally in any direction, or

- A gap of more than 1/8 inch exists between the stud end in a link with a stud welded only on one end.
- Cracks detected by magnetic particle inspection in the internal locking area of detachable link: discard link. External surface defects in detachable links are not cause for rejection if they can be eliminated by grinding to a depth of no more than 8 percent of the nominal diameter of the chain.
- Length over six links exceeding 26.65 times nominal chain diameter or length of individual link exceeding 6.15 times nominal chain diameter: discard links.
- Excessive wear or deep surface crack on shackles, open links, or swivels: Attempt to eliminate by light grinding. If the cross-section area, diameter or critical thickness in any direction is reduced more than 10 percent by wear and grinding: discard the chain.

If a substantial number of adjacent links in a chain section meet the criteria for discarding, the chain section should be removed and the chain joined again by detachable links that have been examined and found to be in acceptable condition.

If a large number of links meet the criteria for discarding and these links are distributed throughout the chain's whole length, replace the chain with a new one.

Re-welding of loose studs in the field is undesirable for the following reasons:

- Welding in the field may produce hard heat-affected zones that are susceptible to cold cracking.
- Hydrogen brittleness may occur from absorption of moisture from the atmosphere or welding electrodes.

Weld repairs on loose studs should be delayed as long as possible. Where a few links are found with loose studs in a short section of a chain, it is recommended that this portion of the chain be cut out and a detachable link inserted. If the major portion of the chain has loose studs, the chain should be scrapped.

Any grinding to eliminate shallow surface defects should be done parallel to the longitudinal direction of the chain, and the groove should be well rounded and should form a smooth transition to the surface. The ground surface should be examined by magnetic-particle or dye-penetrant inspection techniques.

D-9 Types of Wear

The rough treatment to which chain items of towing gear are exposed can lead to various chain problems. Eight common problems for which towing personnel should be alert are described below:

- **Missing studs**. The stud contributes about 15 percent of the chain's strength. A chain link without a stud may significantly increase the possibility of link failure. High bending stresses and low fatigue life in links are predictable consequences of missing studs.
- **Bent links.** A bent link is the result of chain handling abuse. The link may have been excessively torqued when traversing a sharp, curved surface or the chain may have jumped over the wildcat, making point contacts between the link and the wildcat.

- **Corrosion**. Excessive corrosion reduces the cross sectional area of the link, increasing the possibility of chain failure from corrosion fatigue or overloading.
- **Sharp gouges**. Physical damage to the chain surface, such as cuts and gouges, raises stress and promotes fatigue failure.
- **Loose studs**. Loose studs, caused by abusive handling or by excessive stretching of chain, result in lower bending strength of the chain.
- **Cracks**. Surface cracks, flash weld cracks, and stud weld cracks propagate under cyclic loading and result in premature chain failure.
- **Wear**. Wear between links in the grip area and between links and the wildcat reduces the chain diameter. The diameter reduction decreases the load-carrying capacity of the chain and invites failure.
- **Elongation.** Excessive permanent elongation may cause the chain to function improperly in the wildcat, resulting in bending and wear of the links. Wear in the grip area of the chain as well as working loads in excess of the original proof load will result in a permanent elongation of chain.
- Special Precautions

D-10 Special Precautions

Because chain is generally the most rugged component of the towline system, there is a tendency to become overconfident in its capability and somewhat less rigorous in inspection. Avoid overconfidence when using chain.

Personnel tend not to check carefully enough on such items as:

- Adequate radius of curvature on surfaces of fairleads, chocks, and so forth. A ratio of 7:1 is generally accepted as the minimum Diameter ratio of bearing surface to chain size for heavy loads when the chain direction is changed significantly over the surface.
- Wear in the grip (partially hidden contact) area between chain links.
- Looseness from excessive wear in shackles, swivels, and detachable links.
- Presence of detachable links that are not equipped with safety-lock hairpins.

D-11 Chain Specifications

Navy die lock chain characteristics are included in Table D-1. The similar Baldt “ DiLok” chain is 11 percent stronger and 1 percent heavier. Table D-2 provides the characteristics of Navy stud link chain. Navy stud link chain is equivalent to commercial Grade 3 as shown in Table D-3. Commercial Grade 3 chain is about 3 percent stronger than Navy standard die lock. Grade 2 is only about 70 percent as strong as Navy standard die lock and Grade 1 is only about 50 percent as strong.

D-12 Connecting Links

Detachable chain connecting links are frequently used in lieu of more traditional shackles, because they will pass through a smaller space and are less likely to “hang up” during the rigging process. Pear-shaped detachable links fit two chain sizes. The strength of this link is identical to the breaking strength of the larger chain size that it is designed to accommodate. The figures shown in Tables D-4 and D-5 describe detachable links and an improved locking system for use with the tapered link pins. End links (see Table D-6) are special studless links

1/8 inch to 1/4 inch larger than the chain size. They are larger than the chain size to compensate for the lack of a stud. They have the same strength as the parent chain system.

D-13 Safety Shackles

CAUTION
Screwpin shackles, other than the special forged shackles for stoppers, must never be used for connections in towing rigs. The pin could back out due to the constant vibration on the towline.

A safety shackle is characterized by a pin that is secured by a bolt on the outside of the shackle. For towing use, the bolt itself is secured by a small machine bolt with two nuts jammed together to prevent rotation of the large nut. Screwpin shackles, which use a threaded pin that screws into the body of the shackle, are not approved for Navy towing. Some deck layouts present no alternative due to location and size of attachment padeye. Contact NAVSEA 00C for further guidance.

Navy shackles are manufactured in two types, two grades, and three classes of shackles. Mechanical properties can be obtained from Fed Spec RR-C-271D (Ref. E). Tables D-1 through D-8 provide the physical dimensions and strengths of safety shackles. Note the significant difference in strength between Grade A and Grade B shackles. The shackle size and safe working load will be shown in raised or stamped letters on the shackle. The pins and bolts of Grade A - Regular Strength shackles are unmarked, but Grade B pins and bolts are marked "HS."

D-14 Proof Load, Safe Working Load, and Safety Factor

Calculated or predicted design loads are compared to a baseline strength in computing the safety factor. Conversely, the baseline strength is divided by the recommended safety factor to determine the allowable design load. Table 3-2 provides the recommended factors of safety for use in designing towing systems. Note that safety factors, for a given type design and service, are referenced to different baselines such as breaking strength, yield strength, or proof load.

For chain, safety factors are referred to as "proof load," a load demonstrated as part of the manufacturing process, which intentionally introduces a permanent stretch that improves the strength of the chain. Proof load for chain is 66 percent of minimum break strength.

For other forged-type hardware, such as shackles, proof load is a load at which no permanent deformation is observed after the load is released. This is important where the component must mate with other components or where the component has parts that must fit together. In the case of shackles, it is important to be able to remove the pin after use. Unlike chain, however, there is no consistent relationship between proof load and breaking load. The relationship depends upon the metallurgical properties of the material.

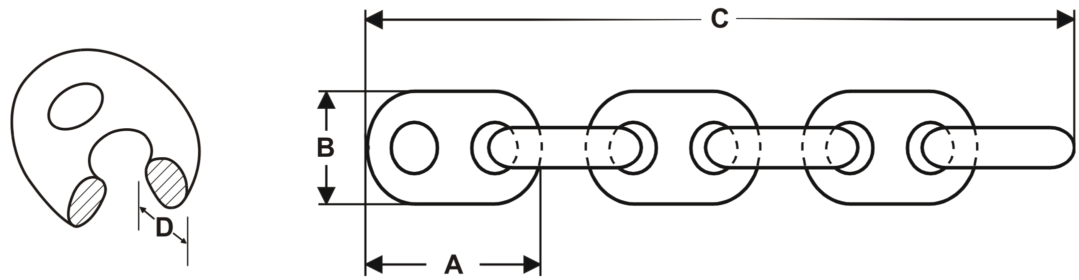
Safe Working Load (SWL) is frequently used for rigging components and systems including such material. The concept of SWL is similar to the use of a "safety factor" and is appropriate where the load is fairly well known and dynamic loads are limited. The typical use of SWL is for lifting purposes. The safety factor inherent in SWL for Navy safety shackles, compared to proof load, is 2 for Grade A and 2.5 for Grade B shackles. This is insufficient for use in towing systems, where the dynamic loads are more difficult to predict, than for simple rigging purposes. Applying the safety factors from Table 3-2 in addition to SWL, however, is overly conservative and will result in unacceptably large components. Therefore, when designing towing systems for strenuous conditions, the safety factors listed in Table 3-2 for shackles should be applied to proof loads listed in Table D-9.

Consider, for example, a predicted steady state tow resistance of 80,000 pounds. This is appropriate for a 2-inch fiber core towing hawser under automatic towing machine control. Table 3-2 requires a safety factor of 3 for shackles. If this factor is applied to SWL, 3 1/2-inch Grade B safety shackles, weighing 310 pounds, would be required in the rig. Applying the required factor of safety to proof load requires more reasonable 2 1/4-inch Grade B shackles.

D-15 Plate Shackles

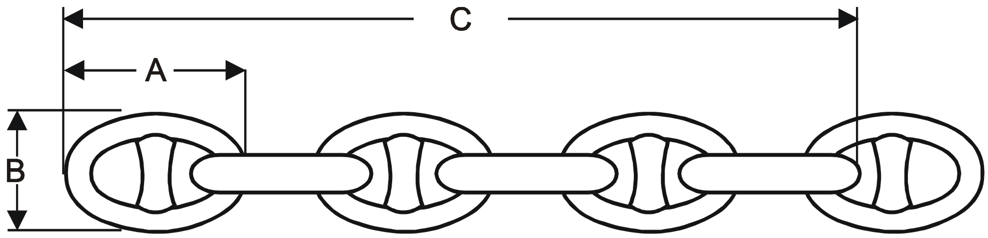
Plate shackles are frequently used in salvage and towing operations because they are simple, efficient, and easily fabricated from commonly available materials. Plate shackles are efficient because many connections of chain to wire and chain to chain would require two safety shackles, back-to-back, whereas one plate shackle will accomplish the task. The cheeks of towing plate shackles are fabricated from “medium” (ABS Grade A or ASTM A36) steel, the most readily available classification, and the pins are fabricated from 150,000 psi minimum yield strength bar stock, also readily available. Appendix I includes drawings of plate shackles for use in towing. Certain salvage ships can be outfitted for heavy-lifting operations. In this case, stronger plate shackles than shown in Appendix I may be required. Check the specific rigging plans for the specified shackles for heavy lifting.

Table D-1. Die Lock Chain Characteristics (MIL-C-19944).



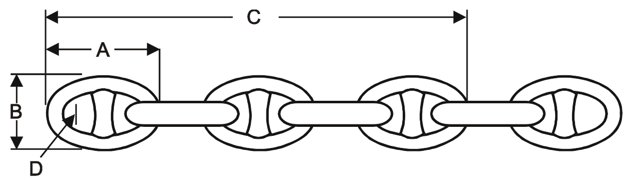
Chain Size		Link Length (Inches) A	Link Length (Inches) A	Length Over Six Links (Inches) C	Number of Links Per 15-Fathom Shot	Approx. Weight Per 15-Fathom Shot (Pounds)	Approx. Weight Per Link (Pounds)	Proof Test (Pounds)	Break Test (Pounds)
Inches	mm								
TYPE I: STANDARD									
3/4	19	4–1/2	2–5/8	19–1/2	359	490	1.4	48,000	75,000
7/8	22	5–1/4	3–1/8	22–3/4	305	680	2.2	64,000	98,000
1	25	6	3–3/16	26	267	890	3.3	84,000	129,000
1–1/8	29	6–3/4	4	29–1/4	237	1130	4.8	106,000	161,000
1–1/4	32	7–1/2	4–1/2	32–1/2	213	1400	6.6	130,000	198,000
1–3/8	34	8–1/4	4–13/16	35–3/4	193	1690	8.8	157,000	235,000
1–1/2	38	9	5–3/8	39	177	2010	11.4	185,000	280,000
1–5/8	42	9–3/4	5–7/8	42–1/4	165	2325	14.1	216,000	325,000
1–3/4	44	10–1/2	6–3/16	45–1/2	153	2695	17.6	249,000	380,000
1–7/8	48	11–3/4	6–3/4	48–3/4	143	3095	21.6	285,000	432,000
2	51	12	7–3/16	52	135	3490	25.9	289,800	439,200
2–1/8	54	12–3/4	7–5/8	55–1/4	125	3935	31.5	325,800	493,200
2–1/4	58	13–1/2	8–1/8	58–1/2	119	4415	37.1	362,700	549,000
2–3/8	60	14–1/4	8–3/16	61–3/4	113	4915	43.5	402,300	607,500
2–1/2	64	15	9	65	107	5475	51.2	442,800	669,600
2–5/8	67	15–3/4	9–3/16	68–1/4	101	6050	59.9	486,000	731,700
2–3/4	70	16–1/2	9–7/8	71–1/2	97	6660	68.7	531,000	796,500
2–7/8	73	17–1/4	10–3/8	74–3/4	93	7295	78.4	576,000	868,500
3	76	18	10–13/16	78	89	7955	89.4	623,700	940,500
3–1/8	79	18–3/4	11–1/4	81–1/4	87	8700	100	673,200	1,015,200
3–1/4	83	19–1/2	11–11/16	84–1/2	83	9410	113.4	723,700	1,089,000
3–3/8	86	20–1/4	12–1/8	87–3/4	79	10112	128	776,000	1,166,400
3–1/2	90	21	12–5/8	91	77	10900	141.6	829,800	1,244,800
3–3/4	95	22–1/2	13–3/8	97–1/2	71	12500	176.1	1,008,000	1,575,000
4–3/4	121	28–1/2	17–1/8	122–1/2	57	20500	359.7	1,700,000	2,550,000
TYPE II: HEAVY DUTY									
2–3/4	70	16–1/2	9–7/8	71–1/2	97	7000	72	584100	882900
3	76	18	10–13/16	78	89	8100	91	685800	1035000
3–1/2	90	21	12–5/8	91	77	12000	156	972000	1530000
TYPE III: HIGH STRENGTH									
3/4	19	4–1/2	2–5/8	19–1/2	359	550	1.5	67,500	91,100
1	26	6	3–3/16	26	267	1,000	3.8	116,100	156,700
1–1/8	29	6–3/4	4	29–1/4	237	1,270	5.4	145,000	195,000
1–3/8	34	8–1/4	4–15/16	35–3/4	193	1,900	9.9	211,500	285,500
1–1/2	38	9	5–3/8	39	177	2,260	12.8	252,000	340,200
1–5/8	42	9–3/4	5–7/8	42–1/4	165	2,620	15.9	292,500	395,000

Table D-2. Navy Stud Link Chain Characteristics (MIL-C-24633).



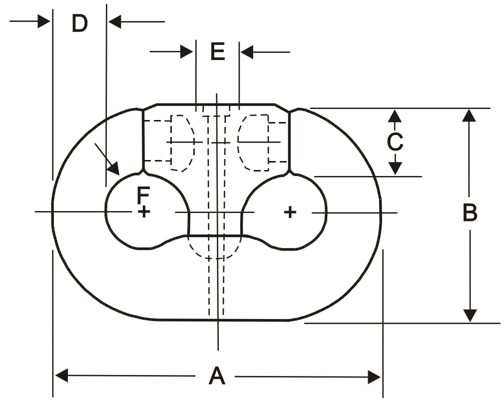
Chain Size (Inches)	Link Length (Inches) (A)	Link Width (Inches) (B)	Length Over 6 Links (C) (Inches)			Number of Links per 15-Fathom Shot	Proof Test Load (Pounds)	Break Test Load (Pounds)	Nominal Weight per 15-Fathom Shot (lb.)†
			Minimum	Nominal	Maximum				
3/4	4-1/2	2-5/8	19-3/8	19-1/2	19-13/16	359	48,000	75,000	480
7/8	5-1/4	3-1/8	22-5/8	22-3/4	23-1/16	305	64,400	98,000	660
1	6	3-9/16	25-7/8	26	26-3/8	267	84,000	129,000	860
1-1/8	6-3/4	4	29-1/16	29-1/4	29-5/8	237	106,000	161,000	1,080
1-1/4	7-1/2	4-1/2	32-5/16	32-1/2	32-15/16	213	130,000	198,000	1,350
1-3/8	8-1/4	4-15/16	35-9/16	35-3/4	36-1/4	193	157,000	235,000	1,630
1-1/2	9	5-3/8	38-13/16	39	39-1/2	177	185,000	280,000	1,940
1-5/8	9-3/4	5-7/8	42	42-1/4	42-7/8	165	216,000	325,000	2,240
1-3/4	10-1/2	6-5/16	45-1/4	45-1/2	46-1/8	153	249,000	380,000	2,590
1-7/8	11-1/4	6-3/4	48-1/2	48-3/4	49-1/2	143	285,000	432,000	2,980
2	12	7-3/16	51-11/16	52	52-3/4	135	318,800	454,000	3,360
2-1/8	12-3/4	7-5/8	54-15/16	55-1/4	56-1/8	125	357,000	510,000	3,790
2-1/4	13-1/2	8-1/8	58-3/16	58-1/2	59-3/8	119	396,000	570,000	4,250
2-3/8	14-1/4	8-9/16	61-7/16	61-3/4	62-3/4	113	440,000	628,000	4,730
2-1/2	15	9	64-11/16	65	66	107	484,000	692,000	5,270
2-5/8	15-3/4	9-7/16	67-7/8	68-1/4	69-1/4	101	530,000	758,000	5,820
2-3/4	16-1/2	9-7/8	71-1/8	71-1/2	72-9/16	97	578,000	826,000	6,410
2-7/8	17-1/4	10-3/8	74-3/8	74-3/4	75-7/8	93	628,000	897,000	7,020
3	18	10-13/16	77-5/8	78	79-3/16	89	679,000	970,000	7,650
3-1/8	18-3/4	11-1/4	80-13/16	81-1/4	82-1/2	87	732,000	1,046,000	8,320
3-1/4	19-1/2	11-11/16	84-1/16	84-1/2	85-3/4	83	787,000	1,124,000	9,010
3-3/8	20-1/4	12-1/8	87-5/16	87-3/4	89	79	843,000	1,204,000	9,730
3-1/2	21	12-5/8	90-9/16	91	92-5/16	77	900,000	1,285,000	10,500
3-5/8	21-3/4	12-15/16	93-13/16	94-1/4	95-5/8	73	958,000	1,369,000	11,300
3-3/4	22-1/2	13-3/8	97-1/16	97-1/2	98-7/8	71	1,019,000	1,455,000	12,000
3-7/8	23-1/4	14	100-1/4	100-3/4	102-3/16	69	1,080,000	1,543,000	12,900
4	24	14-3/8	103-1/2	104	105-1/2	67	1,143,000	1,632,000	13,700

Table D-3. Commercial Stud Link Anchor Chain.



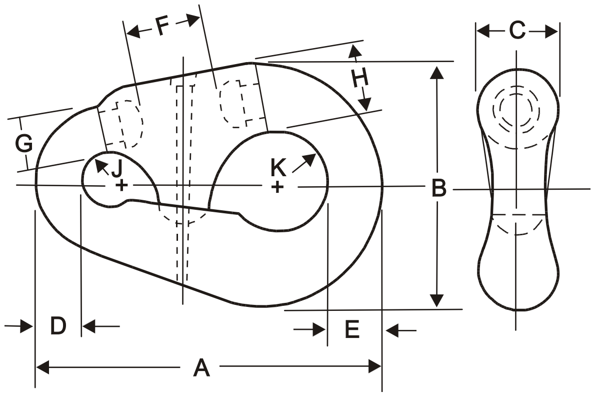
Chain Size		Link Length (Inches) (A)	Link Width (Inches) (B)	Length Over Five Links (Inches) (C)	Grip Radius (Inches) (D)	Approx. Weight per 15-Fathom Shot (lbs)	No. of Links per 15-Fathom Shot	ABS Grade 1		ABS Grade 2		ABS Grade 3	
Inches	mm							Proof Test (lb)	Break Test (lb)	Proof Test (lb)	Break Test (lb)	Proof Test (lb)	Break Test (lb)
3/4	19	4-1/2	2-5/8	16-1/2	1/2	480	357	23,800	34,000	34,000	47,600	47,600	68,000
13/16	20	4-7/8	2-7/8	17-7/8	17/32	570	329	27,800	39,800	39,800	55,700	55,700	79,500
7/8	22	5-1/4	3-1/8	19-1/4	37/64	660	305	32,200	46,000	46,000	64,400	64,400	91,800
15/16	24	5-5/8	3-5/16	20-5/8	5/8	760	285	36,800	52,600	52,600	73,700	73,700	105,000
1	25	6	3-9/16	22	21/32	860	267	41,800	59,700	59,700	83,600	83,600	119,500
1-1/16	27	6-3/8	3-3/4	23-3/8	11/16	970	251	47,000	67,200	67,200	94,100	94,100	135,000
1-1/8	28	6-3/4	4	24-3/4	25/32	1,080	237	52,600	75,000	75,000	105,000	105,000	150,000
1-3/16	30	7-1/8	4-1/4	26-1/8	25/32	1,220	225	58,400	83,400	83,400	116,500	116,500	167,000
1-1/4	32	7-1/2	4-1/2	27-1/2	25/32	1,350	213	64,500	92,200	92,200	129,000	129,000	184,000
1-5/16	33	7-7/8	4-3/4	28-7/8	7/8	1,490	203	70,900	101,500	101,500	142,000	142,000	203,000
1-3/8	34	8-1/4	4-15/16	30-1/4	7/8	1,630	195	77,500	111,000	111,000	155,000	155,000	222,000
1-7/16	36	8-5/8	5-3/16	31-5/8	15/16	1,780	187	84,500	120,500	120,500	169,000	169,000	241,000
1-1/2	38	9	5-3/8	33	63/64	1,940	179	91,700	131,000	131,000	183,500	183,500	262,000
1-9/16	40	9-3/8	5-5/8	34-3/8	1-1/32	2,090	171	99,200	142,000	142,000	198,500	198,500	284,000
1-5/8	42	9-3/4	5-7/8	35-3/4	1-1/16	2,240	165	108,000	153,000	153,000	214,000	214,000	306,000
1-11/16	43	10-1/8	6-1/16	37-1/8	1-3/32	2,410	159	115,000	166,500	166,500	229,000	229,000	327,000
1-3/4	44	10-1/2	6-5/16	38-1/2	1-5/32	2,590	153	123,500	176,000	176,000	247,000	247,000	352,000
1-13/16	46	10-7/8	6-1/2	39-7/8	1-3/16	2,790	147	132,000	188,500	188,500	264,000	264,000	377,000
1-7/8	48	11-1/4	6-3/4	41-1/4	1-1/4	2,980	143	140,500	201,000	201,000	281,000	281,000	402,000
1-15/16	50	11-5/8	7	42-5/8	1-9/32	3,180	139	149,500	214,000	214,000	299,000	299,000	427,000
2	51	12	7-3/16	44	1-5/16	3,360	133	159,000	227,000	227,000	318,000	318,000	454,000
2-1/16	52	12-3/8	7-7/16	45-3/8	1-3/8	3,570	129	168,500	241,000	241,000	337,000	337,000	482,000
2-1/8	54	12-3/4	7-5/8	46-3/4	1-27/64	3,790	125	178,500	255,000	255,000	357,000	357,000	510,000
2-3/16	56	13-1/8	7-7/8	48-1/8	1-15/32	4,020	123	188,500	269,000	269,000	377,000	377,000	538,000
2-1/4	58	13-1/2	8-1/8	49-1/2	1-1/2	4,250	119	198,500	284,000	284,000	396,000	396,000	570,000
2-5/16	59	13-7/8	8-5/16	50-7/8	1-17/32	4,490	117	209,000	299,000	299,000	418,000	418,000	598,000
2-3/8	60	14-1/4	8-9/16	52-1/4	1-9/16	4,730	113	212,000	314,000	314,000	440,000	440,000	628,000
2-7/16	62	14-5/8	8-3/4	53-5/8	1-5/8	4,960	111	231,000	330,000	330,000	462,000	462,000	660,000
2-1/2	64	15	9	55	1-5/8	5,270	107	242,000	346,000	346,000	484,000	484,000	692,000
2-9/16	66	15-3/8	9-1/4	56-3/8	1-11/16	5,540	105	254,000	363,000	363,000	507,000	507,000	726,000
2-5/8	67	15-3/4	9-7/16	57-3/4	1-11/16	5,820	103	265,000	379,000	379,000	530,000	530,000	758,000
2-11/16	68	16-1/8	9-11/16	59-1/8	1-3/4	6,110	99	277,000	396,000	396,000	554,000	554,000	792,000
2-3/4	70	16-1/2	9-7/8	60-1/2	1-13/16	6,410	97	289,000	413,000	413,000	578,000	578,000	826,000
2-13/16	71	16-7/8	10-1/8	61-7/8	1-27/32	6,710	95	301,000	431,000	431,000	603,000	603,000	861,000
2-7/8	73	17-1/4	10-3/8	63-1/4	1-7/8	7,020	93	314,000	449,000	449,000	628,000	628,000	897,000
2-15/16	75	17-5/8	10-9/16	64-5/8	1-7/8	7,330	91	327,000	467,000	467,000	654,000	654,000	934,000
3	76	18	10-13/16	66	2	7,650	89	340,000	485,000	485,000	679,000	679,000	970,000
3-1/16	78	18-3/8	11	67-3/8	2	7,980	87	353,000	504,000	504,000	705,000	705,000	1,008,000
3-1/8	79	18-3/4	11-1/4	68-3/4	2-1/16	8,320	85	366,000	523,000	523,000	732,000	732,000	1,046,000
3-3/16	81	19-1/8	11-1/2	70-1/8	2-1/16	8,660	85	380,000	542,000	542,000	759,000	759,000	1,084,000
3-1/4	83	19-1/2	11-11/16	71-1/2	2-1/8	9,010	83	393,000	562,000	562,000	787,000	787,000	1,124,000
3-5/16	84	19-7/8	11-15/16	72-7/8	2-1/8	9,360	81	407,000	582,000	582,000	814,000	814,000	1,163,000
3-3/8	86	20-1/4	12-1/8	74-1/4	2-3/16	9,730	79	421,000	602,000	602,000	843,000	843,000	1,204,000
3-7/16	87	20-5/8	12-3/8	75-5/8	2-3/16	10,100	77	435,000	622,000	622,000	871,000	871,000	1,244,000
3-1/2	90	21	12-5/8	77	2-5/16	10,500	77	450,000	643,000	643,000	900,000	900,000	1,285,000
3-5/8	92	21-3/4	12-15/16	79-3/4	2-5/16	11,300	73	479,000	685,000	685,000	958,000	958,000	1,369,000
3-3/4	95	22-1/2	13-3/8	82-1/2	2-15/32	12,000	71	509,000	728,000	728,000	1,019,000	1,019,000	1,455,000
3-7/8	98	23-1/4	14	85-1/4	2-15/32	12,900	69	540,000	772,000	772,000	1,080,000	1,080,000	1,543,000
4	102	24	14-3/8	88	2-5/8	13,700	67	571,000	816,000	816,000	1,143,000	1,143,000	1,632,000
4-1/8	105	24-3/4	14-7/8	90-3/4	2-11/16	14,600	65	603,000	862,000	862,000	1,207,000	1,207,000	1,724,000
4-1/4	108	25-1/2	15-5/16	93-1/2	2-3/4	15,400	63	636,000	908,000	908,000	1,272,000	1,272,000	1,817,000
4-3/8	111	26-1/4	15-3/4	96-1/4	2-7/8	16,200	61	669,000	956,000	956,000	1,338,000	1,338,000	1,911,000
4-1/2	114	27	16-3/16	99	2-15/16	17,100	59	703,000	1,000,400	1,000,400	1,405,000	1,405,000	2,008,000

Table D-4. Commercial Detachable Chain Connecting Link.



Chain Size		A	B	C	D	E	F	Proof Test	Break Test	Weight per Link (lbs.)
Inches	mm									
3/4	19	4-1/2	3	1-3/64	3/4	27/32	1/2	67,500	91,100	2.1
13/16 - 7/8	21-22	5-1/4	3-1/2	1-7/32	7/8	63/64	19/32	88,200	119,000	3.4
15/16 - 1	24-25	5	4	1-25/64	1	1-1/8	21/32	116,110	156,700	5.1
1-1/16 - 1-1/8	27-28	6-3/4	4-1/2	1-9/16	1-1/8	1-17/64	47/64	145,000	195,000	7.2
1-3/16 - 1-1/4	30-32	7-1/2	5	1-47/64	1-1/4	1-13/32	13/16	178,200	240,600	9.9
1-5/16 - 1-3/8	33-34	8-1/4	5-1/2	1-29/32	1-3/8	1-35/64	29/32	211,500	285,500	13.3
1-7/16 - 1-1/2	36-38	9	6	2-5/64	1-1/2	1-11/16	83/84	252,000	340,200	17.3
1-9/16 - 1-5/8	40-42	9-3/4	6-1/2	2-1/4	1-5/8	1-63/64	1-1/16	292,500	395,000	22.0
1-11/16 - 1-3/4	43-44	10-1/2	7-1/2	2-7/16	1-3/4	2	1-3/16	352,000	476,000	27.5
1-13/16 - 1-7/8	46-48	11-1/4	7-1/4	2-1/2	1-7/8	2-5/32	1-1/4	285,000	432,000	32
1-15/16 - 2	50-51	12	7-3/4	2-1/2	2	2-5/16	1-5/16	322,000	488,000	36
2-1/16 - 2-1/8	52-54	12-3/4	8-1/4	2-21/32	2-1/8	2-1/2	1-13/32	362,000	548,000	44
2-3/16 - 2-1/4	56-58	13-1/2	8-23/32	2-13/16	2-1/4	2-5/8	1-1/2	403,000	610,000	52
2-5/16 - 2-3/8	59-60	14-1/4	9-7/32	3-1/16	2-3/8	2-3/4	1-9/16	447,000	675,000	61
2-9/16 - 2-5/8	66-67	15-3/4	10-3/16	3-1/4	2-5/8	3-1/16	1-3/4	540,000	813,000	82
2-11/16 - 2-3/4	68-70	16-1/2	10-13/16	3-11/16	2-7/8	3-1/4	1-13/16	649,000	981,000	100
2-13/16 - 2-7/8	71-73	17-1/4	11-1/8	3-19/32	2-7/8	3-11/32	1-29/32	640,000	965,000	107
2-15/16 - 3	75-76	18	11-5/8	3-3/4	3	3-17/72	1-31/32	693,000	1,045,000	120
3-1/16 - 3-1/8	78-79	18-3/4	12-1/8	4	3-1/8	3-5/8	2-3/64	748,000	1,128,000	138
3-3/16 - 3-1/4	81-83	19-1/2	12-5/8	4-1/16	3-1/4	3-5/8	2-5/32	804,100	1,210,000	161
3-5/16 - 3-3/8	84-86	20-1/4	13-3/32	4-7/32	3-3/8	3-15/16	2-1/4	862,200	1,296,000	177
3-7/16 - 3-1/2	87-89	21-1/8	13-25/32	4-13/16	3-3/4	4-1/8	2-13/32	1,080,000	1,700,000	205
3-9/16 - 3-5/8	90-92	21-3/4	14	4-9/16	3-5/8	4-3/16	2-5/16	1,021,100	1,566,000	215
3-11/16 - 3-3/4	94-95	22-1/2	14-1/2	4-11/16	3-3/4	4-11/16	2-7/16	1,120,000	1,750,000	256
3-11/16 - 3-7/8	97-98	23-1/4	15	5	3-7/8	4-1/2	2-5/8	1,205,000	1,863,400	271
3-17/16 - 4	100-102	24	15-1/2	5-3/16	4	4-5/8	2-11/16	1,298,000	1,966,000	288
4-1/8	105	24-3/4	16-1/2	5-7/8	4-1/8	5	2-25/32	1,347,000	2,062,500	384
4-1/4	108	25-1/2	17-3/8	6-1/2	4-3/8	5-1/4	2-7/8	1,393,700	2,134,000	422
4-3/8	111	26-1/4	18-3/8	7-1/4	4-1/2	5-5/8	2-15/16	1,569,700	2,398,000	460
4-1/2	114	27	19-3/8	8	4-5/8	6	3	1,672,000	2,508,000	500
	All specifications in pounds and inches, unless otherwise stated.									
	See Figures D2 and D3 for hairpin locking details.									

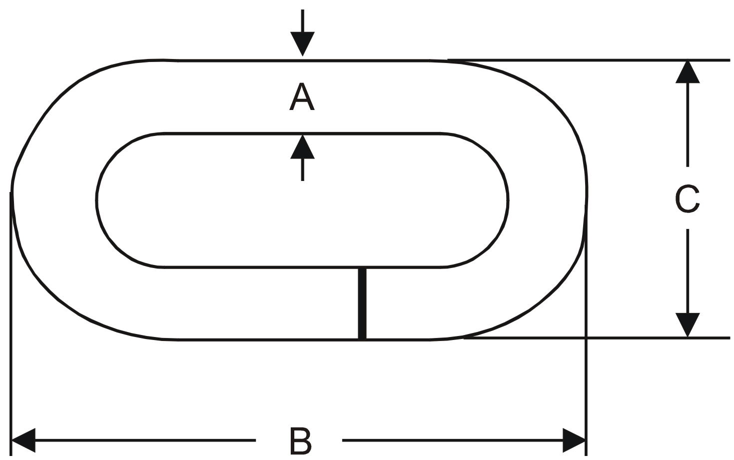
Table D-5. Commercial Detachable Anchor Connecting Link.



Small End Chain Size			A	B	C	D	E	F	G
No.	Inches	mm							
2	3/4 - 15/16	19-24	7-5/8	5-3/16	1-1/2	15/16	1-1/4	2-1/4	15/16
3	1 - 1-3/16	25-30	9-3/8	6-9/16	1-13/16	1-3/16	1-1/2	2-19/32	1-5/16
4	1-1/4 - 1-9/16	32-40	11-3/4	8-1/8	2-5/16	1-9/16	1-7/8	3-1/4	1-9/16 x 1-3/4
5	1-5/8 - 2	42-51	14-7/8	10-1/4	3	2	2-1/2	3-15/16	2-15/16 x 2-3/8
6	2-1/16 - 2-3/8	52-60	17-7/8	12-5/16	3-5/8	2-3/8	3	4-3/4	2-7/16 x 2-7/8
7	2-7/16 - 3-1/8	62-79	22-1/8	14-13/16	4-5/8	3-1/8	3-3/4	5-7/8	3-3/8 x 3-1/8
8	3-3/16 - 3-5/8	81-92	25-3/4	16-1/2	5-1/4	3-5/8	4-7/8	5-7/8	4-3/8 x 4
9	3-11/16 - 3-3/4	94-95	27-1/4	17-1/8	5-3/4	3-7/8	5-1/8	6-1/4	4-7/8 x 5-3/8
10	3-13/16 - 4	97-102	35	22-1/2	7-1/2	4-3/4	6-1/2	7-1/2	5-1/8
11	4-1/16 - 4-1/4	103-108	37	24	8	5	6-7/8	8	6-1/8

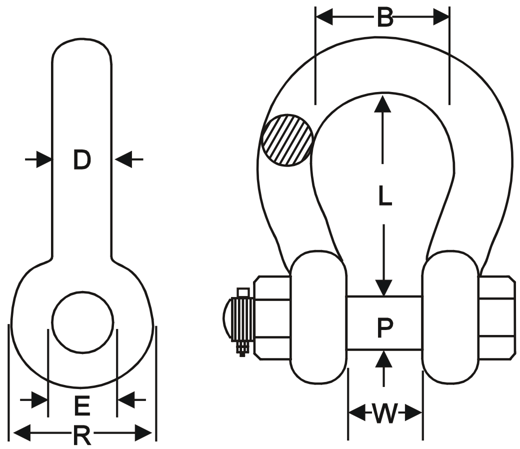
Small End Chain Size			H	J	K	Proof Test	Break Test	Weight pe Link (lbs)
No.	Inches	mm						
2	3/4 - 15/16	19-24	1-3/8	21/32	1-3/16	74,000	113,500	7
3	1 - 1-3/16	25-30	1-3/4	3/4	1-3/8	118,000	179,500	14
4	1-1/4 - 1-9/16	32-40	2-7/32	1-1/32	1-11/16	200,500	302,500	28
5	1-5/8 - 2	42-51	2-29/32	1-1/4	2-1/16	322,000	488,000	60
6	2-1/16 - 2-3/8	52-60	3-15/32	1-15/32	2-17/32	447,000	675,000	107
7	2-7/16 - 3-1/8	62-79	4-3/8	1-29/32	3	748,000	1,128,000	208
8	3-3/16 - 3-5/8	81-92	5-1/8 x 5-1/4	2-1/8	3-1/8	1,021,000	1,566,000	328
9	3-11/16 - 3-3/4	94-95	5-9/16	2-1/4	3-1/4	1,120,000	1,750,000	520
10	3-13/16 - 4	97-102	7-1/8	2-7/8	4-1/4	1,298,000	1,996,500	850
11	4-1/16 - 4-1/4	103-108	7-7/8	3	4-3/8	1,440,000	2,220,000	920

Table D-6. Commercial End Link



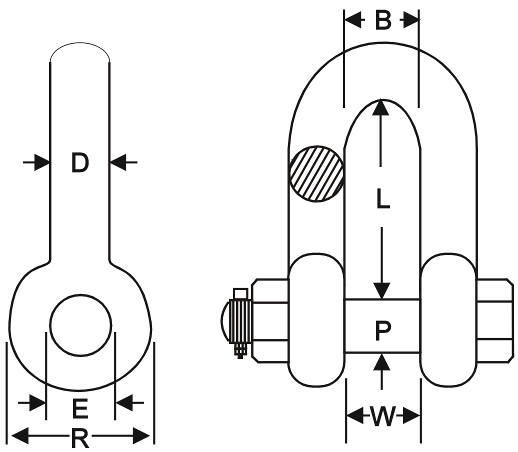
Chain Size		Link Diameter (Inches) A	Link Length (Inches) B	Link Width (inches) C	Weight per Link (lbs)	Proof Test (lbs)
Inches	mm					
11/16 - 3/4	17-19	13/16	5-5/8	2-7/8	1.8	48,000
13/16 - 1	21-25	1-1/16	7-1/2	3-3/4	4.0	84,000
1-1/16 - 1-1/4	27-32	1-3/8	9-3/8	4-7/8	8.0	130,000
1-5/16 - 1-1/2	33-38	1-5/8	11-1/4	5-3/4	14.2	185,000
1-9/16 - 1-3/4	40-44	1-7/8	13	6-5/8	21.6	249,000
1-13/16 - 2	46-51	2-1/8	15	7-5/8	34.2	322,000
2-1/16 - 2-1/4	52-58	2-1/2	16-7/8	8-3/4	45.4	403,000
2-5/16 - 2-1/2	59-64	2-3/4	18-3/4	9-3/4	62.0	492,000
2-9/16 - 2-3/4	66-70	3	20-1/2	10-3/4	81.0	590,000
2-13/16 - 3	71-76	3-1/4	22-1/2	11-5/8	105.0	693,000
3-1/16 - 3-3/8	78-86	3-5/8	25-1/4	13	148.0	862,000
3-7/16 - 3-3/4	87-95	4	28	14-1/2	202.0	1,120,000
3-13/16 - 4	97-102	4-1/4	30	15-1/4	258.0	1,298,000

Table D-7. Type I, Class 3 Safety Anchor Shackle (MIL-S-24214A (SHIPS)).



Size (D) Minimum	Diameter Bolt (P) Minimum	Diameter Inside Eye (E) Maximum	Width between eyes (W)		Length inside (L)		Width Minimum (B)	Diameter Outside Eye (R) Maximum	Approx. Weight pe 100 Shackles
			Nominal	Tolerance (+)	Nominal	Tolerance (+)			
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Pounds
1/2	5/8	23/32	13/16	1/16	1-7/8	1/8	1-3/16	1-3/8	82
5/8	3/4	27/32	1-1/16	1/16	2-13/32	1/8	1-1/2	1-7/8	158
3/4	7/8	31/32	1-1/4	1/16	2-27/32	1/4	1-3/4	2-1/8	280
7/8	1	1-3/32	1-7/16	1/16	3-5/16	1/4	2	2-3/8	395
1	1-1/8	1-7/32	1-11/16	1/16	3-3/4	1/4	2-5/16	2-5/8	560
1-1/8	1-1/4	1-11/32	1-13/16	1/16	4-1/4	1/4	2-5/8	2-7/8	785
1-1/4	1-3/8	1-15/32	2-1/32	1/16	4-11/16	1/4	2-7/8	3-1/4	1,120
1-3/8	1-1/2	1-5/8	2-1/4	1/8	5-1/4	1/4	3-1/4	3-1/2	1,520
1-1/2	1-5/8	1-3/4	2-3/8	1/8	5-3/4	1/4	3-3/8	3-3/4	1,950
1-5/8	1-3/4	1-7/8	2-5/8	1/8	6-1/4	1/4	4	4-1/8	2,410
1-3/4	2	2-5/32	2-7/8	1/8	7	1/4	4-1/2	4-1/2	3,130
2	2-1/4	2-13/32	3-1/4	1/8	7-3/4	1/2	5-1/4	5-1/4	4,630
2-1/4	2-1/2	2-21/32	3-7/8	1/8	9-1/4	1/2	5-1/2	5-3/4	5,650
2-1/2	2-3/4	2-29/32	4-1/8	1/8	10-1/2	1/2	6-3/4	6-1/4	9,400
3	3-1/4	3-13/32	5	1/8	13	3/4	7-3/8	6-3/4	14,500
3-1/2	3-3/4	3-29/32	5-3/4	1/4	15	3/4	9	8-1/2	25,000
4	4-1/4	4-13/32	6-1/2	1/4	17	3/4	10-1/2	9-1/2	35,800

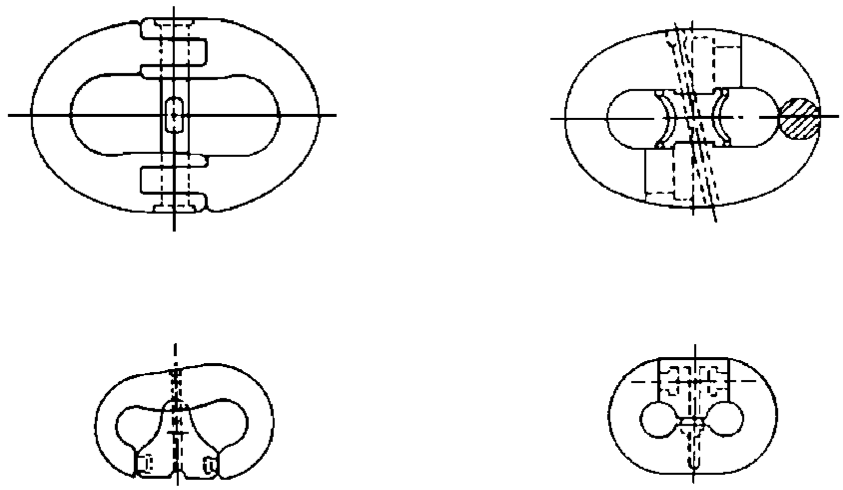
Table D-8. Type II, Class 3 Safety Chain Shackle (MIL-S-24214A(SHIPS)).



Size (D) Minimum	Diameter Bolt (P) Minimum	Diameter Inside Eye (E) Maximum	Width between eyes (W)		Length inside (L)		Diameter Outside Eye (R) Maximum	Approx. Weight per 100 Shackles
			Nominal	Tolerance (+)	Nominal	Tolerance (+)		
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Pounds
1/2	5/8	23/32	13/16	1/16	1-5/8	1/8	1-3/8	76
5/8	3/4	27/32	1-1/16	1/16	2	1/8	1-7/8	156
3/4	7/8	31/32	1-1/4	1/16	2-3/8	1/4	2-1/8	262
7/8	1	1-3/32	1-7/16	1/16	2-13/16	1/4	2-3/8	365
1	1-1/8	1-7/32	1-11/16	1/16	3-3/16	1/4	2-5/8	535
1-1/8	1-1/4	1-11/32	1-13/16	1/16	3-9/16	1/4	2-7/8	727
1-1/4	1-3/8	1-15/32	2-1/32	1/16	3-15/16	1/4	3-1/4	1,020
1-3/8	1-1/2	1-5/8	2-1/4	1/8	4-7/16	1/4	3-1/2	1,335
1-1/2	1-5/8	1-3/4	2-3/8	1/8	4-7/8	1/4	3-3/4	1,850
1-5/8	1-3/4	1-7/8	2-5/8	1/8	5-1/4	1/4	4-1/8	2,310
1-3/4	2	2-5/32	2-7/8	1/8	5-3/4	1/4	4-1/2	2,850
2	2-1/4	2-13/32	3-1/4	1/8	6-3/4	1/2	5-1/4	4,110
2-1/2	2-3/4	2-29/32	4-1/8	1/8	8	1/2	6-1/4	8,450
3	3-1/4	3-13/32	5	1/8	9	3/4	6-3/4	12,300
3-1/2	3-3/4	3-29/32	5-3/4	1/4	10-1/2	3/4	8-1/2	21,800
4	4-1/4	4-13/32	6-1/2	1/4	12	3/4	9-1/2	31,000
See Table D-9 for shackle strengths.								

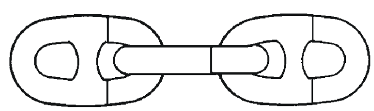
Table D-9. Mechanical Properties of Shackles (FED SPEC RR-C-271D).

Inches	Pounds		Pounds		Pounds	
	Grade A	Grade B	Grade A	Grade B	Grade A	Grade B
3/16	650	1,000	1,430	2,200	3,250	5,000
1/4	1,000	1,500	2,200	3,300	5,000	7,500
5/16	1,500	2,500	3,300	5,500	7,500	12,500
3/8	2,000	4,000	4,400	8,800	10,000	20,000
7/16	3,000	5,200	6,600	11,440	15,000	26,000
1/2	4,000	6,600	8,800	14,520	20,000	33,000
9/16	5,000	8,000	11,000	17,600	25,000	40,000
5/8	6,500	10,000	14,300	22,000	32,500	50,000
3/4	9,500	14,000	20,900	30,800	47,500	70,000
7/8	13,000	19,000	28,600	41,00	65,000	95,000
1	17,000	25,000	37,400	55,000	85,000	125,000
1-1/8	19,000	30,000	41,800	66,000	95,000	150,000
1-1/4	24,000	36,000	52,800	79,200	120,000	180,000
1-3/8	27,000	42,000	59,400	92,400	135,000	210,000
1-1/2	34,000	60,000	74,800	132,000	170,000	300,000
1-5/8	40,000	70,000	88,000	154,000	200,000	350,000
1-3/4	50,000	80,000	110,000	176,000	250,000	400,000
2	70,000	100,000	154,000	220,000	350,000	500,000
2-1/4	80,000	120,000	176,000	264,000	400,000	600,000
2-1/2	110,000	160,000	242,000	352,000	550,000	800,000
2-3/4	120,000	180,000	264,000	396,000	600,000	900,000
3	170,000	220,000	374,000	484,000	850,000	1,100,000
3-1/2	240,000	280,000	528,000	616,000	1,200,000	1,400,000
4	300,000	350,000	660,000	770,000	1,500,000	1,750,000

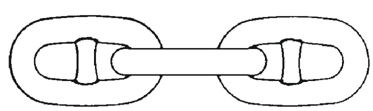


Note

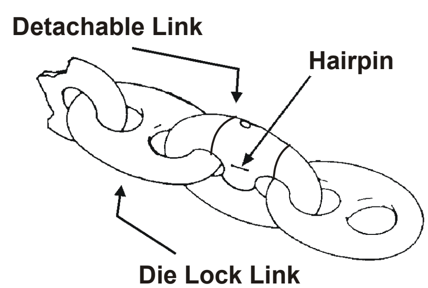
See Appendix Figure D-3 for Navy detachable locking hairpin details



Cast Stud Link



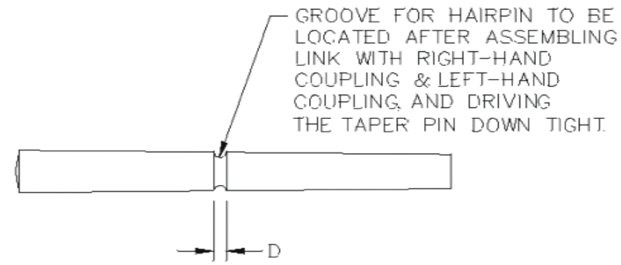
Welded Stud Link



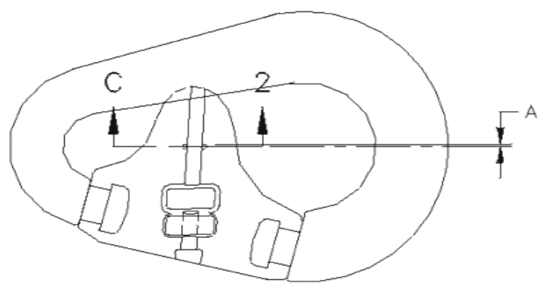
Appendix Figure D-1. Types of Chains and Connecting Links

NOTES

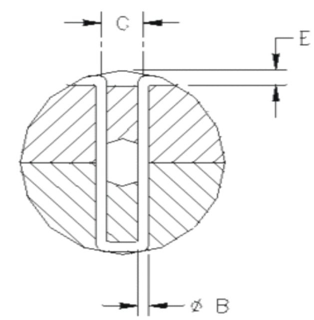
1. INSTRUCTIONS FOR GROOVING
   A REPLACEMENT TAPER PIN:
   A. AFTER INSPECTING AND CLEANING DETACHABLE LINK, INSTALL TAPER PIN WHICH HAS BEEN WIPED WITH OIL.
   B. DRIVE TAPER PIN DOWN TIGHT USING A HAMMER & ASSEMBLING PUNCH.
   C. USING A DRILL 1/32-INCH LESS IN SIZE THAN THE HAIR-PIN DIAMETER, DRILL MARK THE TAPER PIN THROUGH ONE OF THE HAIRPIN HOLES IN THE DETACHABLE LINK.
   D. DRIVE OUT TAPER PIN USING HAMMER & DISASSEMBLING PUNCH. MACHINE THE GROOVE AT DRILL MARK TO THE DIMENSIONS SPECIFIED IN CHART BELOW.



TAPER PIN



DETACHABLE LINK



SECTION C–2

SECTION VIEW SHOWN WITH LINK FULLY ASSEMBLED

LINK SIZE	"A"	"øB"	"C"	"D"	"E"
3/4 HS 7/8 HS	.12	.09	.366	.109	.12
1 HS 1 1/8 HS	.15	.12	.438	.140	.15
1 1/4 HS 1 1/2 HS	.18	.15	.630	.171	.18
1 5/8 HS 1 3/4 HS 2	.28	.25	.768	.265	.28
2 1/8 – 2 3/8	.28	.25	1.082	.265	.28
2 1/2 – 3 1/8 2 3/4 HD 3 HD	.34	.31	1.076	.327	.34
3 1/4 – 3 1/2 3 1/2 HD	.34	.31	1.346	.327	.34

Appendix Figure D-2. Detachable Link with Identifying Marks for Assembly

Appendix E - STOPPERS

E-1 Introduction

The term "stopper," as used in seamanship, describes a device or rigging arrangement that is used to temporarily hold a part of running rigging or ground tackle that may come under tension. The stopper is an indispensable tool in a towing operation.

WARNING
Never pass a stopper on a tension member that is under a strain greater than the safe working load of the stopper, or on a tension member that might be subjected to a heavier loading condition while the stopper is in place.

E-2 Types of Stoppers

There are many types of stoppers and methods of attaching them to the tension members. There is no single "best" type of stopper for all situations. For the three basic types of tension members—chain, fiber line, and wire rope—the following stoppers are recommended:

- Chain. The attachment to the tension member should be made by means of a suitably sized, jaw-type chain stopper (see Figure 418).
- Fiber Line. Fiber line always should be stopped off with fiber stoppers.
- Wire Rope. Wire rope should be stopped off with a carpenter stopper See Figure 419), Klein grip, chain, or fiber stopper using Kevlar.

Most stoppers cannot be released under load and require the held line to be heaved in to slack the stopper and allow its removal. Some stoppers, however, such as the pelican hook and carpenter stopper, can be released when under load. In some cases, it may be possible to use a combination of two stoppers to achieve this capability, for example, attaching a pelican hook to a fiber stopper (the fiber stopper holds the line and the pelican hook holds the stopper, allowing a quick release.)

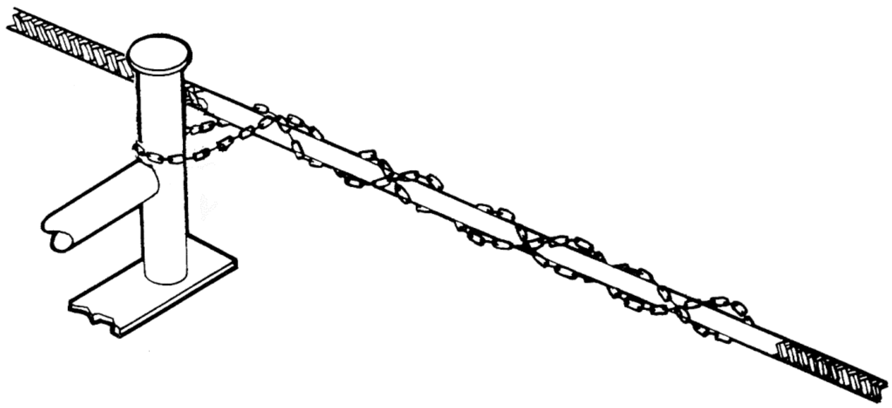
E-3 Prevention of Damage

When passing a stopper, prevention of damage to the tension member is a major consideration, second only to safety of personnel. If the hawser is damaged, the towing ship is essentially out of action. Properly using a stopper on a towing hawser entails considerably more than merely passing the stopper. It requires very close coordination between the Conning Officer on the bridge and the Boatswain's Mate in charge of passing the stopper on the fantail.

During the period when the stopper is in use on the towing hawser or pendant, the Conning Officer should not increase speed or radically change course without first notifying the afterdeck and reaching concurrence with the Afterdeck Supervisor that it is safe to do so. Direct communication between the deck work area and the bridge is mandatory. The Conning Officer should also be well versed in the use of stoppers, especially concerning their applications and limitations.

E-4 Stopping Off a Wire Towing Hawser

If possible, a properly fitted carpenter stopper should always be used when stopping off a wire rope towing hawser. See NAVSHIPS 0994-004-8010 Carpenter Stopper, Operation and Maintenance Instruction (Ref. AD).



Appendix Figure E-1. Crisscross Chain Stopper

In a situation where a carpenter stopper is not readily available, the hawser can be stopped off with a chain. If using a chain stopper, be very careful not to damage the hawser (see Appendix Figure E-1).

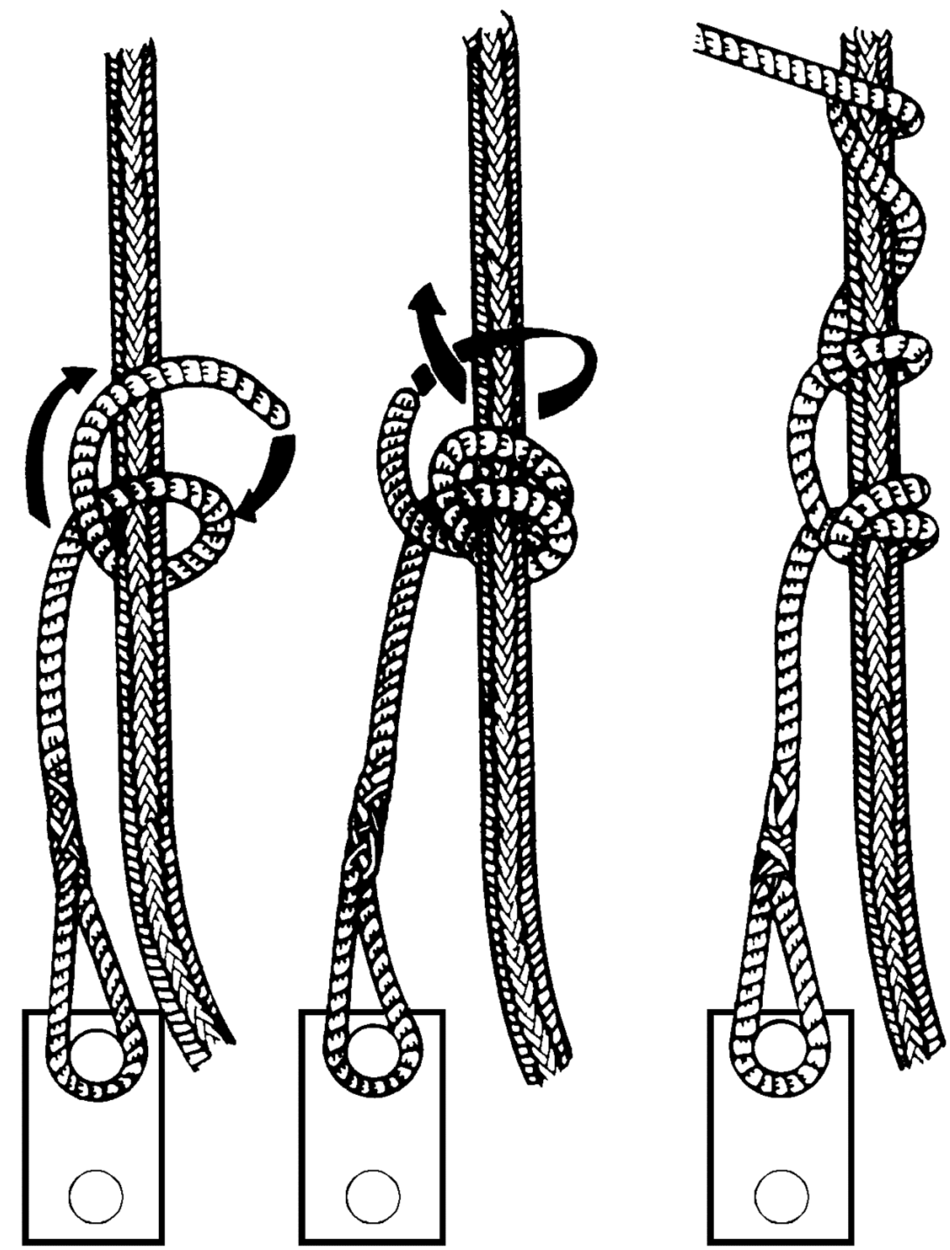
E-5 Synthetic Line

In recent years, synthetic fiber line has replaced virtually all large natural fiber line in the Navy. Synthetic fiber has many good qualities, such as its superior strength and elasticity. Its prime weakness, however, is its susceptibility to physical damage. It is very easily cut by sharp objects, melted by friction, and abraded by rough surfaces. All three types of damage can occur from the action of a poorly passed stopper.

When stopping off a synthetic towing hawser, a synthetic fiber stopper should always be used.

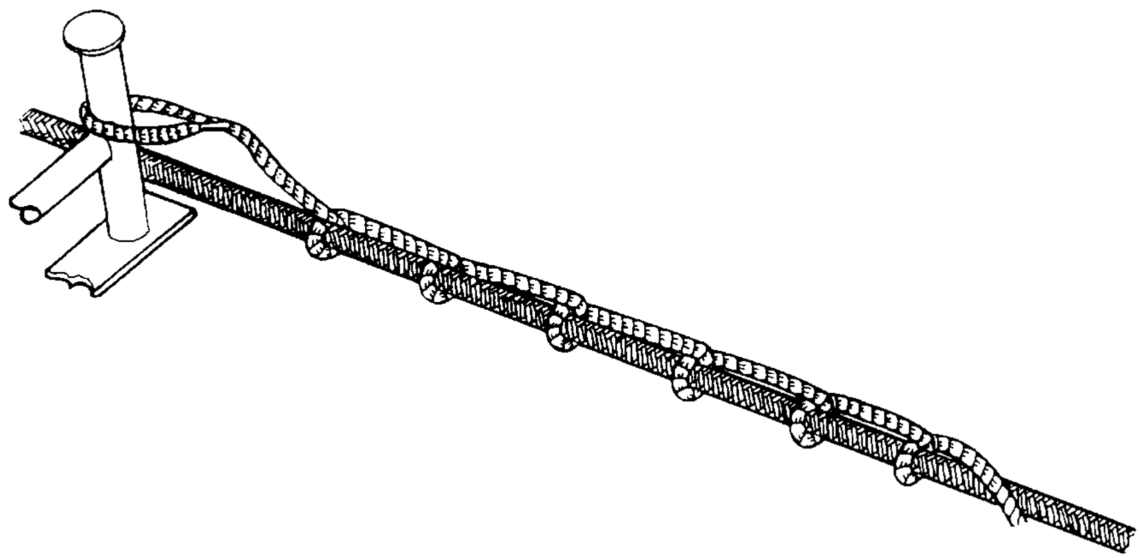
E-6 Stopper Breaking Strength

Ideally, the strength of the passed stopper would be equal to or greater than the strength of the tension member, thus eliminating the stopper as the weak link in the system. This condition is easy to achieve when stopping off relatively small lines such as fiber boat falls.

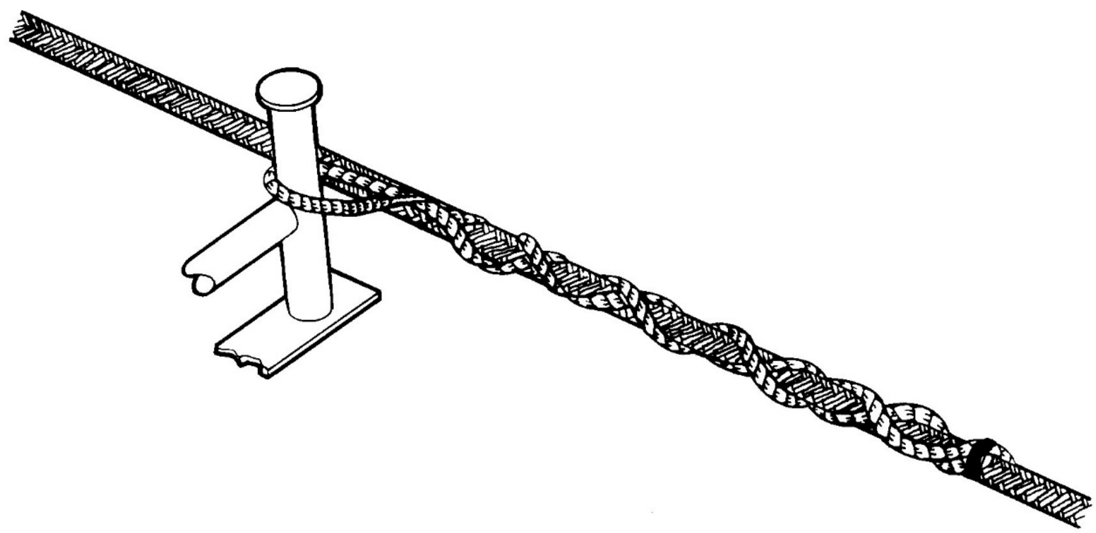


Appendix Figure E-2. Typical Stopper

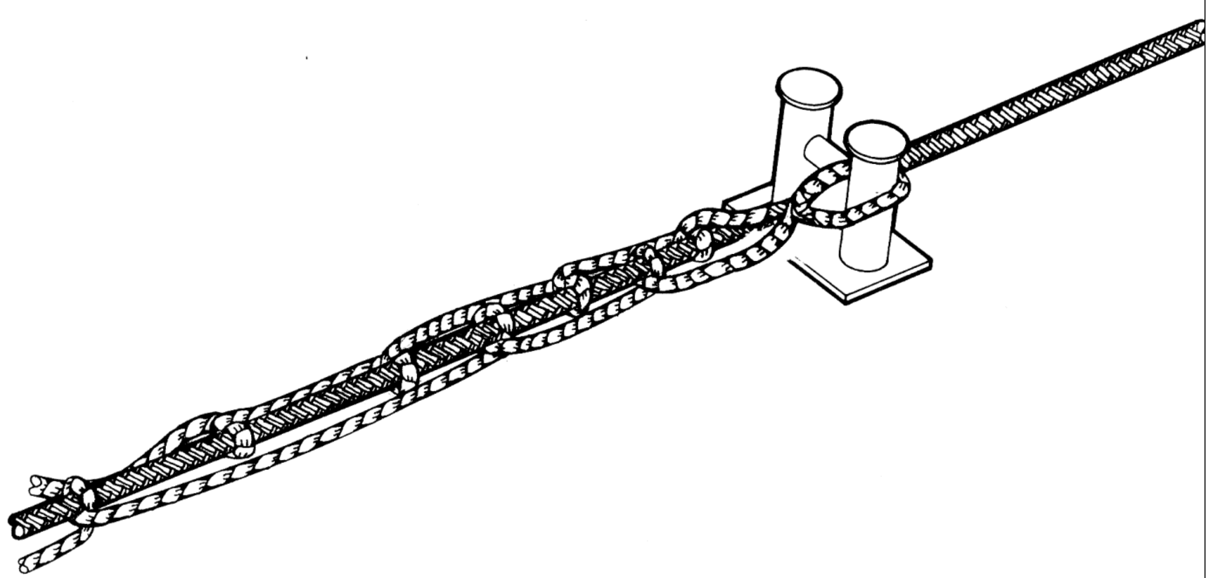
The prime factor limiting breaking strength of a large stopper is the physical size that can be handled manually by the deck seaman. A stopper of ½-inch chain can be passed fairly easily and one of ¾-inch chain can be passed with some difficulty. If, however, one were to try to match the breaking strength of a large towing hawser of 2- to 2½-inch wire, a stopper of 1½-inch or 2-inch chain would be required. From an engineering point of view the numbers would match up, but the seaman would be faced with an impossible task.



Appendix Figure E-3. Half-Hitch Stopper.



Appendix Figure E-4. Crisscross Fiber Stopper



Appendix Figure E-5. Double Half-Hitch Stopper

In cases of heavy rigging, the stopper often becomes the weak link. Thus, all personnel who are involved in the towing hawser/stopper passing procedure must be aware of inherent dangers.

E-7 Fiber Stoppers

Fiber stoppers are the simplest and most commonly used type of stopper (see Appendix Figures E-2 through E-5). One version, called a rat tail stopper, is merely a length of fiber line with an eye in one end and the section of the stopper that makes contact with the tension member flattened. When using a three-strand line, a section is flattened by passing a seizing, unlaying the line, and then weaving the line back together in a three-strand braid. In the case of double-braided line, slip the cover back and remove a section of the core to flatten the stopper.

Stoppers made of Kevlar are now available and are acceptable for use on fiber line.

E-8 Stopper Hitches

A number of methods can be used to attach the stopper to the tension member:

- A rolling hitch backed up with half hitches (see Appendix Figure E-2)
- A long series of half hitches, known as a crossover or Chinese stopper (see Appendix Figure E-3)
- A series of crisscrosses formed by weaving the stoppers over and under the tension member—this is the most preferred method (see Appendix Figures E-1 and E-4)
- Two long series of half hitches formed by half hitching a double stopper to the hawser (see Appendix Figure E-5)
- Any desired number or combination of the above.

Again, there is no universal “best” stopper hitch. The decision about which hitch arrangement to use depends on the size and composition of the line to be stopped, the size and composition of the stoppers available, and the judgment of the Boatswain’s Mate in charge.

E-9 Securing the Passed Stopper

When securing a passed stopper to a part of relatively small, low-tension rigging, such as a boat fall, the end of the stopper is usually held in place by hand. To secure a passed stopper to a large tension member, such as a towing hawser, the ends of the stopper should be securely seized to the hawser with small stuff.

E-10 Setting the Stopper

Once the stopper is in place and all personnel are safely out of the way, the tension member should be very slowly and carefully eased out.

This should continue until a determination can be made as to whether the stopper is holding or not. This critical determination is normally made by the Boatswain’s Mate.

If the stopper is slipping, or shows any indication that it might slip, the stopper should be removed and reattached.

- The Conning Officer must be made aware of any overloading of a towing hawser stopper so that corrective action is taken, such as easing the tension by slowing or stopping the ship.

E-11 Releasing the Stopper

WARNING
Releasing a stopper under load can cause shock loading in the stopped line. Personnel should be kept clear of any potential snapbacks.

WARNING
Carpenter stoppers, once set, may retain tension even after wire is slacked; These stoppers should always be opened with care.

Some stoppers, such as the carpenter stopper, chain stopper, and pelican hook, are designed to be released under tension. These devices all have hinge-type grabs that can be released by striking a pin with a sledge. This pin does not see full line tension and can be removed under load.

Fiber stoppers and stopper hitches cannot be released under load except by cutting. This is not recommended except in an emergency. (It may be prudent to rig a block of wood as a striking surface so the stopper may be cut with a fire axe instead of a knife. This should be done prior to setting the stopper.)

- Normal release of stoppers should be under no tension. The stopped line should be heaved in to allow the stopper to be slacked. The stopper can then be removed safely by personnel. This method is recommended for all stoppers, including quick release types.

Appendix F - TOWING HAWSER LOG

F-1 Introduction

The purpose of this appendix is to establish the requirement for towing ships to keep a Towing Hawser Log. Entries in this log are critical when evaluating past hawser usage, evaluating the present condition of the hawser, and making decisions concerning replacement. The log provides the Commanding Officer with a documented reference to use when determining the readiness of the hawser. Since the condition of the hawser may not be apparent, even to the experienced operator, the record of usage can be a decisive factor in evaluating operational readiness and overall system safety. This appendix replaces the NAVSEAINST 4740 series regarding hawser logs.

F-2 Background

Historically, fewer towline component failures have occurred on ships where close attention has been paid to the condition and history of the hawser and other tensile components of the towline. Life of towline components depends less on age than on care and use. Fiber lines of all types, including natural and synthetic fiber, deteriorate with age, exposure, and usage. The fiber core in wire ropes, particularly if it is natural fiber, also deteriorates with age. Old wires with no documentation should be treated with suspicion.

F-3 Discussion

In some instances when hawsers and other components have failed, it was impossible to ascertain usage, manufacture, and installation data because a log had not been kept. This lack of data precluded a meaningful analysis of the failure.

NSTM CH-613 (Ref. F) describes the fabrication, conditions of use, care, and preservation of wire rope, fiber rope, and cordage. In addition, the Wire Rope Users' Manual (Ref. C) and handbooks and catalogs published by major wire and rope manufacturers are useful.

Keeping a hawser log is mandatory for all towing ships. Selection and identification of other components that should be similarly logged and administered is left to the discretion of the Commanding Officer. Ships may also find it beneficial to keep a similar log on mooring lines. Salvage ships may also find it prudent to keep logs on beach gear components, chain, and connecting hardware.

F-4 Log

Salvage ships, fleet tugs, and surface ships carrying emergency towing hawsers and engaging in tow-and-be towed operations shall maintain a Towing Hawser Log in the format of Attachment A to this appendix. Ships may also keep similar logs on other towline components.

The log shall record a comprehensive history of all towing hawsers on the ship, including the main wire rope hawser, all synthetic hawsers, and target towing hawsers.

It is the responsibility of the command to maintain the log. Periodic review is mandatory. Type Commanders should include the requirement for keeping hawser logs as a check-off item in their Operational Readiness and Administrative Inspection Lists.

F-5 Failures

Ships experiencing failure of hawsers and other logged towline components should advise NAVSEA (Attention SEA 00C and SEA 03P8) and provide details that can be used for technical evaluation.

Whenever a hawser or other logged component breaks under suspicious conditions, save the broken ends and at least twelve feet of good rope (or three links in the case of chain) on each side of the break. Serve the broken ends to prevent unlaying of fiber line or oil them to prevent corrosion of wire rope. Log and describe details of the break. Save fragments and pieces for analysis. Also record names of any witnesses to the failure. If the break occurs in the vicinity of an end fitting, the end fitting also should be sent for test and evaluation, with the broken end wrapped in plastic.

Attachment A to Appendix F

Towing Hawser Log

1. The Towing Hawser Log is used to record data about both wire rope and fiber line hawsers. It may be used to record data about other towline components as well. The Towing Hawser Log should be kept in a standard record book. A separate book or separate section of the same book should be kept for each component.
2. The log for any towing hawser or other component consists of three parts: New Rope Entry, Operations Entry, and Post-Operations Entry.

NOTE
When measuring any rope length and identifying (mapping) a spot along the hawser, always measure back from the original outboard end. Do the same if hawser is end-for-ended, but carefully measure the entire length when end-for-ending and precisely log the conversion technique to be used in subsequent mapping. If the hawser is shortened to install a new end fitting, use the original measuring system; that is, measure as if it were still all there, but make a note in the comments section that the hawser has been shortened for installation of a new end fitting.

PART A: New Rope (Hawser or Component) Entry

Record data as follows:

1. Date and place of installation.
2. Identification of installer (ship's force, yard, etc.).
3. Method of installation. For example, was the line put on drum under back tension? If so, what was tension? How was tension applied? If not applied, what was done to ensure a tight spool?
4. Comprehensive description of new item. For wire rope and fiber line, include material (such as IPS, EIPS, or stainless for wire; nylon or polyester for fiber); size (rope diameter for wire; circumference for fiber line), and breaking strength. Ensure that the Federal Stock Number and any other specifications are included.
5. Details of line construction as found on tag attached or tacked onto shipping reel. Include the actual tag in log if possible, or attach a photocopy.
6. Manufacturer of rope or line (obtain from tag or shipping reel).
7. Date of manufacture of basic rope/line/chain. Also include dates of any rigging loft work.

8. Source of rope (such as NSC or private supplier).
9. Details of end fittings at both ends. Provide details of splices and servings for synthetic hawsers and springs. Include photos.
10. Record any other observations of the hawser or component, such as degree of lubrication, level of rust, discoloration, or other damage. Include observations from internal inspection of rope or line.

PART B: Operations Entry

Record for every employment of the hawser or component:

1. Description of the basic employment, for example, towing an FFG or hauling on a wreck.
2. Duration of use (days/hours).
3. Scope of tow hawser used (if varied, cite maximum and minimum scopes).
4. Maximum strains experienced by hawser or component. This may come from towing machine or other strain measuring instrumentation. Include notations of weather on trip.
5. A map and complete description of all chafe, bearing or nip points and any chafing gear used. Include photos when practical.
6. Description of use of carpenter stopper, chain stopper or other hardware on rope. For example, where was stopper placed on rope (lengthwise)?
7. For fiber line hawsers, include a description of how it was secured on towing vessel: for example, wrapped around main traction sheave/drum, stopped on the Hbitts, etc.
8. Minimum depth of water traversed. For example, did hawser drag bottom?
9. If hawser was passed to a wreck, include a description of how it was passed. Was the hawser floated or dragged across the bottom? If the hawser was dragged, how far was it dragged, and across what type of bottom was it dragged?
10. Other experiences of note, for example surging against hawser/components or fouling on rocks or ship's appendages.
11. Between-use maintenance: type of lubricant applied, how applied, and by whom applied.
12. Respooling method (as listed in Part A-3).

PART C: Post Operations Entry

Record after every use:

1. Specific inspection of hawser for wear points such as carpenter or chain stopper wear points, caprail/nipping chafe area, shock bearing points, sheaves and fairleads, and so forth. Include photographs.
2. Quantification of wear:

a. General and wire rope. Include count of “fish hooks” and record and identify (map) spots. Count fish hooks per strand lay. Count all broken wires, not just those that protrude from the rope. Record maximum number of broken wires per lay (total) and maximum number of broken wires per strand lay. Include information on any “birdcaging,” kinking, broken surface wires, and surface wire flattening. Indicate surface corrosion. Include photographs. Record and map any instance of burying. Periodic inspection/maintenance of hawser or components, which includes opening the lays and internal inspection, need not be performed after every employment, but when undertaken, it should be logged. When lubrication is performed, carefully log stock number and manufacturer’s data on lubricant as well as who performed the maintenance and inspection.

b. Fiber line. Include information on surface chafing and abrasion wear, kinking, or any other visible damage. Include photographs.

c. Chain. Pay particular attention to the link bearing points (the “grip” area). Pay special attention to places along the chain where it passed through or bore against chocks or fairleads. In these latter places a straight edge should be laid against the flat face of the link to ensure that the link is not bent in this plane. Any bending is to be reported as failure and requires replacement.

d. Joining links and shackles of all kinds. Inspect the mechanical joints and screw threads. In the case of safety shackles, measure the mortise to ensure that the bow is not sprung. If sprung, dispose of the shackle. Ensure that all detachable link pieces have serial numbers and are matched in sets. Ensure also that the hairpins fit snugly.

3. General comments. Include as a minimum a general post-f observation of hawser, component, and end fitting.

Appendix G - CALCULATING STEADY STATE TOWLINE TENSION

This appendix provides a method for calculating the towing resistance of various ships and craft. The data required to calculate resistance for self-propelled ships, dry docks, and barges come from different sources; therefore, each category is discussed separately.

Calculating tow resistance is often an iterative process. Starting with the ship or craft to be towed, resistance is usually computed for several assumed towing speeds and for different wind and sea conditions. The resulting values are then compared to the capabilities of available tugs.

Next, the towing connection elements (bridles, chain pendants, etc.) are selected, towing hawser length determined, catenary checked, and towline hydrodynamic resistance estimated. This process may result in a towing ship pull requirement or total hawser tension that will require an adjustment to the assumed tow speed.

G-1 Self-Propelled Surface Ships

The following method combines hull, propeller, wind, and sea state resistances into one calculation for determination of the total tow resistance of a ship. Methods for calculating the resistance of the towline are discussed in Chapter 3 (see Section 34.1.2 and Table 31). Use Table G-1 as a worksheet for determining tow resistance, following the step-by-step procedures below.

NOTE
The coefficients used to calculate resistance account for unit conversion. If recommended units are used, these equations will yield resistance in pounds.

Use Table G-2 for Items 4 Through 9

Item 1

Identify the ship class under consideration, or select a class as close as possible.

Item 2

Select tow speed (V_{TOW}), in knots.

Item 3

Select tow course, in degrees.

Item 4

List the displacement in long tons (Δ). If the ship is known to be lighter than full load, adjust the full load figures from the table accordingly.

Item 5

List frontal windage area (A_T) in square feet. Estimate this number for ships not listed. Ships at lighter than full load condition will have increased windage area than that listed in Table G-2.

Item 6

List wind drag coefficient (C_W).

Item 7

List projected area of all propellers (A_P) in square feet. This value assumes that propellers are locked. If propellers are trailing, reduce this value by one-half. If propellers have been removed, use a value of zero.

Item 8

List the curve number for hull resistance. (See Section G-1.1.)

Item 9

List curve number for sea state resistance. (See Section G-1.2.)

Item 10

The expected sustained wind speed should be used when calculating towline tensions. The estimate should be conservative and should account for anticipated changes in weather.

Item 11

With the aid of Table G-3, determine the Beaufort wind force number. This number is based on expected or measured wind velocity or observation of the sea state (Item 10).

Item 12

List relative wind speed (V_R) in knots. (If unknown, assume worst condition, that is, tow speed plus true wind speed.)

Item 13

Select a heading coefficient (K). If the relative wind is dead ahead, use 1.0. If the relative wind is 15 to 45 degrees off the bow, use 1.2. For 45 to 90 degrees relative wind, use 0.4. There is higher wind resistance to ahead movement when the wind is slightly off the bow than when directly ahead, because of the larger ship area presented to the wind. As the wind veers farther aft, however, the wind effect on the ahead direction falls off faster than the increase of the area presented to the wind. (See Section G-1.3 for additional guidance.)

Item 14

Calculate the wind resistance (R_W) by multiplying 0.00506 by the frontal windage area (item 5) by the wind drag coefficient (item 6) by the relative wind speed (item 12) squared by the heading coefficient (item 13). (See Section G-1.3.).

$R_W = 0.00406 \times (A_T) \times (C_W) \times (V_R)^2 \times (K)$

Item 15

In Appendix Figure G-6, locate the curve identified in item 8 and compare it to the tow speed (item 2). The point where these two values intersect is the value for R_H/. (See Section G-1.1.)

Item 16

Calculate the hull resistance (R_H) by multiplying 1.25 by R_H/ (item 15) by the displacement (item 4). (The factor 1.25 accounts for hull roughness and other variables).

RH = 1.25 x ($R_{H/\Delta}$) x (Δ)

Item 17

In Appendix Figure G-7 locate the curve identified in item 9 and compare it to the Beaufort wind force number identified in item 11. The point where these two values intersect is the sea state resistance (R_S). (See Section G-1.2.)

Item 18

Calculate the propeller resistance (R_P) by multiplying 3.737 by the projected area of the propellers (item 7) by the tow speed (item 2) squared. (See Section G-1.4.)

RP = 3.737 x (A_P) x $(V_{TOW})^2$

Item 19

Calculate the total steady-state tow resistance (RT) by adding the four resistance values (items 14, 16, 17, and 18).

$R_T = R_W + R_H + R_S + R_P$

Item 20

Using Table 31, estimate the hydrodynamic resistance of the towline (R_{WIRE}). If the size of the tow hawser is not yet determined, estimate the towline resistance to be 10 percent of the tow resistance (item 19).

Item 21

To calculate horizontal tow hawser tension, add the tow resistance (item 19) to the tow hawser resistance (item 20).

$R = R^T + R_{WIRE}$

Appendix Figure G-1 through Appendix Figure G-4 contain sample calculations.

G-1.1 Hull Resistance Curves

Hull resistance curves are plotted on a per-ton-displacement basis. Thus they are applicable to similar hull shapes. Hull shapes are largely influenced by speed/length ratio:

$$\frac{V}{\sqrt{L}}$$

Assume that it is necessary to estimate the towing resistance of a large tanker with the following design characteristics:

Displacement:	110,000 long tons

Length:	850 feet
Speed:	15 knots
Speed/length ratio	0.51

NAVSEA 00C can provide assistance in locating a hull of similar dimensions. In this case, the T-AGM 20 is similar; with a speed of 14 knots, a length of 595 feet and, therefore, a speed/length ratio of 0.57. This is close enough for the purpose intended. In Appendix Figure G-6 use curve 5 (from Table G-2) for the T-AGM 20 at the assumed tow speed and read resistance per ton. For instance, at 6 knots, read 0.75 lbs. resistance per ton. If the tanker is at full load, its hull resistance is 1.25 x 0.75 x 110,000 = 103,125 lbs. Even without estimating propeller, wind, or sea state resistance, it is apparent from Figure 6-1 that towing this ship at this speed is impractical for Navy tow ships except the TATF. While working on curve 5, it will save time to also compute the smooth hull resistances for 5, 4, and 3 knots as well, for future use. The resulting smooth hull resistance values are 66,000, 42,600 and 20,600 pounds, respectively.

G-1.2 Additional Resistance Due to Waves

Note that there is no method provided for estimating the effect of other than head seas. Under the more usual sea conditions where the tug has total freedom in course-setting, the effect of the waves on the tow and tug is modest. Under the more strenuous cases, the tug will have to set a course into the seas to maintain stability as well as to relieve dynamic effects on the hawser. It is unlikely that the tug will be able to take advantage of following seas under the more strenuous cases.

For the larger ships (represented by curves 2 and 3 in Appendix Figure G-6), the added resistance is significant at the higher sea states. Under these conditions, however, the tug itself may experience difficulty and may simply have to reduce power to maintain steerageway. Speed over the ground of the tug and tow may well be sternward in this case, and is perfectly appropriate.

Note 1: The method of estimating the added resistance from waves at certain tow speeds is not well developed. The data presented here are developed from stationary (anchored) theory and include no correction for tow course or speed. From the shape of the curves, it can be seen that there is little effect in seas up to State 4 or 5. The added resistance increases rapidly in heavier seas, which usually require the tow to head into the seas. Furthermore, the effect of the additional speed of the tow is small compared to the speed of the seas in this case and can be ignored. Therefore, the amount of error introduced by assuming head seas and neglecting tow speed is small, and, in any event, provides a conservative answer for most tow courses.

Following wind and seas will reduce the tow resistance. However, the dynamic effects of ship motions on the tow hawser may preclude towing downwind under strenuous sea conditions. Likewise, stability of the tug and tow may preclude towing across the wind and seas under strenuous conditions.

Table G-1. Calculation of Steady State Towing Resistance.

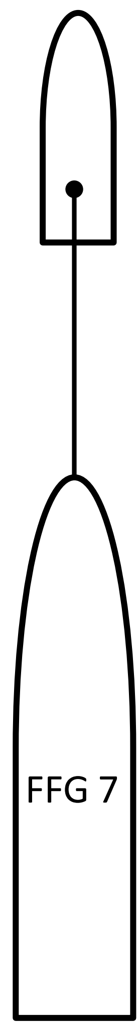
SHIP: ____________________ CALCS BY: ____________________

Item	Description	Symbol	Units	Source			
1	Ship Class (AE, CV, etc.)						
2	Tow Speed	V_{TOW}	Knots				
3	Tow Course	γ	Degrees				
4	Tow Displacement	Δ	Long tons				
5	Frontal Windage Area	Δ_{FULL}	Sq. feet	Table G-2			
6	Wind Drag Coefficient	A_T		Table G-2			
7	Total Projected Area of Propellers	C_W	Sq. feet	Table G-2			
8	Curve Number for Hull Resistance	A_P		Table G-2			
9	Curve Number for Sea State Resistance			Table G-2			
10	True Wind Speed	V_{wind}					
11	Beaufort Number		Knots	Table G-3			
12	Relative Wind Speed	V_R	Knots				
13	Heading Coefficient	K		Table G-1			
14	Wind Resistance	R_W	Pounds	$R_W = 0.00406(A_T)(C_W)(V_R)^2(K)$			
15	Resistance Factor	$R_{H/\Delta}$		Figure G-6			
16	Hull Resistance	R_H	Pounds	$R_H = 1.25(R_H/\Delta)(\Delta)$			
17	Sea State Resistance	R_S	Pounds	Figure G-7			
18	Propeller Resistance	R_P	Pounds	$R_P = 3.737(A_P)(V_{TOW})^2$			
19	Total Steady State Tow Resistance	R_T	Pounds	$R_T = R_W + R_H + R_S + R_P$			
20	Tow Hawser Resistance	R_{WIRE}	Pounds	Table 3-1 or 10% of R_T			
21	Total Tow Hawser Tension	R	Pounds	$R = R_T + R_{WIRE}$			

Example 1. Scenario

Wind @ 20 knots

Towed ship: FFG 7
Full load displacement – 3585 LT
Desired speed – 8 kts
Course – 000 T
Relative wind: 28 kts @ 000 R



The predicted tow resistance is 74486 lbs. Assuming an 2000-ft 2-1/4 inch hawser with 90 feet of 2 1/4- inch chain pendant, the tow hawser resistance will be approximately 2700 lbs. The total tug requirement is 77,186 lbs. Inspection of Figure 3-3 shows that the T-ATF 166 and ARS 50 Classes can perform this tow. The other tugs can tow at a slower speed.

Appendix Figure G-1. Example 1 - Scenario

SHIP: ____________ CALCS BY: LT MARK FIVE

Item	Description	Symbol	Units	Source			
1	Ship Class (AE, CV, etc.)				FFG 7		
2	Tow Speed	V_{TOW}	Knots		8	6	4
3	Tow Course	γ	Degrees				
4	Tow Displacement	Δ	Long tons		3585	3585	3585
5	Frontal Windage Area	Δ_{FULL}	Sq. feet	Table G-2	2200	2200	2200
6	Wind Drag Coefficient	A_T		Table G-2	0.7	0.7	0.7
7	Total Projected Area of Propellers	C_W	Sq. feet	Table G-2	170	170	170
8	Curve Number for Hull Resistance	A_P		Table G-2	2	2	2
9	Curve Number for Sea State Resistance			Table G-2	1	1	1
10	True Wind Speed	V_{wind}			20	20	20
11	Beaufort Number		Knots	Table G-3	5	5	5
12	Relative Wind Speed	V_R	Knots		28	26	24
13	Heading Coefficient	K		Table G-1	1.0	1.0	1.0
14	Wind Resistance	R_W	Pounds	$R_W = 0.00406(A_T)(C_W)(V_R)^2(K)$	6109	5268	4488
15	Resistance Factor	$R_{H/\Delta}$		Figure G-6	4.4	2.9	1.7
16	Hull Resistance	R_H	Pounds	$R_H = 1.25(R_H/\Delta)(\Delta)$	19718	12996	7618
17	Sea State Resistance	R_S	Pounds	Figure G-7	8000	8000	8000
18	Propeller Resistance	R_P	Pounds	$R_P = 3.737(A_P)(V_{TOW})^2$	40659	22870	10165
19	Total Steady State Tow Resistance	R_T	Pounds	$R_T = R_W + R_H + R_S + R_P$	74486	49134	30271
20	Tow Hawser Resistance	R_{WIRE}	Pounds	Table 3-1 or 10% of R_T	2700	2200	1250
21	Total Tow Hawser Tension	R	Pounds	$R = R_T + R_{WIRE}$	77186	51334	31521

Appendix Figure G-2. Example 1 - Worksheet

Table G-2. Characteristics of Naval Vessels (sheet 1 of 4).

		Δ	AT	Cw	AP		
CLASS	DESCRIPTION	FULL LOAD DISPLACEENT (L.TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (Ft)	WIND COEFFICIENT	TOTAL PROJECTED AREA OF ALL PROPELLERS (Ft)	CURVE FOR HULL RESISTANCE SEE FIGURE G-6	CURVE FOR WAVE RESISTANCE SEE FIGURE G-7
AD 15-19	DESTROYER TENDERS	18,400	6,200	0.75	136	5	2
AD 37-44	DESTROYER TENDERS	20,500	8,000	0.75	136	5	2
AE 21-25	AMMUNITION SHIP	16,000	6,490	0.75	187	5	2
AE 26-35	AMMUNITION SHIP	18,000	7,800	0.75	216	5	2
AFS 1-7	COMBAT STORE SHIPS	18,000	6,350	0.70	216	5	2
AGF 11 (ex LPD-11)	MISC. COMMAND SHIP	16,912	8,350	0.75	175	5	2
AGF 3 (ex LPD-1)	MISC. COMMAND SHIP	15,000	8,300	0.75	175	4	2
AGOR 14-15	OCEANOGRAPHIC RESRCH SHIPS	1,915	1,800e	0.75	30e	4e	1
AGOR 21-22	OCEANOGRAPHIC RESRCH SHIPS	1,437	1,080e	0.75	40e	4e	1
AGOR 23	OCEANOGRAPHIC RESRCH SHIPS	2,433	1,500e	0.75	45e	4e	1
AGOR 3, 9-10	OCEANOGRAPHIC RESRCH SHIPS	1,370	1,100	0.75	35e	4e	1
AH 17	HOSPITAL SHIP	15,500	4,900	0.75	115	5	2
AK 283	CARGO SHIPS (C2-S-B1)	11,000	4,375	0.75	106	5	2
AO 177-186	OILERS	26,110	6,300	1.00	220	5e	3
AO 51, 98-99	OILERS	34,040	5,480	1.00	346	5	3
AOE 1-6	FAST COMBAT SUPPORT SHIPS	51,000	9,750	1.00	456	5	3
AOR 1-7	REPLENISHMENT OILERS	37,700	7,590	1.00	274	5	3
AP 110	TRANSPORTS	20,175	6,800	0.75	200	5e	2
AP 121-127	TRANSPORTS	22,574	6,300e	0.75	216	4e	2
AR 5-8	REPAIR SHIPS	16,300	5,460	0.75	136	5	2
ARL 24	SMALL REPAIR SHIP	4,325	2,320	0.75	30	4	1
ARS 38-43	SALVAGE SHIP	2,045	1,500	0.75	56	5	1
ARS 50-53	SALVAGE SHIP	2,880	2,000e	0.75	80	5e	1
AS 11, 17, 18	SUBMARINE TENDERS	17,000	6,200	0.75	136	4	2
AS 19	SUBMARINE TENDERS	19,200	6,200	0.75	136	4	2
AS 31-32	SUBMARINE TENDERS	19,000	6,440	0.75	140	4	2
AS 33-34	SUBMARINE TENDERS	21,089	7,550	0.75	136	5e	2
AS 36-41	SUBMARINE TENDERS	23,000	7,550	0.75	136	5	2
AS 39, 40	SUBMARINE TENDER	22,978	4350	0.75	215e	4e	2
ASR 21-22	SUBMARINE RESCUE SHIPS	3,411	4,500e	0.75	100	3e	1
ASR 9, 13-15	SUBMARINE RESCUE SHIPS	2,320	1,200	0.75	50	5	1
ATF 91-160	FLEET TUGS	1,640	1,100	0.75	43	2	1
ATS 1-3	SALVAGE & RESCUE SHIPS	2,929	2,500	0.75	110	5e	1
AVM 1	GUIDED MISSILE SHIP	15,170	5,300	0.75	136	4	2
BB 61-64	BATTLESHIPS	59,000	8,500	0.70	664	5	3
CA 134-148	GUN CRUISERS	20,950	4,500	0.70	324	5	2
CA 68-124	GUN CRUISERS	17,500	5,300	0.70	308	5	2
CG 10-12	GUIDED MISSILE CRUISERS	19,500	5,300	0.70	308	5e	2
CG 16-24 (DLG)	GUIDED MISSILE CRUISERS	8,250	3,000e	0.70	243	3	1
CG 26-34 (DLG)	GUIDED MISSILE CRUISERS	8,250	3,675	0.70	296	4	1
CG 47-73	GUIDED MISSILE CRUISERS	10,100	7,000e	0.70	254	4e	1
CGN 25 (DLGN)	GUIDED MISSILE CRUISER	8,592	3,040	0.70	239	3	1

"e" represents best estimate

Table G-2. Characteristics of Naval Vessels (sheet 2 of 4).

		Δ	AT	Cw	AP		
CLASS	DESCRIPTION	FULL LOAD DISPLACEENT (L.TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (Ft)	WIND COEFFICIENT	TOTAL PROJECTED AREA OF ALL PROPELLERS (Ft)	CURVE FOR HULL RESISTANCE SEE FIGURE G-6	CURVE FOR WAVE RESISTANCE SEE FIGURE G-7
CGN 35 (DLGN)	GUIDED MISSILE CRUISER	9,127	2,960	0.70	239	3	1
CGN 36-37 (DLGN)	GUIDED MISSILE CRUISERS	10,450	4,000	0.70	238	4e	1
CGN 38-41 (DLGN)	GUIDED MISSILE CRUISERS	11,000	4,000	0.70	207	4e	1
CGN 9	GUIDED MISSILE CRUISER	17,525	7,900	0.70	312	4	2
CV 14-34	AIRCRAFT CARRIERS	42,000	9,000	0.45	300	5	3
CV 41-43	AIRCRAFT CARRIERS	65,000	9,500	0.45	615	5	3
CVN 59-64, 66, 67	AIRCRAFT CARRIERS	81,000	15,000e	0.45	1028	5	3
CVN 68-73,65	AIRCRAFT CARRIERS	91,000	16,600	0.45	895	5	3
CVN 74-77	AIRCRAFT CARRIERS	104,000					
CVN 78-79	AIRCRAFT CARRIERS	105,000	19,500	0.45	895	5	3
CVS 9-39	ASW AIRCRAFT CARRIERS	40,600	9,000	0.45	300	5	3
DD 445 CLASS	DESTROYERS	3,040	1,400	0.70	134	3	1
DD 692 CLASS	DESTROYERS	3,400	1,400	0.70	158	3	1
DD 710 CLASS	DESTROYERS	3,540	1,450	0.70	158	3	1
DD 931-951	DESTROYERS	4,200	2,100	0.70	194	2	1
DD 963-992, 997	DESTROYERS	9,400	4,400	0.70	254	3	1
DDG 1000-1002	DESTROYERS	15,760	6200	0.55	265	2	1
DDG 125-126 (Flight III)	GUIDED MISSILE DESTROYERS	9,700	7,100	0.70	254	4e	1
DDG 2-24	GUIDED MISSILE DESTROYERS	4,500	2,256	0.70	176	2	1
DDG 31-34	GUIDED MISSILE DESTROYERS	4,150	2,100	0.70	194	3	1
DDG 37-46 (EX-DLG 6/9)	GUIDED MISSILE DESTROYERS	6,150	3,000e	0.70	228	3	1
DDG 51-71 (Flight I)	GUIDED MISSILE DESTROYERS	8,300	6,900	0.70	254	4e	1
DDG 72-78 (Flight II)	GUIDED MISSILE DESTROYERS	8,300	6,900	0.70	254	4e	1
DDG 79-124 (Flight IIA)	GUIDED MISSILE DESTROYERS	9,300	6,900	0.70	254	4e	1
DDG 993-996	GUIDED MISSILE DESTROYERS	10,000	5,000e	0.70	254	4e	1
DE 1006 CLASS	DESTROYER ESCORT	1,914	1,342	0.70	79	1	1
ESD / ESB (MLP)	MOBILE LANDING PLATFORM	80,000	8500	0.90	400	5	3
ESD 1-3	EXPEDITIONARY TRANSFER DOCKS	34,500 (104,000 fully submerged)	6000	0.85	315e	5e	3
FF 1040-FF 1051 (DE)	FRIGATES	3,400	1,715	0.70	131	2	1
FF 1052-1097 (DE)	FRIGATES	3,900	2,020	0.70	131	2	1
FFG 1-6 (DEG)	GUIDED MISSILE FRIGATES	3,426	1,715	0.70	131	2	1
FFG 7-61	GUIDED MISSILE FRIGATES	4,100	2,200	0.70	170e	2e	1
LCC	COMMAND SHIP	18,874	5500	0.70	285	5	3
LCC 19-20	AMPHIBIOUS COMMAND SHIPS	18,650	7,360	0.70	220e	5	2
LCS 1 (Freedom Class)	LITTORAL COMBAT SHIPS	3,410	1940	0.60	5	2	1
LCS 2 (Independence Class)	LITTORAL COMBAT SHIPS	3,230	1880	0.60	5	1	1
LHA 1-5	AMPHIBIOUS ASSAULT SHIPS	39,300	11,500	0.70	262	5	3
LHA 6+	AMPHIBIOUS ASSAULT SHIPS	45,000	12600	0.70	295	5	3
LHD 1-8	AMPHIBIOUS ASSAULT SHIPS	41,700	12,000	0.70	262	5	3
LKA 113-117	AMPHIBIOUS CARGO SHIPS	20,700	7,650	0.75	312	5e	2
LPD 1-2	AMPHIBIOUS TRANSPORT DOCKS	14,665	8,300	0.75	175	5e	2
LPD 17-29 (Flight I)	AMPHIBIOUS TRANSPORT DOCKS	25,750	9,770	0.70	323	5	2
LPD 30+ (Flight II)	AMPHIBIOUS TRANSPORT DOCKS	25000+	under construction				

"e" represents best estimate

Table G-2. Characteristics of Naval Vessels (sheet 3 of 4).

		Δ	AT	Cw	AP		
CLASS	DESCRIPTION	FULL LOAD DISPLACEENT (L.TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (Ft)	WIND COEFFICIENT	TOTAL PROJECTED AREA OF ALL PROPELLERS (Ft)	CURVE FOR HULL RESISTANCE SEE FIGURE G-6	CURVE FOR WAVE RESISTANCE SEE FIGURE G-7
LSD 28-35	DOCK LANDING SHIPS	12,000	6,150	0.75	174	5	2
LSD 36-40	DOCK LANDING SHIPS	13,700	7,450e	0.75	348	5	2
LSD 41-52	DOCK LANDING SHIPS	15,730	8,000e	0.75	360e	5e	2
LSD 49	DOCKLANDING SHIPS	16,800	8,100	0.75	360	5	2
LST 1171-1178	TANK LANDING SHIP	7,100	3,400	0.75	82	4	2
LST 1179-1194	TANK LANDING SHIP	8,450	5,200	0.75	108	4	2
LST 47-1088	TANK LANDING SHIP (WWII)	4,000	2,000	0.75	30	4	1
MCM 1-14	MINE COUNTERMEASURE VESSELS	1,040	1,500	0.75	40	2e	1
MHC 51		970					
MSO 427-511	OCEAN MINESWEEPERS	735	1,340	0.75	40	2	1
T-ACS 1-12	AUXILIARY CRANE SHIPS	31,500	5,300e	0.75	300e	5e	3
T-AF 58	STORE SHIP	15,540	5,400	0.75	198	4	2
T-AFS 8-10 (ex RN/RFA)	COMBAT STORES SHIPS	16,792	4,000e	0.75	156e	4e	2
T-AG 194 (ex AGM-19)	MISC.	21,626	5,020	0.70	150e	4	2
T-AGM 10 (ex AP 145)	MISSILE RANGE INST.	17,120	5,000e	1.00	200e	5e	2
T-AGM 20 (ex AO-114)	MISSILE RANGE INST.(T2-SE-A2)	24,710	5,020	0.70	150e	5e	2
T-AGM 23 (ex AG 154)	MISSILE RANGE INST. (C4-S-A1)	17,015	5,550	1.00	200e	5	2
T-AGOR 16	OCEANOGRAPHIC RESRCH SHIPS	3,860	4,500e	0.75	100	4e	1
T-AGOR 7, 12-13	OCEANOGRAPHIC RESRCH SHIPS	1,370	1,100	0.75	35e	4e	1
T-AGOR 8, 11	OCEANOGRAPHIC RESRCH SHIPS	3,886	2,400e	1.00	50e	4e	1
T-AGOS 1-26	OCEAN SURVEILLANCE SHIPS	2,285	2,800e	0.75	55e	4e	1
T-AGS 21-22	SURVEYING SHIPS (VC2-S-AP3)	13,050	2,900e	0.75	120	5e	2
T-AGS 26-27, 33-34	SURVEYING SHIPS	2,800	2,000e	0.75	55e	4e	1
T-AGS 29, 32	SURVEYING SHIPS	4,330	2,500e	0.75	90e	4	1
T-AGS 38	SURVEYING SHIP	21,235	4,050	0.75	200e	4e	2
T-AGS 39-40	SURVEYING SHIPS	15,800	3,500e	0.75	150e	4e	2
T-AGS 62, 64	SURVEYING SHIPS	5,156	2200	0.75	155e	2	1
T-AH 19-20	HOSPITAL SHIPS	44,875	8,400e	1.00	330e	5e	3
T-AK 1010	MPS-CARGO SHIP	22,600e	5,600e	0.75	220e	5e	2
T-AK 2043	MPS-CARGO SHIP (CR-S-66a)	24,300e	5,000e	0.75	210e	5e	2
T-AK 2046	MPS-CARGO SHIP (LASH TYPE)	49,000e	9,000e	1.00	320e	5e	3
T-AK 267	CARGO SHIPS (C4-S-B1)	22,056	4,200	0.75	150e	5e	2
T-AK 271	CARGO SHIPS (C1-ME2-13a)	3,886	1,600	0.75	50e	5	1
T-AK 280-282	CARGO SHIPS (VC2-S-AP3)	11,300	4,100	0.75	119	5	2
T-AK 284-286, 295	CARGO SHIPS (C3-S-33a)	15,404	3,800e	0.75	130e	5e	2
T-AK 3000-3004	MPS-VEHICLE CARGO SHIPS	44,086	9,800	1.00	280e	5e	3
T-AK 3005-3007	MPS-VEHICLE CARGO SHIPS	51,612	10,000	1.00	380e	5e	3
T-AK 3008-3012	MPS-VEHICLE CARGO SHIPS	46,111	9,800	1.00	350e	5e	3
T-AK 3015	CARGO SHIPS	51,531	10,000	1.00	180e	5e	3
T-AK 3016	CARGO SHIPS	50,570	6,500	0.90	322e	5e	3

"e" represents best estimate

Table G-2. Characteristics of Naval Vessels (sheet 4 of 4).

		Δ	AT	Cw	AP		
CLASS	DESCRIPTION	FULL LOAD DISPLACEENT (L.TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (Ft)	WIND COEFFICIENT	TOTAL PROJECTED AREA OF ALL PROPELLERS (Ft)	CURVE FOR HULL RESISTANCE SEE FIGURE G-6	CURVE FOR WAVE RESISTANCE SEE FIGURE G-7
T-AKB 1015, 2049	MPS-CARGO SHIPS (BARGE CARRIER)	53,000e	9,000e	1.00	300e	5e	3
T-AKE	DRY CARGO AND AMMUNITION SHIPS	40350	7000	1.00	395	5	3
T-AKR (new)	VEHICLE CARGO SHIP	24,500	6,200e	0.75	400e	5e	2
T-AKR 287-294	MPS-VEHICLE CARGO SHIPS (SL-7)	55,000e	10,000	1.00	500e	5e	3
T-AKR 295, 297, 3017	LMSR (LARGE, MEDIUM-SPEED, ROLL-ON, ROLL-OFF)	54,450	8,500	0.90	357e	5e	3
T-AKR 296, 298	LMSR (LARGE, MEDIUM-SPEED, ROLL-ON, ROLL-OFF)	59,803	8,500	0.90	357e	5e	3
T-AKR 300-306	LMSR (LARGE, MEDIUM-SPEED, ROLL-ON, ROLL-OFF)	62,069	8,500	0.90	364e	5e	3
T-AKR 310-317	LMSR (LARGE, MEDIUM-SPEED, ROLL-ON, ROLL-OFF)	62,644	8,500	0.90	387e	5e	3
T-AKR 7	VEHICLE CARGO SHIP (C3-ST-14A)	18,286	4,000e	0.75	180e	5	2
T-AKR 9	VEHICLE CARGO SHIP (C4-ST-67A)	21,700	4,100e	0.75	200e	5	2
T-AO 105-109	OILERS	35,000	5,480	1.00	346	5e	3
T-AO 143-148	OILERS	36,000	5,000e	1.00	400e	5e	3
T-AO 187-204	OILERS	40,000	6,750e	1.00	420e	5e	3
T-AO 57, 62	OILERS	25,500	5,480	1.00	346	5e	3
T-AOG 78	GASOLINE TANKERS (T1-M-BT2)	6,047	2,500e	1.00	70e	4e	1
T-AOG 81-82	GASOLINE TANKERS (T1-MET-24a)	7,000	2,500e	1.00	67	4e	1
T-AOT	TRANSPORT OILERS (T5 type)	39,000	5,000e	0.75	180e	5e	3
T-AOT 1203-1205	MPS-TRANSPORT OILERS	44,000e	4,500e	1.00	270e	5e	3
T-AOT 134	TRANSPORT OILERS (T2-SE-A2)	22,380	3,600e	1.00	135e	5e	2
T-AOT 149-152	TRANSPORT OILERS (T5-S-12A)	32,953	4,000e	1.00	200e	5e	3
T-AOT 165	TRANSPORT OILERS (T5-S-RM2A)	31,300	4,600e	1.00	210e	5e	3
T-AOT 168-176	TRANSPORT OILERS	34,100	4,600e	0.75	200e	5e	3
T-AOT 181	TRANSPORT OILERS	35,000	4,700e	0.75	270e	5e	3
T-AOT 50-76	TRANSPORT OILERS (T2-SE-A1)	21,880	3,600e	1.00	120e	5e	2
T-ARC 2, 6	CABLE REPAIR SHIP (S3-S2-BP1)	8,500	2,250e	0.75	72e	5	1
T-ARC 7	CABLE REPAIRING SHIP	14,157	4,700e	1.00	300e	5e	2
T-ATF 166-172	FLEET OCEAN TUGS	2,260	1,700e	0.75	120e	4e	1
T-AVB 3-4	MPS-AVIATION MAINTENANCE SUP.	23,800	6,000e	1.00	370e	5e	2
T-EPF (JHSV)	EXPEDITIONARY FAST TRANSPORT	2,460	450	1.00	5	2	1
WAGB 10-11	(CG) ICEBREAKERS	12,087	4,500	0.75	280e	4e	3
WAGB 281-282	(CG) ICEBREAKERS	6,515	3,150	0.75	182	5e	2
WAGB 4	(CG) ICEBREAKERS	8,449	3,400	0.75	300e	5e	2
WHEC 35, 37	(CG) HIGH ENDURANCE CUTTERS	2,656	1,600	0.70	50e	1e	1
WHEC 379	(CG) HIGH ENDURANCE CUTTERS	2,800	1,600	0.70	47e	1e	1
WHEC 715-726	(CG) HIGH ENDURANCE CUTTERS	3,050	2,000	0.70	154e	2e	1
WMEC 165-166	(CG) MED. ENDUR. CUTTERS (ATF)	1,731	1,200	0.75	43	2e	1
WMEC 6, 167, 168	(CG) MED. ENDUR. CUTTERS (ARS)	1,745	1,500	0.75	56	5e	1
WMEC 615-623	(CG) MEDIUM ENDUR. CUTTERS	1,000	1,400	0.70	40e	2e	1
WMEC 76, 85, 153	(CG) MED. ENDUR. CUTTERS (ATF)	1,731	1,500	0.75	56	2e	1
WMEC 901-913	(CG) MEDIUM ENDUR. CUTTERS	1,780	1,300	0.70	55e	1e	1
YTB 752-836	LARGE HARBOR TUGS	350	560	0.75	22e	2e	1

"e" represents best estimate

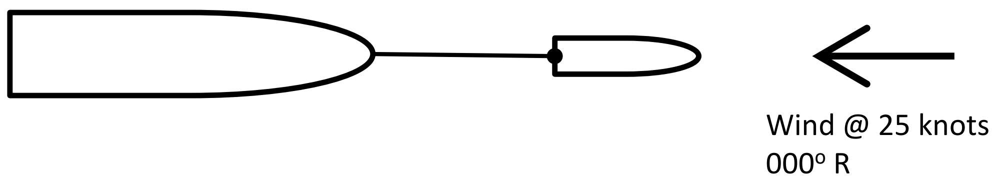
Table G-3. Beaufort Scale.

Beau-fort No.	Knots	Description	Avg. Ht. (ft)	Significant 1/3 Highest (ft)	Avg. Wave Length (ft)	Minimum Duration (Hours)	Avg. Wave Height (ft)*
0	< 1	Calm	---	---	---	---	---
1	1-3	Light air	< 1	< 1	10 in	18 min	---
2	4-6	Light breeze	< 1	< 1	6.7 (ft)	39 min	---
3	7-10	Gentle breeze	< 1	< 1	20-27	1.7-2.4 (hr)	2 (3)
4	11-16	Moderate breeze	1.8-2.9	2.9-4.6	52-71	4.8-6.6	3½ (5)
5	17-21	Fresh breeze	3.8-5.0	6.1-8.0	90-111	8.3-10.0	6 (8½)
6	22-27	Strong breeze	6.4-9.6	10-15	134-188	12-17	9½ (13)
7	28-33	Moderate gale (high wind)	11-16	18-26	212-285	20-27	13½ (19)
8	34-40	Fresh gale	19-28	30-45	322-444	30-42	18 (25)
9	41-47	Strong gale	31-40	50-64	492-590	47-57	23 (32)
10	48-55	Storm	44-59	71-95	650-810	63-81	29 (41)
11	56-63	Violent storm	64-73	103-116	910-985	88-101	37 (52)
12	> 63	Hurricane	> 80	> 128	---	---	45 (-)

1 Figures shown are associated with the low and high wind speed within each force range.

2 Except for the far right-hand column, figures are for fully developed seas. Note that the more strenu ous seas require a progressively longer duration to develop. The fully developed seas associated with 50-kt or stronger winds rarely occur. Average heights listed in the right-hand column are more representative of waves actually encountered under the stated wind conditions.

3 For tow planning purposes, use “average height” column in computing added resistance due to waves. These are the more usual wave heights encountered, due to the long duration required to achieve the "fully developed sea" for the stated wind conditions. Figures in parentheses represent the occasional highest wave in the average spectrum. These occasional highest waves have little longterm impact on the towing resistance.



DD 963 @ 7500 LT displacement

What is the maximum speed each Navy tug can achieve?

Solution: Compute hawser tension at 10, 8, 6, 4 knots and plot in Figure 3-3

Tow Speed	Tow Resistance	Hawser Resistance	Total Pull Required
10 kts	173,449 lbs.	Negligible	173,449 lbs.
8 kts	122,159 lbs.	1,500 lbs.	124,059 lbs.
6 kts	82,336 lbs.	1,850 lbs.	84,186 lbs.
4 kts	53,044 lbs.	1,100 lbs.	54,144 lbs.

The attached Figure G-4 work-up shows hawser tensions for the 6 and 8 knot cases

Figure G-5 is a replica of Figure 3-3, with this resistance curve plotted on it. This provides the following likely maximum tow speeds for each of the tug types listed, with total hawser average tension.

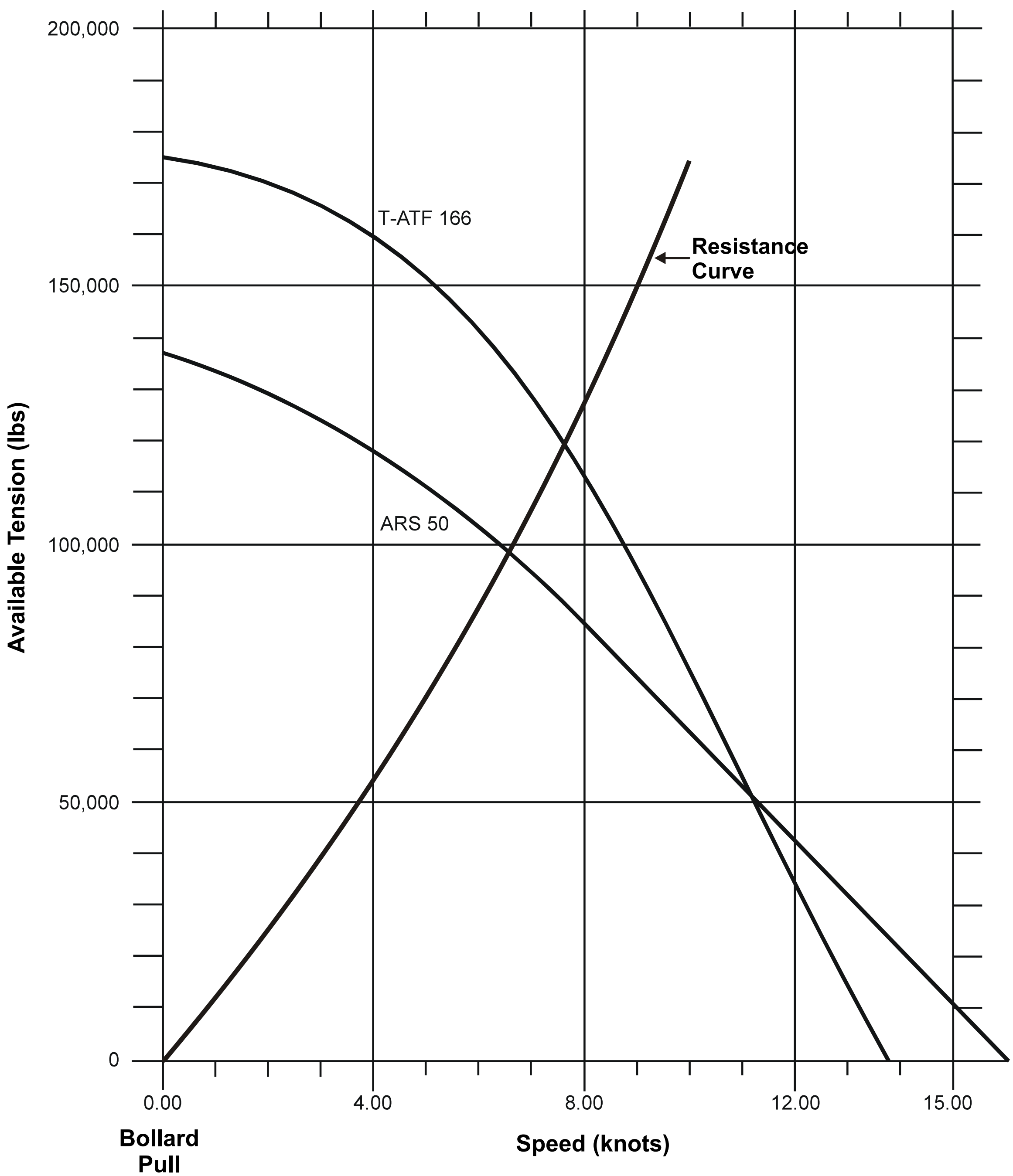
	Max. Tow Speeds	Average Tension
T-ATF 166	7.6	117,000
ARS 50	6.9	98,000

Appendix Figure G-3. Example 2 - Scenario

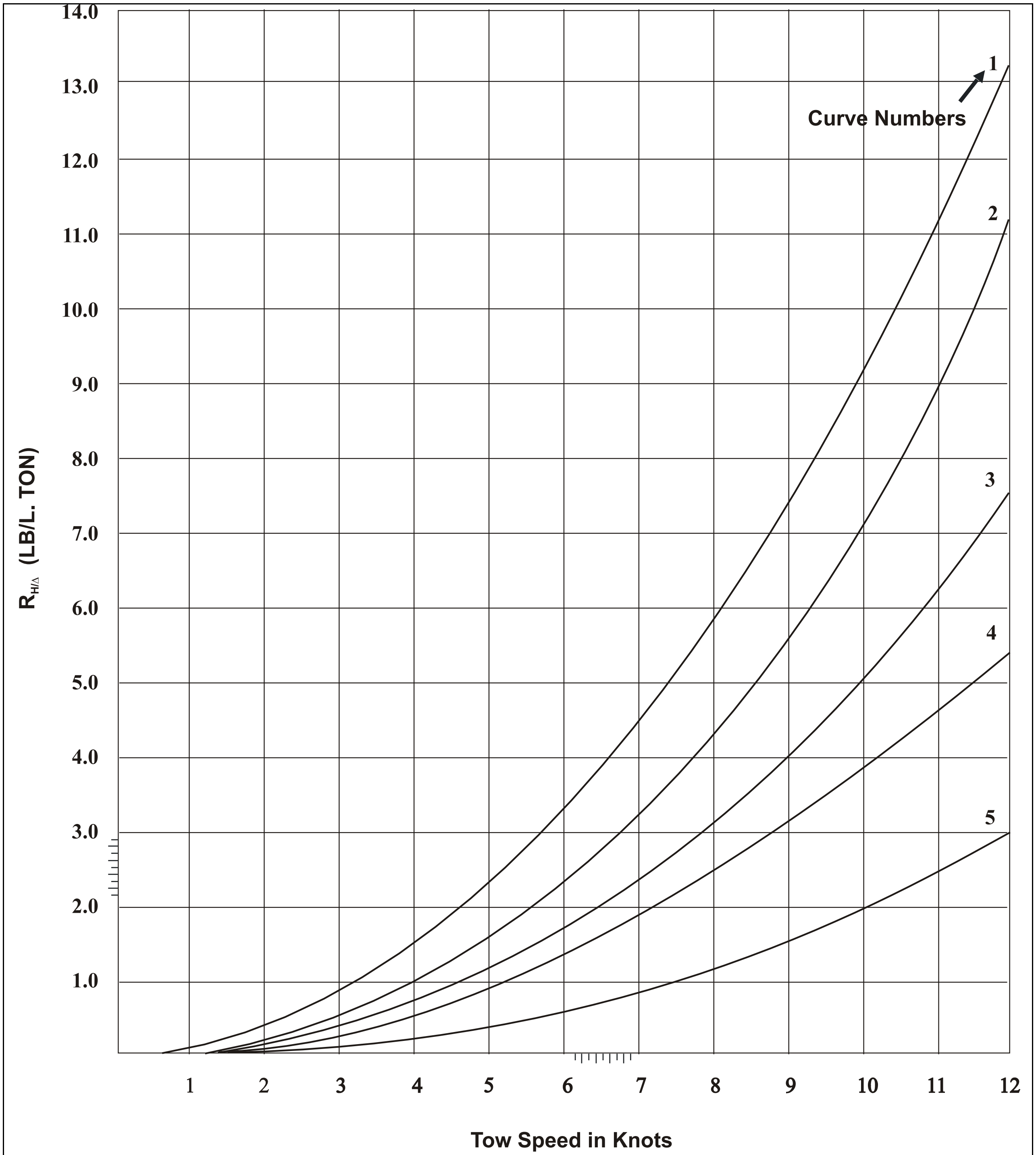
SHIP: ______________ CALCS BY: LT MARK FIVE

Item	Description	Symbol	Units	Source			
1	Ship Class (AE, CV, etc.)				DD 963	DD 963	
2	Tow Speed	V_{TOW}	Knots		8	6	
3	Tow Course	γ	Degrees				
4	Tow Displacement	Δ	Long tons		7500	7500	
5	Frontal Windage Area	Δ_{FULL}	Sq. feet	Table G-2	4400	4400	
6	Wind Drag Coefficient	A_T		Table G-2	0.7	0.7	
7	Total Projected Area of Propellers	C_W	Sq. feet	Table G-2	254	254	
8	Curve Number for Hull Resistance	A_P		Table G-2	3	3	
9	Curve Number for Sea State Resistance			Table G-2	1	1	
10	True Wind Speed	V_{wind}			25	25	
11	Beaufort Number		Knots	Table G-3	6	6	
12	Relative Wind Speed	V_R	Knots		33	31	
13	Heading Coefficient	K		Table G-1	1.0	1.0	
14	Wind Resistance	R_W	Pounds	$R_W = 0.00406(A_T)(C_W)(V_R)^2(K)$	16972	14977	
15	Resistance Factor	$R_{H/\Delta}$		Figure G-6	3.3	2.1	
16	Hull Resistance	R_H	Pounds	$R_H = 1.25(R_H/\Delta)(\Delta)$	30938	19688	
17	Sea State Resistance	R_S	Pounds	Figure G-7	13500	13500	
18	Propeller Resistance	R_P	Pounds	$R_P = 3.737(A_P)(V_{TOW})^2$	60749	34171	
19	Total Steady State Tow Resistance	R_T	Pounds	$R_T = R_W + R_H + R_S + R_P$	122159	82336	
20	Tow Hawser Resistance	R_{WIRE}	Pounds	Table 3-1 or 10% of R_T	1900	1850	
21	Total Tow Hawser Tension	R	Pounds	$R = R_T + R_{WIRE}$	124059	84186	

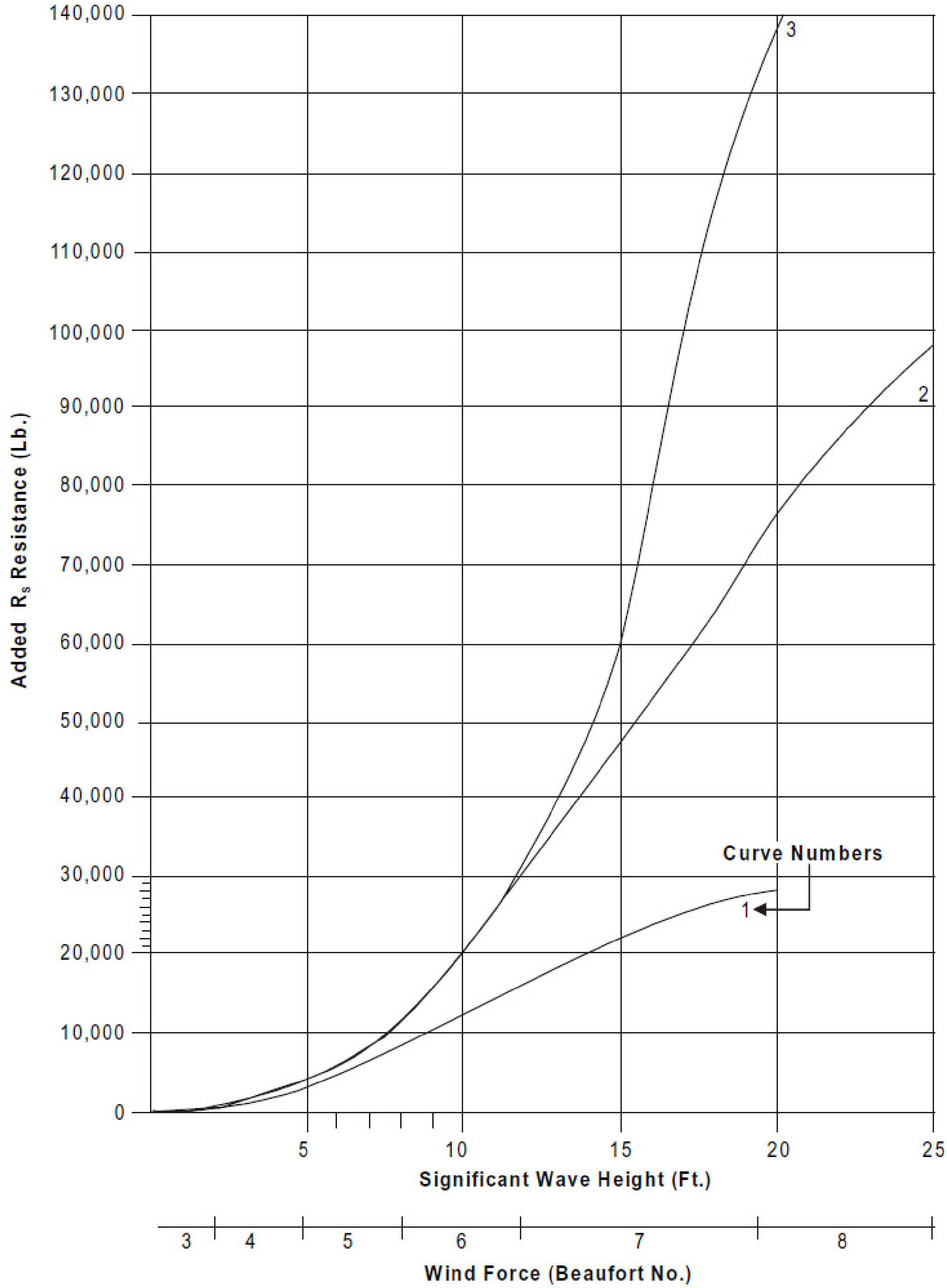
Appendix Figure G-4. Example 2 Worksheet.



Appendix Figure G-5. Available Tension vs. Ship's Speed for U.S. Navy Towing and Resistance Curve



Appendix Figure G-6. Hull Resistance Curve, RH/Δ vs. Tow Speed.



Appendix Figure G-7. Wave Resistance Curve R_S vs. Wave Height and Wind Force.

G-1.3 Wind Resistance

The prediction of wind resistance is also simplified in the manual. The sea conditions associated with the most significant winds generally dictate towing into or close to the wind. The ability to precisely predict the reduction of tow resistance from a Force 10 wind off the quarter is not too important. Furthermore, in those cases where there is insufficient pitch or duration of the strong winds to raise fully-developed waves, the tug will base operational decisions on actual observations of the towline, not on the predicted assistance from strong stern winds.

Note 2: At higher wind strengths, Force 5 to 7, (the latter with winds of 28 to 33 knots), the tow will be forced to head into the wind because of the sea conditions. Therefore, the most severe weather expected should be checked for head wind and seas to confirm tug and especially tow hawser selection.

G-1.4 Propeller Resistance

Ships of comparable size (displacement) and speed have comparable propeller size. For ships not listed in Table G2, select a comparable listed ship for propeller projected area. In the case above, there is no comparable ship listed in Table G2. The T-AGM 20 is assumed to have a similar hull shape as the tanker, since it has a similar speed/length ratio. The propeller projected area for the TAGM 20 is 150 square feet. The displacement of the ship in question is 4.4 times as large as the TAGM 20, so it will require roughly 4.4 times the power for the same speed. Therefore, estimate the propeller projected area as 4.4 x 150 square feet, which equals 660 square feet.

G-2 Floating Dry Docks

The following method for determining the total tow resistance of non self-propelled floating dry docks is based on the now out-of-circulation Towing Non Self-Propelled Floating Structures (Technical Publication NAVDOCKS TPDM26, 1 October 1953). This procedure, which has been successfully used for many years, is recommended for estimating tow resistance for these types of craft. Table contains the various constants used in the following formulas.

G-2.1 Frictional Resistance

The data used for determining frictional resistance are based upon a series of experiments on model and actual conditions. The resistance caused by the friction of water on the vessel's wetted surface depends upon:

- Area of surface below the waterline
- Nature of surface
- Speed of tow.

Thus the formula for frictional resistance of a vessel passing through water is:

$$R = f_1 \times S \times (V/6)^2$$

where:

R	=	Resistance in pounds
f_1	=	A coefficient depending on the shape of the ship's hull (from Table G-4)

S = Area of the vessel's wetted surface below the waterline, in square feet (from Table G-4)

V = Speed of tow in knots relative to still water.

Table G-4. Drydock Towing Coefficients.

Ship Class			H	S	F_2	B	F3	C
AFDB-1	Section	256 x 80	.45 to .8	23,000	.3	720	.7	3,800
AFDB-4	Section	240 x 101	.45 to .8	26,000	.3	900	.7	4,500
AFDM-1	3-Piece	496 x 116	.45 to .8	50,000	.6	750	.67	7,000
AFDM-3	3-Piece	488 x 124	.45 to .8	52,000	.6	800	.67	7,800
ARD-1	1-Piece	390 x 60	.45 to .8	20,000	.2	250	.61	2,000
ARD-2	1-Piece	486 x 71	.45 to .8	34,000	.2	370	.61	3,700
ARD-12	1-Piece	492 x 81	.45 to .8	40,000	.2	480	.61	4,400
AFDL-1	1-Piece	200 x 64	.45 to .8	13,000	.4	220	.7	1,400
AFDL-7	1-Piece	288 x 64	.45 to .8	19,000	.4	210	.7	1,500
AFDL-35	1-Piece	389 x 84	.45 to .8	38,000	.3	780	.67	1,900
AFDL-47	1-Piece	488 x 97	.45 to .8	46,000	.5	420	.7	2,500
AFDL-48	1-Piece	400 x 96	.45 to .8	48,000	.4	1,350	.7	2,540
YFD-7	3-Piece	488 x 124	.45 to .8	52,000	.6	800	.67	7,800
YFD-68 to 71	3-Piece	474 x 118	.45 to .8	48,000	.6	750	.67	7,300

G-2.2 Wave-Forming Resistance

Data for wave-forming resistance are based on model tests and depend on:

- Area below water line (maximum cross section)
- Form of bow and stern
- Speed of tow.

Thus the formula for wave-forming resistance of a body passing through water is:

$$G = 2.85 \times B \times f_2 \times V^2 \times K$$

where:

G = Resistance in pounds

B = Cross-sectional area of vessel below waterline in square feet (from Table G-4)

f_2 = A coefficient depending upon the configuration of the vessel's bow and stern (from Table G-4)

V = Speed of tow in knots relative to still water

K = 1.2 (multiplying by this number adds 20 percent for additional resistance from rough water and eddies)

G-2.3 Wind Resistance

Data used for determining wind resistance are based on a series of experiments on models. The resistance caused by wind blowing against a vessel depends upon:

- Cross-sectional area of vessel above waterline subjected to wind
- Speed of wind
- Speed of tow
- Shape of vessel subjected to wind.

Thus the formula for frictional resistance caused by wind is:

$$\mathbf{W = C \times .004\ (V_W + V)^2 \times f_3}$$

where:

W	=	Resistance in pounds
C	=	Cross-sectional area of vessel above waterline in square feet (from Table G-4)
V_W	=	Speed of wind in knots
V	=	Speed of tow in knots, relative to still water
f_3	=	A coefficient depending on the shape of vessel subjected to wind (from Table G-4).

G-2.4 Total Tow Resistance for Dry Docks

The total tow resistance for docks (R_{TOT}) is the sum of the frictional resistance, wave-forming resistance, and wind resistance. This total tow resistance is then used in selecting the tow ship and designing the tow connection as described in Chapter 3. This does not include towline resistance when figuring total towline tension.

$$\mathbf{R_{TOT} = R + G + W}$$

G-2.5 Example

The following example is given to show the use of the four resistance formulas already outlined.

The problem is to determine the extreme requirements for towing AFDL 1 Class floating dry dock under all weather conditions. To illustrate this design, the following known factors have been selected:

- Hurricane wind speed: 64 knots
- Towing speed during hurricane: 6 knots
- Bottom condition of dry dock — moderately rough and in need of cleaning: use f1 coefficient of 0.65

Substitute into resistance formulas, using above factors and coefficients from Table G-4.

$$R = f_1 \times S\ (V/6)^2$$

$$= 0.65 \times 13{,}000 \times (6/6)^2$$

$$= 8{,}450 \text{ lbs.}$$

$$G = 2.85 \times B \times f_2 \times V_2 \times K$$

$= 2.85 \times 220 \times 0.4 \times 62 \times 1.2$

$= 10{,}835$ lbs.

$W = C \times 0.004 \times (V_W + V)^2 \times f_3$

$= 1{,}400 \times 0.004 \times (64 + 6)^2 \times 0.7$

$= 19{,}208$ lbs.

Total resistance

$R_{TOT} = R + G + W$

$= 8{,}450 + 10{,}835 + 19{,}208$

$= 38{,}493$ lbs.

G-3 Barges

The previous section on towing resistance of dry docks can be adapted for computing the total resistance of barges.

G-3.1 Frictional Resistance

The method is identical to the one used in Section G-2.1. The wetted surface (S), is simply the barge's length times beam (for bottom) plus perimeter times draft (for sides, bow, and stern).

G-3.2 Wave-Forming Resistance

The cross section area (B) equals beam times draft. For the typical rake-ended barge, use $f_2 = 0.2$. This also is applicable to the comparatively blunt ship-shaped bow of some barges such as YFBNs and APLs. For square-ended barges, use $f_2 = 0.5$.

G-3.3 Wind Resistance

Use the formula contained in Section G-2.3. The cross sectional area (C), is the freeboard times beam plus height times width of the deck house or any deck cargo. Use $f_3 = 0.60$ as an average barge figure in the formula.

G-3.4 Total Barge Resistance

To calculate total tow resistance (R_{TOT}), add the frictional resistance, wave-forming resistance, and wind resistance from the previous three sections.

$R_{TOT} = R + G + W$

G-3.5 Example

Assume a berthing barge (YRBM) is to be towed. Dimensions are:

Length:	265 feet
Width:	65 feet
Draft:	7 feet
Hull Depth:	12 feet

Deck House: 220 ft. x 55 ft. x 25 ft.

Desired tow speed is 10 knots, maximum head wind is 20 knots. Bottom conditions are average. The hull has rake-shaped ends.

G-3.5.1 **Frictional Resistance**

Estimate average length below the waterline as 250 feet, with the bottom being 245 feet.

S = Wetted surface

= 7 x 2 (250 + 65) + (245 x 65)

= 20,335 square feet

Therefore:

R = $.65 \times 20{,}335 \times (10/6)^2$

= 36,716 lbs.

G-3.5.2 **Wave Forming Resistance**

B = Cross sectional area

= 65 x 7

= 455

Therefore:

G = 2.85 x 455 x 0.2 x 102 x 1.2

= 31,122 lbs.

G-3.5.3 **Wind Resistance**

C = Frontal area

= 65 x (12 - 7) + (25 x 55)

= 1,700 square feet

Therefore:

W = 1,700 x .004 (20 + 10)2 x .6

= 3,672 lbs.

G-3.5.4 **Total Resistance**

RTOT = R + G + W

= 36,716 + 31,122 + 3,672

= 71,510 lbs.

Inspecting Figure 31 shows that this tow is within the capability of the TATF and ATS 1 Classes, at the assumed towing speed of 10 knots. Clearly, other towing ships would be adequate for this tow at lower speeds.

Appendix H - CHECKLIST FOR PREPARING AND RIGGING A TOW

H-1 Checklist

The following checklist is designed to help the preparing activity ready a tow for sea. It lists pre-tow preparations and general requirements which must be completed before the towing unit will accept the tow for sea. If the preparing activity has questions concerning this checklist or preparations required to ready the tow, it should communicate these concerns to the towing unit or it's Immediate Superior in Command (ISIC). The preparing activity is responsible for completing this checklist. Items that are not applicable or cannot be accomplished must be cleared through the towing unit or it's ISIC. All not applicable or not accomplished items shall be documented. Rationale for accepting the tow with not accomplished items shall be documented as a part of the completed Towing Inspection Checklist.

The command conducting the tow should conduct a preliminary pre-tow inspection as soon as possible to preclude misunderstandings and rework. In special situations, the standards reflected in this checklist can be relaxed and an "acceptable risk" tow accepted. The Commanding Officer of the towing ship and the ISIC must agree to all acceptable risk tows, as such tows do not relieve them of responsibility or safe practice. Acceptable risk tows are not routine.

The Commanding Officer of the towing ship conducts a final inspection of the tow, accompanied by a representative of the preparing command. Upon satisfactory completion of this inspection, the preparing activity sets condition ZEBRA on the tow and the towing ship's Commanding Officer accepts and signs for the tow.

Note: For more information on preparing a tow for sea, refer to Chapters 3 and 4.

TOWING INSPECTION CHECKLIST	
Vessel Name:	Hull Number:
Owner:	P.O.C. and 24 Hour #:
Departure Port:	Arrival Port:
Receiving Activity Port:	P.O.C. and 24 Hour #:

Vessel Characteristics

Length:	Beam:	Displacement:
Draft fwd:	Draft aft:	Mean draft:
Freeboard fwd:	Freeboard aft:	Freeboard mid:
MTI:	TPI:	KG:
GM:	Maximum Ht above WL:	
Maximum Navigational Draft (include sonar domes, propellers, etc.):		

	YES	NO
Is craft designed and authorized to be ocean-towed in accordance with requirements set forth in this manual?		

Provide rationale for accepting the tow with items not accomplished.

Use separate sheet if additional space is needed.

The tow described above is seaworthy in all respects. The material condition is noted. Copies of the master inventory and storage keys are receipted for.	
Representative of command having prepared the tow for sea	Date

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1. SHIP INFORMATION		Reference	N/A	Yes	No
a.	Is the booklet of general plans available?				
	Location of booklet:				
b.	Is damage control book, curves of forms, or other stability data available?				
	If yes, provide location:				
c.	Are liquid load diagrams and damage control flooding plates available on board?				
	If the answer is Satisfactory, provide location:				
d.	Are instructions posted in after steering for lining up hydraulic steering systems to hand pump?				
e.	Are plans and date of the last dry-docking available?				
	Date of last dry-docking:				
	Location of plans:				
f.	Were hull thickness recordings taken during last dry-docking?				
g.	Is record of sonic drill test satisfactory?				
	If not, has a satisfactory report of ultrasonic testing been provided?				
h.	Has a list of equipage been provided to the towing activity? ***Note:*** *The preparing activity is responsible for providing a list of equipage assigned to the craft that is pilferable and must be on board at destination. Preparing and towing representatives' signatures are required. Provide list on separate sheet.*				
i.	List remaining HAZMAT on board:				
j.	If craft is a floating dry-dock, has a representative of NAVSEA inspected it?				
	If satisfactory, provide name of inspector and date of inspection:				
k.	Do you hold a signed copy of the inspection?				

2. RIDING CREW		Reference	N/A	Yes	No
a.	Will a riding crew be employed? If so, attach a copy of the directive (message, letter, etc.) and proceed with the following checks. ***Note**: Riding crews are not ordinary practice for open ocean tows.*	*5-3*			
b.	Authority that authorized a riding crew.				
c.	Is a copy of the authorizing message attached?				
	Number of crew members:				
d.	Has a list of the riding crews been provided to the towing activity? Note: A list of the riding crew is entered in towing ship's diary (name, rate, SSN, and NOK; address and phone number of rider and NOK for civilians).				
e.	Are enough life rafts on board with emergency rations and water for the riding crew in the event that they have to abandon ship? Location of life rafts:				
f.	Date life rafts were last tested/inspected:	*5-8.1.6*			
g.	Are a sufficient quantity of life jackets and life rings on board? Number, type, and location				
h.	Means of communication with the towing ship: Note: Both visual and radio are recommended.				
i.	Has the riding crew been trained in damage control and support systems? Note: The preparing activity is normally responsible for such training.	*5-7*			
j.	Is habitability and sustenance sufficient from on-board assets?	*5-4.3*			

3. SEAWORTHINESS		Reference	N/A	Yes	No
a.	Does craft have a fixed rudder or a skeg?				
b.	Is craft ballasted? Type and location of ballast:	*5-6.3*			
c.	If not, will craft require additional ballast?				
d.	Types of ballast required:	*5-6.4*			
e.	Describe where ballast will be placed and how much:				
f.	Draft after craft is in proper trim:	*5-6.3*			
	Forward:				
	Aft:				
	Max. Navigational draft:				
g.	GM after craft is in proper trim:				
h.	KG after craft is in proper trim:				

		Reference	N/A	Yes	No
i.	If GM is not known, "sally ship" to establish period of roll: Normally T = $2\sqrt{\text{Beam(ft)}}$ T (observed): ***Note:*** *This method to assess the adequacy of ship's stability is fully explained in Section 5-6.4.*	*5-6.4*			
j.	Are all sea valves closed and wired shut?	*5-6.5*			
k.	Is there a two-valve protection from the sea for all sea openings? ***Note:*** *Two-valve protection consists of either two valves wired shut or one valve and a blank flange. A list of all valves should be attached.*	*5-6.5*			
l.	Is a list of sea valves attached?				
n.	Are all sounding tubes capped?				
o.	Is there a list of all sounding tubes attached? (Required)				
p.	Are all between-tank sluice valves closed?				
q.	Are all normally dry compartments dry?				
r.	Are all bilges free of oil and water?				
s.	Are there any broken, cracked or weak frames, longitudinals, plates, welds, or rivets?	*5-6.6*			
t.	Have repairs been made?				
u.	Has the hull structure been inspected to the best of your ability?				
v.	Type(s) of hull inspection conducted, including location: (e.g., ultrasonic interior, exterior, voids) ***Note:*** *All compartments should be entered and inspected.*				
w.	Have all compartments been inspected?				
x.	Has steel wire or cable been used to secure all equipment to prevent any movement in heavy weather? ***Note:*** *All moveable equipment must be secured in place with wire or by welding. No fiber rope or line will be accepted.*	*5-9.1*			
y.	Are all rudders locked? ***Note:*** *The rudders should be locked by using structural steel of acceptable size and quantity. The lock should transfer the rudder load from the yoke to structural members of the tow's hull. Refer to Chapter 4 for typical configurations and sizing.*	*5-6.7*			
z.	Type of locking device used:				
aa.	Are all shafts locked?	*5-6.2.2*			
bb.	Are propellers removed?	*5-6.2.1*			
cc.	Are shafts equipped with extra rings of packing in the gland to allow emergency repair during transit?	*5-6.2.2*			
dd.	Is the gland tightened to its tightest position but not two-blocked?	*5-6.2.2*			

		Reference	N/A	Yes	No
ee.	Ensure that there is no leak off at the stern tube. Can the stern tube-packing gland be tightened at least two more inches before it is two-blocked? ***Note:*** *Leaving two more inches will allow additional sealing room should there be leakage. If this room is not available, it is a good indication that the packing has deteriorated to an unacceptable point.*	*5-6.2.2*			
ff.	Are locking nuts tight on packing glands to prevent their backing off?	*5-7.1.11*			
gg.	Are all portholes sealed and covered with metal to prevent breakage?				
hh.	Are all vents that are subject to ***heavy weather flooding*** (e.g., air, fresh water, fuel tank) sealed? ***Note:*** *Wood covers are not considered adequate. The recommended procedure is to remove and blank flange or weld close.)*	*5-9.1*			
ii.	Do vents allow for the escape of air or gas? ***Note:*** *Vents to tanks and other closed spaces should be covered to prevent water entry, but not plugged so as to prevent the escape of air or gas. Plugging a vent allows pressure to build up within the tank if the temperature rises. Barge sides and decks have been known to bulge severely. If necessary, cover compartment vents with canvas socks that prevent water from entering yet allow air to escape.*	*6-6.3* *5-9.1*			
jj.	Are all hatches, scuttles, doors, and other watertight closures provided with pliable gaskets?	*5-9.1*			
kk.	Have weather decks and main transverse bulkhead watertight closures been chalk tested?				
ll.	Are all dogs on watertight closures operable and functioning as designed?				
mm.	Is forward one-fifth of craft designed to withstand constant pounding during transit? If the answer is Unsatisfactory, bow should be shored properly.	*5-7.5*			
nn.	If the craft to be towed is a barge, and inspection reveals signs of serious deterioration, or the barge is suspected of being weakened, it may require shoring, particularly in the forward one-fifth of its length. Is shoring required? ***Note:*** *Steel "K" shoring should be installed on all longitudinals in forward and after compartments.*	*5-6.6*			
oo.	Has shoring been accomplished?				
pp.	For LST-type tows, all of the following must be answered Satisfactory, or the vessel ***will not be accepted for ocean tow,*** even as a calculated risk:	*7-7*			
	i. Do the bow doors have hydraulic rams connected?				
	ii. Are mud flaps at the bottom of the doors secured?				
	iii. Are all dogs, heavy weather shackles, ratchet-type turnbuckles and strongbacks in place, tight and secure so that they cannot work free?				
	iv. Are bow ramp operating instructions posted in the hydraulic control room?				
qq.	If craft is equipped with a bow or stern ramp, is it secured in accordance with notes listed below? ***Note:*** *YFU/LCUs are inherently unseaworthy due to wide beams and flat bottoms. A lift of opportunity should be used whenever possible. If it is absolutely necessary to tow these craft, the following must be strictly adhered to:*	*7-7*			

		Reference	N/A	Yes	No
	i. The bow ramp will be secured with a minimum of four angle straps on each side, welded on the outside of the ramp. The size of these straps should be at a minimum of 4” by 3/8” and overlap the bow ramp and sides of the craft at a minimum of 10”.				
	ii. All normal securing devices (i.e., ramp chains, dogs, and turnbuckles) are in place and in good mechanical order.				
	iii. All hatches, scuttles, and doors have good gaskets and all securing devices are in proper operating condition.				
rr.	Are 1-foot by 3-foot draft marks painted on the sides of the hull forward, aft, and midships at the water’s edge to allow visual inspection for proper trim during transit?	*5-6.1.6*			
ss.	Are all lifelines in place and in good condition?				
tt.	Are ladders available for boarding on both port and starboard sides?	*Figure 5-7*			
uu.	Do rungs go all the way to the WL?				
vv.	For unmanned ships with freeboard over 10 feet, are rungs welded to the sides?				
ww.	Is condition ZEBRA set throughout the tow? If the answer is Unsatisfactory, list exceptions on separate sheet.				
xx.	Is damage control inspection routes marked by paint/diagrams and/or reflective tape?	*5-7.4*			
yy.	Is interior access sufficiently marked for DC teams?				
zz.	Shoring may be required to prevent damage to deck fittings, wirings, scuttles, doors, etc. Has this been accomplished?				
4.	**FLOODING**	Reference	N/A	Yes	No
a.	Are amber (upper) and white (lower) alarms lights installed?	*5-6.1.2*			
b.	Are flooding alarm lights visible for 360º and centered forward on the tow? ***Note:*** *Are additional spares available for long tow?*	*5-6.1.3*			
c.	Are both the low and high water flooding alarm lights rigged with two bulbs each?	*5-6.1*			
d.	Are flooding alarm lights rigged with a separate battery source? ***Note:*** *Flooding alarm lights must not be connected to navigational lights.*	*5-6.1.2*			
e.	Are batteries sufficient to provide continuous operation for the duration of the tow?	*5-6.1.2*			
f.	Total amperage capacity: Sufficient amperage must be calculated and available to cover the following: 1.) Wattage of the bulbs serviced 2.) Distance of bulbs from battery source (wiring losses) 3.) Duration of tow				
g.	Are flooding alarm lights rigged with flasher-type units?	*5-6.1.3*			
h.	Is all wiring connected to sensor indicator lights run below decks insofar as possible?	*5-6.1.1*			
i.	Is all wiring secured and protected from any chafing?	*5-6.1.2*			

		Reference	N/A	Yes	No
j.	Is all topside wiring protected from weather damage?	*5-6.1.2*			
k.	Are flooding alarms rigged in all major compartments closest to the keel?	*5-6.1.1*			
l.	Do all below-waterline areas have alarms? ***Note:*** *If the answer is "unsatisfactory," attach a list of below-waterline areas that do not have alarms. Tanks and voids that can be flooded without sounding an alarm should be identified and the decision not to install alarms justified.*	*5-6.1.1*			
m.	Is this list attached?				
n.	In large craft or in barges where compartments run athwart ships, are flooding alarms rigged on both port and starboard sides?	*5-7.1.1*			
o.	Are flooding alarm sensors well secured to fixed objects such as stanchions, drainage pipes, or ladders?	*5-7.1.1*			
p.	Is the lower indicator light wire rigged to the 1-foot flooding alarm sensors?	*5-7.1.1*			
q.	Is the upper indicator light wire rigged to the 3-foot flooding alarm sensors?	*5-7.1.1*			
r.	Are the batteries secured for heavy weather? ***Note:*** *If topside, batteries must be in a watertight box. The location should be carefully selected and secured from heavy seas. If possible, batteries should be inside the ship.*				
s.	Is battery ventilation adequate?				
5.	DEWATERING	Reference	N/A	Yes	No
a.	Is dewatering equipment required?	*5-7.3.1*			
b.	Are all main spaces accessible for adequate dewatering capability?	*5-7.3.3*			
c.	Is a list of spaces that are unreachable by dewatering equipment attached?				
d.	Location of pumps/generators/eductors:				
e.	Has equipment been tested?				
f.	Amount/location/size of hose:				
g.	Is adequate fuel available for pumps/generators?	*5-7.3.2*			
6.	FIRE FIGHTING	Reference	N/A	Yes	No
a.	Is fire fighting equipment required?	*5-7.2*			
b.	Have pumps been demonstrated to have sufficient suction lift and discharge head?	*5-7.2*			
c.	Are at least two P-100s or operating fire pumps and all other necessary fire fighting equipment on board?				
d.	Is there enough P-100 fuel on board?	*5-7.2*			
e.	Is means for storage of fuel adequate?				

7.	NAVIGATION	Reference	N/A	Yes	No
a.	Are proper navigation lights installed for towed unit?	*5-6.1*			
b.	Is each light rigged with two bulbs, so that if one burns out the craft still complies with COLREGS?	*5-6.1*			
c.	Is all wiring well secured and protected from damage by the elements?				
d.	Is the tow equipped with a solar switch or time switch?	*5-6.1*			
e.	Are the batteries secured for heavy weather? ***Note:*** *If topside, batteries must be in a watertight box. The location should be carefully selected and secured from heavy seas. If possible, batteries should be inside the ship.*				
f.	Is battery ventilation adequate?				
g.	Are the batteries charged with sufficient amperage available to keep the lights burning brightly for the duration of the trip?	5-6.1			
h.	Total ampere capacity of the bank: Sufficient amperage must be calculated and available to cover the following: 1.) Wattage of the bulbs serviced 2.) Distance of bulbs from battery source (wiring losses) 3.) Duration of tow (taking into consideration the solar/time switch and length of the period of darkness).	*Table 5-4*			
i.	Are day shapes rigged in accordance with COLREGS?				
8.	**CARGO**	**Reference**	**N/A**	**Yes**	**No**
a.	Will craft have cargo on board?				
b.	If liquid cargo, give location and type (include any residual liquids):				
c.	Is solid cargo stowed below the main deck secured in position? If so, list location and type:				
d.	Is solid cargo stowed topside secured in position? If so, list location and type: ***Note:*** *All solid cargo on board must be well-secured from heavy weather. All cargo topside must be secured with wire straps and properly secured turnbuckles or equivalent securing devices. In some cases, shoring will be required.*				
e.	Will cargo stowed on board adversely affect the stability of craft? If so, revise stability calculations in Section 4 of this checklist.				
.	Has a manifest of all cargo been prepared for the towing ship?				

9.	MAIN TOWING GEAR	Reference	N/A	Yes	No
a.	Have towing attachment points and fairleads (including chocks/bullnose) been non-destructively tested? ***Note***: *Dye penetrates recommended.*	4-5			
b.	Date of last test:				
c.	Test procedure(s) used (visual, dye, MT): ***Note:*** *If there is any evidence of damage, rust, misalignment, or other damage, visual inspection should not be relied on.*				
d.	Has all chain in the towing bridle been measured in accordance with NSTM 581 and Appendix D? ***Note:*** *The towing bridle is normally chain on ocean tows. On some service craft, especially barges, wire has been successfully used. Wire should be used with extreme caution, however, due to problems with chafing.*	4-6.6			
e.	Is the Annual Towing Machine/Towing Winch Certification on hand?	5-8.14			
f.	Does the vessel have a copy of its Tow Hawser Certification?	5-8.3			
g.	Is the Master's Towing Certificate onboard (Commercial Vessels)?	5-8.15			
h.	Is towing bridle of sufficient size and strength, according to the restrictions listed below? The following restrictions apply: 1.) For service craft up to 500 tons, no less than 1 1/4" chain. 2.) For service craft above 500 tons, no less than 1 5/8" chain. 3.) For ships, the bridle must be equal in size to the ship's anchor chain, but not less than 1 1/4". Large ships do not need chain larger than 2 1/4" when towed by U.S. Navy towing ships. More powerful commercial tugs will require larger chain bridles. 4.) Non-magnetic chain and attaching hardware will not be used for towing bridles. 5.) Single leg bridles of ships must be anchor chain or larger, but not less than 1 5/8". 6.) The length of each leg of the bridle from the towing attachment point to the flounder plate after rigging is completed must be equal to or greater than the horizontal distance between the attachment points. 7.) A bridle apex should be between 30 and 60 degrees, with 60 degrees the optimal angle. 8.) On some ships with high bows (e.g., CV, AD, AOR, AFS), it may be necessary to rig a one or two-shot chain pendant between the bridle flounder plate and the towing hawser. ***Note:*** *Preparing activity should check with the towing activity as to the desired rig.*	4-6.6			
i.	Are all detachable links in the bridle legs and chain pendant locked with a hairpin? ***Note:*** *If not, the towing bridle is unsatisfactory.*	4-6.6			
j.	Are all bridle legs of the same size chain and equal in length when rigging is complete? Link count: ***Note:*** *To ensure accuracy, counting links prior to rigging and painting benchmarks is the only positive method. Total links per bridle should be equal at the attachment point on the tow.*	4-6.6			

·		Reference	N/A	Yes	No
k.	If a wire bridle is used, and there is a point of chafe on the tow, has sufficient chafing protection been provided? ***Note:*** *Chafing of wire bridles can be severe. Chafing protection must be used to prevent failures.*	*4-6.6*			
l.	If towing pads do not exist and bitts or cleats must be used, are they substantial enough to handle the strain of towing?	*6-2.6.2*			
m.	Are fairlead chocks and/or bullnose substantial enough to handle strain of towing?				
n.	Is the tow bridle fairlead angle sufficiently straight to preclude excessive side loading to fairlead points?				
o.	If mooring bitts are used, state the condition of bitts and surrounding deck areas. If any doubt exists, request that the area be non-destructively tested.	*6-2.6.2*			
p.	Is the towing bridle rigged with a backup system?	*4-6.6*			
q.	If mooring bitts are used a bridle attachment points, has heavy channel iron been welded across the bitts to prevent the wire or chain from jumping out? ***Note:*** *A minimum of 4-inch channel iron is recommended.*	*6-2.6.2*			
r.	Type of backup, cleats, bitts, padeye:	*4-6.6*			
s.	Distance from towing pad or bitts to backup point:				
t.	When using a chain bridle and sets of bitts as the towing point, it is preferable to terminate the chain before reaching the bitts, using wire to make the connection to the bitts. When load-sharing between two sets of bitts, take only one round turn around one barrel of the first set and lead the wire to the second set, where it is terminated with a round turn followed by “figure eights”. Has this been done?	*4-6.6*			
u.	Has all slack been taken out of the “figure-eights”?	*4-6.6*			
v.	Has all the slack been removed from the backup wires so that all parts will take an equal strain if the attachment points fail?	*4-6.6*			
w.	In most cases, the bridle legs are run through closed chocks before being connected to the towing pads or bitts. The lead angle from the connecting to the chocks must be fairly straight to prevent bending and failure of the chain where it passes through the chock. Does the towing rig conform to the above?				
x.	Is there sufficient and adequate metal thickness at all potential chafing points to prevent the bridle from cutting into the chocks, gunwale, or hull?				
y.	Is the size of the bridle-retrieving pendant adequate (i.e., providing a 4:1 safety factor in lifting bridle weight, but no less than 5/8-inch rope?)	*4-6.8*			
z.	Is there an adequate number of wire clips securing the retrieval pendant?	*Table 4-1*			
aa.	When attached from the bow of the tow to the flounder plate, is there enough slack to allow the retrieval pendant to droop slightly with no strain when the unit is being towed?	*Figure 4-16*			
bb.	Are flounder plates and plate shackles of approved design, and rigged in accordance with this manual?	*Appendices D and I*			
cc.	Is there a clearance in excess of 1/16” in securing pins in plate shackles, flounder plates and other towing jewelry? ***Note:*** *If not, the rig is unacceptable.*	*Appendix I*			

		Reference	N/A	Yes	No
dd.	All plate and safety shackle pin nuts must be locked with a minimum of a 5/16-inch machine bolt through a drilled hole in the plate shackle nut and pin. Secure the machine bolt in place with jam nuts. It is highly recommended that the bolt be peened over. Has this been done?	*4-6.1* *Appendix I*			
ee.	Lateral movement must be removed from the plate shackle connections by using washers or welding bosses on the plates. Has this been accomplished? ***Note:*** *Welding is not acceptable.*	*Appendix I*			
ff.	Are all safety shackles of the approved types and materials listed in the Appendix D?	*4-6.1* *Appendix D*			
gg.	If a multiple tow is planned (and you are the planning activity), have you checked to ensure that all the necessary equipment is available to rig and stream the tow in accordance with the appropriate towing method? ***Note:*** *Standard U.S. Navy practice allows three possible versions: the Christmas Tree, Honolulu, and Tandem rigs. Any rig selected must be rigged in accordance with this manual.*	*Appendix I*			
hh.	Rig selected:				
ii.	Normally, an open-ocean tow has solid connecting jewelry, but in cases of damaged and some calculated risk tows (such as some SINKEXs), an emergency quick-disconnect method such as a pelican hook is advisable. If this is such a tow, is an emergency quick disconnect provided?	*6-6.2.3* *6-7.6*			
jj.	If so, provide the method used:				
kk.	If an emergency quick disconnect is provided, will all jewelry fit through all fairleads through which it must pass (e.g., the bullnose)?	*6-7.6*			
ll.	Has the system been designed with a safety link?	*4-7*			
mm.	Identify the weakest element in the towing rig: Breaking strength of the weakest element:				
10.	ANCHORING	Reference	N/A	Yes	No
a.	Has an emergency anchoring system been rigged?	*5-7.5*			
b.	Is anchor rig capable of holding the vessel in 60’ of water with at least 3:1 ratio of scope of depth?	*5-7.5*			
c.	Is there a need for a deeper anchoring system?				
d.	If so, what is the depth required?				
e.	Is the rig capable of meeting this deeper requirement with at least a 3:1 ratio of scope to depth?				
f.	Is it rigged for quick release?	*5-8.5*			
g.	Is it secured for heavy weather?				
h.	Has the anchor windlass brake been tested?				
i.	If plans have been made to anchor the tow at port of delivery, is power available to raise the anchor?				

11.	SECONDARY TOWING GEAR	Reference	N/A	Yes	No
a.	Are the secondary towing system's attachment and fairlead points adequate to tow the vessel?	*4-4*			
b.	Is adequate chafing protection provided for the vessel's secondary towing systems?				
c.	Is the secondary towing pendant *or the ship's emergency tow pendant* at least 1 5/8" wire rope?	*4-4*			
d.	Is the secondary towing pendant stopped off in bights on one side of the tow?	*4-4*			
e.	Are the stops sufficient to hold in heavy weather, but accessible to allow cutting and light enough to be broken without damaging the towing pendant or tow?	*4-4*			
f.	Will the secondary pendant fall free without turns that will cause kinking as they pull out?	*4-4*			
g.	Is the secondary towing pendant fitted with a synthetic line messenger to facilitate passing it to the tug?	*4-4*			
h.	If the tow is unmanned, is polypropylene floating retrieval line (5"-8" circumference) attached to the end of the messenger with a small buoy secured at its end?	*4-4*			
12.	SPECIAL CONSIDERATIONS				

Some types of tows require special consideration. For instance, YTBs, YTMs, and other self-propelled service craft were not designed to go to sea and are not very seaworthy. In these craft, the watertight envelope must be absolutely complete; they have low freeboards and water will constantly be breaking over them in moderate seas. Because of the constant pounding of the seas caused by their flat bottoms, submarines are not designed with towing in mind. Generally, a towing padeye is installed near the sail as a single towing point. See Section 7-5 and Appendix J of the *U.S. Navy Towing Manual* for data concerning submarine tows. Extensive information concerning towing of unmanned, defueled, nuclear powered submarines is contained in NAVSEAINST 4740.9 Series. (For unmanned, defueled, nuclear powered cruisers, see NAVSEAINST 4740.10 Series.)

There are many hulls whose design will require special towing rigs. Additional work may be required to rig an applicable bridle to ensure safe delivery of a craft from port to port. This will require additional lead-time to prepare the tow(s) for ocean transit. Submarines, wooden-hull minesweepers, sailing craft, etc., fall into this category.

When towing a sharp "V-shaped" hull that has a bullnose and a bulbous bow/sonar dome, the single leg bridle is the preferred method of rigging. Rig using at least two shots of the tow's anchor chain if that chain is acceptable.

13. REMARKS:

H-2 SAMPLE CERTIFICATE OF SEAWORTHINESS/DELIVERY LETTER

FIRST ENDORSEMENT

1. Upon inspection of the tow described above, the following unsatisfactory conditions were found, which render the tow unseaworthy or not ready for towing (if none, so state).

    a.

    b.

    c.

    d.

2. (Cross out the statement, which is not applicable).

a. I find the tow described above in a condition satisfactory for towing, and hereby assume responsibility for delivery to the port of destination prescribed in my sailing orders.

b I will accept the tow as an acceptable risk only upon authorization of my operational commander. I have notified my operational commander of the reasons for this action.

Commanding Officer, USS ______________________________ Date ________________

SECOND ENDORSEMENT (To be accomplished only if an acceptable risk tow is acceptable to delivery authority).

1. The following conditions listed in the first endorsement remain uncorrected.

a.

b.

2. It is requested that you accept this tow in the above condition as an acceptable risk.

______________________________	______________________________
Representative of command having cognizance of towed unit.	Date

THIRD ENDORSEMENT

1. As authorized by ____
(DTG reference of operational commander's message)

I accept this tow, with conditions existing as described in the second endorsement, as an acceptable risk for delivery to the port designated in my Sailing Orders.

____

Commanding Officer, USS ___________________________________ Date __________________

____

SAMPLE DELIVERY LETTER

From: (Receiving Activity)

To: (Commanding Officer of Towing Vessel)

1. Received custody of (describe tow) this date.

______________________________	______________________________
Representative of Receiving Activity.	Date

Appendix I - TOWING RIGS

I-1 Introduction

This appendix includes towing plans and drawings of towing equipment and rigging associated with towing operations. Towing rigs can be made up in various configurations. Select the tow rig based on its past performance and the needs of the particular tow. Although most Navy tows are simple, single-tug, single-unit operations, some tows are considerably more complex, consisting of a single tug with multiple towed units. Occasionally, the displacement of the towed unit requires using more than one tug.

The enclosed drawings are intended to serve as both guidance and examples of typical tow configurations. Exercise care in selecting compatible components. Keep these important points in mind:

- Each leg of a bridle should be strong enough to assume the entire resistance of the tow.
- When using underiders, using chain bridles and pendants will promote a deeper catenary and minimize interference with intermediate tows.
- Towing flounder plates and plate shackles are designed to be fabricated easily. Flounder plates and cheeks of plate shackles can be fabricated from common steel (that is, ABS Grade A or ASTM A-36). Pins must be machined from 150,000 psi minimum yield material such as AISI 4140. When pins are fabricated, it is recommended that a material certification be required.
- Plate shackles shown in these drawings are not necessarily suitable for beach gear or heavy lifting rig applications. These efforts generally require more robust hardware.

I-2 Single Tug, Single Tow Configurations

Three common variations of the single tug, single tow configuration are a single hawser with pendant, a single hawser with bridle, and towing alongside. A fourth variation, the Liverpool Bridle, is used in special circumstances where extra control is required.

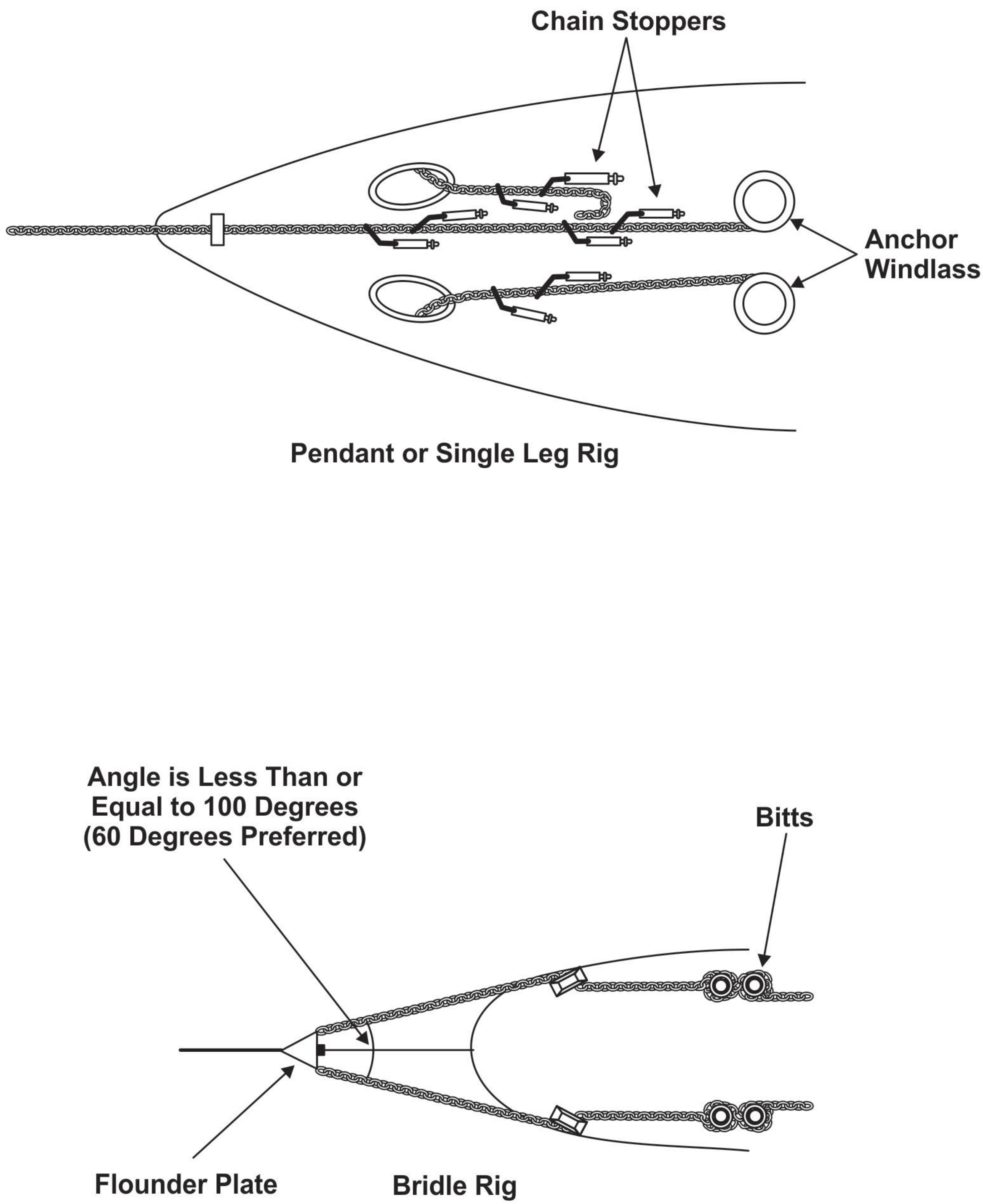
I-2.1 Pendant or Single Leg Rig

The pendant rig is the simplest and most straightforward rig and generally is used for open-ocean towing of ships with fine bows, sonar domes, bulbous bows or when the tow is most stable in this configuration (see Appendix Figure I-1). All of the components are linked in a series. A distinguishing element of the pendant rig is the deployment of a single chafing pendant to a single attachment point on the towed vessel. The pendant rig is usually used for emergency towing. Outboard of the tow's fairlead, the chafing pendant usually is connected via a leading chain and/or a towing pendant to the tug's hawser. The advantage of the pendant rig is its ease of connection. There is little, if any, likelihood of the pendant fouling on the cutwater or other outboard structure

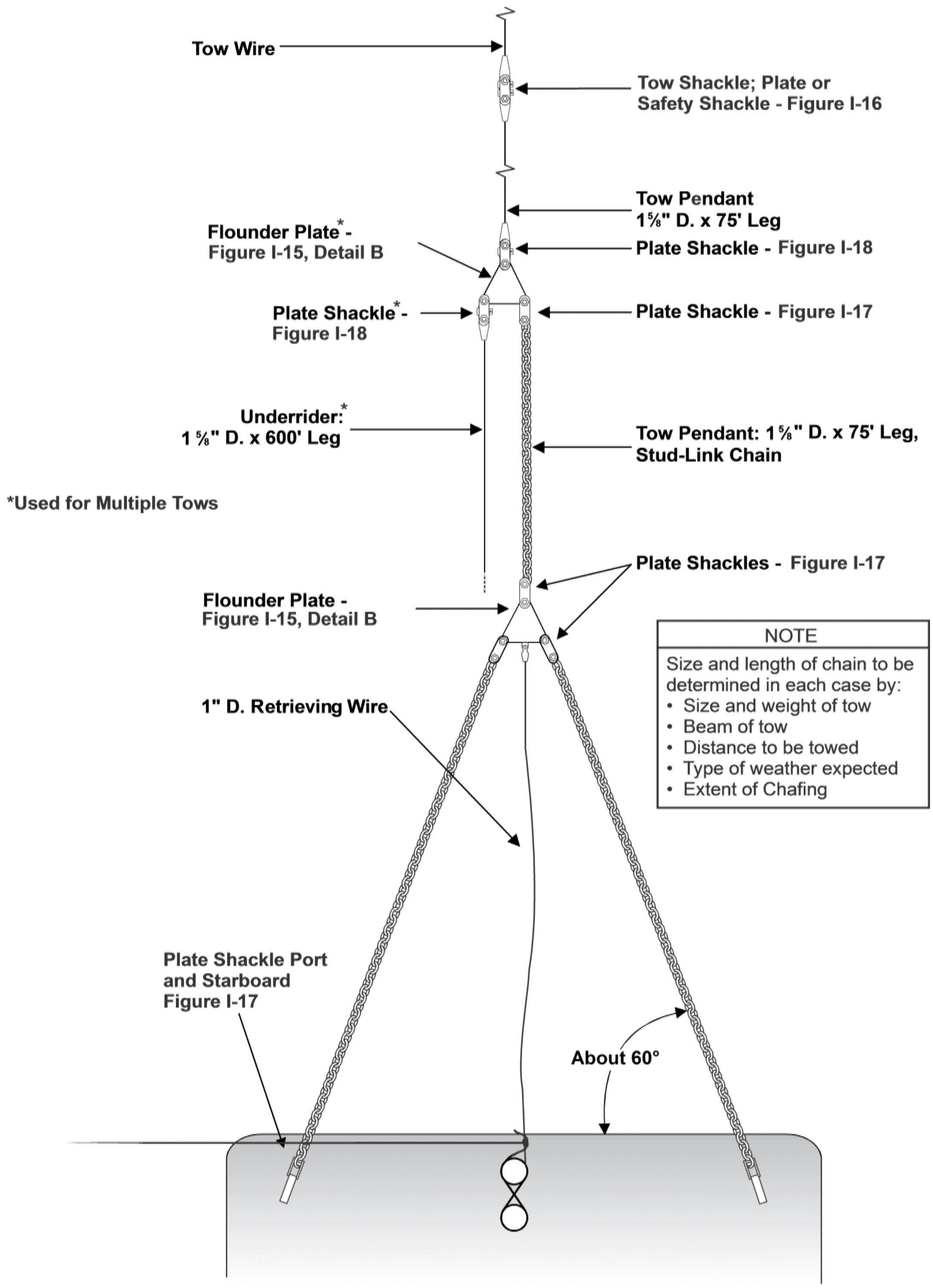
I-2.2 Bridle Rig

CAUTION
Each leg of a bridle should be strong enough to assume the entire resistance of the tow.

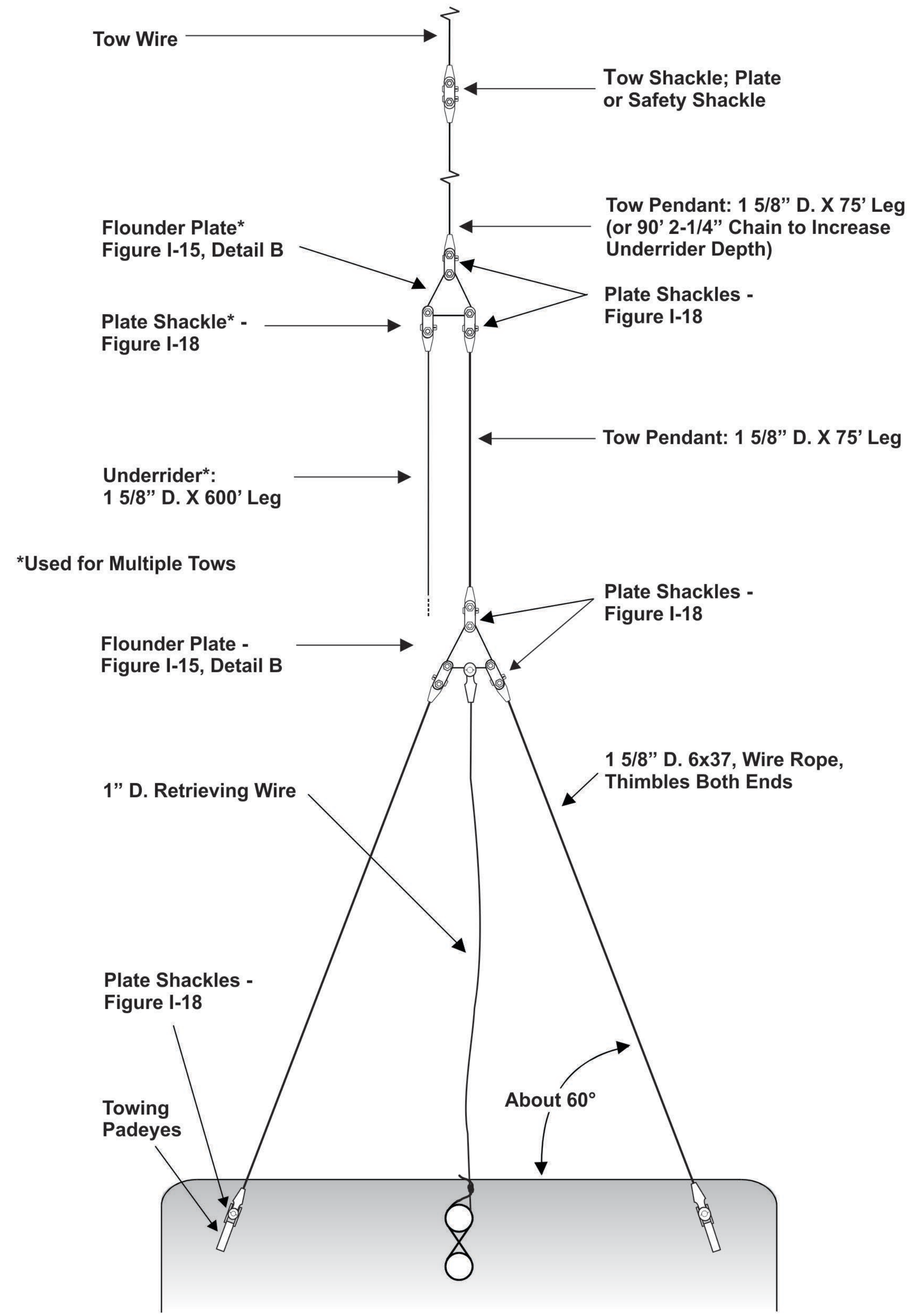
The bridle rig is characterized by a two-legged bridle instead of the single pendant on the towed vessel (see Appendix Figure I-1). The length of each bridle leg should be approximately equal to the beam of the towed vessel.



Appendix Figure I-1.Towing Rigs (Plan View)



Appendix Figure I-2. Example of Chain Bridle with Chain Pendant.



Appendix Figure I-3. Example of Wire Bridle with Wire Pendant.

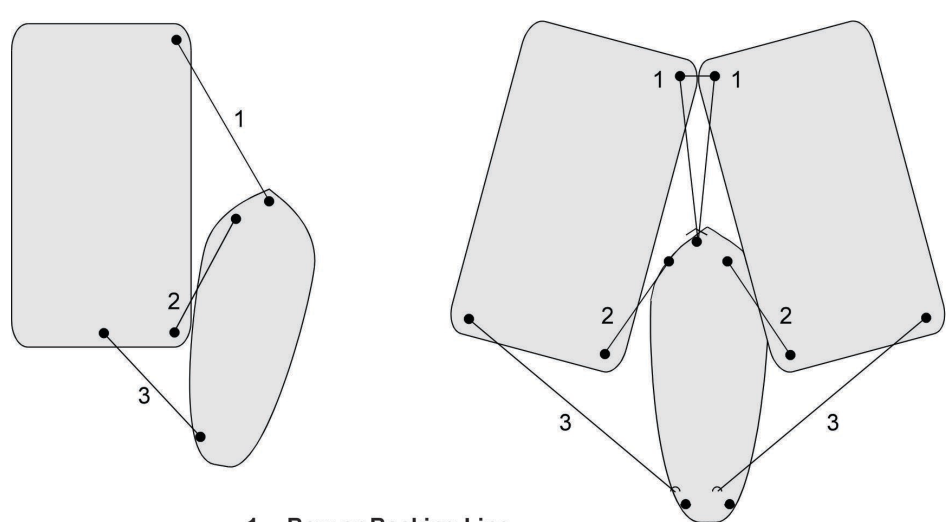
The fitting at the apex usually is a flounder plate with the two bridle legs connected at its base and the apex usually connected to the lead chain and/or towing pendant, which in turn is connected to the tow hawser.

The bridle rig places more and heavier rigging outboard of the towed vessel. This can lead to rigging problems on the deck of the tow. Furthermore, the bridle rig, by definition, uses two off-centerline fairleads. As a consequence, if the tow does not track the tug directly astern, there may be an off-center dynamic load. This load, while tending to be self-correcting, unbalances the loads on each bridle leg. Therefore, each bridle leg must be of full towline strength. Finally a critical problem of the bridle rig occurs when turning, or when the tow sheers off to the side of the tug's track, and the bridle leg on the far side can ride against the cutwater of the tow, causing damage to itself as well as to the tow.

In many cases, the foredeck arrangement, hydrodynamic characteristics or need to tow the vessel backwards does not permit the use of a bridle rig. For example, aircraft carriers and LSTs have forecastle arrangements that require using a pendant rig. Bridle rigs are commonly used on ships with blunt bows and barges.

I-2.3 Towing Alongside

Towing alongside or "towing on the hip" is a configuration often used in congested waters (see Appendix Figure I-4. Towing alongside offers excellent control. This configuration is not recommended for the open ocean, however, because of motion between the tug and tow in a seaway. When complex maneuvering is required, consider having harbor tugs to do the job or assist during difficult phases of the maneuvers.



1. **Bow or Backing Line.**
2. **Towing Line (Power).**
3. **Stern Breast or Turning Line.**

Appendix Figure I-4. Towing Alongside.

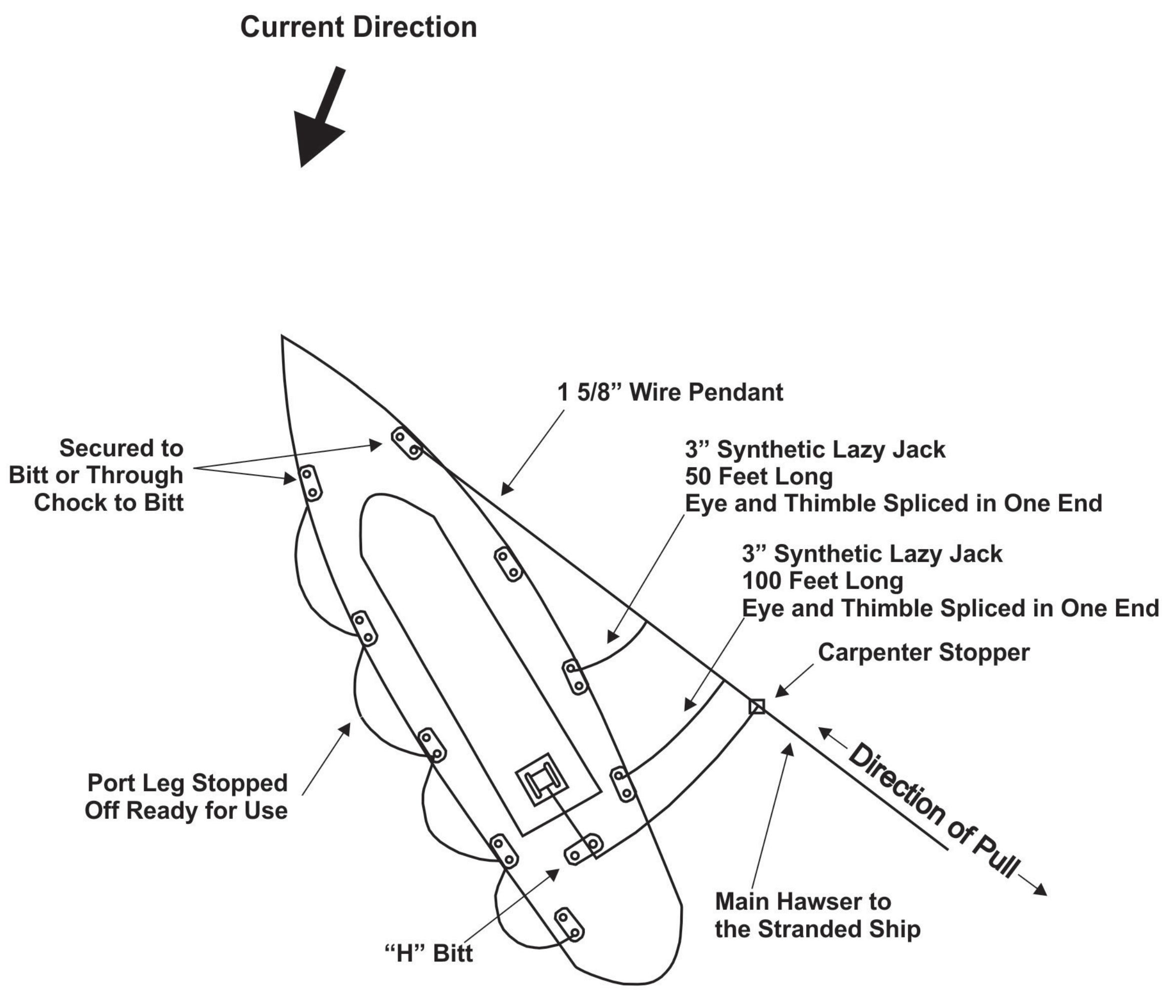
For towing alongside, the tug generally secures to one side of the tow, well aft on the tow to increase the control effectiveness of her propellers and rudder.

CAUTION
When towing alongside, keep all lines taut until ready for streaming the tow. This will prevent the tow from pounding alongside the tug and ensure effective control of the tow.

I-2.4 Liverpool Bridle

CAUTION
In operating the Liverpool Bridle, limit the tension to the safe working load of the bridle's 1 5/8-inch wire rope pendant.

The Liverpool Bridle, as shown in Appendix Figure I-5, is a towline harness designed to permit a towing vessel to maintain fine control over heading and position. The Liverpool Bridle is needed in circumstances, typically strandings, where currents and weather make it impossible for a conventionally rigged tug to maintain its station in relation to the tow. The Liverpool bridle is particularly useful when the heading of the tug must be different than the direction of application of towing force.



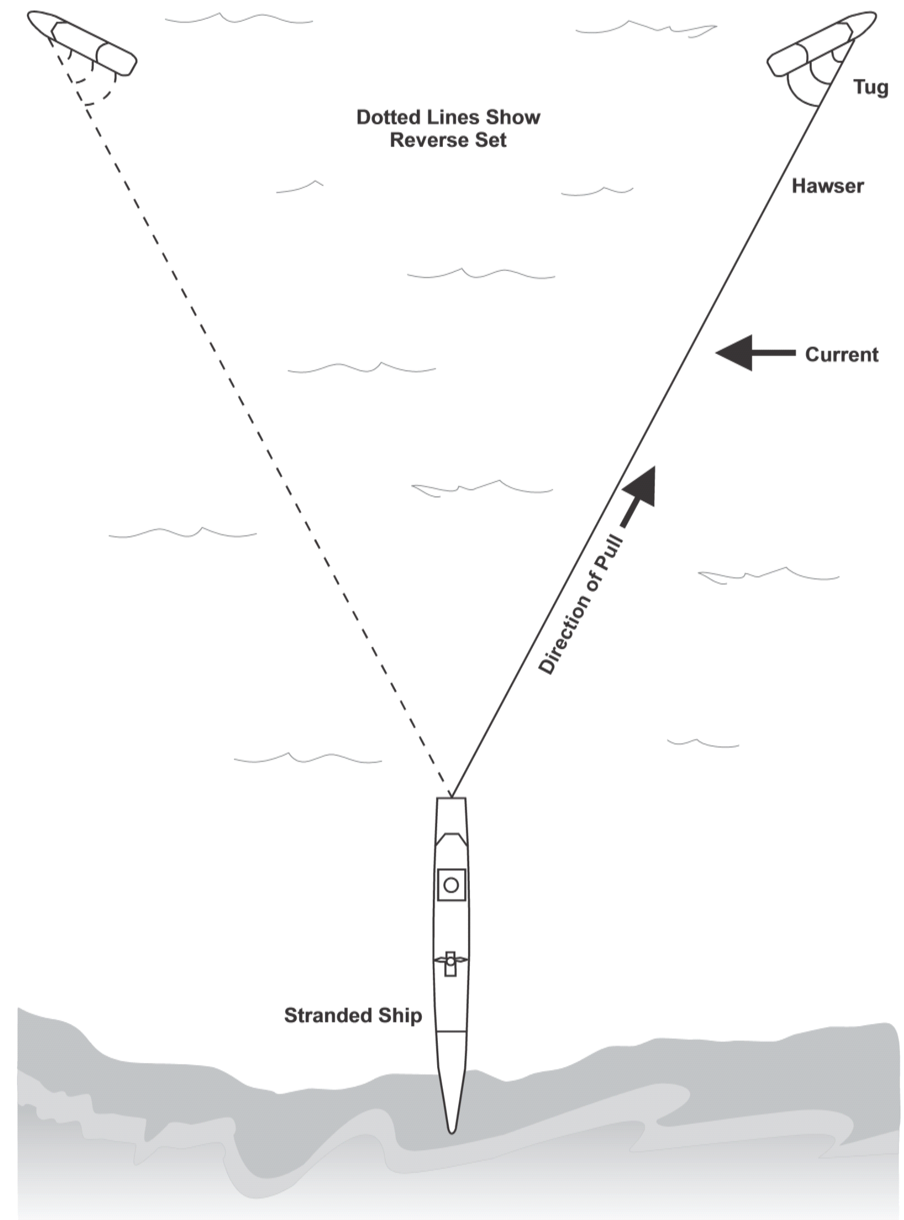
Appendix Figure I-5. Liverpool Bridle.

The Liverpool Bridle requires:

- A towing winch
- One carpenter stopper secured to the towline
- Two pendants of 1 5/8-inch wire rope with a soft eye spliced in one end and an eye with a thimble spliced in the other end.
- Two 3-inch synthetic fiber lazy jacks: one 50 feet long and the other 100 feet long, each with eye and thimble spliced in one end. The lazy jacks are retrieving lines only and take no strain.

One pendant is used on the starboard side, the other on the port side. By rigging a bridle on either side of the tug, the towing point can be shifted from side to side to facilitate ship control. The pendants should be long enough to run slack from the forward rail or shoulder bitts, which are closest to the pivot point of the ship, outboard and in over the quarter to a point on the centerline about 20 feet abaft the towing H-bitts. Thus configured, the point of tow is forward of the vessel's normal pivot point, and the tug is able to maneuver to keep her head in the desired direction.

A typical application of a Liverpool bridle is shown in Appendix Figure I-6.



Appendix Figure I-6. Use of Liverpool Bridle on Stranding Salvage.

I-3 Single Tug, Multiple Unit Tow Configurations

Single tug, multiple unit tows consist of one tug and several tows; the connection and makeup of the tows can be varied. The U.S. Navy currently uses four versions: the Christmas, Honolulu, Tandem, and Nested rigs.

I-3.1 Christmas Tree Rig

The Christmas Tree rig is used for open-ocean towing (see Appendix Figures I-7 through I-10). It requires a review of water depths and bottom conditions prior to use. The catenary of the towline from tug to the first tow and subsequent connecting wires must be deep enough to ensure that the underrider passes safely below the bow of the leading tow(s). It is important to have adequate water depth to prevent grounding the towline. Using chain bridles and pendants will promote a deeper underrider and minimize interference with intermediate tows.

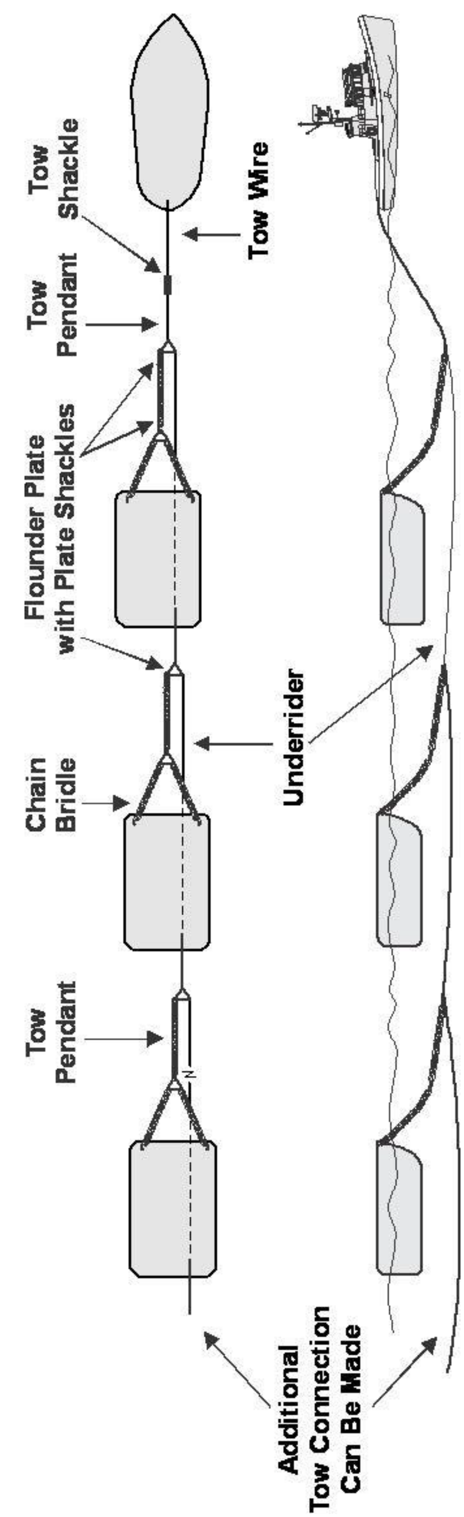
Harbor tug assistance usually is required to break up the Christmas Tree rig before entering port. With the assistance of harbor tugs, it is feasible to break out one of the tows without disrupting the remainder. Although a strong rig, it is difficult to make up and disconnect and does not facilitate getting all elements in step. Appendix Figure I-10 shows a series of barges at the pier, ready for streaming.

The forward most tow wire will be subject to the total resistance of all of the attached assets. The strength of this gear must be checked carefully.

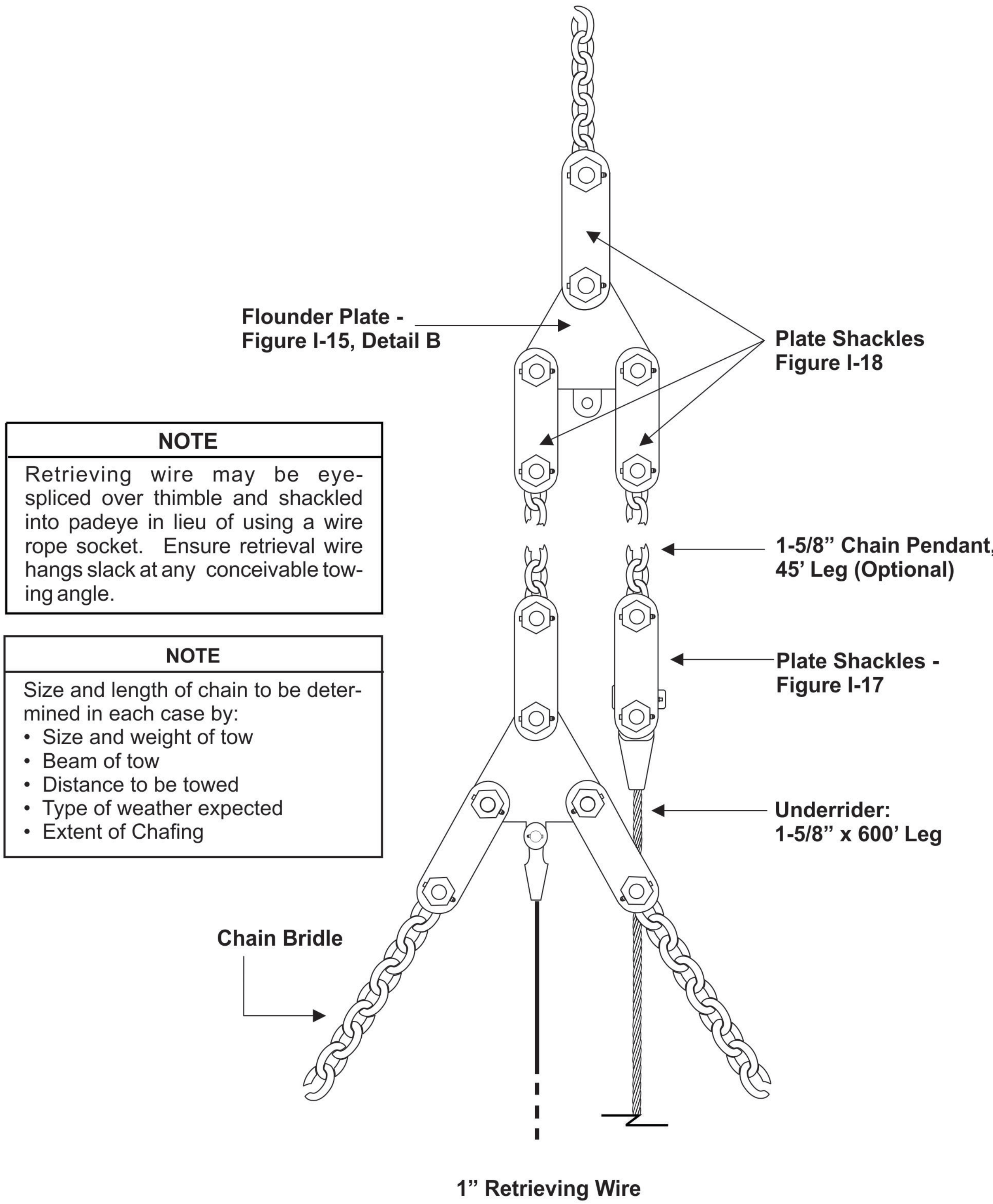
I-3.2 Honolulu Rig

The Honolulu rig was developed for inter-island towing, where individual units of multiple tows were delivered to or picked up from different ports (see Appendix Figure I-11).

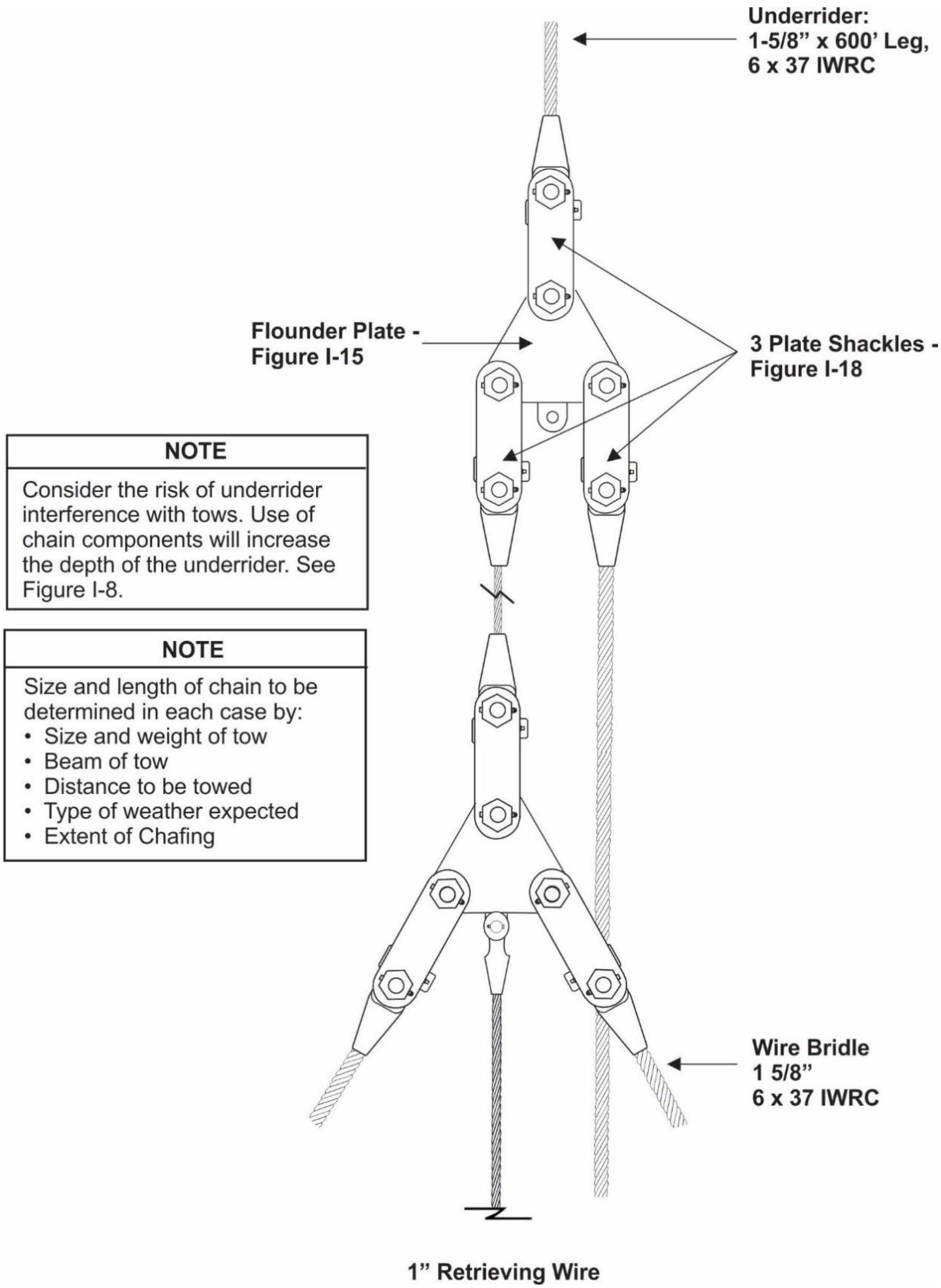
The first tow streamed is connected to the main tow wire and streamed farthest aft. Additional tows are connected with auxiliary tow wires to quarter bitts or auxiliary drums. The Honolulu rig allows independent connection of the two tows, disconnecting and control are readily workable, and it is relatively uncomplicated to get both tows in step with the tug. Additionally, each tow wire is subject to the resistance of only one asset.



Appendix Figure I-7.Christmas Tree Rig



Appendix Figure I-8. Example of Christmas Tree Rig Configuration with Chain Bridle.



Appendix Figure I-9. Example of Christmas Tree Rig Configuration with a Wire Bridle.

I-3.3 Tandem Rig

The Tandem rig, with its close-coupled tows, is generally used only in congested waters where good control is required (see Appendix Figure I-12). This is the least desirable of the single tug/multiple tow arrangements, as it lacks the flexibility and control of the other rigs for break-up upon entering port.

The rig connects the tug to the first tow, with subsequent tows connected to the one in front of it. The intermediate towline connects the first tow to the second, and must allow a proper catenary depth to minimize the surging action between the tug and first tow, and between the first and second tows. It is difficult to keep all elements in step with this type of rig. Similar to the Christmas Tree Rig, the forward most tow is subject to the forces of all assets. It may be that the fittings available for tow points on the after end of the first tow are insufficient to withstand the strain of subsequent tows. Remember that these must not only survive the steady tension of the additional tows, but also the dynamic tensions. These attachment points must be inspected using the same criteria for primary attachment points.

I-3.4 Nested Rig

A nested rig tow employs multiple tows secured alongside each other so they may be towed as a single unit. Advantages of using a nested rig include maneuverability, ease of preparation, and ease of retrieval. Because the nested vessels can work against each other and inflict considerable damage, this rig is to be used only in protected waters. A nested rig is generally controlled by a tug tied alongside or by specially designed pusher boats. Rider lines can be used, but a short scope should be maintained to ensure adequate control. Care must be taken to ensure barges do not break free during these operations.

When using any of the above rigs, use one of the flounder plate arrangements shown in Appendix Figure I-8 and Appendix Figure I-9. Chain should be used as bridles when possible to reduce chafing. Wire bridles can be used if proper care is taken to minimize chafe points and it is calculated that wire provides sufficient strength when using the Christmas Tree rig or the tandem rig. (Remember that the forward most gear will be subject to the combined tow forces of all of the attached assets. This gear should be sized accordingly.)

I-4 Multiple Tug, Single Tow Configurations

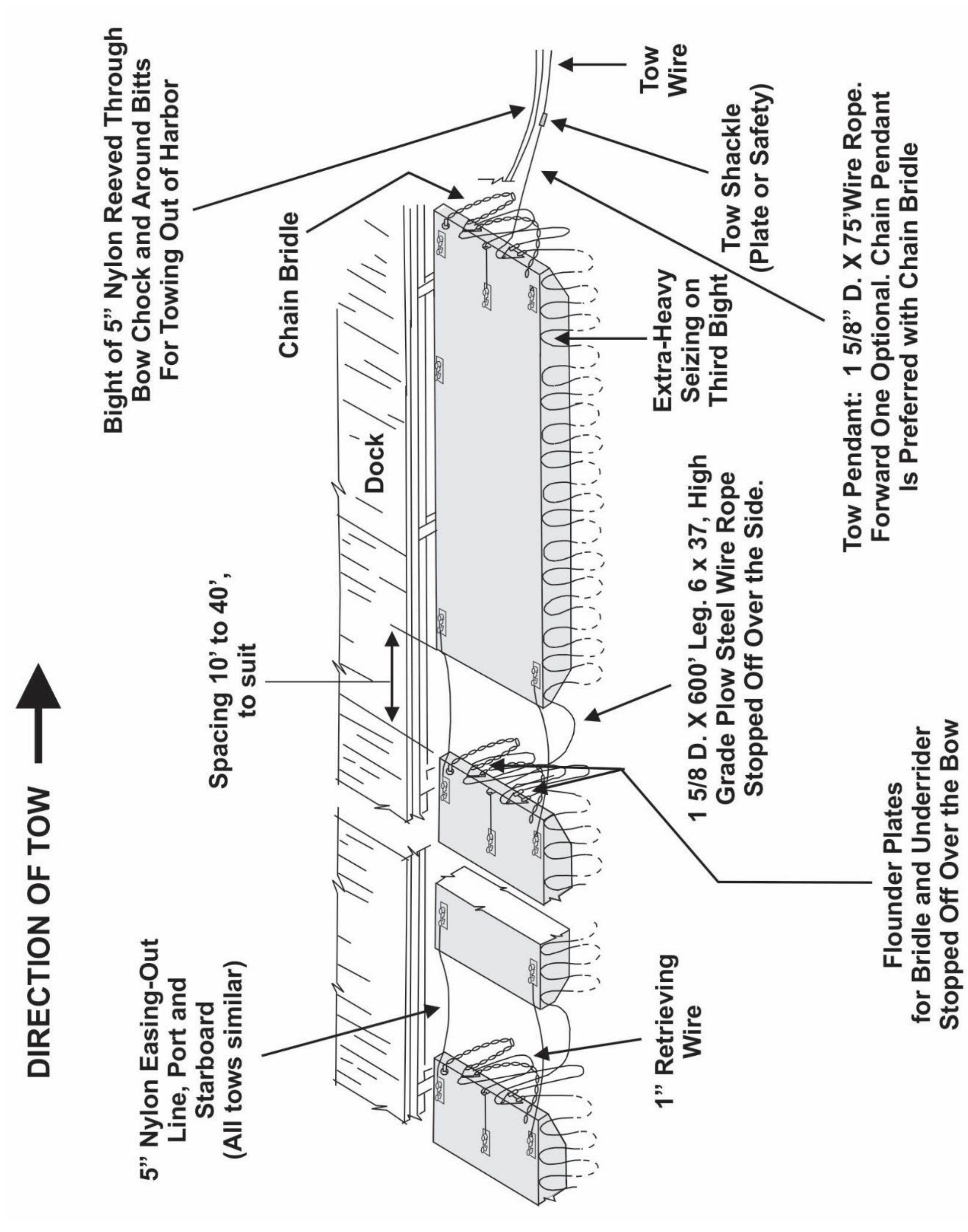
It may be desirable to use more than one tug for a single tow. Greater power, increased towing speed and better control may be obtained in a multiple tug tow. Multiple tugs are generally used to tow large ships, deep-draft large-displacement dry-docks, deep-draft barges, or battle casualties.

I-4.1 Side-By-Side Towing

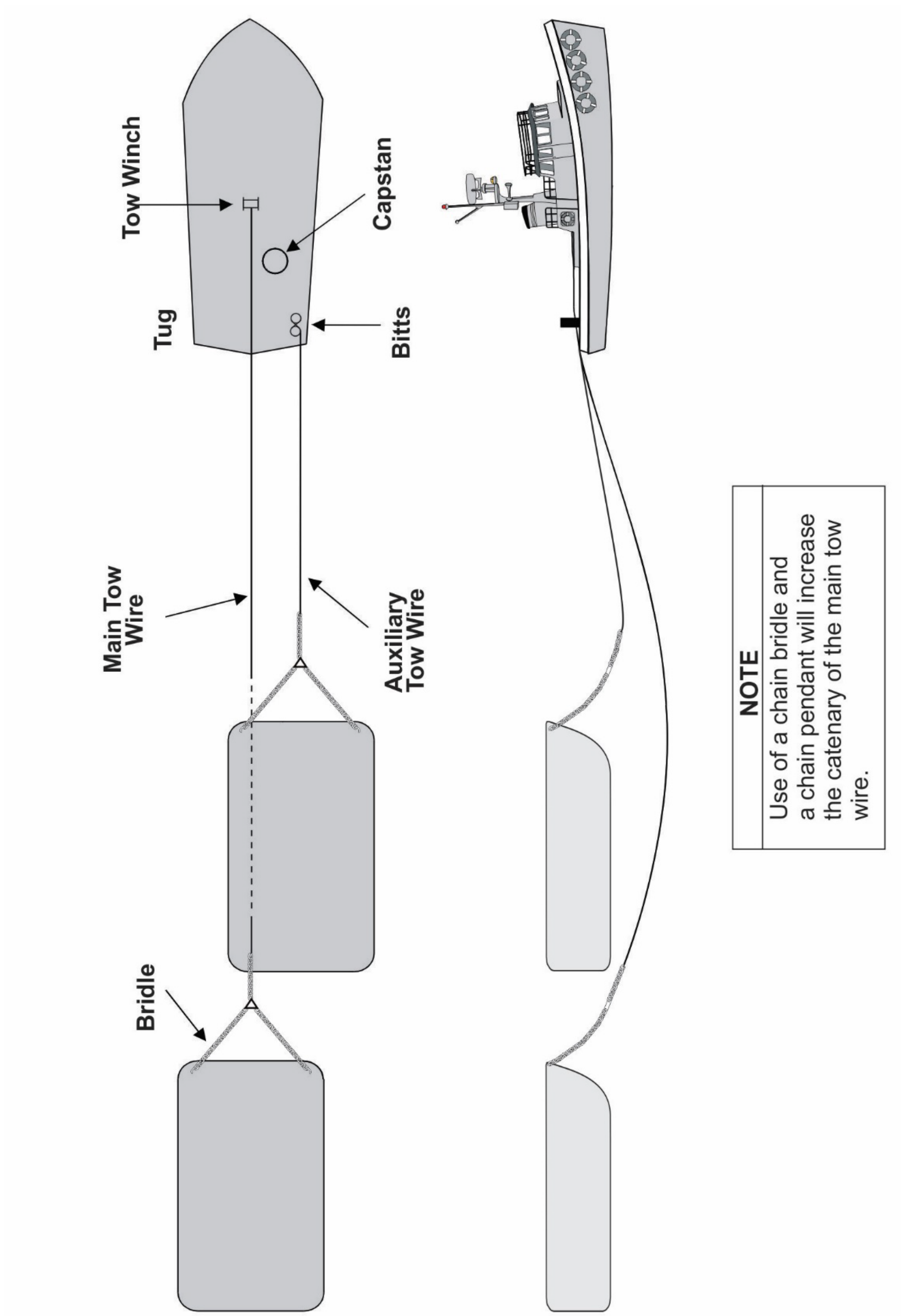
Appendix Figure I-13 shows side-by-side tugs towing a single tow. Each towline should have its own connector and chafing fairlead. There is no universally preferred method of two-tug towline arrangement. Most operators prefer to tow “side-by-side” with equal hawser scopes to avoid sweeping over the other tug’s towline. A few operators prefer different scopes to minimize the risk of tug collision. In such cases, the more powerful tug is designated lead tug, with a longer hawser scope. The lead tug may use a longer lead chain to increase the catenary depth. This reduces the chance of interference, should the following tug suffer some untoward event that results in its crossing the lead tug's towline.

I-4.2 Steering Assistance

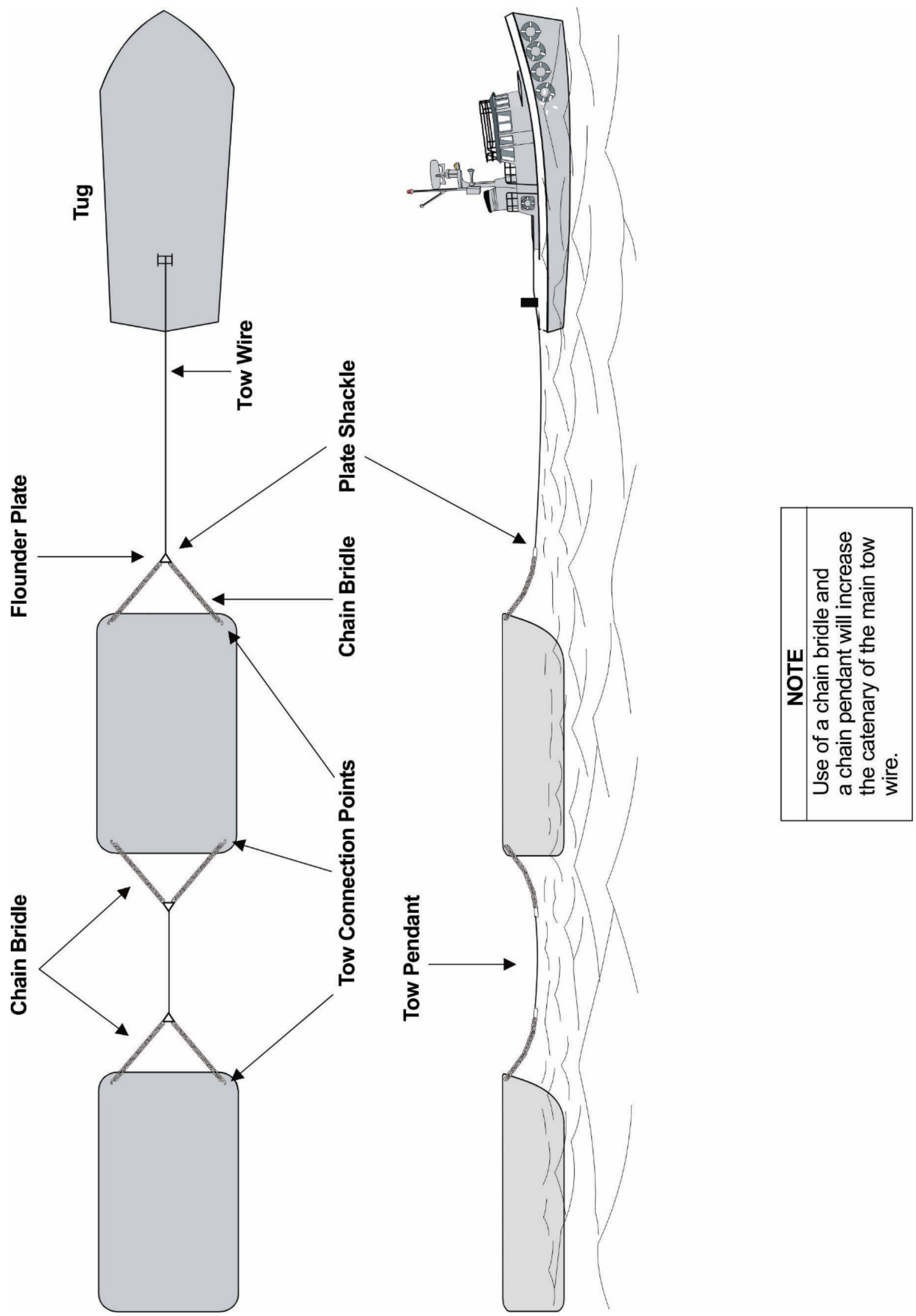
At times when a tug has a tow at short scope in restricted waters, steering assistance is needed. This assistance can be provided by another tug, normally a harbor tug, astern of the tow. Usually the steering tug's main effect is to restrain the movement of the tow, primarily in yaw. U.S. Navy towing ships rarely perform this function. Use of steering tugs varies widely, depending upon local practice, tug design, and pilot preference. No attempt is made herein to provide information on steering tug connections.



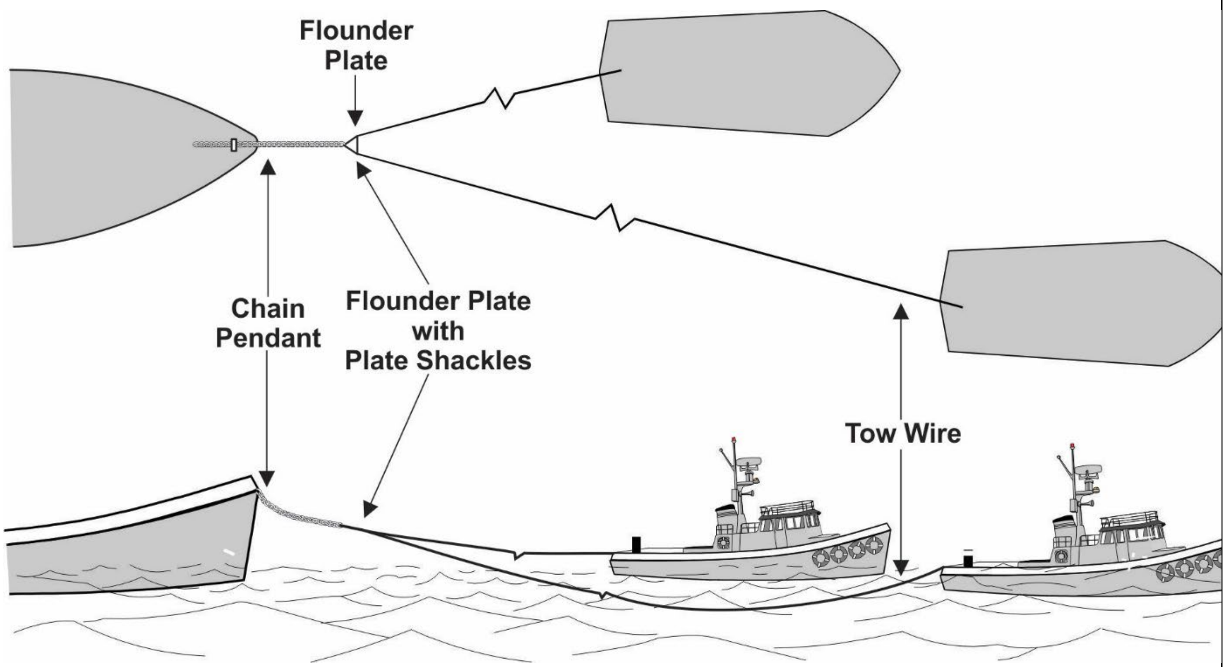
Appendix Figure I-10. Three Barge Tow in Christmas Tree Rig Ready for Streaming.



Appendix Figure I-11. Honolulu Rig.

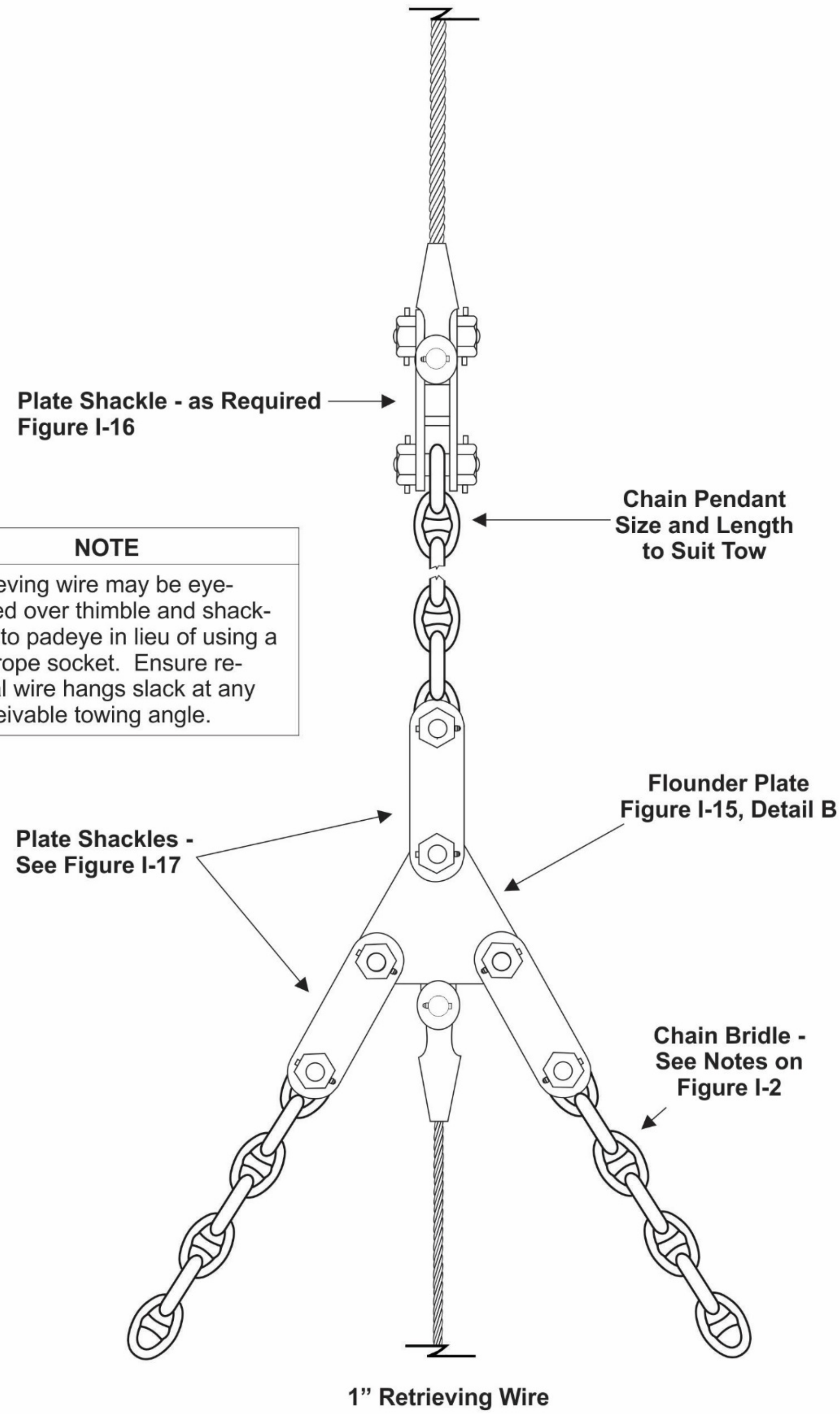


Appendix Figure I-12.Tandem Rig.



NOTE
The side-by-side towing arrangement shown here with the tugs towing on unequal towline scopes, is not necessarily preferred over an arrangement where the tugs use equal towline scopes. Section I-4.1

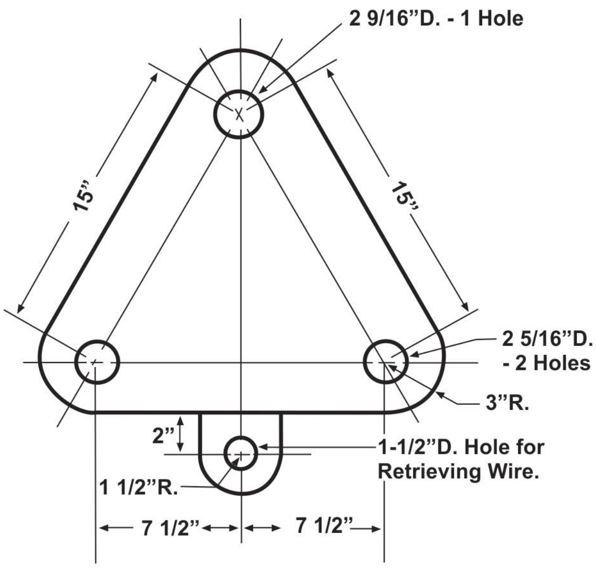
Appendix Figure I-13. Two-Tug Tows

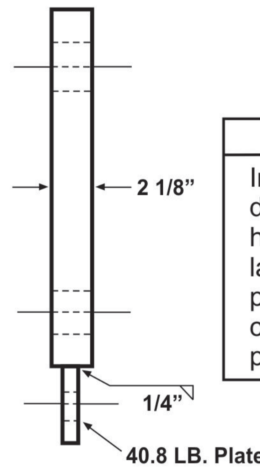


NOTE

Retrieving wire may be eye-spliced over thimble and shackled into padeye in lieu of using a wire rope socket. Ensure retrieval wire hangs slack at any conceivable towing angle.

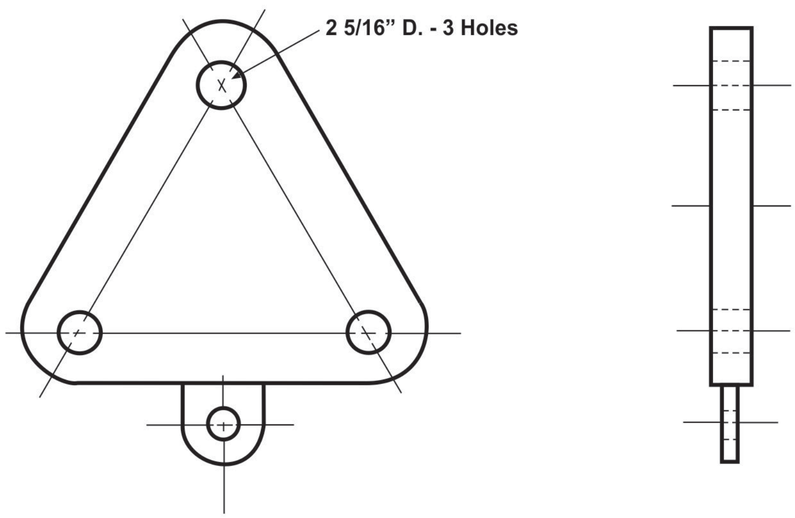
Appendix Figure I-14. Example of Chain Bridle and Pendant.





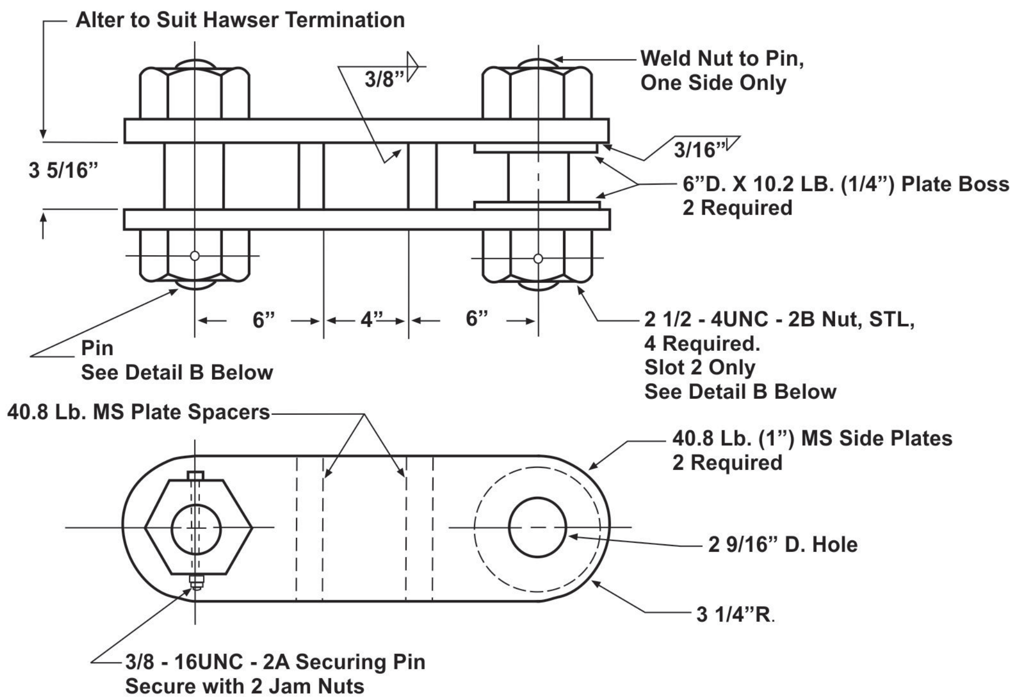
NOTE
In no case should diameter of flounder plate holes be more than 1/4" larger than the shackle pin diameter. A 1/16" clearance on diameter is preferred.

Detail A - Flounder Plate Medium Steel
for Use with 2-1/2" Pin Shackle and 2-1/2" Shackles

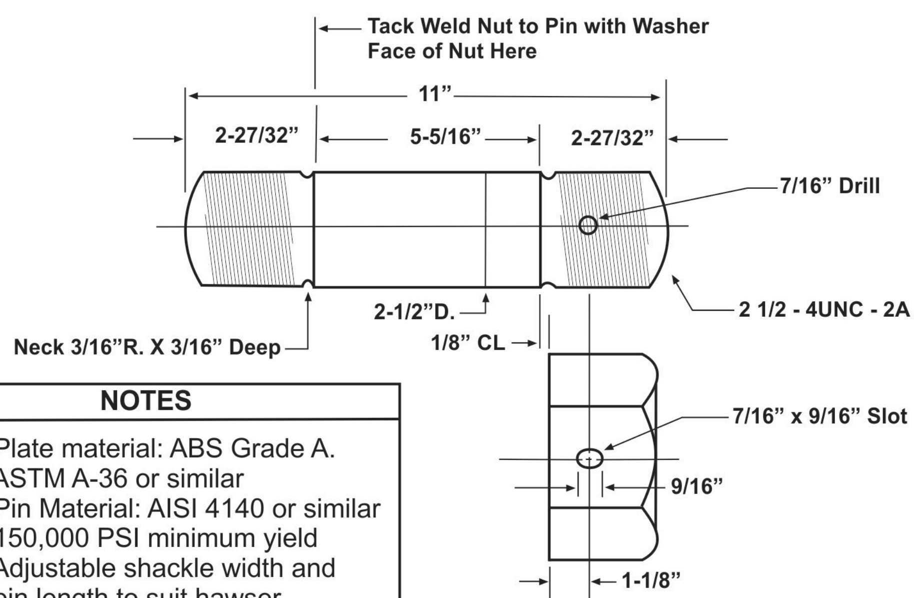


Detail B -- Flounder Plate Medium Steel
Similar to Detail 'A' Except as Noted.
ABS Grade A, ASTM A-36 or Equal

Appendix Figure I-15. Flounder Plate.



Detail A
Tow Plate Shackle

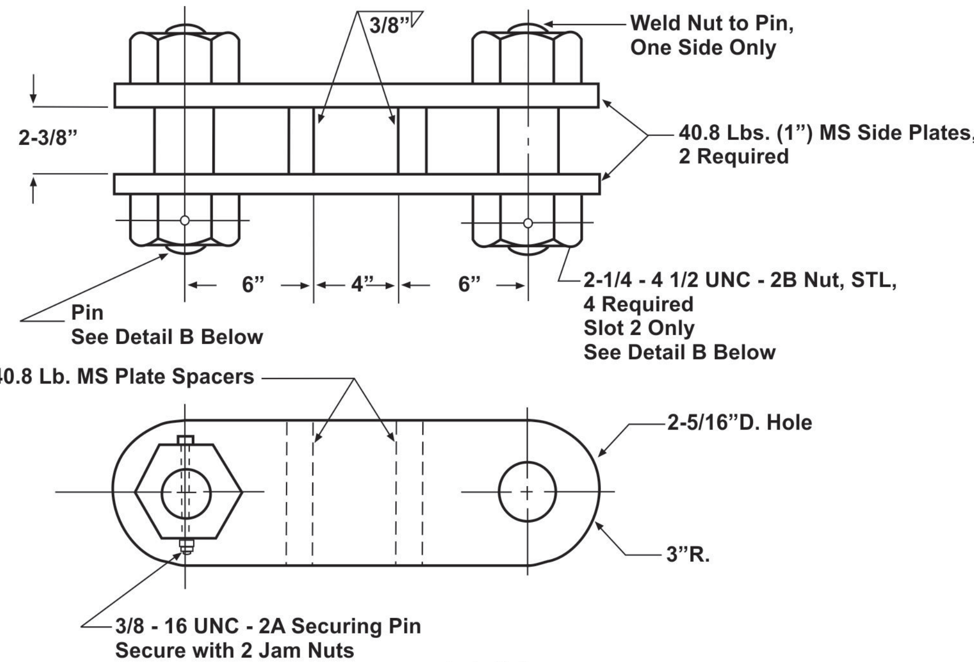


NOTES

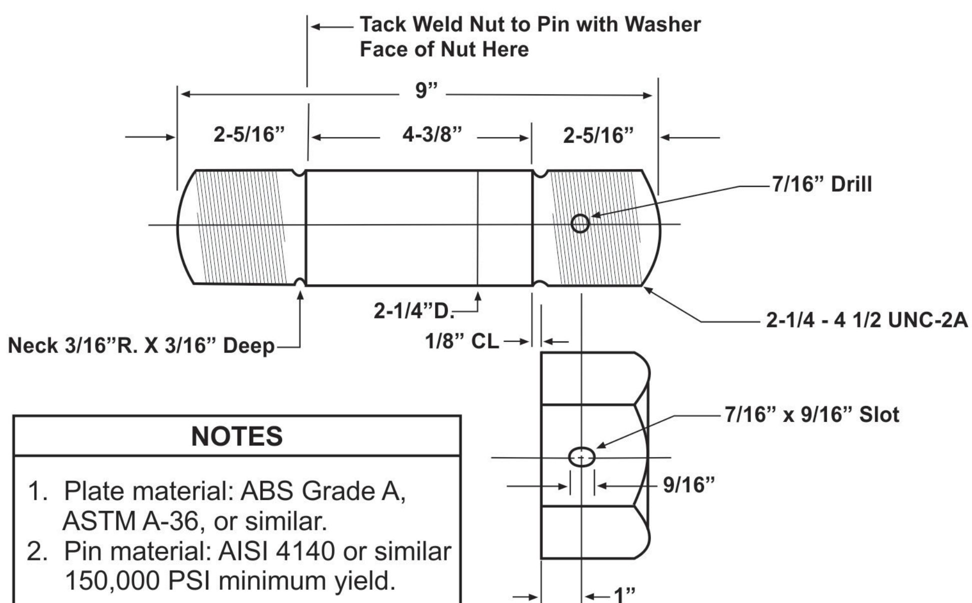
1. Plate material: ABS Grade A. ASTM A-36 or similar
2. Pin Material: AISI 4140 or similar 150,000 PSI minimum yield
3. Adjustable shackle width and pin length to suit hawser termination.

Detail B
Shackle Pin - 2 Required

Appendix Figure I-16. Plate Shackle and Pin for 2-Inch Closed Socket.



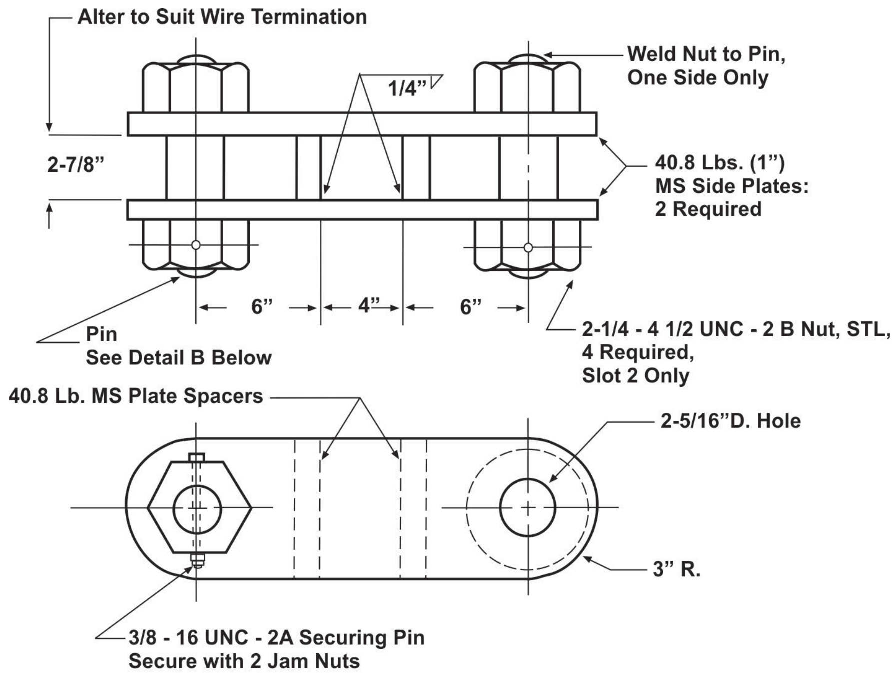
Detail A
Plate Shackle for 1-1/2 - 2-1/4" Chain



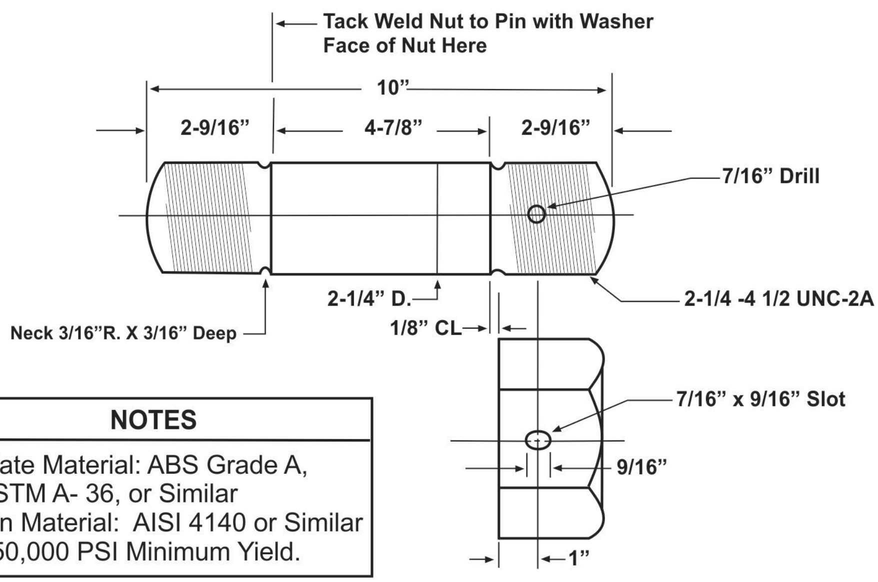
NOTES
1. Plate material: ABS Grade A, ASTM A-36, or similar. 2. Pin material: AISI 4140 or similar 150,000 PSI minimum yield.

Detail B
Shackle Pin - 2 Required

Appendix Figure I-17. Plate Shackle and Pin (for Chain).



Detail A
Plate Shackle for 1-5/8"D. Wire Rope



NOTES
1. Plate Material: ABS Grade A, ASTM A- 36, or Similar 2. Pin Material: AISI 4140 or Similar 150,000 PSI Minimum Yield.

Detail B
Shackle Pin - 2 Required

Appendix Figure I-18. Plate Shackle and Pin (for Wire Rope).

Appendix J - EMERGENCY TOWING OF SUBMARINES

This appendix provides information on the towing attachment points of several classes of submarines. This information is provided to assist the tow ship in planning an emergency (that is, unplanned) tow of a submarine. The information is not all-inclusive, but covers most submarine classes. The principles can be adapted to other submarine designs.

Every U.S. Navy submarine has a plan for being towed that is described in the ship's information book. In general, all submarines built prior to the SSN 688, SSN 21, and SSBN 726 Classes have similar towing arrangements; these earlier submarines are discussed here as one group. The SSN 688, SSN 21, and SSBN 726 Class submarines are discussed separately. Table J-1 contains relevant technical data for the 594, 616, 637, 688, 21, and 726 Classes of submarines.

J-1 Submarines Prior to the 688 and 726 Classes

J-1.1 Tow Attachment Points

Most submarines built prior to the 688, 21, and 726 Classes have a tow pad at or near the base of the forward end of the sail or attached to the forward escape trunk. Lateral strength is considerably reduced, so a tow fairlead must be used. The hole size in the padeye is 2 9/16 inches in diameter in all cases.

Most of these submarines have retractable mooring cleats, forward fairlead chocks, and capstans. Many have capstans and fairlead chocks aft as well. The inside dimensions of all the chocks are 10½ x 16½ inches except for chocks on the 594 Class (which have an 8-inch diameter) and the 598 Class (which are 7½ x 12 inches). The oldest SSNs (578 and 585 Classes) have fairleads of insufficient strength for towing. For these submarines, either the towing pendant will have to be centered laterally by using the mooring cleats or an alternative tow connection will have to be made. For all other submarines, the fairlead can and should be used. The smaller fairleads must be checked carefully to confirm that towing jewelry and chafing chain will pass through the small dimensions provided.

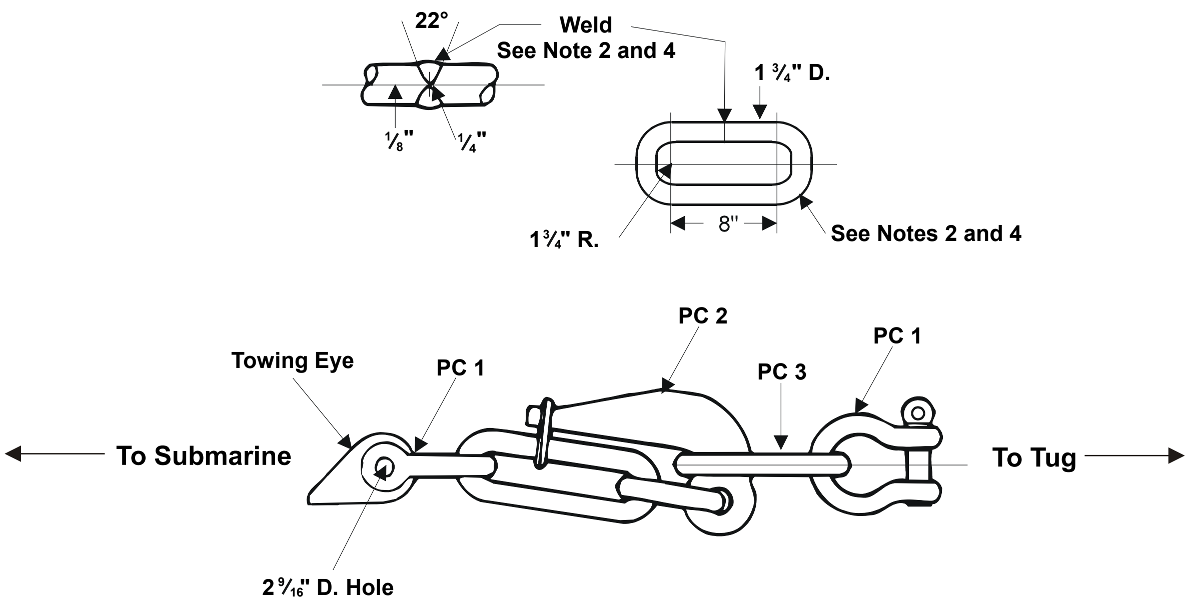
Submarine capstans are designed to handle mooring lines and can withstand the breaking strength of the mooring lines. The capstan can be used, with caution, as an emergency towing connection if a tow pad is not available. The capstan, however, is neither powerful nor fast. It will generally provide a 3,000pound pull at 40 fpm and a 4,500-pound pull at creep. Accordingly, the capstan will be of little use in passing the tow hawser. The tow ship should plan this procedure to minimize the use of the submarine's capstan.

J-1.2 The Towing Rig

CAUTION
In operating the Liverpool Bridle, limit the tension to the safe working load of the bridle's 1 5/8-inch wire rope pendant.

Table J-1. Towing Arrangement for Higher-Population Submarine Classes.

Ship/Class	Designed Tow Arrangement (See Text Caveats on Use)	Tow Point Location /Strength (SWL)	Fairlead Chock Size/Strength (SWL)	Capstan Location, Linepull, Max Pull, Structural Strength	Anchor Location, Anchor wt. Chain size
TRIDENT SSBN 726 Class	Cleats - 2" wire bridle including coupling for 450' x 8 1/2" DB nylon hawser. Note: entire tow Rig stored ashore.	FR 15 P/S 70,000 lbs (ea)	Aft only 5.5" x 11" 70,000 lbs	Forward. Only 3000 lb /40 fpm 4500 lb max 70,000 lbs	Aft 4600 lbs 1" chain
SEAWOLF SSN 21 Class	Onboard Emergency Towing Pendant - 1.125" chafing chain, and 1.25" wire rope with two NATO standard links concealed in trough with ready access on port side of sail. Cleats - 1 5/8 " wire bridle including flounder plate provided by the tug.	FR 12 Port FR 16 Stbd 70,000 lbs (ea)	Aft only 5.5" x 11" 140,000 lbs	Forward. Only 3000 lb /40 fpm 4500 lb max 70,000 lbs	Aft 1985 lbs 7/8" chain
LOS ANGELES SSN 688 Class	Cleats - 1 3/8" wire bridle, pelican hook, 31' x 1 3/8" chafing pendant, coupling for 450' x 5" DB nylon hawser. Towing gear carried aboard.	FR 21 P/S 70,000 lbs (ea)	Aft only 5.5" x 11" 70,000 lbs	Forward. Only 3000 lb/40 fpm 4500 lb max 70,000 lbs	Aft 2800 lbs 3/4" chain
STURGEON SSN 637 Class (SSN 671 and 685 have similar tow arrangements)	Padeye - fairlead chock 1 7/8" pelican hook with 1 3/4" screw pin anchor shackles and link. Towing gear may be carried aboard.	FR 27 (at sail) 47,000 lbs	Fore and aft 10.5" x 16.5" 47,000 lbs	Fore and aft 3000 lb/40 fpm 45000 lb max 25,000 lbs	Aft 2800 lbs 3/4" chain
LAYFAYETTE SSN 616 Class	Two Baxter Bolt type padeyes, 1" wire bridle legs, each with pelican hook plus flounder plate. Some ships have arrangements similar to SSN 637 CL.	FR 43 50,000 lbs (ea)	Fore and aft 10.5" x 16.5" 50,000 lbs	Fore and aft 6,000 lb/40 fpm unspecified max 36,000 lbs	Aft 2800 lbs 1" chain
PERMIT SSN 594 Class	Padeye, pelican hook and Clevis.	FR 18 (at forward escape hatch) 47,000 lbs	Fore and aft 8" dia 47,000 lbs	Fore and aft 3000 lb/40 fpm 4500 lbs max 25,000 lbs	Aft 2800 lbs 3/4" chain



Arrangement of Towing Gear

NOTES:

1. PC 1 TO BE SIMILAR TO FIG. 6–208 NO. 950–2 OF CROSBY-LAUGHLIN CO., FORTWAYNE, INDIANA OR EQUAL.
2. PC 3 TO BE FORGED AT 2000–2200ºF AND COOLED SLOWLY. PREHEAT TO 400–600ºF BEFORE WELDING. WELDING TO BE FINISHED BEFORE HEAT TREATMENT.HEAT TREAT TO 1525–1575ºF. QUENCH IN OIL AND TEMPER AT 1200ºF TO GIVE PHYSICAL PROPERTIES AS FOLLOWS:
   - TENSILE STRENGTH – 125,000 MIN.
   - YIELD STRENGTH – 95,000 MIN.
   - ELONGATION IN 2" – 16% MIN.
3. PROOF TEST ASSEMBLY TO 80,000 LBS.
4. LINK PC 3 TO BE WELDED WITH ELECTRODE TY NT 4140 OF MIL-E-88979.
5. GALV PC 3 TO SPEC ASTM/A 153.
6. BEFORE GALV AND AFTER PROFF TESTING PC3 SHALL BE MPI INSPECTED.

Piece #	Name / Dimensions
PC-1	Shackle – Anchor, Screw Pin, 1-3/4"
PC-2	Pelican Hook 1-7/8" Stock, For 1-1/4 Wire
PC-3	Link 1-3/4" x 15

WARNING

Do not use this towing rig for ocean tows. Screw pin shackles should never be used in ocean towing.

Appendix Figure J-1. SSN 637 Class Towing Gear (Harbor Towing Only)

Most of the submarines in this group carry designated towing gear onboard. In general, this gear includes shackles, a pelican hook, and a wire chafing pendant of 1-inch diameter or larger. See Appendix Figure J-1 which is adapted from a typical submarine towing plan. The proof test of the rig is 80,000 pounds. This towing rig is designed for short intra-harbor tows. It should not be used for planned open-ocean towing. The shackles shown in the submarines towing plans are 1¾-inch screw-pin anchor shackles. Do not use these shackles for towing. Use only comparable safety shackles. Note that the standard tow pad will accept the pin of a standard 2-inch safety shackle. The tug should provide more robust gear if time permits.

J-1.3 Chafing Pendant

The submarine's own towing rig may include a short wire chafing pendant. It may be only a 3/4-inch or 1-inch pendant, however, and may not provide adequate chafing protection for a long-distance, deep-catenary tow, especially in the fairlead chock. The tow ship should provide its own chafing pendant of sufficient length to make the final connection to the tow hawser on the fantail of the tow ship. The pendant should be made up to include a short length of chain to ride in the fairlead chock for chafing protection.

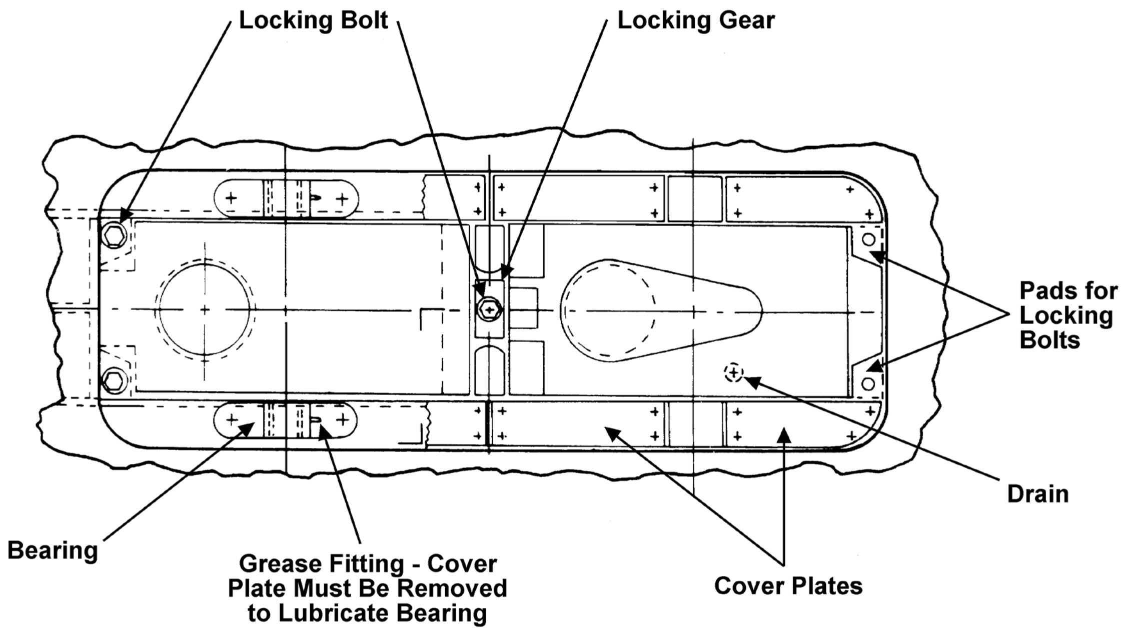
Some submarines may carry a 450-foot, 5-inch circumference nylon tow hawser. This hawser is not recommended for use when a tow ship can provide longer or heavier gear. In this regard, note the current limitations on the use of synthetic towing hawsers discussed in Appendix C.

J-2 SSN 688 Class Submarines

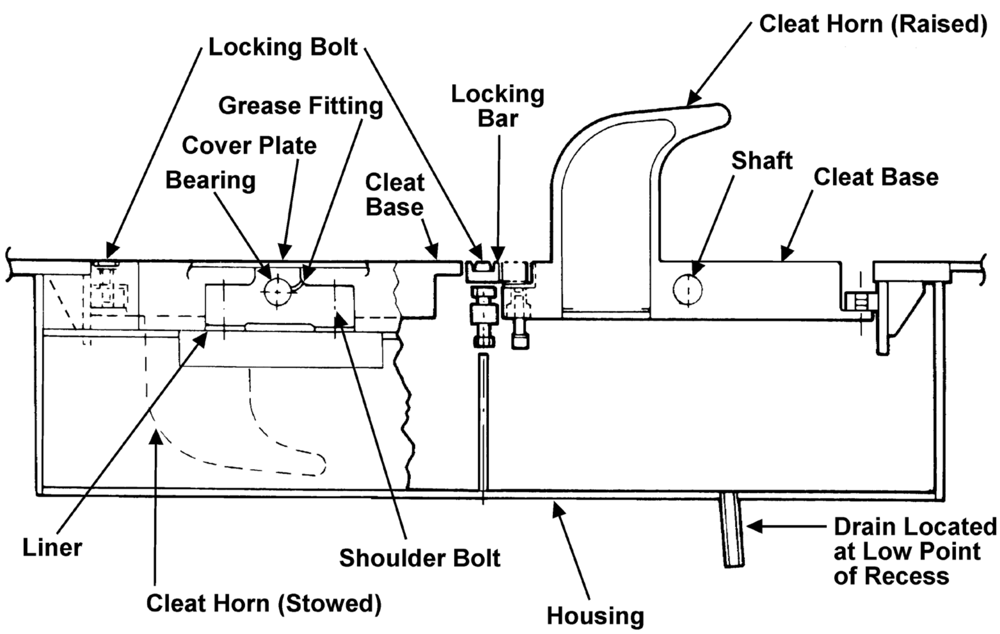
Submarines in the SSN 688 Class have no tow pads or forward fairleads. There is a small 5 ½-inch x 11-inch fairlead aft. The ship is designed to be towed using a bridle attached to the forward pair of hinged mooring cleats. Each cleat has a safe working load of 70,000 pounds. Appendix Figure J-2 is a diagram of a hinged cleat and Appendix Figure J-3 is a schematic of the towing rig carried onboard the SSN 688 Class. It requires modification for use in open-ocean towing.

The bridle is made up of two 15-foot lengths of 1 3/8-inch, 6 x 37 galvanized IPS steel wire. The chafing pendant is 31 feet of 1 3/8-inch wire and the intended towing hawser is 450 feet of 5-inch circumference double-braid nylon with a 5 1/2-inch rope coupling at each end. As noted previously, neither the intended pendant nor the hawser is recommended for ocean towing of this submarine. The tug should provide a 1 5/8-inch chafing pendant of sufficient length to make the hawser connection on its own fantail.

Use of the 1 3/8-inch bridle provided for this submarine is acceptable for towing this class. The soft eyes in the bridle legs must be appropriately lashed to ensure that they do not jump off the cleats. Use of a pelican hook is not recommended for ocean tows unless a quick release is mandatory. If a pelican hook must be used, it should be installed such that the jaw will open away from the submarine (towards the tug) if released in an emergency (see Appendix Figure J-3 for proper configuration).

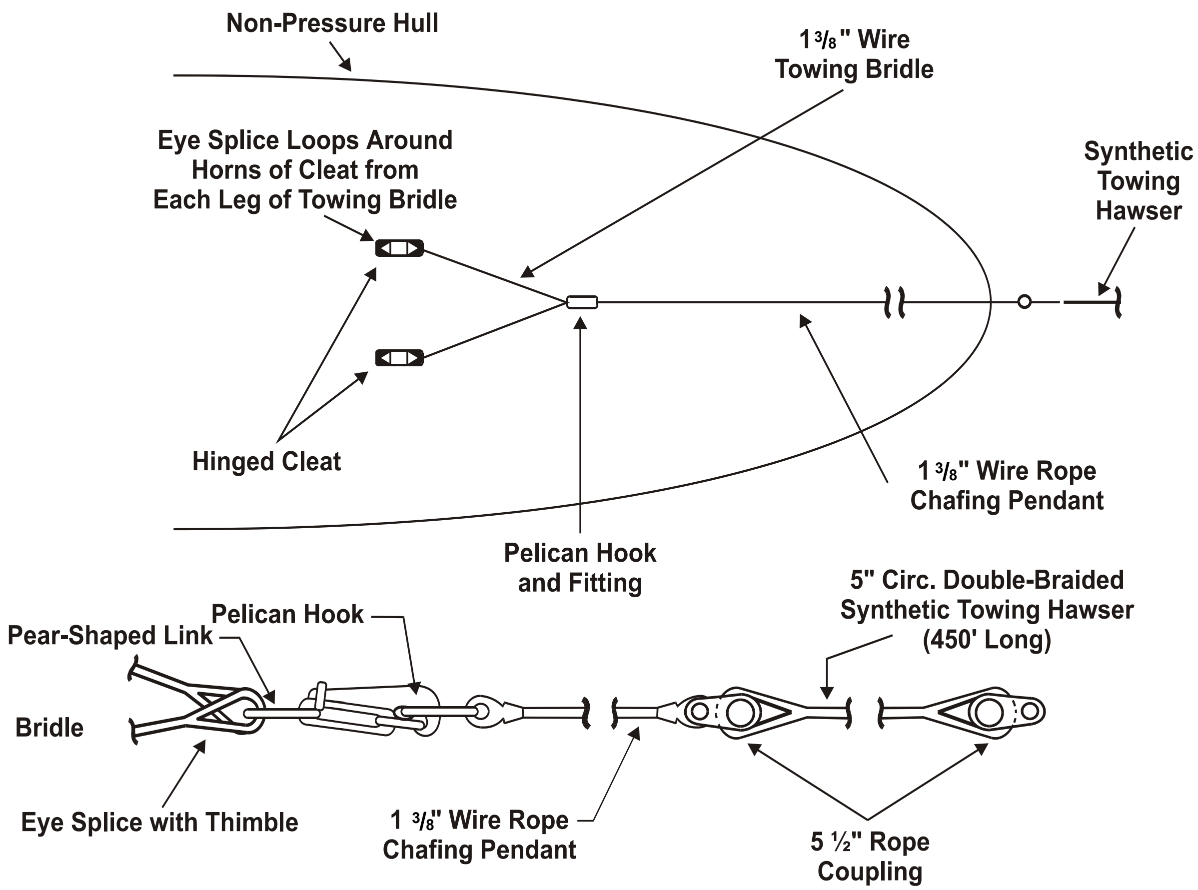


Plan View



Section View

Appendix Figure J-2. Hinged Cleat for SSN 688 Class.



Appendix Figure J-3. Towing Gear Arrangement for SSN 688 Class (Harbor Towing Only).

J-3 SSBN 726 Class Submarines

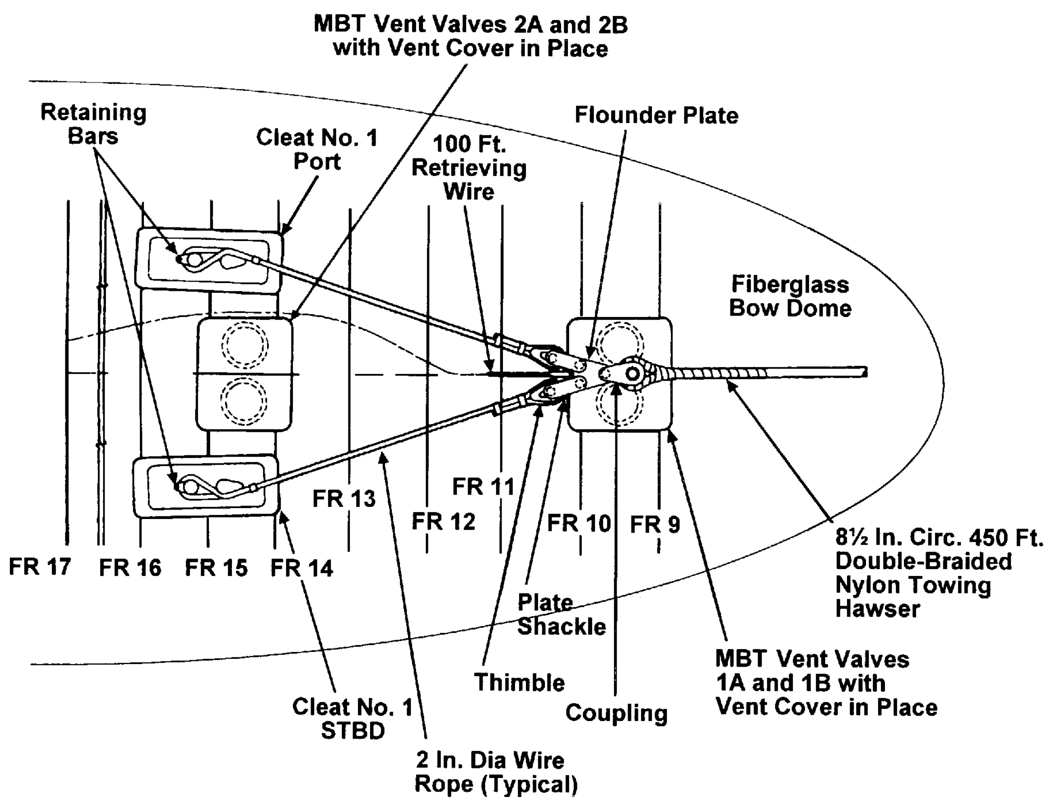
These large submarines, like those of the SSN 688 Class, are designed to be towed with a bridle attached to the forward-most pair of mooring cleats (see Appendix Figure J-4). This bridle is more robust than the bridle used on other submarines, but it is **not** carried onboard the submarine. The bridle and associated hardware is stored at Trident Refit Facilities.

Appendix Figure J-4 shows two 14-foot, 2-inch diameter wire bridle legs with soft eyes for connecting to the cleats. Unless the tow originates at a Trident Refit Facility, where the designed towing rig is stored, this bridle may not be available. If an SSBN 726 Class must be picked up in an emergency, the tug can easily make up its own bridle rig using equal length legs of at least 1 5/8-inch diameter wire, safety or plate shackles and a flounder plate. **The chafing pendant should be at least 1 5/8-inch wire, although heavier wire is preferred.** The pendant should be long enough to permit connection to the main tow hawser onboard the tow ship.

Because of the weight of the towing gear, a retrieving wire (100 feet of 5/8-inch wire) is recommended, as shown in Appendix Figure J-4.

The retrieving wire will reach the capstan 32 feet aft of the cleats for rigging purposes. Otherwise, the retrieving wire is secured to the No. 2 set of mooring cleats in such a way as to preclude it from being placed under strain under any possible towing bridle orientation.

To prevent damage from the flounder plate, the No. 1 and No. 2 main ballast tank vent covers must be installed prior to rigging the SSBN 726 Class for tow.



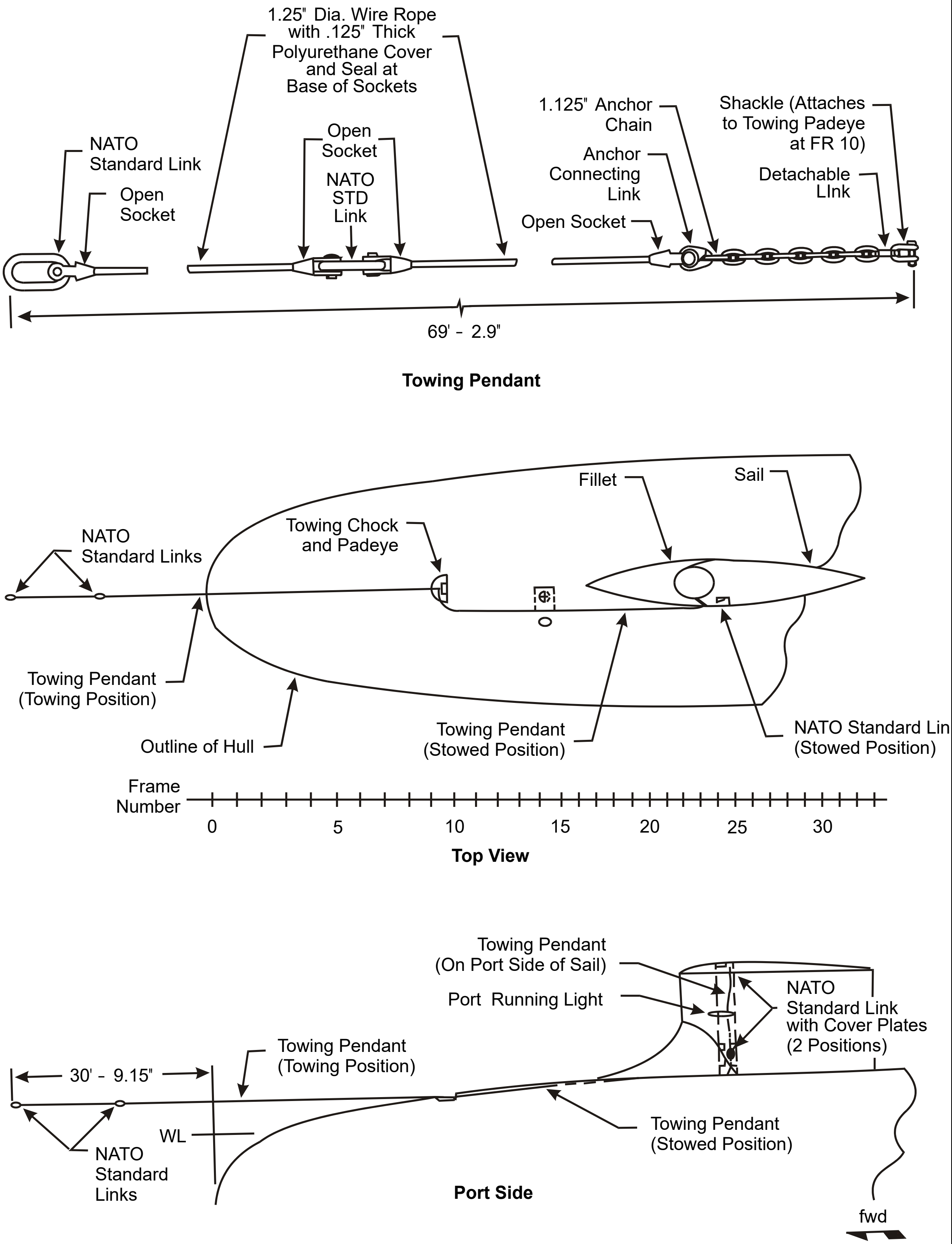
Appendix Figure J-4. Towing Arrangement for SSBN 726 Class.

J-4 SSN 21 Class Submarines

These large submarines have an on board emergency towing pendant designed for emergency towing.

The emergency towing pendant assembly consists of a towing padeye, towing chock, chafing chain, wire rope and sockets, and two North Atlantic Treaty Organization (NATO) standard links. An intermediate fitting in the towing pendant is four feet above the hull on the port side of the sail at frame 24 where the pendant is stowed and faired to the sail. This fitting, consisting of a NATO standard link, allows a towing line to be attached. The entire towing assembly is normally not visible. It is stowed in a trough, covered with Neat Dura-1 material and faired to the hull and sail. See Appendix Figure J-5 for emergency towing pendant assembly details.

Under certain conditions, the ship may be towed using a bridle attached to the forward pair of hinged mooring cleats. Each cleat has a safe working load of 70,000 pounds. The towing ship can easily make up its own bridle using appropriate lengths of at least 1 5/8-inch diameter wire, safety or plate shackles, and a flounder plate. **The chafing pendant should be at least 1 5/8-inch wire, although heavier wire is preferred.** The pendant must be long enough to permit connection to the main tow hawser onboard the tow ship.



Appendix Figure J-5. Emergency Towing Pendant Assembly for SSN 21 Class.

Appendix K - COMMERCIAL TUG CAPABILITIES

K-1 Introduction

This appendix addresses considerations and features of commercial oceangoing tugs, both foreign and domestic, that may be called upon for planned or emergency use by the U.S. Navy. It provides information to assist towing planners and to encourage careful selection of commercial tugs to fulfill Navy requirements.

K-2 Tug Characteristics

This section addresses features of ocean-going tugs, with emphasis on salvage tugs. This is not to suggest that other types of tugs are not capable of safely executing assigned tasks. In fact, specialized tugs are usually more economical to hire than fully equipped and fully manned salvage tugs. The salvage tug is used here, however, as the benchmark by which to compare others, since it is the most versatile type of tug.

K-2.1 Salvage Tug Attributes

Salvage tugs are large, powerful, and extremely seaworthy tugs. They can perform many different tasks and carry a wide variety of equipment and material as well as a relatively large crew. They have the crews and equipment to execute salvage tasks and the high power needed to refloat stranded vessels. They are excellent in rescue missions; they possess sufficient speed to reach the casualty promptly, the extra manpower and gear to make the tow connection under strenuous conditions, and the power to tow the casualty to safety. Finally, salvage tugs have the power, stores, and fuel capacity to make them excellent for long-distance tows of large ships and heavy objects. In terms of capital cost and operating expenses, each of the three salvage tug missions—salvage, rescue, and towing—could probably be accomplished more economically and efficiently by a tug specializing in only one of these areas. No other type of tug, however, can fulfill all three missions, under all kinds of circumstances, as well as the salvage tug.

Not surprisingly, the lines separating the classes of tugs are sometimes blurred by overlapping design features, and often by what owners choose to call their tugs. There is no universal acceptance of any particular salvage tug description. In fact, few owners actually refer to their salvage tugs as such, preferring simply to list them as “tugs.” Some that are called “salvage tugs” may be low-powered vessels intended for support of salvage operations, often inshore, and would be totally unsuited for a rescue mission, long ocean tow, or stranding on an unprotected shore.

The problem of identifying tugs by type is further complicated by the advent of many high-powered but very specialized support craft involved in the offshore oil industry. Consequently, there are anchor-handling tugs, supply tugs, and anchor-handling/supply tugs. These can be useful in an emergency situation, but may have minimum crew sizes, limited cruising range, and a lack of the wide assortment of gear useful in rescue towing or salvage.

The following sections describe the attributes of salvage tugs.

K-2.1.1 **Length**

Length is a major contributor to seaworthiness and provides for good arrangements and ample storage for crew, stores, and equipment. Length promotes efficient free-running speed. The disadvantages of incremental length are higher construction cost and less maneuverability. Salvage tugs generally exceed 200 feet in length.

K-2.1.2 **Draft**

Draft promotes seaworthiness and directional stability against off-center towing forces and provides for efficient propeller, design, and placement. Salvage tugs, however, must work in shallow water around strandings, so their drafts must be compromised. Salvage tugs generally have drafts of 16 to 20 feet.

K-2.1.3 **Freeboard/Depth**

High freeboard forward improves seaworthiness. Freeboard aft is a compromise between the desire to provide a work space that is safe and dry versus one that is located conveniently close to the work site, which is often near the waterline.

K-2.1.4 **Beam**

Beam improves stability, provides the internal volume for storage and other functions, and promotes efficient work spaces. Too much beam, however, handicaps free-running speed and increases fuel consumption. Salvage tug beams are 45 feet or more.

K-2.1.5 **Crew**

The crew of a salvage tug is significantly larger than the crews of other tugs. Commercial salvage tug crews vary from 15 to 25. Less tangible is the experience level of the crew. The best salvage and towing people often gravitate toward the salvage tugs; man-for-man, the experience level is often superior in these ships.

K-2.1.6 **Towing Equipment**

Some salvage tugs have automatic towing machines. Most commercial salvage tugs have at least an automatic rendering winch. This is an important clue to the capabilities of salvage tugs. Appendix L has a more complete discussion of towing machines and winches. Section 42 discusses strength of towing hawsers and related equipment.

K-2.1.7 **Power**

Power is obviously a critical attribute for tugs because it provides for prompt transit to the location of the casualty, assists in refloating the stranded ship, and facilitates towing the casualty. The citation of horsepower rating for tugs varies; this must be understood to make valid comparisons between tugs. This subject is addressed in Section K-2.2.

K-2.1.8 **Bollard and Towline Pull**

Bollard and towline pull are measures of maximum pull while dead in the water and available pull when the tow is underway. These attributes are also discussed in Section K-2.2.

K-2.2 Power, Bollard Pull, and Towline Pull

Towing is a very competitive endeavor, with business often sold on the basis of tug power. Custom, along with regional differences, dictates different methods for reporting a tug's attributes, as described below.

K-2.2.1 **Power**

The power of a tug can be quoted in shaft horsepower, horsepower, indicated horsepower, or kilowatts, as follows:

Shaft Horsepower (shp) is the power delivered to the propeller. Generally, only Navy tugs use shaft horsepower to describe their power; this, however, is the truest measure of power delivered by the tug.

Horsepower (hp) is generally the brake horsepower (bhp) of the tug's propulsion engines—that is, the power delivered at the engines shaft (not propeller shaft). This description ignores the reduction gear and propeller shaft losses, which may be considerable. Most American owners and the worldwide offshore oil industry use horsepower to describe their tugs. Some foreign ship-owners use kilowatts as units of power. Kilowatts (1 kW = 1.341 hp) may be assumed to be measured at the engine.

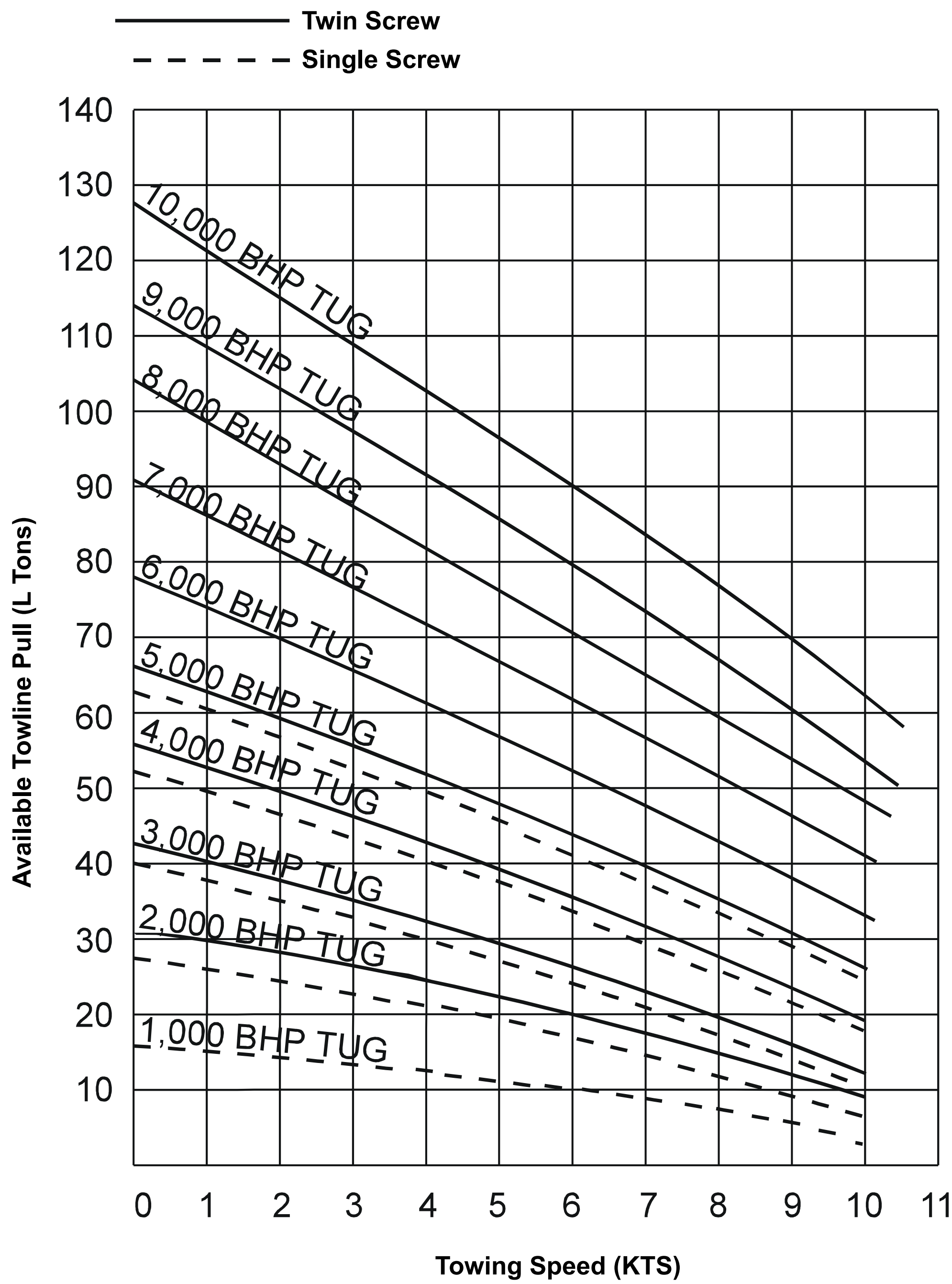
Indicated Horsepower (ihp) originates from the days of reciprocating steam engines and ignores heat, friction, valve, and engine-driven auxiliary losses within the engine. Furthermore, some owners may add the generator engines and thruster power to the total, so indicated horsepower may exceed horsepower by a factor of 1.2 to 1.6 or more. Of course, an owner reporting in horsepower also may add generators and other power sources or users to the total. Most European and Asian salvage operators report tug power in indicated horsepower and are reluctant to report otherwise for fear of losing a competitive advantage. It has been noted, however, that more owners are now reporting in kilowatts to avoid the confusion between horsepower and indicated horsepower.

K-2.2.2 **Bollard Pull**

Bollard pull is the zero speed pulling capability of the tug. It is a measure of the usefulness of the ship in a stranding scenario or in holding a large tanker or aircraft carrier off a lee shore. Keep in mind, however, that bollard pull figures, like horsepower, may be open to interpretation.

Ideally, bollard pull is tested when a tug is built and certified by one of the classification societies. Bollard pull tests are also sometimes performed after major engine overhauls. Tug owners whose tugs have been tested usually provide a copy of the certificate attesting to the bollard pull figure.

Bollard pull, like horsepower, is a selling point for tugs and is sometimes overstated. For instance, there are rules of thumb for converting propeller power (shaft horsepower) to bollard pull, such as one ton pull per 100 horsepower for a conventional propeller or 1.2 to 1.5 tons pull per 100 horsepower for a propeller fitted with a nozzle. The owner may save the cost of a bollard pull test and simply apply one of the factors to convert propeller power to bollard pull without ever knowing what the real figure is. It is unlikely that the owner would ever select a conservative conversion factor.



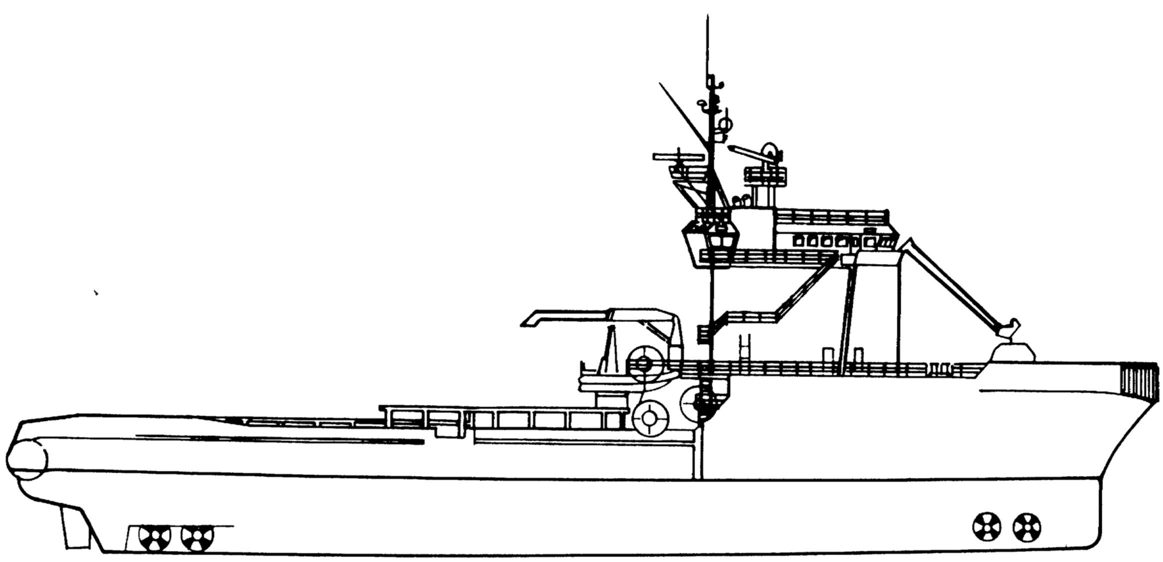
Appendix Figure K-1. Towline Pull vs. Towing Speed for Tugs with Controllable-Pitch Propellers and Nozzles.

European owners generally report bollard pull in their literature and reputable salvage tug owners are generally able to produce a certificate to document the test. American owners and the worldwide offshore oil support industry, on the other hand, rarely report bollard pull. When they do, the figure may not have been validated by a test. Horsepower is probably a more reliable measure among ships of these types.

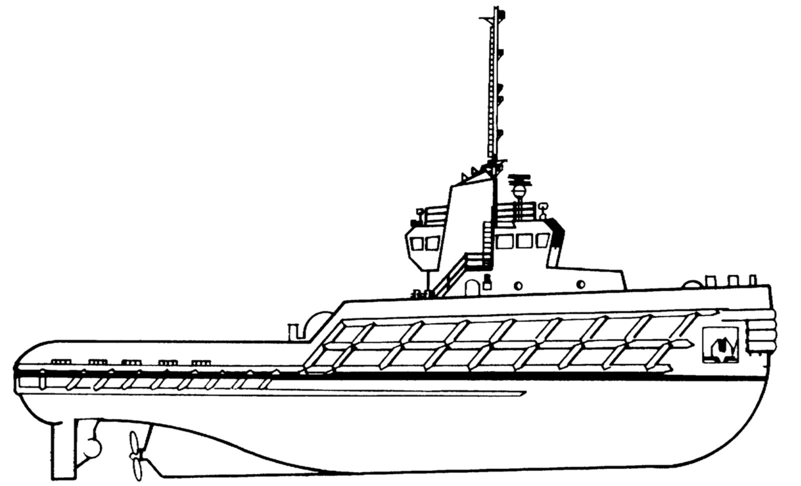
K-2.2.3 Towline Pull

Bollard pull is not the only useful measure of the pulling capability of a tug. Except in stranding cases, the objective of the tug is to move its tow. In towing, some of the tug's power is spent on overcoming the hull resistance of the tug itself and some is spent on the hydrodynamic resistance of the towing hawser. Bollard pull can be maximized by propeller and nozzle design, but only at the expense of towline pull at towing speeds. This adversely impacts free-running speed and fuel usage. Most tug designs, however, are optimized for towing.

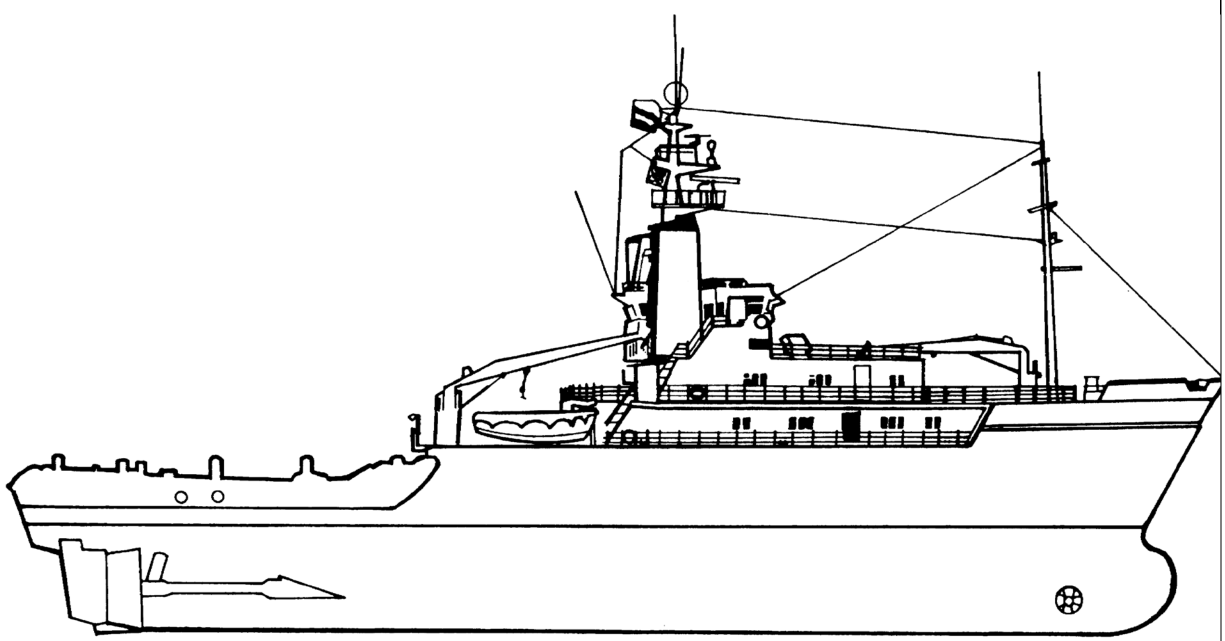
Tugs are generally expected to operate in the 4 to 8 knot speed range. Modern tugs usually use advanced propeller designs so that bollard pull still is quite high, but tug speed and fuel consumption are significantly reduced. A tug optimized for rescue towing, on the other hand, would probably not employ nozzles, being more concerned with high speed running to the casualty than in efficiency of the tow itself. Appendix Figure K-1 displays towline pull vs. speed for typical tug designs using controllable-pitch propellers turning inside nozzles. The figure is adapted from Blight and Dai, Resistance of Offshore Barges and Required Tug Horsepower, OTC 3320, 10th Offshore Technology Conference Proceedings (Ref. AE).



Appendix Figure K-2. Anchor-Handling/Supply Tug.



Appendix Figure K-3. Point-to-Point Towing Tug.



Appendix Figure K-4. Salvage Tug.

K-2.2.4 **Maneuverability**

Tugs are available with both ocean-going towing capabilities and enhanced maneuvering characteristics. Examples of these are tugs equipped with azimuthing Z-drive propulsion or Voith propulsion systems. The azimuthing Z-drive propulsion is trainable through 360 degrees and can be positioned in the hull during design to provide either a stern drive or a tractor tug. A tug such as Point Chebucto has two azimuthing stern drive units with a reported bollard pull of 64 tonnes and a speed of 12 knots.

The Voith-Schneider propeller generate thrust at right angles to the axis of rotation which, through control of the angle of attack of the vertical propeller blades, can be directed through 360 degrees thus acting as both propeller and rudder. This permits abandoning the conventional stern propulsion position and allows placing the propeller at the point of best interaction between the vessel, propeller, and towing. With the Voith-Schneider in the forebody there is free inflow and outflow in all directions and thrust forces act ahead of the vessel pivot point.

The main point of this discussion is that a tug should be considered as a balanced design, with some tugs being more suitable for some types of tasks than other tugs. This point applies to the task as well. Chartering a 20,000-ihp salvage tug to tow a 200foot barge would be just as inappropriate as sending a 5,000-hp platform supply ship, with no tow hawser or winch, on a rescue tow mission.

K-3 Ocean-Going Tugs for Hire

This section provides sample specifications for typical oceangoing tugs and statistics on the number of tugs available for hire.

K-3.1 Ocean-Going Tug Examples

Appendix Figures K-2 through K-4 are drawings of typical salvage tugs, point-to-point towing tugs, and anchor-handling/supply tugs. Table K1 provides data on these and other tugs.

Table K1. Typical Commercial Salvage/Towing Vessels for Hire Compared with US Navy Salvage Ship.

Name	USS Safeguard	Atlantic Salvor	Fotiy Krilov	Baraka II
Type	USN Salvage and Rescue	Towing and Salvage	Salvage	Salvage
Year	1985	1975	1989	1994
LOA (ft)	225	254	321.5	227
Beam (ft)	51	43.25	64	51
Draft (ft)	15.5	21.5	23.5	24.25
Horse Power	4200	8800	24482	16000
Bollard Pull (tons)	54	127	250	161
Max Speed (kts)	13.5	16	18	17

Name	Smit Singapore	Otto Candies	Star Sirius	Salvigour
Type	Towing and Salvage	Anchor Handling	Anchor Handling	Salvage
Year	1984	1985	1985	1990
LOA (ft)	247	140	213	218.1
Beam (ft)	50.1	42	47.5	48.2
Draft (ft)	25	20.1	24.5	20.7
Horse Power	13500	7200	9180	6600
Bollard Pull (tons)	188	100	112	110
Max Speed (kts)	13	14	12	16

K-3.2 Decline in Salvage Tug Availability

Traditionally, salvage and towing companies maintained their best ships “on station” waiting for a casualty to occur. The “station” could be a semi-permanent strategic location such as Jamaica, Gibraltar, Aden, or Singapore, with backup by a shore base, or a seasonal location such as the North Sea in winter or the Cape of Good Hope during the Southern Hemisphere’s winter. Work was contracted on the well-understood Lloyd’s Open Form “No Cure—No Pay” terms, and usually went to the first tug to arrive.

Several factors have led to the decline of the traditional “fire house” nature of the salvage and towing business. To list a few:

- Improved navigational aids resulted in fewer casualties.
- The advent of large offshore oil structures and VLCC and ULCC tankers required construction of large, very powerful, and expensive salvage tugs.
- Increased ship size resulted in fewer ships to potentially suffer casualties. Furthermore, since fewer ships were operating, marginal operators and crews were gradually forced out.
- Crews demanded improved habitability, working conditions, and wages.
- The worldwide reduction in oil consumption caused a reduction in shipping and, therefore, casualties, in the early 1980s.
- Owners of casualties tended to avoid the “no cure—no pay” contract in favor of more price competitive bidding. This placed the traditional salvage tug operators at a disadvantage because of their higher equipment, labor, and standby costs.

Consequently, tug owners sought routine, long-distance towing tasks to keep their expensive assets at work. Others laid up their ships or went out of business. Consequently, “stand-by” assets were greatly reduced.

K-3.3 Availability of Ocean-Going Tugs

A 1996 survey reported 221 tugs and 841 supply tugs having 1,000 brake horsepower (bhp) or greater. Of these, 97 tugs and 52 supply tugs claim 6,000 to 10,000 bhp and 18 tugs and 2 supply tugs are listed at over 10,000 bhp. The total numbers are probably understated, since some well-known salvage/towing firms are not listed in the survey and only a few former Communist bloc ships listed. On the other hand, the ships were listed as reported by the owners, without comment. Many of the smaller, less-powerful tugs are unsuited for any but the most benign tows. In addition, many quite powerful tugs, in the 4,000- to 8,000-ihp range, are well under 150 feet in length. The ships are optimized beautifully for point-to-point towing but may be handicapped seriously in a rescue tow scenario under strenuous sea conditions. Again, tugs must be matched to particular missions very carefully.

K-4 Obtaining Tug Assistance

This section provides guidance in obtaining commercial tug assistance.

K-4.1 Emergency Tug Assistance

Since a Navy ship requiring emergency towing assistance communicates with its operational and administrative superiors by designated means, it is helpful (subject to security restrictions) to query the UHF and VHF emergency channel frequencies to determine if competent assistance is available close by. Salvage tugs always monitor the distress frequencies; most other tugs monitor these channels frequently. Availability information along with pertinent data on the tug and its owners, is useful to the operational superiors in resolving the problem.

K-4.2 Restrictions in Contracting

U.S. Navy ship Commanding Officers are not authorized to commit the U.S. Government to indefinite obligations or claims. A Lloyd’s Open Form contract requires arbitration in, and is subject to, the laws and courts of Great Britain. The United States will not permit itself to be subject to such requirements. Furthermore, even a per diem (fixed rate) salvage contract involves an indefinite value. The net result is that the Commanding Officer of a U.S. Navy ship is severely restricted in contracting for emergency assistance.

K-4.3 Contracting for Emergency Commercial Towing Assistance

If Navy towing assets are not available, the appropriate superior in the chain of command can arrange for emergency commercial towing assistance in two ways:

- Contacting the cognizant U.S. Government procurement office. This office can provide data on potential nearby assistance and arrange for an appropriate per-diem-type contract with the tug's owners, who will immediately advise the tug.
- Contacting the U.S. Navy Supervisor of Salvage (Director of Ocean Engineering NAVSEA 00C) by message (COMNAVSEASYSCOM WASHINGTON DC/00C) or by telephone at (202) 781-1731 (DSN 326-1731).

NAVSEA 00C can be reached 24 hours a day through the NAVSEA Duty Officer at (202) 781-3889 (DSN 326-3889). SUPSALV maintains standing salvage contracts that can respond immediately worldwide. Frequently, the Navy salvage contractor subcontracts with the most appropriate salvage/towing firm anywhere in the world. Thus, an available commercial tug can be directed to provide emergency assistance with very little delay and without subjecting all parties to protracted legal efforts after the fact.

K-4.4 Arranging for Routine (Non-Emergency) Tows by Commercial Tugs

The tow planner will normally request the tow from the appropriate Navy operational Surface Force Commander, who will arrange for a U.S. Navy or Military Sealift Command tow. If neither is available, the tow should be arranged through the local supply/procurement agency. In the latter case, if tows are arranged infrequently, or the tow is technically unusual, obtaining advice/assistance from SUPSALV is recommended.

Appendix L - TOWING MACHINERY

L-1 Introduction

For the purpose of tow planning, this appendix provides a brief overview of the different types of towing machinery installed in U.S. Navy tugs and towing ships. It describes the capabilities and limitations of the towing machinery in these ships. This appendix is not a substitute for specific design or operating data contained in the technical manuals for the equipment installed in any given ship.

This appendix addresses the machinery used in classic towing arrangement where the tug is attached to the tow by a fiber or wire hawser. It does not address tug-barge combinations (where the tug is mechanically attached to the tow).

L-2 Background

Because the primary mission of a tug is towing, the towing machinery must be carefully selected, designed, operated, and maintained. The value of the towing machinery cannot be underestimated. This point is supported by the president of a major, privately owned European salvage and towing company who once reported that, for modern, high power tugs, the cost of the towing machinery at least equals the cost of the ship's entire main propulsion plant.

L-2.1 Terminology

Automatic towing machinery evolved from the original towing winch. Application of steam power to the towing winch resulted in frequent use of the term towing engine. Today, towing machine is the preferred term for automatic towing machinery and is the one used in the NSTM. A non-automatic towing winch is appropriately called a towing winch. The terms traction machine or traction winch are both used, depending on the number of automatic features installed.

L-2.2 Functions of Towing Machinery

All towing ships need a means for handling the towing hawser. The mechanism must be able to:

- Deploy/retrieve hawser
- Attach the hawser to the tug
- Adjust the deployed length of the hawser
- Stow the unused portion of the hawser
- Provide for quick release while the hawser is under tension
- Minimize damage and wear to the hawser while in use and while stowed.

L-2.2.1 **Attachment of the Hawser to the Tug**

Older, smaller tugs may have no more than a bollard or bitts for attaching the hawser. Smaller European tugs often use a towing hook that swivels about a strong bearing on a platform. More modern tugs generally combine the hawser securing function with the storage and/or transport system.

L-2.2.2 **Hawser Scope Adjustment**

Paying out additional line when the hawser is secured to bitts can be accomplished by hand, but at considerable personnel risk. When using a towing hook, which requires a permanent eye at the end of a hawser, paying out the line requires inserting a specific length of additional hawser. In each case, shortening the length of deployed hawser is difficult and requires power assistance if the hawser is under strain. Modern ships combine the hawser adjustment function into a powered winch traction machine.

L-2.2.3 **Storage of Unused Hawser**

On smaller, older tugs, hawsers may be simply “faked down” on deck or stored on reels, which may be powered. Since the advent of wire hawsers, larger ocean tugs generally combine the hawser securing, adjusting, and storage functions into a selfcontained winch. More recently, traction machines have been developed to overcome problems inherent in the typical winch. Two factors that led to this development are:

- The advent of very powerful tugs (10,000 hp or more) require very long, heavy wire hawsers. These ships, not yet seen in the U.S. Navy, often have two hawsers and towing machines. Each hawser may be 72 mm (27/8 inch) in diameter and up to 1800 meters (5900 feet) long. Each such hawser weighs about 38 long tons and requires a massive reel for storage that must be robust enough to withstand direct application of tensile loads. Optimal location of the towing point is at the main deck, on centerline, close to midlength of the ship. This is prime space for arrangement purposes and presents a significant drawback to stability when large weights are needlessly located at that height. Consequently, these large tugs frequently use traction machines to adjust and hold the wire, while the unused wire is stored at more appropriate locations on relatively light storage reels. These reels need only sufficient power to take up the slack between reel and traction machine. Wire hawser traction machines are similar in principle and appearance to the fiber line machines used by the U.S. Navy.
- The use of large, long, synthetic fiber hawsers. The poor compression rigidity of these hawsers precludes towing directly from a storage reel because the part of the line under tension would embed itself in the preceding layers of stored line. Furthermore, synthetic lines are relatively bulkier than wire hawsers, making reel-type storage impractical. The unused fiber hawser is generally stored in a bin or dedicated compartment, which may be adjacent to the traction machine. The traction mechanism operates on the hawser and separates the hawser’s unloaded, stored portion from its deployed, tensioned portion.

L-2.2.4 **Quick Release of the Hawser under Tension**

Emergency conditions, such as the tow’s sinking or being set toward danger, require quick release of the hawser, often while under strain. Fiber hawsers may be cut with an axe. Wire hawsers may be cut with an oxyacetylene torch or power cutters. Cutting the hawser is hazardous and may be impossible in a heavy seaway. The towing hook has an advantage in that it can be tripped, often remotely, to release the hawser. For the typical reeltype towing winch, the reel can be disconnected from the driver mechanism so that it will freewheel, allowing the hawser simply to pull itself off the reel. The bitter end of the wire is easily disconnected by the momentum of the wire coming off the reel. Traction winches can generally be disconnected the same way, but a rapidly-running, large-diameter fiber hawser presents significant hazards to personnel and equipment. Unless the bitter end of the hawser is very close to the traction mechanism, the unloaded portion of the hawser may have to be cut.

L-2.2.5 **Protection of the Hawser**

The hawser must be protected from two principal hazards. The first is damage and wear to the hawser from scuffing, abrasion, small diameter bending, crushing of stored layers under loaded turns on a reel, and adverse environmental conditions. This damage is minimized by the careful arrangement of towing machines and deck equipment. The second principal concern is protection of the hawser from overload due to surges caused by relative movements of tug and tow in a seaway. This is addressed in part by proper operating parameters (speed, scope of hawser, and course) and often by including automatic payout and retrieval features in towing machinery. Both concerns are further addressed by using towing machinery instrumentation that provides hawser tension and scope readouts. This instrumentation may operate independently of towing machinery. The next section discusses reasons for including automatic features on towing machinery.

L-3 Automatic Tension Control

This section provides a historical perspective and brief discussion of surge loading of towing hawsers and the advantages of automatic tensioning towing machinery.

L-3.1 Tow Hawsers Surge Loading

Most seamen do not perceive the surge motions of ships at sea, because there is no reference from which to measure the motion. When two ships are connected by a tow hawser, however, the effects of surge motion are quite apparent. Towing people have long been aware of the relative motion of tug and tow in ocean wave systems. For small tugs and/or tows, the hawser itself exerts considerable restraint to the motion of the ships from their completely independent states. But if the tug and tow are both relatively large, a strenuous sea state can easily impart sufficient relative motion to cause hawser failure.

L-3.1.1 **Early Automatic Towing Machinery**

Experienced tug seamen have known the dangers of load surges for at least a century. Steam power led to larger, more powerful tugs, and to the use of wire hawsers when manila hawsers grew to unmanageable sizes. As steam deck machinery was developed, it was in course applied to a winch for the towing hawser. The throttle to the winch steam engine could be cracked open (by trial and error) to provide an automatic feature to the winch. When the steam pressure behind the pistons was overcome by the tension of the hawser, the winch would pay out; likewise, slack would be taken in automatically when the load eased. Simple controls were added to quantify the set point and to limit the total amount of wire paid out, or taken in, without human intervention. Through this arrangement, large potential surges in hawser loading were significantly reduced with the “automatic” steam towing winch. This improved safety and wire wear and permitted use of more power than otherwise would have been available.

L-3.1.2 **Electric Towing Machinery**

The introduction of diesel power to large tugs in the 1930s was a major advance for propulsion power and endurance, but a setback for automatic towing machinery. The steam-powered winch was no longer an option. Electric-driven automatic towing machinery was developed, but it tended to be relatively expensive and complex. While the U.S. Navy was a leader in the use of automatic towing machinery, beginning early in World War II, much of the rest of the world returned to non-automatic towing machinery.

Arguments against the use of automatic features are often heard. Among other things, automatic towing machines are thought to be inaccurate, unreliable, too heavy, too expensive, too noisy, too complex, and impossible to maintain. Nevertheless, the arguments for automatic towing machines are compelling when one understands the magnitude of surge tensions, as described below.

L-3.1.3 **Wire Surge Example**

Section 34.2 provides data on catenaries of wire towing hawsers. As the strain increases, the catenary becomes flatter, with less “spring” available. In fact, if it were not for the stretch of the wire itself, it can be shown that a 1000foot, 2inch FC hawser, with a steady tension of 50,000 pounds, would break if the tug and tow were separated by only an additional 2 feet. Fortunately, the hawser has considerable elasticity. Figure 313 compares tug-tow separation to hawser tension for 1,000 foot and 1,800-foot hawser scopes. A 1,000-foot length of 2-inch wire, with initial tension of 50,000 pounds, will have tension increasing to the wire’s safe working limit of 187,000 pounds (.65 x 288,000) when the tug and tow are separated by an additional 9 feet, still a relatively low figure. Further stretch will permanently damage the wire, and it will break when increased separation has reached a total of 15 feet beyond the separation characterized by the 50,000-pound initial tension. The same wire, with initial tension of 100,000 pounds, can absorb increased tug-tow separation of only approximately 10 feet.

The figures for 1,800 feet of the same hawser at 50,000 pounds initial tension are somewhat more advantageous. The system can absorb 19 feet of increased tug-tow separation before reaching its safe working limit. Overall, the ability of wire hawsers to absorb changes in the distance between tug and tow is relatively limited, compared to probable ship motions under strenuous sea conditions.

L-3.2 Automatic Features on Towing Machines-General

The full-featured automatic towing can be set to maintain hawser tension within a selected range. It will pay out hawser if the hawser tension exceeds the set point, and will recover hawser when tension falls below another set point. Typically, the total amount of hawser allowed to be paid out or retracted is limited. Some towing machinery will pay out, but not retract, automatically.

L-3.3 Limitations in Quantitative Understanding

The responsiveness of actual U.S. Navy automatic towing machines to real dynamic loading of their towing hawsers is not well understood at present. The automatic payout feature does reduce the potential peak tension, but quantitative data on towing machine time constants and responsiveness need study.

L-4 Types of Towing Machines

This section provides an overview of the types of towing machines used by the U.S. Navy, with reference to other types of machines for technical interest.

L-4.1 Conventional Towing Winches and Machines

Conventional towing winches and machines, which store the unused hawser on a horizontal drum, are the most prevalent.

L-4.1.1 **Drum Arrangements**

Units may have one or two main drums; one for each hawser if there is more than one. In the U.S. Navy, two-drum units have drums side by side. Commercial tugs often have the second drum forward and above the first drum in a “waterfall” arrangement. The drums are generally capable of independent operation. They may be equipped with level wind apparatus and may be strong enough to withstand the breaking tension of the wire applied directly onto the drum. Some U.S. Navy units are equipped with one or two auxiliary drums to accommodate work on mooring lines or long target-towing hawsers.

L-4.1.2 **Drum Securing Features**

Towing hawser drums can generally be secured with a pawl or “dog.” For control, a brake system is also provided.

L-4.1.3 **Drum Prime Movers**

The more sophisticated units use DC electric motors to provide infinitely variable speed control. Some newer machines use an electro-hydraulic arrangement. These machines have a very quick response time. The double drum units may have two drive units that can be clutched separately (one to each drum) or in tandem to a single drum for increased power. Less sophisticated units have a self-contained diesel engine drive, connected through a torque converter and/or an appropriate mechanical transmission.

L-4.1.4 **Automatic Features**

The most desirable automatic feature of a towing machine is the ability to increase the hawser scope when towline tensions exceed a certain level. All machines have brake systems that will slip at some point, but the set level may not be very reliable and the drum can be locked by a dog or pawl. The next highest level of sophistication is automatic payout of the line when the tension exceeds a set level. There may be a limit on the total length of hawser permitted to be paid out automatically. Finally, the most sophisticated machines have an automatic reclaiming capability, with a limitation on the net allowable length to be reclaimed.

L-4.1.5 Instrumentation and Controls

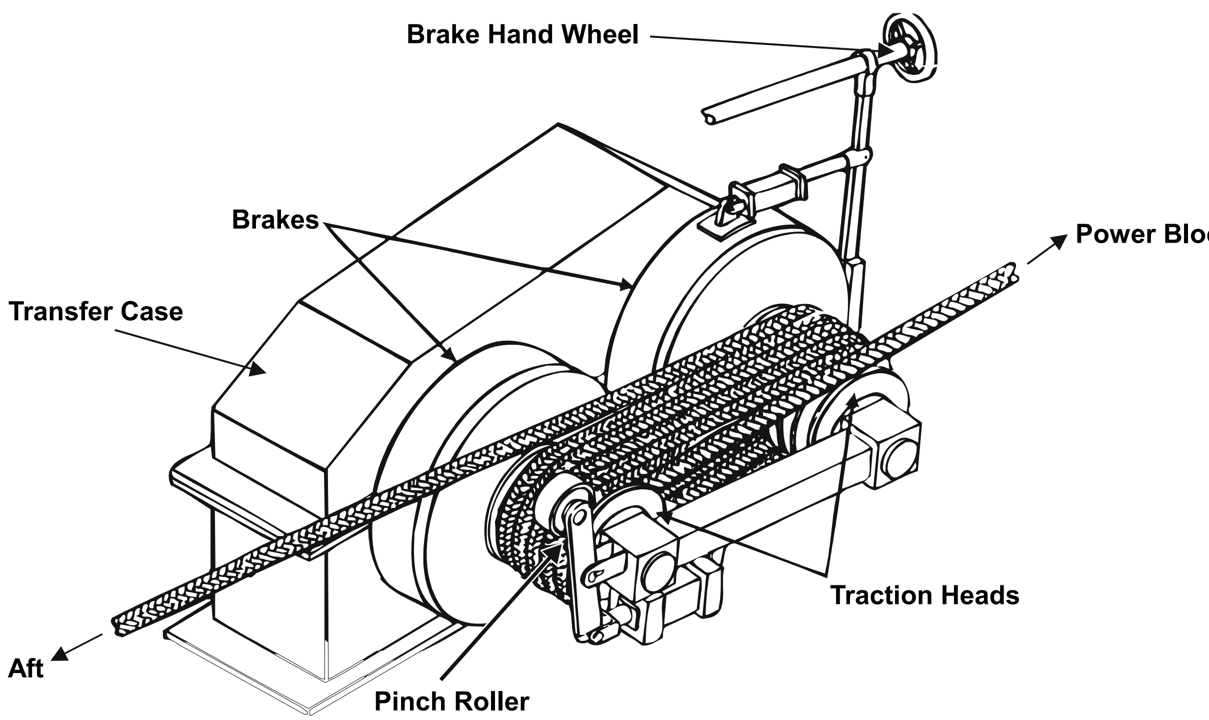
All units can be controlled locally and many have a remote operation station. Instrumentation generally includes cable tension, length of cable paid out, motor speed indicator, and automatic pay out/reclaim set points. Some of the instrumentation may be repeated on the bridge.

L-4.2 Traction Winches

In the U.S. Navy, traction winches were introduced for use with the large synthetic hawsers that gained popularity in the 1960s. Traction winches also are finding application with wire hawsers in powerful commercial tugs.

L-4.2.1 General Description

Traction winches have two parallel cylinders with grooves sized to accept the intended hawser (see Appendix Figure L-1). There are four or more complete wraps of the hawser around the two cylinders. Both cylinders are powered, to transport the hawser. The orientation of the cylinders or drums can be either horizontal or vertical. In principle, traction winches are similar to



Appendix Figure L-1. Multi-Sheave Traction Winch.

capstans. The two-drum arrangement eliminates the axial skidding of the rope inherent in capstans and provide grooved drums that improve support and reduce wear on the line.

Unlike drum-type winches, a long line can be loaded onto a traction winch at any point within its total length. This is used for mooring purposes and was the reason for their first marine use—for control of mooring lines on large ships and for Single Point Moorings used in the offshore oil industry.

L-4.2.2 **Hawser Storage**

Conventional winch designs are not used with fiber towing hawsers for two reasons—the large size required and problems inherent in wrapping and storing a tensioned, highly elastic line on itself. Storing the untensioned fiber hawser on a drum is feasible, but storage bins are universally used. The traction winch can easily pull the hawser from its storage location, via appropriate fairleads. Re-stowing the hawser as it is recovered, however, is more difficult and sometimes requires hands-on effort.

L-4.2.3 **Traction Winch Operation**

Traction winches are motor-driven and some are equipped with variable speed capability. They have brakes and clutches for control. When the clutch is released, the winch can be overhauled by the hawser to provide for free release of the hawser in an emergency. Some traction winches have an automatic tension payout capability, but automatic reclaim is rare on fiber line systems because of the hawser storage system described above.

L-4.2.4 **Controls and Instrumentation**

Traction winches have local and/or remote station controls. Most have tension readouts and some have hawser scope instrumentation (without stretch compensation). Some traction winches have end-of-hawser warning or shutdown systems.

L-5 U.S. Navy Towing Machinery Descriptions

This section provides more detailed descriptions of specific towing machinery installed on U.S. Navy towing ships. This is not a substitute for technical manuals for the specific machines. Towing machinery installed on mine warfare ships is not addressed. In the following sections, “AAJ” refers to Almon A. Johnson, Inc., a major designer and builder of towing machines.

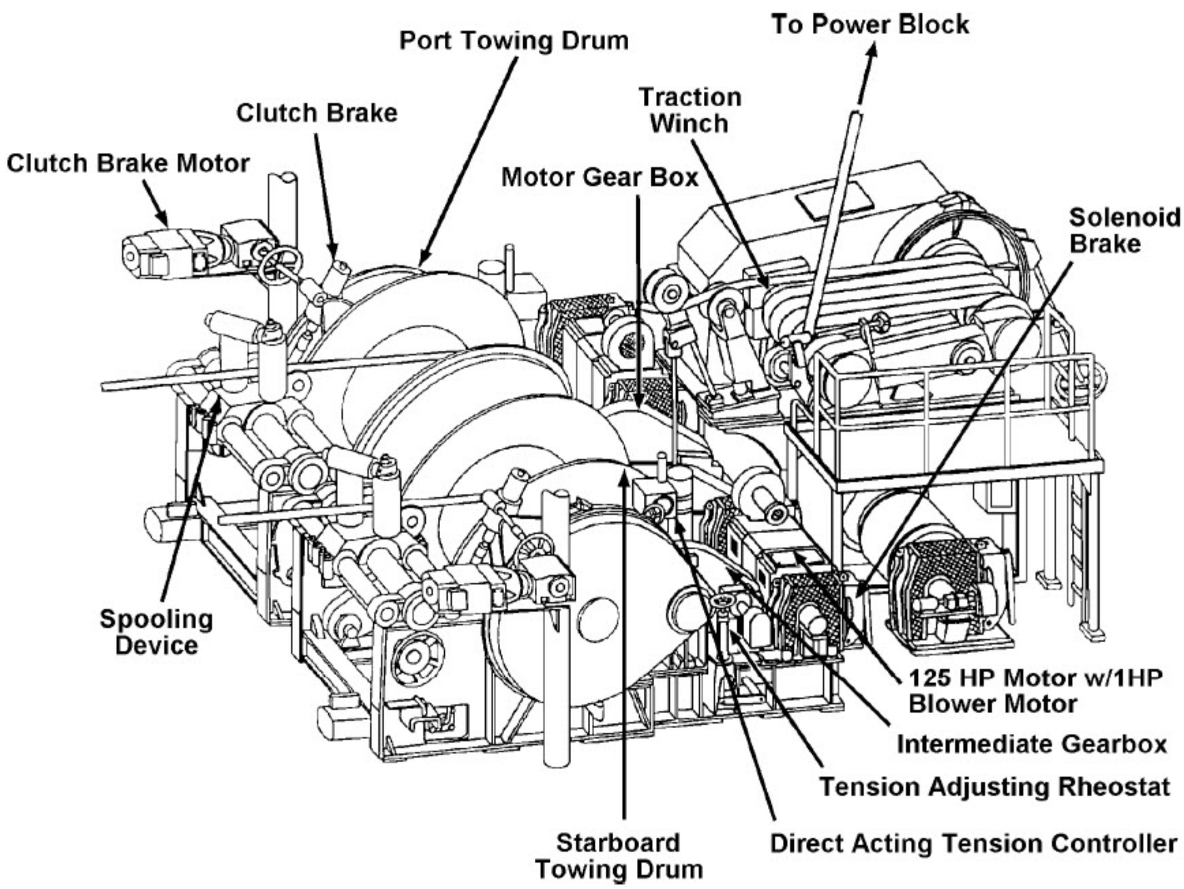
L-5.1 T-ARS 50 Class Towing Machinery

The ARS 50 Class is equipped with an AAJ Series 322 automatic towing machine which has two side-by-side main drums, each capable of spooling 3,000 feet of 2 1/4inch wire (see Appendix Figure L-2). It has level winds that can be adjusted to spool 2 1/2inch wire as well. Power is provided by two 125 hp DC electric motors, which can be connected singly or in combination to either drum. Each drum can heave a maximum 110,000 pounds at 37 fpm at an average layer. Maximum line speed is 100 fpm. Each drum can be set for automatic operation within the range of 25,000 to 115,000 pounds. Automatic operation includes payout and reclaim, with limits on maximum and minimum hawser scope.

The ARS 50 has a Series 400 traction machine located adjacent to, and forward of, the Series 322 machine. The traction winch is designed for use with 3½-inch to 14-inch circumference fiber line. It has a power block that back-tensions the line and assists in transporting the line to the storage bin. The traction winch has an automatic payout capability, with a set range of 15,000 to

110,000 pounds, but has no automatic reclaim capability. The machine requires some monitoring to control the towline tension without gradually paying out all the line, although it does have a “cable-off” device that will control the winch. Maximum heave is 110,000 pounds at 20 fpm; maximum line speed is 90 fpm.

Both machines are totally enclosed within the ship’s deck house. Normal operation is from an enclosed operating station in the aft portion of the space, which is equipped with all controls and instrumentation. Much of the instrumentation is repeated in the pilot house. Emergency shutdown controls are located in the towing machine compartment. The ARS 50 towing machine has no auxiliary drum incorporated into the design.



Appendix Figure L-2. ARS 50 Class Towing Machinery

L-5.2 T-ATF 166 Class Towing Machinery

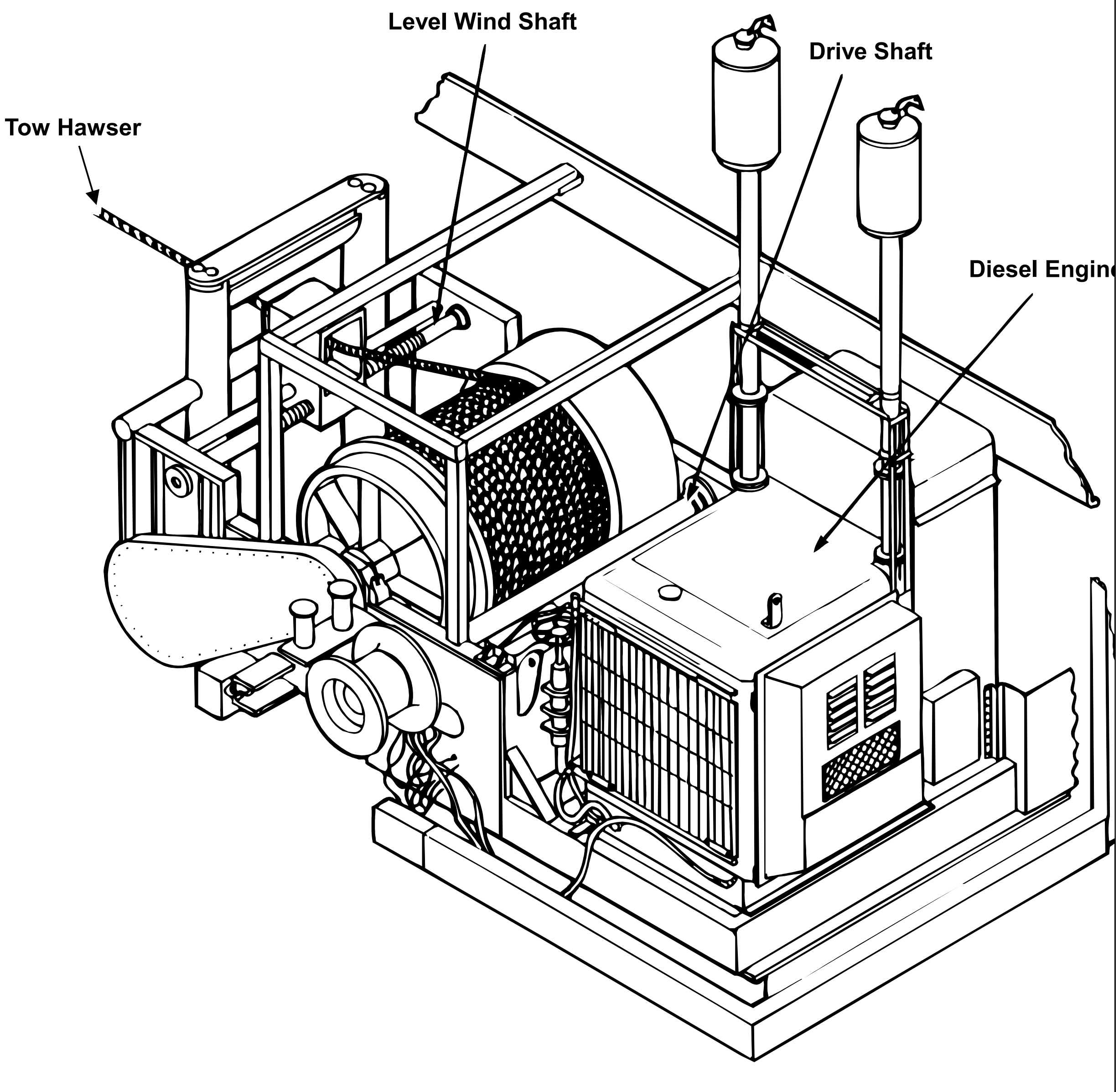
The T-ATF 166 Class is equipped with a SMATCO Type 1 towing winch and a Lake Shore traction winch. The SMATCO winch is a single-drum machine capable of spooling 2,500 feet of 2 ¼-inch wire. A level wind is provided (see Appendix Figure L-3). There is no automatic payout or reclaim capacity in the initial design. Wire tension measurement is provided by strain gauges in the winch foundation. There is a remote tension readout, but no instrumentation for scope out of wire. Maximum hawser heave-in is 179,000 pounds at 14 fpm; maximum hawser speed is 280 fpm at 18,000 pounds tension on the first wrap. At the top wrap (twelfth layer) maximum line speed is 775 fpm at 6,000 pounds tension. Maximum pull on the twelfth layer is 64,000 pounds at 38 fpm.

A major difference between the SMATCO towing winch and those found on other Navy towing ships is that the SMATCO is diesel-driven through an air-operated clutch, a torque converter, and a gear train. For various reasons, towing is frequently accomplished with the drum locked on a "dog," rather than riding the brake. To increase hawser scope, or even let it run free in an emergency, the engine must be started, engaged, and the load taken off the dog before the dog can be released. The problem is aggravated by the fact that the pneumatic control system on the SMATCO winch can fail in the "open" position. In this event, there is no way to release the dog. However, if the winch is not dogged, loss of air will lead to free-wheeling and loss of the towline. Managing the hawser with this system is more difficult than with the standard U.S. Navy towing machines.

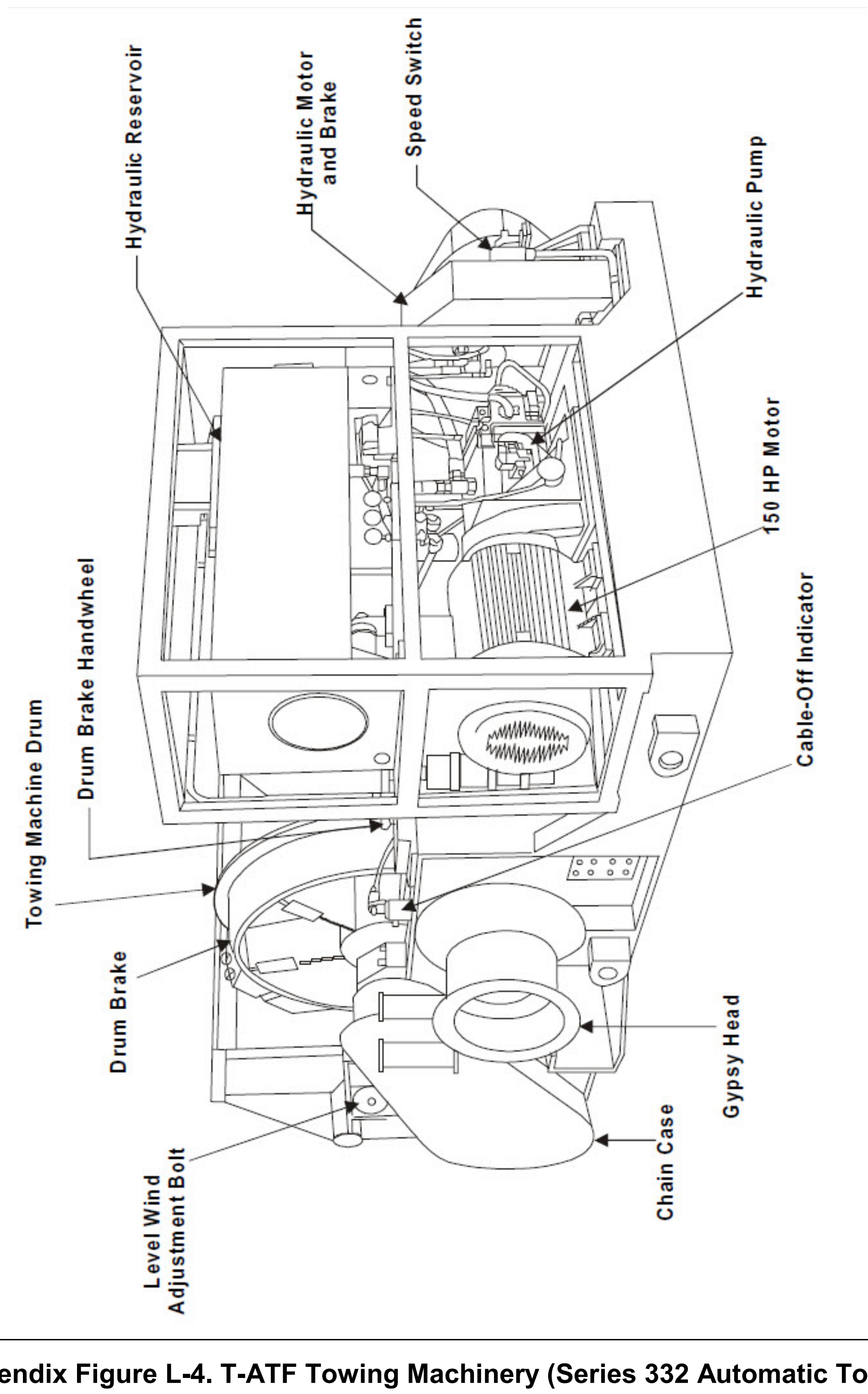
Some T-ATF vessels have had their SMATCO towing winch modified by Almon A. Johnson, Inc., to allow for automatic operation. This new configuration is labeled as an AAJ Type Series 332 towing winch. Modifications include the replacement of the diesel drive system with a closed-loop electro-hydraulic drive, and the addition of a programmable logic controller (PLC) based solid state control system. Hydraulic fluid flow and pressure for the hydraulic drive motor is supplied by a hydraulic power unit mounted immediately forward of the towing machine. Automatic operation is achieved by PLC control of the hydraulic pump swash plate as determined by tow line scope and tension.

As shown in Appendix Figure L-4, the AAJ Type Series 332 is a single-drum machine capable of spooling 2,500 feet of 2 1/4-inch wire with a level wind. It is capable of automatic operation in a range of 30,000 pounds to 110,000 pounds, and manual operation to 250,000 pounds. The modified towing winch has a line speed rating of 0 to 36 feet per minute at 110,000 pounds at the mid layer of the drum. The operator control panel is located on the 01 level overlooking the fantail. A remote panel located on the bridge shows line pull, line scope, and status lights and alarms.

The TATF 166 Class has a separate Lake Shore traction winch suitable for fiber hawsers up to 15inch circumference. The hawser is stored in a below-deck storage room with appropriate fairleads to the winch. The winch has no automatic functions. The Lake Shore Traction Machine is electric motor-driven, with infinite speed adjustment available. Maximum line pull is from 175,000 pounds at 12 fpm. No-load maximum line speed is 370 fpm in payout, 134 fpm heaving in. The unit can be declutched to permit the lines to run free in emergencies. There is a manual brake to control disconnected payout. The winch will hold and structurally withstand the breaking strength of a 15inch circumference double-braided nylon hawser.



Appendix Figure L-3. T-ATF Towing Machinery (SMATCO Winch)



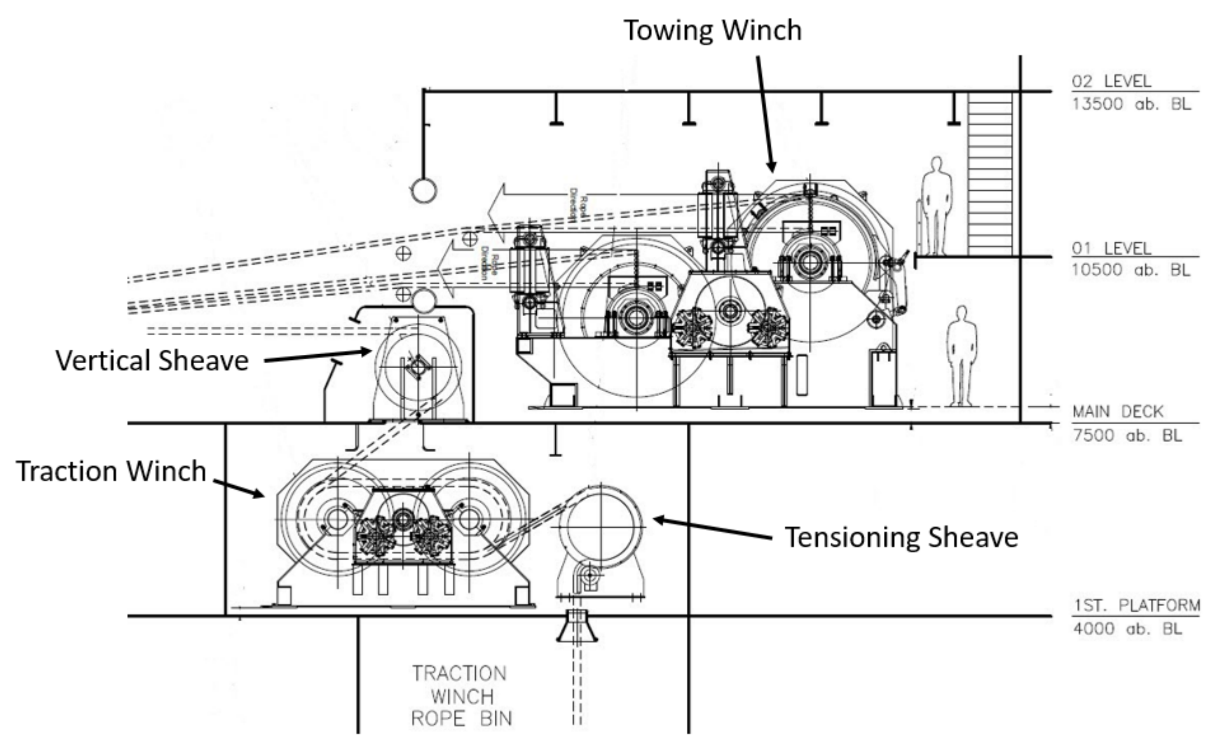
Appendix Figure L-4. T-ATF Towing Machinery (Series 332 Automatic Towing Machine).

L-5.3 T-ATS-6 Class Towing Machinery

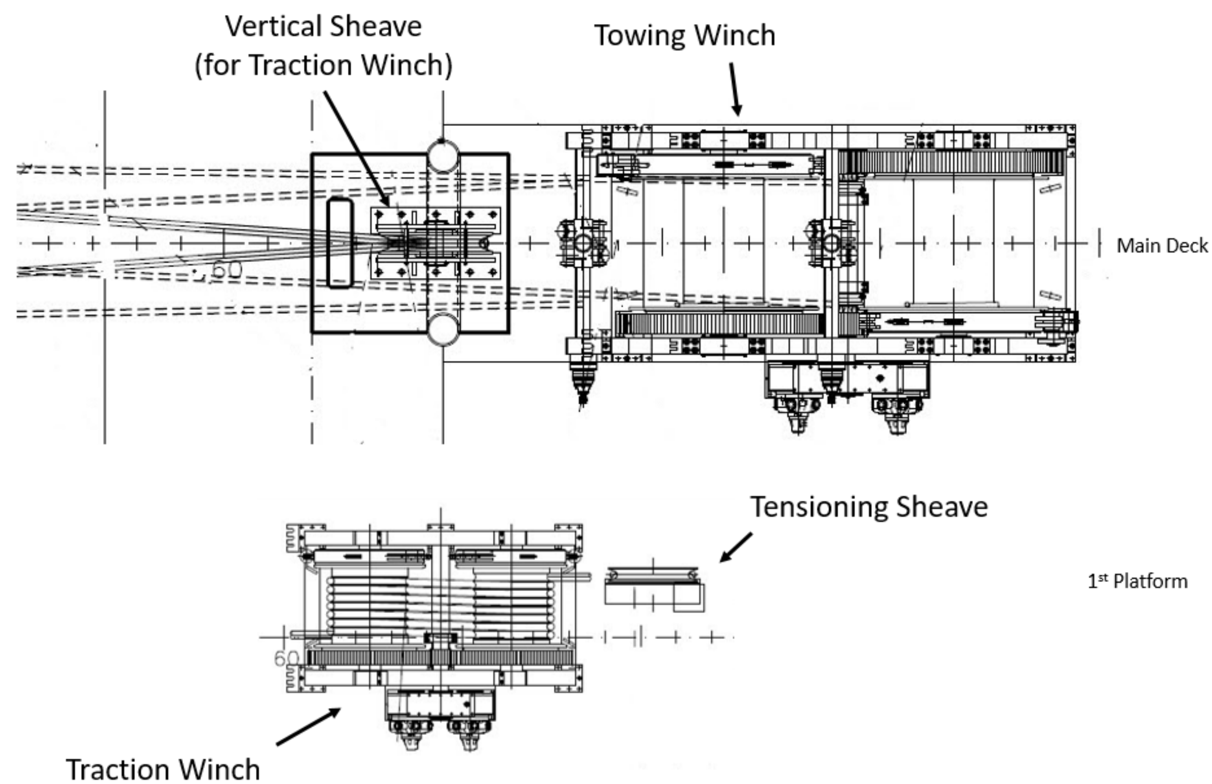
The NAVAJO Class Salvage ship (T-ATS-6) will replace the capabilities of both retiring Rescue and Salvage Ship (T-ARS-50) class and Fleet Ocean Tug (T-ATF-166) class. While as of this printing, the first ship of the class is not yet completed, the nature of the towing machinery is known and described below. Appendix Figures L-5 through L-6 show the profile and plan view of this machinery.

The main towing winch, supplied by MacGregor, is located on the main deck and will have a rated line pull of 177 short tons and braking capacity of 330 short tons. The winch will incorporate two drums in a waterfall configuration, one provided with 915 meters (3,000 ft) of 2.5” wire rope tow hawser and one provided with 1,067 meters (3,500 ft) of 3” wire rope tow hawser. These tow wires are appropriately sized for the vessel’s bollard pull and towing machine line pull. The towing machine will incorporate a power-driven level wind for each drum.

The traction winch, also supplied by MacGregor, is located on the first platform shall be capable of line pulls up to 100 metric tons with synthetic lines ranging from 3 to 15 inch circumference. A vertical sheave, located on the main deck will provide a fairlead from the afterdeck to the traction winch one deck below. A traction winch storage room directly under the tensioning sheave will be fitted with a mechanical means to take the line to and from the traction winch.



Appendix Figure L-5. T-ATS Towing Machinery Profile View



Append Figure L-6. T-ATS Towing Machinery Plan View

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Appendix N - GLOSSARY

21-thread. A light line used to stop off a hawser or other heavy line.

Abrasion resistance. Material's ability to resist exterior damage due to frictional contact.

Advance. Distance gained in the direction of the original course when turning a ship, measured from the point at which the rudder is put over to the point where the ship has changed heading 90 degrees.

Amidships. In or toward the middle of a ship.

Anchor shackle. A U-shaped fitting with pin.

Anchor windlass. The machine used to hoist and lower anchors.

Assisting command. A naval shipyard, private ship yard, or naval station which installs towing systems, supplies riding crews, and provides other assistance.

Assisting tugs. Tugs used during slow speed maneuvers, namely getting underway, docking, and other harbor movements.

Athwartship. At right angles to the fore and aft centerline of a ship or boat.

Attachment point. Point of attachment between the tow and the towed vessel. The attachment point transmits the towing load from the towline to the vessel.

Automatic towing machine. A device which maintains safe tension on the hawser during towing without action by the operator.

Auxiliary towline. A tug's spare or secondary hawser used for multiple tows or secondary functions such as target towing.

Auxiliary vessel. A vessel that maintains, supplies, or supports combatants.

Backing down. Using a stern throttle to rapidly reduce the forward speed of a tug. A dangerous practice in towing due to the risk of failed tow lines or collision.

Bail. The part of a pelican hook or chain stopper that holds the hook closed.

Ballast. The weight added to a ship or boat to ensure stability; to pump sea water into empty fuel tanks.

Barrel. The rotating drum of a capstan or winch. Also, one of two standing posts of a bitt.

Beach gear. A generic term for specialized ground tackle, purchases, and ancillary equipment used to extract a grounded ship.

Beam. A ship's breadth at its widest point; any of the heavy horizontal crosspieces of a ship.

Beam sea. A sea that runs athwart the vessel's course.

Beam wind. A wind that blows athwart the vessel's course.

Bear down. To approach the target.

Beaufort No. A numerical value (from 0 to 12) used for rating wind velocity, in ascending strength.

Billboard. An inclined platform used to stow an anchor for rapid deployment.

Bird caging. The phenomenon of wires flaring out around the full diameter of a wire rope, with resulting kinks in the wires. This can occur when there is a sudden release of a heavy load on a wire rope.

Bitt. A pair of metal posts to which mooring or towing lines are made fast.

Bitter end. The absolute end of a piece of line or cable, especially the last link of anchor chain in the chain locker.

Bollard. Single posts secured to a wharf or pier and used for mooring vessels by means of lines extending from the vessel.

Bollard pull. The maximum pulling power that a tug can generate with zero forward speed.

Bowline. A classic knot that forms a loop that will not slip or become tighter under tension.

Bow (of the) shackle. The curved end of a shackle.

Bow thruster. A propulsor at the bow of the ship which aids in moving the bow sideways.

Breaking of a tow. The release of a towed vessel.

Breaking strength. The actual or ultimate rated load required to pull a wire, strand, or rope to destruction.

Breakwater. Structure that shelters a port or anchorage from the sea.

Bridles. A length of chain or wire extending from the bow of a tow. Usually refers to the rigging of a tow with two legs from the tow's bow to a flounder plate.

Broach. To be turned broadside to a surf or heavy sea.

Bulbous bows. An extension of the bow of a ship below the water line that is designed to reduce wave drag.

Bulkhead. Walls or partitions within a ship, generally referring to those with structural functions such as strength or water-tightness.

Bullnose. Closed chock at the bow of a ship.

Bull rope. Colloquial term referring to a towing hawser.

Bulwark. Section of a ship's side continued above the main deck as a protection against heavy weather.

BUSHIPS. Bureau of Ships, now Naval Sea System Command.

Cable. A heavy rope, chain, or wire of great strength. Applications include attachment to anchors and towing. Also a unit of length, equivalent to 120 fathoms or 720 feet.

Calculated risk. Accepting an operation or decision based on less than satisfactory conditions. As applied to towing, accepting a tow when the tow's material condition, seaworthiness, weather, etc., makes the tow less than satisfactory. This should be rarely used as a basis of acceptance of the tow.

Calm water resistance. The hydrodynamic resistance created by a tow without the influence of waves created by the weather, tug, tow, or other outside influences; approximates steady tension.

Caprail. Rounded radius on the stern of a towing vessel, over which the sweep of the tow wire rides.

Capstan. A revolving device with a vertical axis used for controlled deployment and retrieval of lines.

Careen. To cause a vessel to have a permanent list to one side. Specifically, as in a drydock, to rotate the dock 90E, placing one sidewall below the water line. This is done to reduce the beam to allow passage through canals or other restricted waterways.

Carpenter stopper. A mechanical device consisting of a cover that encloses a sliding wedge within the body that can be opened by knocking away a latch that holds them closed. Used for stopping off wire rope.

Catamaran. A twin-hulled vessel or boat on which the individual hulls are joined together by an above water line structure.

Catenary. The downward curve or sag of a rope, wire, or chain suspended between two points.

Center of gravity (CG). The point in a ship where the sum of all forces and moments of weight is zero.

Chafing. Wear or damage to a ship or ship materials due to friction.

Chafing gear. Material used to prevent chafing and wear on both the hawser and the tug's structure.

Chafing pendant. A length of chain used to reduce chafing or wearing.

Chain bridle. Two legs of chain joined by a flounder's plate extending from the bow of a tug.

Chain connecting link. See "Detachable link."

Chain pendant. A single length of chain extending from the bow of a tug used as a towing connection element, usually fitted with an eye at one or both ends.

Chain shackle. A U-shaped fitting with a pin used for chain connections in a towing rig.

Chain stopper. A device used to secure chain, thereby relieving the strain on the windlass; also used to secure the anchor in the housed position in the hawsepipe.

"Chinese" moor. Denotes that two ships are alongside each other in such a manner that the stern of one is facing the same direction as the bow of the other.

Chock. A heavy smooth-surfaced fitting usually located near the edge of the weather deck through which wire ropes or fiber hawsers may be led.

Cleat. An anvil-shaped deck fitting for securing or belaying lines.

Clip, wire. Fitting for clamping two parts of wire rope to each other.

Closed socket. A wire rope termination similar to a padeye or ring.

COLREG. U.S. Coast Guard Rules of the Road.

Compartment. Room or space on board ship.

Condition ZEBRA. The condition of maximum watertight integrity of a ship.

Constructional stretch. The elongation of a wire rope caused by a virgin rope's helical strands constricting the core during initial loading. This property is no longer exhibited after several loadings.

Controllable pitch propeller (CPP). A screw propeller with separately mounted blades and in which the pitch of the blades can be changed, and even reversed, while the propeller is in operation.

Core. The axial member of a wire rope, about which the strands are laid. It may consist of wire strand, wire rope, synthetic or natural fiber, or solid plastic.

Cotter keys. Also called cotter pins, are used to secure or block nuts, clevises, etc. Driven into holes in the shaft, the eye prevents complete passage, and the split ends, deformed after insertion, prevent withdrawal. Cotter keys are not used in towing.

Crest. The top of a wave.

Cutwater. The stem of a ship, the forward most portion of the bow, which cuts the water as the ship moves.

Dewatering. Process used to remove flood water from a ship.

Deshackling kit. A tool set used to assemble and disassemble detachable links. Tools included in these sets are hammers, punches, lead pellets, spare taper pins, and hairpins.

Detachable link. A joining link that can be opened and is used to connect chain to mooring, towing, or beach gear equipment.

Die lock chain. Chain formed by forging.

Dipped shackle, padeye. The placement of a shackle through a padeye or connection, as opposed to passing the pin of the shackle through opening in the padeye. The padeye is shaped to accept a shackle as described.

Discharge head. A measurement of the discharge pressure of a pump in feet of water which takes into account friction losses and velocity head.

Displacement. The weight of water displaced by a vessel, expressed in long tons.

Dog. A pawl; a device applied to the winch drum to prevent rotation. See "On the dog."

Draft. Depth of a ship beneath the waterline, measured vertically to the keel.

Abrasion resistance. Forces opposing direction of motion due to friction, profile, and other components.

Drift rate. The motion of a vessel caused by the action of the wind, the sea, and the current.

Drogue. A device used to slow rate of movement, usually towed or attached astern of the vessel.

Drum. A cylindrical barrel, either of uniform or tapering diameter, on which rope is wound either for operation or storage; its surface may be smooth or grooved.

Dye-penetrant test. An inspection method used to detect weld surface discontinuances.

Dynamic load. Relating to energy or physical force in motion; as opposed to static load, a force producing motion or change.

Dynamic tension. Resistance of the ship to be towed, the tow hawser, and the vertical component of wire catenary. This resistance cannot be accurately predicted.

Eductor. A pumping device which uses the flow of water through a restriction to create a reduced pressure and cause the flow of water out of a space or compartment.

End link. The last link in a length of chain.

EIPS wire. Extra Improved Plow Steel wire.

Elastic stretch. The elongation of a wire rope or synthetic line caused by the deformation of the material during loading.

Extreme towline tension. The additive accumulation of the complex dynamic responses of tug, tow, and towline.

Eye splice. A loop formed in the end of a rope by tucking the strand ends over and under the strands of the standing part of the rope. A thimble is often used in the loop.

Fairlead. Metal fittings which lead lines in a desired direction.

Fairlead chock. A chock with a roller(s) installed to lead a line to a bitt or cleat.

Fake (faked down). To lay out a line lengthwise in long, flat bights, so that when needed, it will pay out freely.

Fantail. The open deck area or topside overhanging part of the deck at the stern of a ship.

Fatigue. The tendency for materials or devices to break under repeated (cyclic) loading.

Fenders. Energy-absorbing materials or devices used to reduce contact between vessels.

Fetch. The distance a wind blows over the sea surface without a significant change of direction. A factor in the buildup of waves.

Fiber core. Cord or synthetic fiber used as the axial member of a rope.

Fillet weld. A weld that has a triangular cross section, joining two surfaces that are perpendicular to each other.

"Fish hooks." Outer wires of wire rope that break and cause short ends to project from the rope; a sign of wire rope deterioration.

Fish plate. See Flounder plate.

Fitting. A specially designed piece on a ship's deck used to control or secure a line or rope (e.g., chock, bitts, padeye, etc.).

Flood effect diagrams. Diagrams which show the effect of flooding of a particular compartment.

Flounder plate. A triangular steel plate to which bridle legs are connected, sometimes called "fish plate."

Forecastle. Raised forward section of a ship's weather deck. This area contains most of the ship's deck machinery and tow fittings.

Freeboard. Distance from the weather deck to the waterline.

Free-running speed. Maximum speed of a tug without a tow.

Free-spooling. To pay out scope by releasing the brake and allowing the towing drum to rotate as a result of the drag of the tow, with the tow motor disengaged.

Freshening the nip. Paying out or hauling in the hawser to move the contact point in order to distribute wear on the hawser, stern roller, towing bows, H-bitts, winch drum, etc.

Frictional resistance. The force created by an object as it moves through a fluid such as water or air.

Fuse pendant. A pendant of wire rope or chain specifically designed to fail at a known tension. May be used to protect the rest of the rigging arrangement. Also called a "weak link."

GM. See "Metacentric height."

Grapnel. A small, 4-armed anchor used mainly to recover objects in the water. This device may also be helpful in establishing a method of boarding a vessel without assistance from the deck.

Grommet. An endless circle or ring fabricated from one continuous length of strand or rope.

Ground tackle. General term for all anchoring equipment aboard ship.

Gypsy head. The horizontal drum of a winch, around which a rope is wound for heaving in or paying out.

H-bitt. Short steel posts mounted forward and aft that are used to lead or stop off a tow hawser. A hard point used for towing.

Hairpin. A metal pin which is used to secure a detachable link.

Harbor towing. Includes docking/undocking, standby duty, and safety escort duty in protected waters.

Hatch. Access opening in the deck of a ship, fitted with a hatch cover for watertight closure.

Hawse pipe. Heavy casting through which the anchor chain runs from deck down and forward through ship's bow plating.

Hawser. A heavy line or wire rope of over 5 inches in diameter.

Headed fair. An expression meaning bearing toward an object or an area. In towing, this refers to the tow bearing in the same direction as the tug.

Heave. Vertical displacement of a ship in a seaway, as distinct from pitching, which is essentially a rotation about an athwartships axis. Heave generally refers to an upward movement, bodily, of the entire ship. Also, to haul in or retrieve a line or rope.

Helix. The twist or curvature of the individual strands of a wire rope.

High line. A single line rigged between two ships under way transferring stores.

Hockle. Kinking of one or more strands of twisted fiber line or wires on a wire rope.

Hog (hogging). Deviation of the keel from a straight line, in which the keel is concave downward.

Hogging strap. A restraining line exerting force on the hawser to hold it close against the caprail and/or closer to the fantail.

Hookup. The process of making up the connections to tow a vessel.

Horizontal stern rollers. A large-diameter roller, set in the stern bulwarks on the centerline and faired to the caprail. Provides a minimum chafe point for the tow wire during heave-in and payout.

Horsepower, brake. The power delivered at the engine's shaft.

Horsepower, indicated. Power measured in diesel engine cylinders by means of an instrument (the "indicator"), which continuously records the steam or gas pressure throughout the length of the piston travel.

Horsepower, shaft. Power transmitted through the shaft to the propeller. It is usually measured aboard the ship as close to the propeller as possible by means of a torsionmeter. The power actually delivered to the propeller is somewhat less than that measured by the torsionmeter.

Hydrodynamic resistance. The force exerted by the motion of fluids upon a body immersed in the fluid. As applied to towing: the resistance created by water as a body moves through it.

Hummock. An irregular ridge or hillock on sea ice.

IMO. International Maritime Organization.

IPS. Improved Plow Steel.

"In Irons". An expression used by ship handlers to indicate limited control in maneuvering the ship. In towing, this can be caused by a tow wire that is "captured" at the stern, reducing the effect of the rudder of the tug.

Inland towing. Point-to-point towing performed on inland waterways such as rivers.

"In step". An expression used to indicate that the towing ship and its tow are each riding the crests and troughs of waves simultaneously.

IWRC. Independent wire rope core. A wire rope used as the axial member of a larger wire rope.

Jack stay. Wire or line rigged for a special purpose, such as hanging seabags.

Jacob's ladder. Portable ladder, with rope or wire sides and wooden rungs, slung over the side for temporary use.

Jam nuts. A second nut installed hard against the first nut to prevent rotary motion of the first nut.

Jaw width. The dimension of the opening between the eyes of a shackle.

Jewelry. Gear used to fasten together system components.

Kenter detachable link. A type of connection normally used to join two pieces of stud link or cast chain. See "Detachable link."

Kink. A unique deformation of a wire rope caused by a loop of rope being pulled down tight. It represents irreparable damage to and an indeterminate loss of strength in the rope.

Kort nozzle. A nozzle used to enclose the propeller of a ship as a means of boosting power.

Lateral control wire. An auxiliary wire used to limit the motion of the tow hawser in the athwartships direction.

Lay. The direction of the twist of strands of a rope.

Lay length. The distance measured parallel to the axis of the rope (or strand) in which a strand (or wire) makes one complete helical revolution about the core (or center).

Layer. A single thickness, coat, fold, wrap, or stratum. In towing, wraps of wire around a towing winch are counted as layers.

Lazy jacks. Small lines used to tend and recover the towline when rigging a recovery for a Liverpool bridle.

Leading pendant. A length of chain or wire used between the tow and the towing hawser to ensure a safe distance during hookup and disconnect.

Lee. An area that is sheltered from the wind.

Leeward. Away from the wind.

Level wind. A device used during retrieval of a wire to move the wire along the length of the drum to allow it to be stored evenly on the drum of a towing machine.

Lighter. To use a boat or barge to service larger ships in harbors, or to remove fuel or cargo from a stricken vessel.

Line. A term frequently applied to a fiber or synthetic rope, especially if it moves or is used to transmit a force.

Links. A connecting component of towing systems.

Liverpool bridle. A method of rigging a tow hawser; most commonly used in refloating a stranded ship. This method allows the tow vessel to head into the predominant set while still pulling the strand directly to sea.

Load cell. An instrument for measuring tension or torque.

Locking pin (keeper). Device used to hold or maintain a chain stopper, shackle, or other similar devices in a designated position.

Longitudinal. A term applied to the fore-and-aft frames of a ship. Generally, the fore-and-aft direction on a ship.

NDT (Non-Destructive Test). Various methods of checking for imperfections in metals, especially welds.

Messenger. A light line used for hauling over a heavier rope or hawser.

Metacenter. The imaginary point through which the force of buoyancy acts for small angles of heel.

Metacentric height (GM). Distance between the metacenter and the center of gravity of a ship; a measure of stability.

Minimum bend radius. The safe minimum radius for a given diameter, material, and method of bending. Bends of less than this radius may cause damage to the rope or line.

Moment arm. The perpendicular distance from the point of application of a rotational force to the line of action of the force.

Mortise. The opening of a shackle or detachable link. The inside dimension, measured across the opening of a shackle or detachable link.

MPI (Magnetic Particle Inspection). A nondestructive test, using a magnetic field and steel filings or particles to locate and define flaws in steel structures.

Natural pivot point. The location on a tug about which the tug turns in the horizontal plane. It is generally located on the centerline of the ship about one-third of the ship's length from the bow.

NAVSEA 00C. Naval Sea Systems Command, Director of Ocean Engineering/Supervisor of Salvage and Diving, Washington, DC.

Nip. A sharp bend in a line or wire.

"Nipping" the wire. To periodically adjust the scope of the wire to reduce the wear on any one point.

Norman pins. Steel pins mounted along the aft bulwarks of a ship that limit the forward sweep of the tow wire.

OCIMF. Oil Companies International Marine Forum.

Ocean towing. Point-to-point towing outside of protected harbors.

Ocean tugs. Ocean-going vessels designed specifically for towing.

Offset plate shackle. A device used to connect towing components of different sizes.

"On the brake." Towing with the tow hawser restrained by the brake system of the towing machine or winch.

"On the dog." Towing with the winch having a pawl engaged in the ratchet teeth of the towing machine's drum.

Open socket. A wire rope termination that is shaped similarly to a shackle; mates with a closed socket.

OTSR. Optimum Track Ship Routing.

P-100. Self-priming, diesel-driven dewatering pumps that pump about 100 gallons per minute.

P-250. Gasoline-driven pumps used for dewatering.

Padeye. A metal fitting welded to a deck or bulkhead designed to accept a chain or shackle.

Parceling. Wrapping a line or wire with strips of canvas.

Pawl. A device that engages cogs in a wheel allowing rotation in only one direction.

Pay out. To slack off on a line, or let it run out.

Pear-shaped detachable links. A detachable link used to connect a small fitting or chain to a larger fitting or chain.

Pelican hook. A hook that can be opened while under strain by knocking away a locking ring which holds it closed; used to provide an instantaneous release.

Pendant (pendant rig). A single wire or chain that leads from the apex of a towing bridle to the towline; a single wire or chain that leads from the bow of the tow to connect to the tow hawser; a length of wire used as an underrider wire in a "Christmas Tree" rig.

Pitch. Fore-and-aft angular motion of a ship's bow or stern in a seaway about the athwartships axis. See also "sway" and "yaw."

Plate shackle. A connecting device made up of two metal plates and bolts, used to connect the towing pendant and the towline, or to serve as a connecting unit in other parts of a towing rig.

Point-to-point towing. Towing a vessel from one harbor to another.

Popped core. The phenomenon of wires flaring out on one side of a wire rope, exposing the core of the wire. This can occur when there is a sudden release of a heavy load on a wire rope.

Port. The left-hand side of a ship when looking forward; the opposite of "starboard".

Poured socket. A wire rope termination installed by pouring molten zinc over splayed wire, often referred to as "spelter socket."

Power block (transport block). A portable, hydraulic motor-driven line sheave, providing back tension to the traction winch.

Preventer. Any line, wire, or chain whose general purpose is to act as a safeguard in case something else carries away.

Proof load. See page D-6, paragraph D-14 for a discussion of proof load as it applies to chain and to other forged hardware.

Quarter. One side or the other of the stern of a ship.

Racking. Horizontal movement of the shackle which tends to force the jaws of the shackle against the padeye plate causing the jaws to open.

Rail. An open fence or hand rail aboard ship.

Range. The layout of anchor chain in even rows.

Range up. To reduce the range between tow and tug, accompanied by the tendency for the tow to overtake the tug by sheering out to the side.

Reaching pendant. Used between the tow and the towing hawser to ensure a safe stand off during hookup or disconnect. (See also “Leading pendant.”)

Reeving. The threading of a line or wire through a block, sheave, or other parts of a wire rope system.

Relative drift. The difference in the rates and directions of motion of two vessels caused by their differing reactions to wind, sea, and current.

Repair lockers. Storage spaces within the ship which contain damage control equipment for the repair and control of damage due to battle, flooding, or fire.

Rescue towing. Saving a stricken ship at sea, or towing a disabled ship from the scene of a successful salvage to a safe refuge.

Reserve buoyancy. A measure of the capability of a ship to be flooded or ballasted without sinking.

Resistance. A force that retards, hinders, or opposes motion.

Retrieval pendant. A wire rope leading from the deck of the tow to the end of the towing pendant or flounder plate to facilitate bringing the tow gear back onto the foredeck.

Riding lines. Lines used for greater manageability when the tow is brought close to the tug’s stern.

Rockwell C. A measurement of material hardness.

Roll. Side-to-side angular motion of a ship about its longitudinal axis. See also “pitch,” “sway” and “yaw.”

Roll period. A measurement of the time required for a ship to roll from starboard to port and back to starboard or vice versa.

Roller chock. A chock fitted with a roller.

Saddle. A device on the stern of the towing vessel against which the bow of the tow can be brought up hard and maintained in position during ice operations.

Safe haven. An area that can provide shelter from the sea and the weather.

Safe working load. The load for which a rope, fitting, or working gear is designed. (See pg. for discussion.)

Safety factor. A multiple representing extra strength over maximum intended stress.

Safety shackle. A connecting device similar to the common shackle except that the mortise is held closed by a nut and bolt.

Safety track. A T-shaped track running the length of the submarine's topside to which personnel safety lines can be attached.

Sag (sagging). Deviation of the keel from a straight line when the keel is concave upward. Also, the concave curve of a towline said to have catenary.

Sail. The part of a modern submarine extending above the main deck or hull, housing the periscope supports, various retractable masts, and the surface conning station or bridge.

Sail area. The vertical hull surface of a ship on which the wind exerts force.

"Sally the ship." A term referring to the practice of imparting a rolling motion to a ship by the crew's repeatedly moving from one side of the ship to the other.

Salvage towing. Follows very closely after a salvage operation, such as fire fighting, flooding control, battle damage repair, or retraction from stranding.

Scope. The amount of towline streamed.

Screw. The propeller of a ship.

Screw-pin shackle. A type of shackle in which the pin passes through one side of the shackle and threads into the other side of it to form a closure.

Scuttle. Small, quick-closing access hole.

Sea anchor. A device, usually made of wood and/or canvas, streamed by a vessel or boat in heavy weather in order to hold the bow or stern into the sea.

Secondary towline. An emergency towline rigged on the tow prior to getting underway. It can be deployed rapidly without assistance from personnel on board the tow.

Section modulus. As used in reference to wire rope, the effective area of the steel in wire rope multiplied by the modulus of elasticity of the steel.

Seize. To bind with small stuff, as one rope to another or a rope to a spar.

Serving. To wrap small stuff tightly around a rope that has been previously wormed and parceled.

Shackle. U-shaped metal fitting, closed at the open end with a pin, used to connect wire, chain, and similar components.

Shaft horsepower. See “Horsepower, shaft.”

Sheave. A pulley with a rim, used to support or guide a rope in operation.

Sheering. In towing, the tow’s meandering from the towing vessel’s track. The tow may sheer out to a constant position on one side of the tug’s track, or it may swing from one side to the other with a fairly long period of several minutes or more.

Shoring. Process of placing props against structure or cargo to prevent braking, sagging, or movement in a seaway, or to hold ship upright in drydock.

Short stay. A minimum distance between tug and tow used during harbor operations; “to bring to short stay.”

Shot. A standard length of chain, 15 fathoms (90 feet).

SHP. Shaft horsepower. See “Horsepower, shaft.”

Side-slipping. Moving sideways through the water.

SITREP. Situation Report. A special report generally in a prescribed format, required to keep higher authority advised. Required under certain predictable circumstances, but also may be required at any time.

Skeg. A portion of the underwater hull with significant longitudinal and vertical dimensions but without appreciable transverse dimensions. Its purpose is to give directional stability to the hull. On some moveable twin-skegged tows the skeg may be moved to increase directional stability and reduce yawing.

Slip. To part from an anchor by unshackling the chain. To release completely or let run overboard.

Small stuff. Any small-circumference line used for general purposes.

Smit towing bracket. Two vertical plates similar to a pair of free-standing padeyes with an elliptical pin fitted between them.

Snapback. The sudden recoil occurring when a line parts.

Snatch block. A type of fairlead that can be opened easily to insert a bight of line.

Socket. A wire rope termination attached by zinc or resin. Sockets poured with resin are not approved for towing. See “Poured socket.”

Sound. To measure depth of water at sea or the depth of a liquid in a ship’s tanks. To strike a chain link with a hammer to detect cracks or loose studs.

Spelter socket. See “Poured socket.”

Splay. To unlay and broom the bitter end of a wire rope, usually done preparatory to attaching a socket.

Spliced eye. A wire rope termination formed by inlaying the rope and intertwining the strands to form an eye.

Sponsoring command. The command that requires a tow, and is responsible for preparing the towed vessel for sea.

Spooling. Winding a rope on a reel or drum.

Spring lay rope. A rope combining fiber and wire.

Spring line. Mooring line leading nearly fore and aft with the purpose to prevent the longitudinal movement of the ship at the pier or when tied alongside another ship."

Spring, stretcher. A pendant or grommet used to dampen towline surges.

Stability. Ability of a ship to right itself after being heeled over.

Starboard. The right-hand side of a ship when looking forward. Opposite of "port."

Static load. The force applied by deadweight, often referred to as the "average" or "mean" load.

Steady (or static) towline tension. Resistance of the ship to be towed, the tow hawser, and the vertical component of wire catenary.

Stem. The forward extremity of a ship's hull.

Stern. The rear section of a ship.

Stern planes. The after horizontal control surfaces of submarine normally used to control depth and angles.

Stern rollers. The horizontal and vertical rollers at the stern of a tug used to lead, capture and control the tow hawser.

Stokes stretcher. A wire mesh container used to transfer injured personnel through hatches onboard ship.

Stopper. A short length of line wrapped around a line to stop it from running.

Strongback. A wood or metal bar which is used to hold a patch or shoring in place.

Stud-link. A chain link with a bar fitted across the middle to prevent the chain from kinking.

Strap. A short working wire with a spliced eye at each end.

Strain. To draw or stretch tight; to injure or weaken by force, pressure, etc.; to stretch or force beyond the normal, customary limits; to change the form or size of, by applying external force.

Stream. To extend or increase the scope of the tow hawser.

Submersible pump. Watertight electric pump that can be lowered into a flooded compartment to pump it out.

Suction lift. A measurement in feet of the ability of a pump to raise water or liquid to the intake of the pump that takes into account friction and entrance losses.

Swage. To connect, splice, or terminate wire rope by use of steel fittings installed under extremely high pressure.

Sway. Motion of a ship in which it is displaced laterally, as distinct from rolling. See also “pitch,” “roll,” and “yaw.”

Swivel. A removable anchor chain link fitted to revolve freely and thus keep turns out of a chain.

SWL. See “Safe Working Load.”

Synthetic hawser. A line or pendant used for towing, made from any of a group of continuous or synthetic fibers.

Termination. The fitting installed on the end of a wire rope or chain used in towing.

Thimble. A grooved metal buffer fitted snugly into an eye splice.

Tiller (tiller arm). Casting or forging attached to the rudder stock.

Timber packing. Large wooden planks used to reinforce hull plating.

Towing bows. Transversely installed beams or pipe that bridge the caprails on the afterdeck of the tug.

Towing bracket. See “Smit Towing Bracket” or “Tow pad.”

Towing chock. Chock designed or dedicated to use during a towing operation.

Towing command. The command that performs the tow.

Towing hawser. Generally, the main towline that is carried by the tug or the principal segment of the towline.

Towing hook. Heavy steel hooks mounted on vertical pins used to hold the eye of a tow hawser.

Towing machine. A towing winch with automatic features.

Towing pad. Large padeye to which a towline may be attached.

Towing rig. Describes the entire system of components that make up the connection between the tug and the tow.

Towing winch. A basic winch used in towing that stores, pays out, and heaves in the towing hawser to compensate for variations in towline tension.

Towline. See “Towing hawser.”

Towline fatigue. The weakening of a towline due to cyclic application of load.

Towline strength. The nominal breaking strength of the tow hawser.

Towline tension. The stress imparted to a towline during a towing operation.

Tow point. The point on the tug where the towline exerts its force. This may be the winch, H-bitts, caprail, norman pins, or other points, depending on the towing configuration.

Tow resistance. The total force resisting the movement of the tow.

Tow ship. A vessel specifically designed for ocean towing.

Traction winch. A multi-sheaved device that generates line tension. Tension is generated by friction between the line and traction heads.

Transfer. Distance travelled by a ship at right angles to original course when turning.

Transverse. Lateral dimension or placement.

Tripping. When a frame or padeye experiences transverse loading, it may result in out-of-plane deformation such that it is no longer perpendicular to the deck or hull plating. It has the appearance of having “fallen over” and is said to be tripped. A structure in this condition has significantly reduced strength.

Tucks. In splicing, the insertion of the end of a strand between the strands of a rope.

Turnbuckles. A metal device consisting of a threaded link bolt and a pair of opposite-threaded screws capable of being tightened or loosened and used for setting up standing rigging or stoppers.

Two-blocking. Term describing when the two blocks of a block-and-tackle have been drawn together or tightened so that they touch.

Two valve protection. Consists of either two valves wired shut or one valve and a blank flange.

Ultrasonic inspection. A non-destructive testing method that uses high frequency sound waves to check for material thickness, laminations, and defects or inclusions.

Underrider. The wire rope, chain, or combination used as a pendant heavy enough to pass under a leading tow to a trailing tow at a sufficient depth not to foul on the leading tow.

Veer. To pay out.

Vertical stern rollers. Vertical rolling pins mounted on the caprail of a tug to restrain the tow hawser sweep.

Voith-Schneider propeller. A propeller that generates thrust at right angles to the axis of rotation which, through control of the angle of attack of the vertical propeller blades, can be directed through 360 degrees thus acting as both propeller and rudder.

Wallis brake. A wire brake used for keeping a steady load on a wire rope as it is installed on a drum.

Warping tug. A small boat used to control the heading and speed of a tow during connection of the tow line.

Water brake. A device attached to the stern of a vessel (usually in lieu of a propeller) that provides drag for directional stability.

Wetted surface. The area of the vessel below the waterline which is exposed to the sea.

Williams target sled. The target used most for gunnery exercises.

Winch. An electric, hydraulic, or steam machine aboard ship used for hauling in lines, wire, or chain.

Windward. Toward the wind.

Wire rope. Rope constructed of wire strands twisted together, as distinct from the more common, and weaker, fiber rope.

Wire rope pendant. A length of wire with a termination fitting at each end.

Y-gate. A piping connection with a large inlet section and two smaller outlet sections to permit hookup of two hoses to one pump outlet.

Yard tugs. Vessels that dock/undock, provide standby duty and safety duty services of harbor towing.

Yawing. Failure of a vessel to hold a steady course because of forces of wind, sea, damage to vessel, etc. In towing, yaw angle is the difference between the tow's heading and the tug's heading. Yawing can be manifested by an oscillation of the tow's heading by a small angle to either side of the base course, with the tow remaining on the same track as the tug. See also "sheer," "sway," "pitch," and "roll."

Yield strength. A measure of the maximum stress that can be applied to a material without permanent deformation. This is the value of the stress at the elastic limit for materials for which there is an elastic limit.

YTB class. The largest tugs used for harbor towing.

YTL class. Small size tugs which move small craft and unloaded barges from one berth to another within a harbor.

YTM class. Medium size tugs which move vessels of all sizes from berth to berth within a harbor and assist vessels of all sizes in getting underway and mooring.

Z-drive propulsion. A mode of propulsion that uses a propulsar which can be trained through 360 degrees and can be positioned in the hull during design to provide the optimum propulsion.

Appendix O - USEFUL INFORMATION

O-1 Introduction

This appendix contains miscellaneous information useful during salvage operations. Ground reaction is measured in long tons. Freeing and lifting forces are measured in short tons.

O-2 Weights and Measures

This section lists general information needed for performing salvage calculations in both metric and English systems. Use this material with salvage formulae found throughout this manual.

Table O-1. System of Metric Measures.

LENGTH	
1 meter (m)	= 10 decimeters (dm) = 100 centimeters (cm) = 1,000 millimeters (mm)
1,000 meters	= 1 kilometer (km)
AREA	
1 square meter (m2)	= 1,000,000 square millimeters (mm2) = 10,000 square centimeters (cm2) = 100 square decimeters (dm2)
1 square kilometer	= 1,000,000 square meters
VOLUME	
1 liter (l)	= 10 deciliters (dl) = 100 centiliters (cl) = 1,000 milliliters (ml) = 1 cubic decimeter (dm3)
1 kiloliter (kl)	= 1,000 liters = 1 cubic meter (m3)
1 milliliter (ml)	= 1 cubic centimeter (cc)
MASS	
1 kilogram (kg)	= 1,000 grams (g)
1 gram (g)	= 1,000,000 micrograms (µg) = 1,000 milligrams (mg) = 100 centigrams (cg)
1,000 kilograms	= 1 metric ton (tonne)
FORCE	
1 kilogram force (kgf)	= 9.807 newtons (N)
1 newton (N)	= 0.102 kgf
1 kilonewton (kN)	= 1,000 newtons = 102 kgf
1 meganewton (MN)	= 1,000,000 newtons = 102,000 kgf = 102 tonnes force (tonnef)

Table O-2. System of English Measures.

LENGTH	
1,000 mils	= 1 inch (in)
12 inches	= 1 foot (ft)
3 feet	= 1 yard (yd)
6 feet	= 1 fathom (fm)
15 fathoms	= 1 shot of chain= 90 feet
120 fathoms	= 1 cable's length= 720 feet
6,080 feet	= 1 nautical mile (NM)= 2,027 yards
AREA	
144 square inches (in2)	= 1 square foot (ft2)
VOLUME	
1,728 cubic inches (in3)	= 1 cubic foot (ft3)
27 cubic feet (ft3)	= 1 cubic yard (yd3)
231 cubic inches	= 1 U.S. gallon (gal)
277.27 cubic inches	= 1 imperial gallon
42 U.S. gallons	= 1 barrel= 5.615 cubic feet
1 cubic foot	= 7.48 U.S. gallons
	= 6.23 Imperial gallons
BOARD MEASURE	
board feet	= Length in feet x width in feet x thickness in inches: therefore:
12 board feet	= 1 cubic foot
DRY MEASURE	
1 pint	= 0.5 quart = 33.6 in3
LIQUID MEASURE	
16 ounces	= 1 pint
2 pints	= 1 quart
4 quarts	= 1 gallon
NOTE: :English system dry measure and liquid measure quarts and pints are not equivalent volumes. All Imperial liquid measures are therefore larger than the corresponding U.S. measure by a factor of 277/ 231, or 1.2.	
FORCE AND WEIGHT	
7,000 grains (gr)	= 1 pound (lb)
16 ounces (oz)	= 1 pound
2,000 pounds	= 1 short ton
2,205 pounds	= 1 metric ton (tonne) = 1,000 Kg
2,240 pounds	= 1 long ton

Table O-3. Basic English/Metric Equivalents.

MEASURES OF LENGTH			
1 millimeter	= 0.03937 inch	1 inch	= 25.4 millimeters
1 centimeter	= 0.3937 inch	1 inch	= 2.54 centimeters
1 meter	= 39.37 inches	1 inch	= 0.0254 meter
1 meter	= 3.281 feet	1 foot	= 0.3048 meter
1 kilometer	= 0.62 mile	1 mile	= 1.6 kilometers
1 kilometer	= 0.54 nautical mile	1 NM	= 1.85 kilometers

1 kilometer 1 kilometer	= 1,094 yards = 3,281 feet	1 mile 1 NM	= 1,609 meters = 1,853 meters
MEASURES OF AREA			
1 square mm (mm2) 1 square cm (cm2) 1 square meter 1 square meter 1 square kilometer	= 0.00155 square inch = 0.155 square inch = 10.76 square feet = 1.196 square yards = 0.386 square mile	1 square inch 1 square inch 1 square foot 1 square yard 1 square mile	= 645.2 square millimeters = 6.452 square centimeters = 0.0929 square meter = 0.836 square meter = 2.59 square kilometers
MEASURES OF VOLUME			
1 cc or ml 1 cubic meter (m3) 1 cubic meter 1 liter 1 liter	= 0.061 cubic inch = 35.3 cubic feet = 1.31 cubic yards = 61.023 cubic inches = 0.0353 cubic foot	1 cubic inch (in3) 1 cubic foot (ft3) 1 cubic yard (yd3) 1 cubic foot (ft3)	= 16.39 cc or ml = 0.0283 cubic meter = 0.764 cubic meter = 28.32 liters
LIQUID MEASURE			
1 liter (l) 1 liter (l) 1 cubic meter	= 1.057 U.S. quarts = 0.264 U. S. gallons = 264.17 gallons	1 U.S. quart (qt) 1 U.S. gallon (gal) 1 U.S. gallon	= 0.946 liter = 3.79 liters = 0.0038 cubic meter
DRY MEASURE			
1 liter (l)	= 0.908 dry quarts	1 dry quart	= 1.101 liters
MEASURES OF WEIGHT AND MASS			
1 kilogram (kg)	= 2.205 pounds mass	1 pound mass (lbm)	= 0.454 kilograms = 454 grams
1 tonne	= 1.1023 short tons = 2205 pounds	1 short ton	= 0.972 tonne = 907.2 kilograms
1 tonne	= 0.9842 long tons	1 long ton	= 1.016 tonne = 1016 kilograms
1 milligram 1 gram	= 0.0154 grain = 15.432 grains	1 grain	= 64.8 milligrams = 0.0648 gram
1 newton 1 meganewton	= 0.225 pounds force = 100.4 long tons = 112.4 short tons = 224,799 pounds	1 pound force (lbf) 1 long ton 1 short ton	= 4.448 newtons = 0.009964 MN = 0.008896 MN

Table O-4. Circular or Angular Measure.

60 seconds 60 minutes 90 degrees 4 quadrants 2 radians 1 radian	= 1 minute of arc = 1 degree = 1 quadrant or right angle = 1 circumference = 1 circumference = 180	 = 360 degrees = 57.3 degrees

Table O-5. Common Pressure Conversions.		
Feet of seawater	0.445	psi
Feet of fresh water	0.434	psi
Psi	2.25	feet of seawater
Psi	2.3	feet of fresh water
Inches of mercury	0.49	lb/in^2
Lb/in2	2.04	inches of mercury
Atmospheres	14.7	lb/in^2
Lb/in2	0.07	atmospheres
Atmospheres	10.0	meters of seawater

Table O-6. Common Pressure Conversions		
MULTIPLY	BY	TO OBTAIN
Lb/ft3	16.02	kg/m^3
	0.01602	g/cc
Kg/m3	0.0624	lb/ft^3
	0.001	g/cc
m3/tonne	35.87	ft^3/long ton
ft3/long ton	0.0279	m^3/tonne

Table O-7. General Conversion Factors.		
MULTIPLY	BY	TO OBTAIN.
Atmospheres	760	mm of mercury (mm Hg)
	76.0	cm of mercury (cm Hg)
	33.9	feet of fresh water (ffw)
	34	approx. ffw
	33.1	feet of seawater (fsw)
	10	approx. meters of seawater
	33	approx. fsw
	29.92	inches of mercury (in Hg)
	1.033	kg/cm^2
	10,332	kg/m^2
	14.7	lb/in^2 (psi)
	1.06	$tons/ft^2$
Barrels	5.615	cubic feet (ft^3)
	42	U.S. gallons (gal)
	0.159	kiloliters, cubic meters
Cubic centimeters	0.0002642	gallons (U.S.)
	0.0338	ounces
Cubic feet	28,320	cubic cm (cc)
	1,728	cubic inches (in^3)
	0.02832	cubic meters (m^3)
	7.48	U.S. gallons (gal)
	28.32	liters
	0.178	barrels (bbl)
Cubic feet/minute	0.02832	
	7.48	cubic meter/min (m^3/min)
	1.43	U.S. gallons/min (gpm)

		bbl/hour
Cubic inches	16.39	cubic cm (cc)
	0.0005787	cubic feet (ft^3)
	0.00001639	cubic meters (m^3)
	0.004329	U.S. gallons (gal)
	0.01639	liters (l)
Cubic meters	61,023	cubic inches (in^3)
	35.31	cubic feet (ft^3)
	264.2	U.S. gallons (gal)
	6.29	barrels
	1,000	liters (l)
	1	kiloliters (kl)
Cubic meters/minute	35.31	ft^3/min

Table O-7. (Continued) General Conversion Factors.

MULTIPLY	BY	TO OBTAIN.
Feet	304.8	millimeters
	30.48	centimeters
	0.3048	meters
	0.0001645	miles (nautical)
Feet of fresh water	0.0295	atmospheres
	0.8827	in Hg
	0.0305	kg/cm^2
	62.4	lb/ft^2
	0.434	lb/in^2
Feet of seawater	0.0303	atmospheres
	0.9048	in Hg
	0.03124	kg/cm^2
	64.0	lb/ft^2
	0.445	lb/in^2 (psi)
Feet/second	30.48	cm/sec
	1.097	km/hour
	0.5921	knots
	0.6818	miles/hour
	0.01136	miles/min
Foot-lbs	1.355	newton-meters
	0.1383	kilogram-meters
	13830	gram-centimeters
Foot-tons (long tons)	3,036.7	newton-meters
	0.00303	meganewton-meters
	0.3	meter-tonne
Foot-tons (short tons)	2,711	newton-meters
	0.00271	meganewton-meters
	0.276	meter-tonne
Gallons (U.S.)	3,785	cubic cm (cc)
	0.1337	cubic feet (ft^3)
	231	cubic inches (in^3)
	1.2	Imperial gallons
	0.0238	barrels (bbl)
Gallons (Imperial)	0.833	U.S. gallons (gal)
Inch-Pounds	0.113	newton-meters
	1153	gram-centimeters
Kilograms	2.205	pounds

Table O-7. (Continued) General Conversion Factors.		
MULTIPLY	BY	TO OBTAIN.
Kilograms/m2	0.2048 0.00142	lb/ft2 lb/in2 (psi)
Kilograms/m3	0.0624	lb/ft3
Kilograms/cm2	14.226	lb/in2 (psi)
Kiloliters	6.29 264.2 35.31	barrels (bbl) U.S. gallons cubic feet (ft3)
Kilometers	3,281 0.54	feet miles (nautical)
Kilometers/hour	27.78 0.9113 0.5396	cm/sec feet/sec knots
Knots	6,080.2 1.8532 0.5148 1.1516 1.689	feet/hour kilometers/hour meters/sec statute miles/hour feet/sec
Liters	61.02 0.0353 0.2642 0.00629	cubic inches (in3) cubic feet (ft3) U.S. gallons (gal) barrels (bbl) (oil)
Meganewtons	100.4 112.4 102 101,954 224,809	long tons (lton) short tons tonne kilograms (kg) pounds (lb)
Meganewton-meters	329.4 368.8 102	foot-tons (long tons) foot-tons (short tons) meter-tonne
Meganewtons/meter	30.6 34.3 102	long ton/ft short tons/ft tonne/meter
Meters	39.37 3.281 0.000539 1.094	inches feet miles (nautical) yards
Meters/second	1.944 3.281 3.6 0.03728	knots feet/sec km/hour miles/min

Table O-7. (Continued) General Conversion Factors.

MULTIPLY	BY	TO OBTAIN.
Miles (nautical)	1,853.15	meters (m)
	1.853	kilometers (km)
	6,080	feet (ft)
	2,027	yards (yd)
	1.1516	miles (statute)
Miles/hour	44.7	cm/sec
	88	feet/min
	1.467	feet/sec
	1.609	km/hour
	0.8684	knots
	0.447	meters/sec
Millimeters	0.03937	inches (in)
Millimeters of mercury	0.00132	atmospheres
	0.00435	feet of seawater (fsw)
	0.00446	feet of fresh water (ffw)
	13.6	kg/m^2
	0.0193	lb/in^2 (psi)
Newtons	0.225	pounds (lb)
Newtons/meter	0.102	kg/m
	1.356	lb/ft
Ounces	0.0625	pounds (lb)
Ounces (fluid)	1.805	cubic inches (in3)
	0.02957	liters (l)
	0.0313	quarts, liquid (qt)
	0.0078	U.S. gallons (gal)
Pounds	0.454	kilograms
	16	ounces
	4.448	newtons (N)
Pounds/ft2	0.0004725	atmospheres
	4.882	kg/m^2
	0.006944	$pounds/in^2$ (psi)
Pounds/in2	0.068	atmospheres
	2.25	feet of seawater (fsw)
	2.3	feet of freshwater (ffw)
	703.1	kg/m^2
	144	lb/ft^2
	0.0005	short $tons/in^2$
	0.000446	long $tons/in^2$
Quarts, U.S. liquid	0.946	liters (l)
	0.0334	cubic ft (ft3)
	57.75	cubic inches (in3)
	32	fluid ounces
	4	gallons

Table O-7. (Continued) General Conversion Factors.

MULTIPLY	BY	TO OBTAIN.
Square feet	929 0.0929 144	square cm (cm^2) square meters (m^2) square inches (in^2)
Square inches	6.452 0.006944	square cm (cm^2) square feet (ft^2)
Square kilometers	0.3861 0.29155	square miles square nautical miles
Square meters	10.76 1.196	square feet (ft^2) square yards (yd^2)
Square miles	2.590 27,878,400	square kilometers square feet
Square yards	0.8361	square meters (m^2)
Tons (long)	1,016 2,240 1.12 1.016 0.009964	kilograms pounds tons (short) tonne (metric) meganewtons (MN)
Long tons/square inch	2,240 1,574,508 1,574.5 157.5 15.44	lbs/in^2 (psi) kg/m^2 $tonne/m^2$ kg/cm^2 $meganewtons/m^2$
Long tons/foot	1.12 3.33 3,333.7 32,693.6 0.0327	short tons/foot tonne/meter kg/m newtons/meter (N/m) Meganewtons/meter (MN/m)
Tons (short)	907.2 2,000 0.8929 0.9072 0.008897	kilograms pounds tons (long) tonnes (metric) neganewtons (MN)
Short tons/ square inch	2,000 1,406,15 1 1,406.15 140.62 13.79	lb/in^2 kg/m^2 $tonne/m^2$ kg/cm^2 MN/m^2
Short tons/foot	0.8929 0.276 2,976.5 29,190.6 0.0292	long ton/ft tonne/meter kg/m newton/meter (N/m) MN/m

Table O-7. (Continued) General Conversion Factors.

MULTIPLY	BY	TO OBTAIN.
Tonne (metric)	0.984	long tons
	1.1023	short tons
	2,205	pounds (lbs)
	1,000	kilograms
	0.009807	meganewtons (MN)
Tonne/meter	0.3	long ton/ft
	0.336	short tons/ft
	672	lb/ft
	9,807	newtons/meter
Yards	91.44	centimeters
	0.9144	meters

Table O-8. Power Conversion.

MULTIPLY	BY	TO OBTAIN.
Horsepower	0.746	kilowatts
Kilowatts	1.3404	horsepower
BTU	778.2	foot-pounds
Foot-pounds	0.001285	BTU
BTU	0.0003930	horsepower hours
Horsepower hours	2,554	BTU
BTU	0.0002931	Kilowatt hours
Kilowatt hours	3,412	BTU

Table O-9. Temperature Conversion.

$$°F = \frac{9C}{5} + 32$$

$$°C = \frac{5}{9}(F - 32)$$

ABSOLUTE TEMPERATURE

Rankine (R) = Degrees Fahrenheit + 460

Kelvin (K) = Degrees Celsius + 273

Table O-10. Common Flow Rate Conversion.

MULTIPLY	BY	TO OBTAIN.
Liters per second (lps)	15.83	gpm
	2.12	cfm
Liters per minute (lpm)	0.26	gpm
	0.0353	cfm
Tons seawater per hour	261.8	gal/hour
	4.36	gpm
	0.583	cfm
	0.276	lps
	0.995	m3/hour
Tonnes seawater per hour	4.295	gpm
	0.574	cfm
	0.271	lps
	0.976	m^3/hour
	4.475	gpm
Tons fresh water per hour	0.598	cfm
	0.282	lps
	1.016	m^3/hour
	4.4	gpm
	0.588	cfm
M3/hour	0.278	lps
	1.01	tons seawater/hour
	0.98	tons fresh water/hour
	1.025	tonnes seawater/hour
	15850.2	gpm
	2118	cfm
M3/sec	7.48	gpm
	0.472	lps
Ft3/min (cfm)	28.32	lpm
	1.714	tons seawater/hour
	1.671	tons fresh water/hour
	1.741	tonnes seawater/hour
	0.00047	m^3/sec
	1.7	m^3/hour
	0.134	cfm
	0.063	lps
U.S. gallons per minute (gpm)	3.79	lpm
	0.229	tons seawater/hour
	0.223	tons fresh water/hour
	0.233	tonnes seawater/hour
	0.00006	m^3/sec
	0.228	m^3/hour

Appendix P - HEAVY LIFT SAMPLE CALCULATIONS

P-1 Introduction

This Appendix demonstrates sample calculations for the procedures outlined in Chapter 8, Heavy Lift Transport. These calculations can be used to actually perform the heavy lift or to check the contractor's calculations. Because the heavy lift of the damaged USS COLE (DDG 67) is not only the most recent, but also the most complex of the heavy lift transport operations undertaken by the US Navy, it has been used to show the calculations involved.

P-2 Information

On 12 October 2000, while USS COLE was in the port of Aden, Yemen for refueling, terrorists bombed USS COLE using an explosive laden small boat which was deliberately driven into the port side of USS COLE and exploded causing structural damage. It was determined that the best method for returning COLE to a port where the damage could be repaired was to use a heavy lift vessel.

Information relative to USS COLE used in the calculations to follow comes from data on ship's characteristics from the Trim and Stability Booklet and the Docking Drawing updated for observed condition of loading and damage. This information is summarized in Table P-1.

Using the drafts of 26.5 ft forward, 22 ft aft for the damaged condition the following information can be derived from the DDG 51 Draft Diagram and Functions of Form (Appendix Figure P-1). (This requires extension of the data to cover the area of interest. These extensions are shown as dashed lines on (Appendix Figure P-1). This displacement includes the free flooding water in the damaged compartments. This condition was needed to address the drafts to be cleared to get the ship over the blocks.

WARNING
When trim exceeds one foot, especially by the bow, a more rigorous analysis, preferably by a computer program, should be used to obtain the hydrostatic information.

Determine the displacement and other parameters as follows:

Given: Draft Forward 26 feet 6 Inches

Draft Aft 22 feet 0 Inches

On the Draft Diagram and Functions of Form (Appendix Figure P-1), draw a straight line connecting these drafts and where it crosses the center of floatation scale, read

Displacement 10,700 Tons

Transverse Metacenter (KMt) 29.05 feet

Project a line horizontally from this point and where it crosses the other scales, read:

Tons per inch immersion 53.9 Tons/inch

Moment to alter trim one inch 1,532 foot-tons

Longitudinal Center

of Buoyancy (LCB) 5.9 feet aft of ⊗

Project a line vertically, where it crosses the scale at the bottom (center of flotation curve) shows the center of flotation

LCF 23 feet aft of ⊗

Using the Displacement & Other Properties Table from the docking drawing or the Curves of Form drawing, you can also get these values at the mean draft. For a damaged ship, especially with a large amount of trim, a computer should be used to check this information. This was also verified by using the POSSE program and the NAVSEA Flooding Casualty Control program (FCCS).

The next step is to determine the Longitudinal Center of Gravity, LCG, as follows:

Determine the trim between drafts:

(Draft aft -Draft fwd) = 26.5 ft - 22 ft = 4.5 ft fwd ⊗

Determine the trimming lever (TL)

Estimating the KG requires estimating weight changes from a known condition. For COLE heavy lift, we were given

Full Load Condition:

Dispacement 8,886 Tons

Draft(mean) 21.3 feet

KG 24.28 feet

Vertical Moment (KG x Displacement) 215,752 foot-Tons

This was a good start and was used on COLE because the ship was in the process of refueling to a full load condition. With compensated tanks, the ship would be a little heavier (sea water is heavier than fuel oil) and the KG a little lower than if the tanks were full of fuel. The loads equate to 2,127 Tons at 12.68 feet.

To estimate a KG for the ship at 10,700 Tons

Observed Condition:

Observed Displacement	10,700 Tons
Full Load Displacement	8,886 Tons
Difference is flooding water	1,814 Tons

To estimate the KG, first bracket the range of centers of gravity. First, for a low level we will use the group average of the loads (12.68 feet). For another level, we will use the estimated VCG of the flooding water in the area between the observed drafts and the tank top (14.00 ft).

Estimate the range of KG:

	8,886 Tons	24.28 feet	215,752 foot-Tons
add	1,814	12.68	23,002
new high	10,700	22.31	238,754

	8,886 Tons	24.28 feet	215,752 foot-Tons
add	1,814	14.00	25,396
new low	10,700	22.54	241,148

For the damaged condition, we also have to estimate the free surface effect of the flooding water. Free surface equates to:

$$FS = \frac{l \times b^3}{12 \times \nabla \times 35\ \text{ft}^3/\text{ton}}$$

$$l = 80\ \text{ft (length of flooding between Fr 174-254)}$$

$$b = 66.5\ \text{ft (beam of COLE)}$$

$$= 80\ \text{ft} \times (66.5\ \text{ft})^3 / 12 \times 10700 \times 35$$

$$= 5.2\ \text{ft}$$

Therefore the virtual KG (taking into account the free surface effect of the flooding water) could range from:

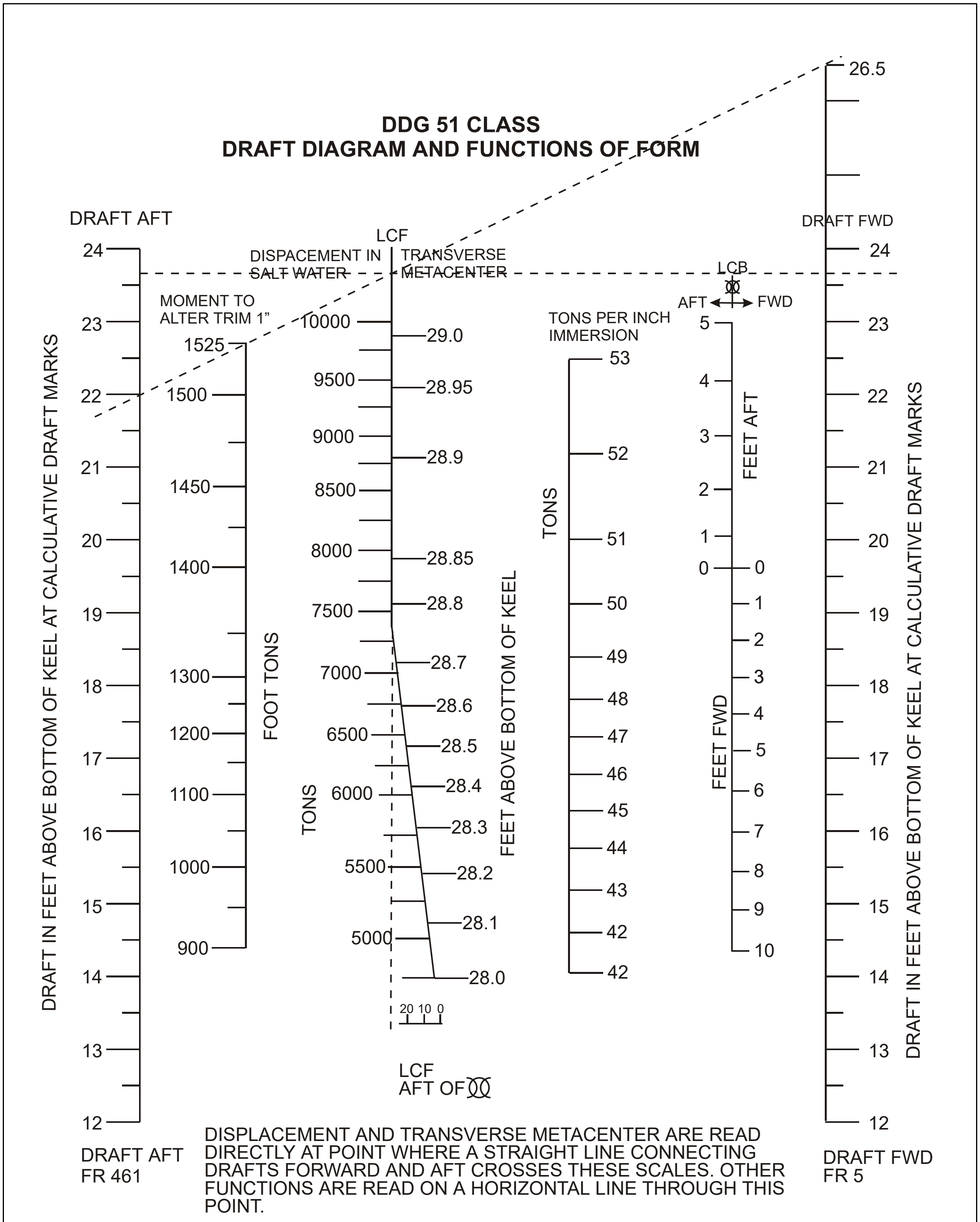
The flooding water in this condition would run out of the ship as it is lifted. Once lifted the displacement of COLE would be essentially the same as that of the ship prior to damage. Items known to be removed would be subtracted for the condition. To this is added, estimated weights for sand bags and equipment on the weather decks and damage material in the overhead or trapped flooding water.

Estimate for USS COLE:

Full Load	**8,886 Tons**	**24.28 feet**	**215,752 foot-Tons**
Removals:			
Fuel	60	10.00 feet	600
Crew and effects	40	50.00	2,000

Additions:			
Trapped Flooding Water	80	10.00 feet	800
Sandbags and Salvage Equipment	20	60.00	1,200
Estimated Condition	8886	24.21	215,152

Note: The new KG is determined by dividing the sum of the moment column by the sum of the weight column (i.e. 215, 152 ¸ 8,886 = 24.21)



Appendix Figure P-1. DDG 51 Draft Diagram and Functions of Form.

Table P-1. DDG 67 Information.

LOA	504.5 feet	
LBP	465.5 feet	Note: BY DESIGN LBP=466 ft
Beam	66.5 feet	
	Damaged	**Fully Loaded**
Draft Fwd	26.5 feet	
Draft Aft	22.0 feet	
Draft ⊗	24.25 feet	21.3 feet
Trim	4.5 feet	
Displacement	10,700 tons	8,886 tons
KG	22.54 feet	24.21 feet
MT1	1,532 ft-ton/in.	1460 ft-ton/in.
TP1	53.9 ton/in.	52.1 ton/in.
LCB	5.9 aft ⊗	2.80 aft ⊗
LCG	1.83 ft fwd ⊗	0.62 fwd ⊗
LCF	23.00 ft aft ⊗	23.00 aft ⊗
Underwater Projections		
	Sonar Dome forward	~ 10 feet below the keel
	Propellers	~ 5 feet below the keel
Length of Keel Block System	312 feet	From Docking Drawing
Distance from aft end of knuckle block to ⊗	147.26 feet	From Docking Drawing
Distance from aft end of knuckle block to LCG	147.88 feet	Calculated
Distance from aft end of knuckle block to LCF	124.26 feet	Calculated

P-3 Draft-at-Instability

This section demonstrates the calculations to determine the draft-at-instability for the COLE landing on the blocks of BLUE MARLIN. If COLE is not leaning against the guide posts and landed on the keel and side blocks before the draft-at-instability is reached, the ship will roll off the blocks. See Section 85.2.3 for more information on these calculations. The following equation represents the balance of the buoyancy moment and the displacement moment. The draft at which these two are equal will be the draft-at-instability.

$$KM(-R_{kn}) = KG_o$$

Table P-2 shows the information required to perform this calculation. The displacement moment is a constant: D x KG = 8886 tons x 24.21 feet = 21.5 x 10^4 ft-tons. For the damaged condition the displacement moment is 10,700 tons x 27.5 feet = 29.4 x 10^4 ft-tons.

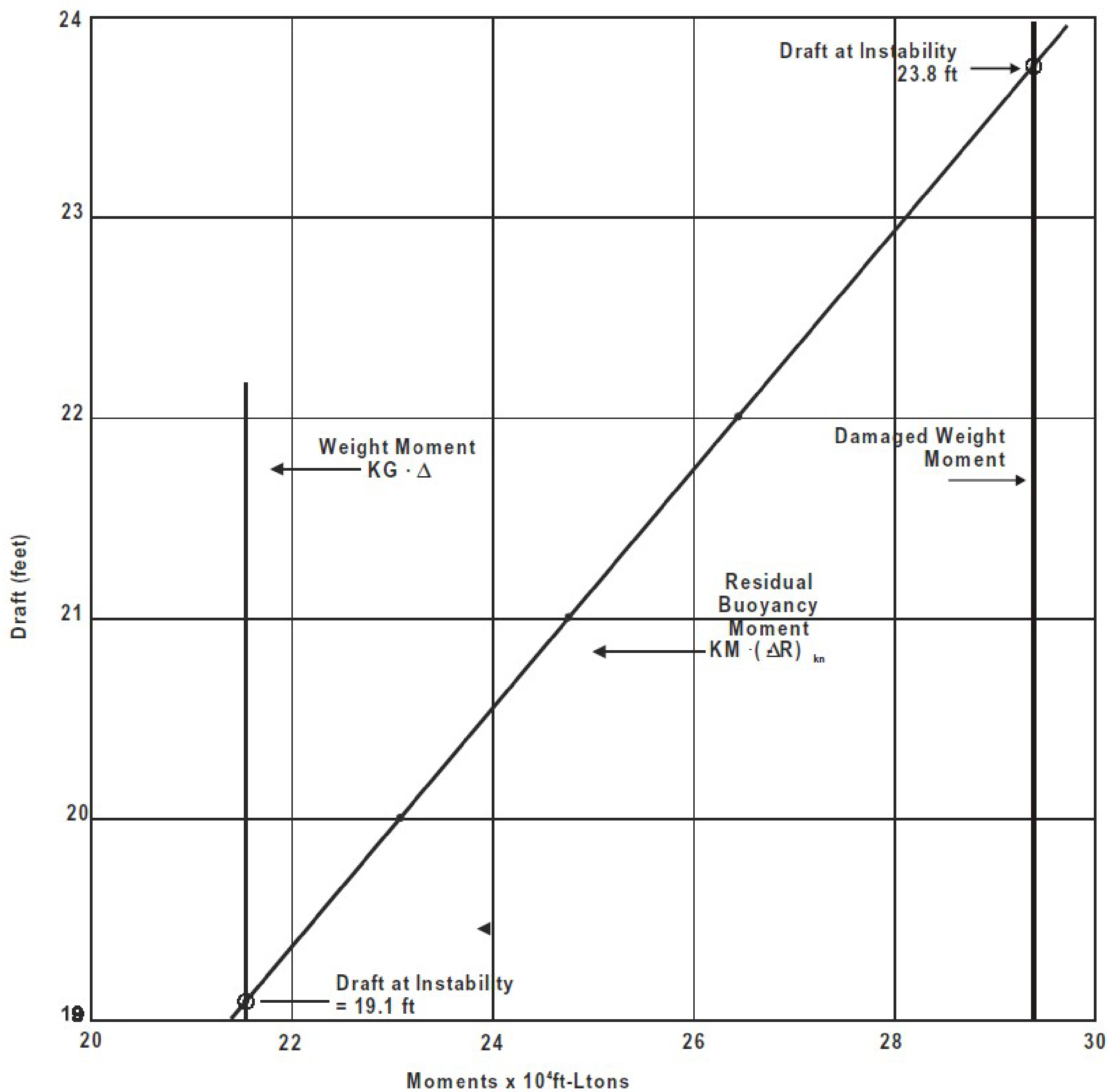
The bouyancy moment is found for a range of drafts. Table P-3 displays the results of this calculation. Appendix Figure P-2 shows these results graphically. Both KM and the residual buoyancy can be found from the draft diagram (Appendix Figure P-1). In Appendix Figure P-2, the intersection of the buoyancy moment line and the displacement moment line represents the draft-at-instability for the example provided. The draft-at-instability for this example is 19.1 feet, for COLE after the flooding water runs out. However, the draft-at-instability during landing could be as much as 23.8 feet. The drafts of COLE in the damaged condition were 26.5 ft fwd and 22 ft aft with a mean draft of 24.25 feet. COLE could go unstable if it was picked up on one end. For this reason, BLUE MARLIN matched the trim and list of COLE in the damaged condition for loading the ship.

Table P-2. Draft at Instability Information.

Required Information	Source
Draft	Assume a series of drafts (19' - 24')
Residual Buoyancy (Δ-R_{kn}) at Assumed Drafts	Draft Diagram (see Appendix Figure P-1)
Height of Metacenter (KM) at Assumed Drafts	Draft Diagram (see Appendix Figure P-1)
Original KG (KG_o)	Table P-1
Displacement (Δ)	Table P-1
Displacement Moment (lifted condition)	21.5 x 10^4 ft-tons
(flooded condition)	29.4 x 10^4 ft-tons

Table P-3. Draft at Instability Results.

Draft ft.	Residual Buoyancy $\Delta - R_{kn}$ (tons)	Height of Metacenter above Keel, KM (ft)	Residual Buoyancy Moment $KM \cdot (\Delta - R_{kn})$ (ft-tons)
19	7481	28.72	21.4×10^4
20	8090	28.80	23.3×10^4
21	8703	28.85	25.1×10^4
22	9330	28.91	26.9×10^4
23	9965	28.97	28.8×10^4
24	10,600	29.1	30.8×10^4



Appendix Figure P-2. Draft at Instability Results.

P-4 Draft-at-Landing Fore and Aft

This section demonstrates the calculations to determine the draft at landing for the COLE landing on the blocks of the BLUE MARLIN. The draft-at-landing acceleration takes into account a ship with trim pivoting around the knuckle block. When the two moments are equal, the trim will be removed and the ship will be landed fore and aft. See Section 8-5.2.3 for more information on these calculations. Figure 8-13 depicts the relationship of LCB and LCG to the reaction of the COLE landing on the knuckle block. The moments created by the buoyancy force (acting through LCB) and the displacement force (acting through LCG) must be equal for the COLE to land fore and aft. These two moments are calculated and graphed to determine the draft at which this occurs. Table P-4 shows the information necessary to make the calculations.

WARNING
When trim exceeds one foot, especially by the bow, a more rigorous analysis, preferably by a computer program, should be used to obtain the hydrostatic information.

Two conditions will be considered. The first is for the ship in the flooded condition. The second is for the ship in the lifted condition with the flooding water drained out.

For the first condition LCG is located 1.83 feet forward of amidships (see Table P-1) which equals a distance of 149.09 feet from the aft end of the knuckle block. The displacement moment about the knuckle block is a constant 10,700 tons times 149.09 feet which equals 15.95 x 105 ft-tons. In Appendix Figure P-3 this is a vertical line. The buoyancy moment is found for a range of drafts (Table P-5) and is plotted as a line in Appendix Figure P-3. The intersection of the two lines represents a draft at landing of 25.2 feet for the flooded condition.

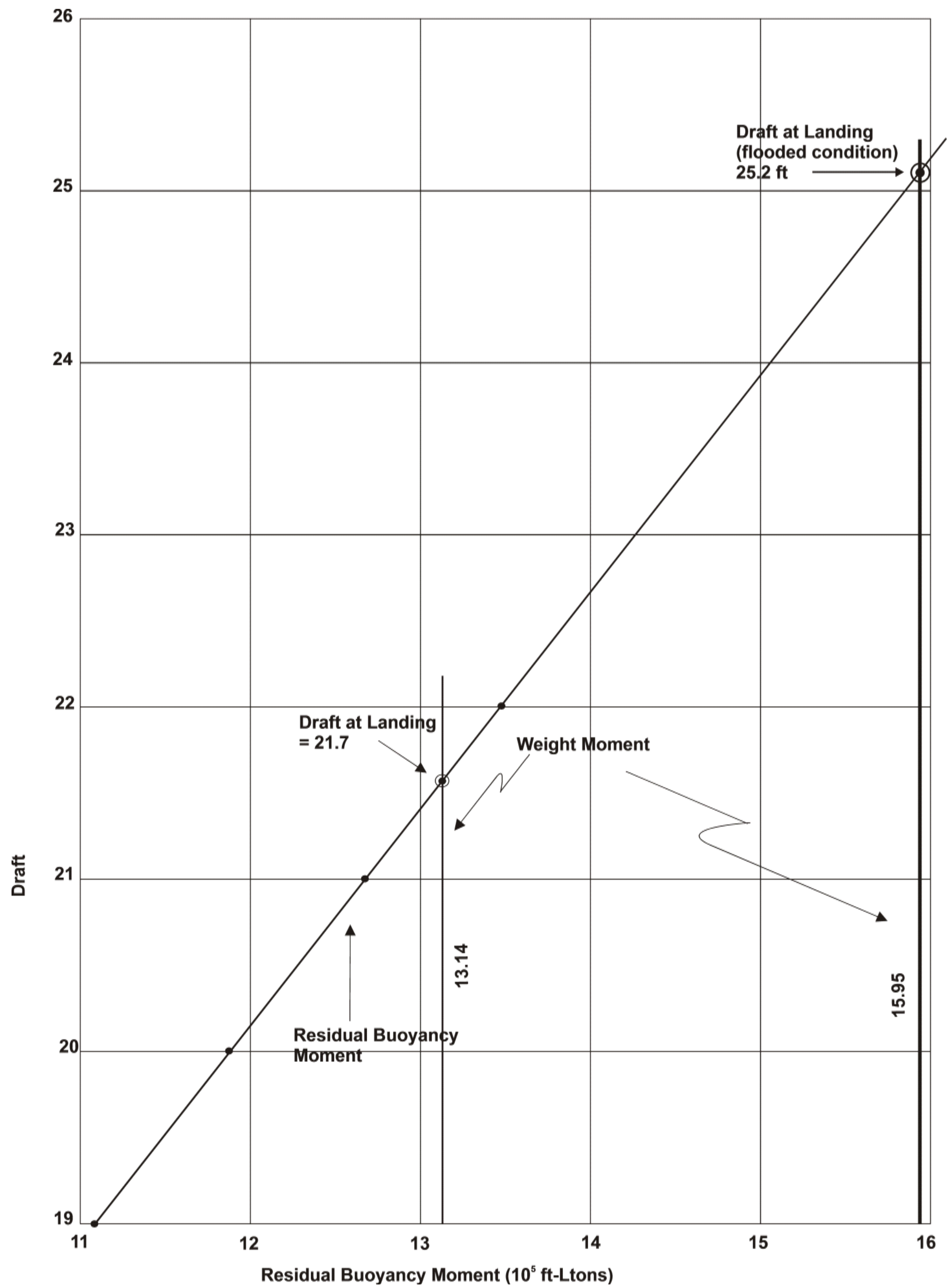
For the second condition, LCG is located 0.62 feet forward of amidships (see Table P-1) which equals a distance of 147.88 feet from the aft end of the knuckle block. The displacement moment about the knuckle block is a constant 8,886 tons times 147.88 feet which equals 13.14 105 ft-tons. In Appendix Figure P-3 this is a vertical line. The buoyancy moments are the same as those plotted in the previous paragraph. The intersection of the two line represents a draft at landing of 21.7 feet for the dewatered condition.

For COLE, BLUE MARLIN was trimmed to match the trim of COLE so that COLE landed level fore and aft to minimize the loading on the knuckle block and on the end of the skeg of COLE. This approach was taken due to the uncertainty in the longitudinal strength of COLE.

Table P-4. Draft-at-Landing Fore and Aft Information	
Information	**Source**
Draft	Drafts from 19 ft - 23 ft
Residual Buoyancy (- R_{kn}) at Assumed Drafts	Appendix Figure P-1
LCB at Assumed Drafts	Appendix Figure P-1
LCG	Table P-1
Displacement (D)	Table P-1
Distance from aft end of knuckle block to LCG	Table P-1
Displacement Moment (lifted condition)	13.14 x 10^5 ft-tons
(flooded condition)	15.95 x 10^5 ft-tons

Table P-5. Draft-at-Landing Fore and Aft Results.

Draft	Dist. ⊗ to Knuckle Block (ft)	Dist LCB to ⊗ (ft)	Dist LCB to Knuckle Block (ft)	Residual Buoyancy Δ-R_{kn}(tons)	Residual Buoyancy Moment (ft-tons)
19	147.26	1.2 fwd	148.46	7481	11.11 x 10^5
20	147.26	0.9 aft	146.36	8090	11.84 x 10^5
21	147.26	2.2 aft	145.06	8703	12.62 x 10^5
22	147.26	3.8 aft	143.46	9330	13.38 x 10^5
23	147.26	5.0 aft	142.26	9965	14.18 x 10^5
24	147.26	6.0 aft	141.26	10600	14.97 x 10^5



Appendix Figure P-3. Draft-at-Landing Fore and Aft.

P-5 Keel Block Build and Loading

The height of the keel block row should be as low as possible to improve stability, minimize the required submergence depth for onloading, and minimize the complexity of build of the keel and side blocks. It should be high enough to provide at least one foot of clearance under any hull appendage, protrusion, or penetration. For COLE, propeller pits were cut in the deck of BLUE MARLIN so that a keel block height of 16 inches could be used.

It is necessary to evaluate the stress on the keel blocks to ensure that they are strong enough to survive the expected loading conditions of the transit. The stress on the blocks will be affected by the loading condition of the asset and the dynamic motions of the heavy lift ship. To determine the stress on the blocks, it is necessary to look at these motions. Tables 8-4, 8-5, and 8-6 are used to evaluate the ship motions for the heavy lift ship and the validity of the contractor's Ship Motion Analysis. Sea State 7 (7m significant wave height) was the expected maximum condition for the transit of the COLE. Expected ship motions as predicted by Ship Motion analysis are also presented for comparison in Table P-6.

Table P-6. Heavy Lift Ship (HLS) Blue Marlin Characteristics and Motions

Item	Value		Source
LOA	712 ft		Load Manual
LBP	677 ft		Load Manual
Beam	137.8 ft		Load Manual
Draft	28.7		Load Manual
Maximum Submerged Depth of Cargo Deck	32.8 ft		
Maximum Cargo Deck Load	27.5 $\frac{mT}{m^2}$		
Displacement (Δ)	65177 ton		Load Manual
KG with DDG 67	39.08 ft		Load Manual
LCG with DDG 67	349.25 ft fwd AP		Load Manual
TCG with DDG 67	0.01 ft Port		Load Manual
Gm with DDG 67	31.4 ft		Load Manual
(z) Distance between DDG 67 KG and HLS KG = 30.17 feet aft (x) Distance between DDG 67 LCG and HLS LCG = 39.85 feet (y) Distance between DDG 67 TCG and HLS TCG = 17.0 feet			

Table P-6 (Continued). Heavy Lift Ship (HLS) Blue Marlin Characteristics and Motions			
Heave Acceleration	0.2 g	8-4	-
*Pitch Angle (P)	4°	8-5	4.38°
*Pitch Period (T_P)	7 sec	8-5	5.47 sec
*Roll Angle (R)	20°	8-6	16.7°
*Roll Period (T_R)	9.8	8-6(see below)	8.25 sec

* For Sea State 7

The roll period of the heavy lift ship can be estimated using

$$T_r = \frac{(C_C \times B)}{\sqrt{GM}}$$

$$C_C = 0.40 \frac{\text{sec}}{\sqrt{\text{ft}}}$$, Table 8-6, Note 3

B = 137.8 ft

GM = 31.4 ft for HLS with DDG 67 loaded

$$T_r = \frac{\left(0.40 \frac{\text{sec}}{\sqrt{\text{ft}}} \times 137.8 \text{ ft}\right)}{\sqrt{31.4 \text{ ft}}}$$

$$T_r = 9.84 \text{ sec}$$

Ship motion analysis gave T_r = 8.25 sec and 16.7° roll

Once the motions for the ship are determined, the acceleration factors that result from these motions can be determined. Use the equations from Section 8-6.2.1 to determine these acceleration factors.

$$a_z = 1 + h + \frac{0.0214 \text{ Px}}{T_p^{\ 2}} + \frac{0.0214 \text{ Ry}}{T_r^{\ 2}}$$

$$a_z = 1 + 0.2 + \frac{0.0214(4 \text{ deg})(39.85 \text{ ft})}{(7)^2} + \frac{0.0214(20 \text{ deg})\ (17.0 \text{ ft})}{\left(9.84^2\right)}$$

$$a_z = 1 + 0.2 + 0.07 + 0.8$$

$$a_z = 1.35$$

Ship Motion Analysis gave

a_z = 1.214 which will be used in the following computations.

The hand calculations confirm that the ship motion analysis results are reasonable. They are also within the commercial rule of 20° roll with a 10 second period and 10° pitch in a 10 second period.

Use this vertical acceleration factor to determine the loading on the keel blocks, DL_k.

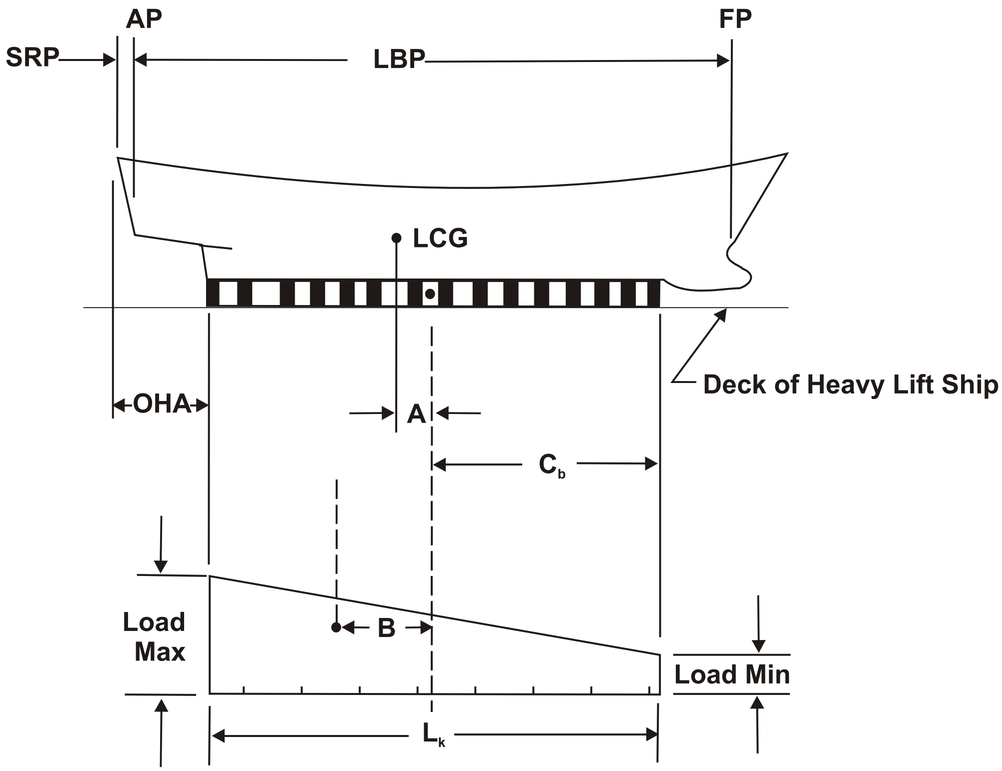
$$DL_K = wa_z$$

$$DL_K = 8,886 \text{ tons} \times 1.214$$

DL_K = 10,788 tons (Note: This is sufficient to encompass the flooded condition of COLE at 10,700 tons at loading)

Since the loading of the keel block row is relatively continuous for its length and uniform for its width, we will use the trapezoidal approximation method described in Section 8-6.2.5 to determine the distribution. Figure 8-13 shows the geometric relation of the components of these calculations. This figure is repeated as Appendix Figure P-4 to show the specific relationships for the DDG 67. These dimensions are taken from the DDG 67 Docking Drawing. For the purposes of these calculations, it is assumed that the continuous row of keel blocks will extend from roughly the after-most part of the DDG 67 skeg to the after limit of the sonar dome. The keel is 36 inches wide for the majority of its length but narrows to 18 inches wide at the end of the skeg. Some exclusions for items such as the Prairie-Masker belts and hull penetrations/sea chests are also assumed. These exclusions will not affect the length of keel blocking (L_k) but must be considered when evaluating the total effective contact area. Since these exclusions will not occur in the area of LoadMax, they will not be included in those calculations. Note: If you consider that a normal docking block of 48" wide by 40" long and that one or 2 blocks can be left out without appreciably affecting the keel block loading, the assumption that the keel block row is continuous can be used unless 3 or more keel blocks are left out, especially near one end.

The maximum (LoadMax) and minimum (LoadMin) loads will be determined from this approximation. The concern is the overall load carrying capacity of the keel block row, the maximum expected local stress on the keel blocks, and the load carrying capacity of the cargo deck of the heavy lift ship. The equation for LoadMax returns a value in tons per foot.



FP = Forward Perpendicular = 0

AP = After Perpendicular = 465.5 ft

LBP = Length between perpendiculars of asset = 465.5 ft

SRP = Distance from AP to point from which distance to keel blocks is measured = 4.5'

LCG = Asset's longitudinal center of gravity = 237.82 ft fwd of SRP

OHA = Distance from SRP to keel block = 90'

L_k = Length of keel blocking = 312'

$C_b = \frac{L_k}{2}$ = Center of blocking = 156'

$B = \frac{L_k}{6}$ = Approximate Center of Trapezoid = 52'

A = Distance from asset's LCG (center of Gravity) to C_b (center of Blocking)
(($OHA + C_b$) - LCG)
($OHA + C_b$) - LCG = 90 + 156 - 237.82 = 8.18 ft aft

Appendix Figure P-4. Load Distribution

$$\text{LoadMax} = \frac{\text{DL}_K}{\text{L}_K}\left(1 + \frac{A}{B}\right)$$

$$\text{LoadMax} = \frac{10788 \text{ tons}}{312 \text{ ft}}\left(1 + \frac{8.18 \text{ ft}}{52 \text{ ft}}\right)$$

$$\text{LoadMax} = 40.01 \text{ tons/ft}$$

$$\text{LoadMin} = \frac{\text{DL}_K}{\text{L}_K}\left(1 - \frac{A}{B}\right)$$

$$\frac{10788 \text{ tons}}{312 \text{ ft}}\left(1 - \frac{8.18 \text{ ft}}{52 \text{ ft}}\right)$$

$$\text{LoadMin} = 29.13 \text{ tons/ft}$$

In a normal dry-docking, this would be used to evaluate the stress on the last block in the line. Since heavy lifts are often done with a continuous row of keel blocks, the last foot of blocking will be evaluated. To determine the maximum stress on the last section of keel blocking, use LoadMax and the equation from Section 8-6.2.5.

$$S = \frac{\text{LoadMax}}{A_e} \times \frac{2240 \text{ lb}}{\text{ton}}$$

$$S = \frac{40.01 \text{ tons/ft} \times 1 \text{ ft} \times 2240 \text{ lb/ton}}{36 \text{ in} \times 12 \text{ in}}$$

$$S = 207.5 \text{ psi}$$

The stress of 207.5 psi is acceptable for the entire keel block row as it is below the compressive limit for Douglas Fir (370 psi). Recalculating for an 18-inch wide keelblock, the stress of 415 psi exceeds the 370 psi limit. It should be noted that this stress is above the limit set for a 18-inch keel block at the end of the skeg when looking at knuckle loading. To spread the load over the block, a 1-inch thick steel plate was installed on top of the knuckle block under the skeg. Since the keel block loading was so high (40.01 tons/ft), it was checked against the load carrying capacity of BLUE MARLIN's cargo deck which is 27.5 mT/m^2. The location was changed so that the end of the skeg landed over a transverse bulkhead and spreader beams were placed under the keel blocks in these areas to spread the load.

It should be noted that this calculation assumes that the keel blocks will bear the entire deadweight and dynamic load of COLE. In reality, the side blocks will provide a significant contribution to supporting the load of COLE.

P-6 Side Blocks

The number of side blocks required will be calculated in a two step process. Step 1 will determine the minimum number of side blocks required for loading of the asset and deballasting of the heavy lift ship. Step 2 will determine the number required for the transit.

Step 1. To calculate the number of side blocks needed for loading, refer to the equations in Section 8-7.2. The first consideration is to support the dead (or static) load. The two components of this loading are the assumed sharing of the vertical load (estimated at 15 percent) and the increase in this load when the BLUE MARLIN heels or rolls during loading. Sea State 4 will be the maximum observed during the loading and blocking operation and the numbers for roll amplitude (R) and period (T_r) are assumed for this condition. From Table 8-8, BLUE MARLIN would roll approximately 5 degrees in Sea State 4. Due to the damage the COLE was listed 2 degrees. Therefore, a reasonable angle for the loading operation was 7 degrees. The number of blocks needed for one side for this weight and assumed keel angle is found by:

$$N_d = \frac{DL_s + DL_r}{S_p \times A_e}$$

Where DL_s = 0.5 x 0.15 x w = 0.5 x 0.15 x 8886 = 666 tons per side

DL_r = wSinR = 8886 sin7° = 1083 tons per side

S_p = 800 psi for Douglas Fir

A_e = 24 in x 36 in = 864 in^2

$$N_d = \frac{666 + 1083 \times 2240}{800 \times 864} = 5.67 \text{ or 6 blocks per side}$$

As noted in Section 8-7.3, this number of side blocks is only for the loading operation. Special consideration should be given to selecting the locations for the initial side blocks for landing. The locations should be taken from the side block locations on the docking drawing for the best possibility of correct fit. The lowest side block with the least curvature should be selected to minimize the height. Areas of damage should be avoided due to uncertainty of the shape or strength of the hull. On past heavy lifts, use of wedge material or air bags was required at loading because the asset landed out of position or the side blocks did not fit well to the hull. These blocks may need to be replaced or not counted in the final total of required side blocks.

Step 2. To determine the final side blocking and seafastening, the number of additional side blocks that need to be added, both wind loading and dynamic loads from ship motions for the transit must be considered. The magnitude of these forces will depend on the expected conditions. If the blocking build will take place at a site other than the load site, the conditions for the transit to the building site must also be evaluated. If the build is to take place in an exposed area, the conditions at that site must be considered. The conditions for the complete transit to the final destination must also be evaluated. However, the expected conditions for all phases of the operation must be evaluated to ensure a safe transit. For these example calculations, the transit conditions will be used.

To complete Step 2, first, the moment from wind forces is found using the recommended winds from section 8-5.1.1. This wind (86.8 knots) must be multiplied by a gust factor of 1.21 which equals 105 knots. It is also necessary to know the area upon which this wind will act, assuming a beam wind. The area for the DDG 67 above the waterline is published in various sources, and an estimate of the below waterline area is made or an estimate of the entire sail area can be made.

A_s of superstructure = 40 x 190 = 7600 ft^2

A_s above the water line = 22 x 506 = 11132 ft^2

A_s below the water line = 22 x 466 ft = 10252 ft^2

A_s = 28984 ft^2

This area is used in the equations found in Section 8-7.2.5 to find the number of side blocks required to resist the wind forces. The value, L_3 is an approximation of the moment arm from the deck of the heavy lift ship to the center of the projected area. The factor, 0.004, in the moment equation accounts for the conversion in units (using feet and knots).

L_3 = 35 ft

$$M_w = 0.004\ A_s L_3 V^2$$

For a 25 knot wind speed

$$M_w = 0.004 \times 28984 \times 35 \times 25^2 = 25.4 \times 10^5 \text{ft}-\text{lbs}$$

For the 86.8 knot wind speed

$$M_w = 0.004 \times 28984 \times 35 \times 105^2 = 44.7 \times 10^6 \text{ft}-\text{lbs}$$

$$N_w = \frac{M_w}{A_e S_p L_2}$$

Where L_2 =11.25 ft for the inner row and 17 ft for the outer row

For the 25 knot wind speed

$$N_w = \frac{25.4 \times 10^5}{36 \times 18 \times 800 \times 11.5}$$

$$N_w = 0.319 \text{ side blocks}$$

This can be accounted for within the initial 6 side blocks.
For the higher wind speed (105 kts)

$$N_w = \frac{44.7 \times 10^5 \text{ft} - \text{lbs}}{36 \times 18 \times 800 \times 17}$$

$$N_w = 3.8 \text{ side blocks}$$

The outer row of side blocks was chosen because they are easier and quicker to install. On the COLE heavy lift, these blocks were installed first and immediately after loading in case the weather became worse during the period of final side blocking and seafastening. Next, the amount of additional side blocking for ship's motion during transit must be computed. Using Tables 8-6, 8-7, and 8-8 and some historical weather data, the motions of the heavy lift ship with the asset aboard are determined. For this example, sea state 7 is used as the maximum expected condition. The factors listed in Table P-6 will be used to find the accelerations associated with rolling.

$$a_y = \text{Sin R} + \frac{0.0107 \text{ Px}}{T_p^2} + \frac{0.0002 R^2 y}{T_r^2} + \frac{0.0214 \text{ Rz}}{T_r^2}$$

$$a_y = \text{Sin}(20^o) + \left(\frac{0.0107(4°)(39.85 \text{ ft})}{(7)^2} + \frac{0.0002(20°)^2(17.0)}{(9.8)^2} + \frac{0.0214(20°)(30.2 \text{ ft})}{(9.8)^2} \right)$$

$$a_y = 0.342 + 0.035 + 0.014 + 0.135$$

$$a_y = 0.526$$

Ship Motion Analysis gave a roll of 16.7° and a_y = 0.435

These accelerations can then be used to find the moment associated with rolling.

$$M_r = W \times a_y \times (KG) \times 2240$$

$$= 8886 \text{ tons} \times 0.435 \times 24.21 \text{ ft} \times 2240 \text{ lbs/ft}$$

$$= 209.62 \times 10^6 \text{ ft-lbs}$$

Once the moment is known, the number of sideblocks that are required to resist that moment can be found. In this equation, L_2 represents the distance from the centerline of the ship to the centerof the side block. This is the location through which the resultant force will act. While this number will be different for every block, the value of 17.5 represents an average or a typical block. This information comes from the docking drawing

$$N_r = \frac{Mr}{A_e S_p L_2}$$

$$N_r = \frac{209.62 \times 10^6 \text{ ft-lbs}}{36 \text{ in} \times 24 \text{ in} \times 800 \text{ lb/in}^2 \times 17.5 \text{ ft}}$$

$$N_r = 17.3 \text{ per side}$$

Therefore, the combined total number of side blocks could be determined by combining step 1, total side blocks for loading ($T_{SB1} = N_d + N_w = 5.67 + 0.32 = 6$) and step 2, total side blocks for transit loadings

($T_{SB2} = N_w + N_r$)

$$\text{Final total side blocks} = N_d + N_w + N_r = 5.67 + 3.8 + 17.3$$

$$= 26.77 \text{ or } 27 \text{ side blocks on each side}$$

The DDG 67 docking drawing indicates that 15 to 21 side blocks are required in a normal docking. This means that there will be insufficient room to install 27 side blocks and that spur shores will have to be used to resist the higher roll angles and dynamic overturning moments.

To determine the number of shores required, we will reassess the number of side blocks required for ship's motion (N_w). We will start with determining the assumed number of side blocks to support the static angle of roll.

The position of the side blocks on the docking drawing are designed to resist angles of roll up to 15 degrees. The assessment used should reflect the angle of roll under consideration (maximum static angle of roll from the ship's motion analysis, i.e. 16.7.) The first term in the equation for A_y is SinR where R is maximum roll angle. The equation for DL_r can be reworked using the maximum angle of roll for R.

DL_r = w SinR

= 8886 (sin 16.7°)

= 2553.5 tons

$$N_r = \frac{2553.5 \times 2240}{800 \times 24 \times 36} = 8.3 \text{ sideblocks}$$

Spur shores must resist all angles above 15 degrees and should be spaced accordingly. The number of shores required to resist dynamic loading during transit is then determined from the number of side blocks and the maximum allowable reaction of the shores. The position of the shores and the side blocks is also a factor in considering how many shores are required.

Then the number of shores can be reworked for the remainder of the dynamic load. This methodology will give a reasonable idea of how the spur shores should be distributed. See Section 8-7.4 for more information.

$$N_s = \frac{M_r - DL_r \cdot L_2}{\sigma_s L_3}$$

L_2 is the average distance off centerline for the side blocks for ship motions. For COLE we used side blocks in the outer row, L_2 = 17.5 feet.

L_3 is the average distance off centerline for shore spur locations against the hull of the COLE = 21 feet

$$= \frac{209.62 \times 10^6 - 2553.5 \times 2240 \times 17.5}{195 \times 2240 \times 21}$$

$$= 12 \text{ shores per side}$$

Therefore the total side blocking would consist of side blocks and spur shores. Side blocks equal to $N_d + N_w + N_r$ = 5.67 + 3.8 + 8.3 = 17.33 or 18 per side. To this is added 12 spur shores per side.

Now that we know how many shores we needed, we need to determine how to make the shores.

To start, it is necessary to determine the maximum allowable stress of the shores. This is based both on material and geometry.

For USS COLE, heavy, steel I-beams were chosen for the spur shores. These were designed for a loading of 195 tons/shore to be installed under the intersections of the transverse and longitudinal back up structure to the shell plating as specified by NAVSEA O5P. The spur shores were capped with a steel spreader plate and 1” thick dense rubber.

To ensure that the spur shore could develop its full compressive yield strength (σ_y) without column buckling, it was limited to 40.

Column strength

$$\sigma_{cr} = \text{Compressive yield strength } \frac{P}{A} \left(\text{if slenderness ratio, } \frac{L}{r} \leq 40\right)$$

Noting that

$$\sigma_y = 32 \text{ Ksi for mild steel}$$

$$P = 195 \text{ tons}$$

Therefore the minimum cross sectional area of the shore would be

$$A = \frac{P}{\sigma_{cr}} = \frac{195\text{Ton} \times 2240\frac{1b}{\text{Ton}}}{32000 \text{ psi}} = 13.65 \text{ in}^2$$

$$\text{Chosen I – beams were } 300\text{mm} \times 300\text{mm} \times 11\text{mm} \times 19\text{mm}$$

					A(mm^2)
Flange	300	x	II		3,300
Web	(300-22)		x	19	5,282
Flange	300 x 11				3,300
					11,882

$$\frac{11,882}{(25.4)^2} = 18.417 \text{ in}^2$$

Buckling strength To ensure adequate buckling strength, the slenderness ratio, must be less than 40.

$$L = \text{unsupported length of spur shore} \qquad b = \text{flange width}$$

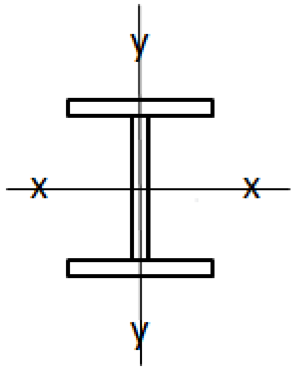
$$r = \text{least radius of gyration of the section} \qquad d = \text{depth of web}$$

$$r = \sqrt{\frac{I}{A}}$$

where I = moment of Inertia

A = cross sectional area of the shore

Properties of the I-beam



For x axis	A(mm²)	X(mm)	M = AX(mm³)	Ix = MX(mm⁴)	$I_y = \frac{bd^3}{12}(mm^4)$
Upper flange	300 x 11 = 3300	$300 - \frac{11}{2} = 294.5$	971850	286209825	33275
Web	(300-22) x 19 = 5282	$\frac{300}{2} = 150$	792300	118845000	34017841
Lower flange	300 x 11 = 3300	$\frac{11}{2} = 5.5$	18150	99825	33275
	11,882		1782300	405154650	34084391

$$I_N = I_x + I_y - \frac{M^2}{A} = 405154650 + 34084391 - \frac{(1782300)^2}{11882}$$

$$= 171894041 \text{ mm}^4$$

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{171894041}{11882}} = 120.27 \text{ mm (minmum radius of gyration)}$$

For y Axis	A	Y	M	I_x	I_y
300 x 11	3300	150	495000	74250000	24750000
(300 - 22) x 19	5282	150	792300	118845000	158900
300 x 11	8300	150	495000	74250000	24750000
	11882		1782300	267345000	49658900

$$I_N = I_x + I_y - \frac{M^2}{A}$$

$$= 267345000 + 49658900 - \frac{(1782300)^2}{11882}$$

$$= 267345000 + 49658900 - 2634500$$

$$= 49658900$$

$$r = \sqrt{\frac{I}{A}} = 64.65 \text{ mm (minimum radius of gyration)}$$

$$\frac{L}{r} \leq 40$$

$$\text{Therefore } L \leq 40r$$

Using the minimum radius of gyration:

$$\leq 40(64.65\text{mm}) = \frac{2586\text{mm}}{25.4\frac{\text{mm}}{\text{in}}}$$

Therefore, shores have to be less than 8.48 ft in length or they have to be braced such that no unsupported length is greater that 8.48 ft. That is, spur shores cannot be longer than 17 ft if supported or 8.5 ft if unsupported. They are welded at the base to the cargo deck of the heavy lift ship.

P-7 POSITIONING OF SPUR SHORES

Once the number of spur shores is determined, the locations and orientation of the spur shores needs to be assessed. The locations are determined as to how high on the ship's hull they need to be to overcome the overturning moment, M_o. An estimated starting point is with the shore at the turn of the bilge. Under the turn of the bilge, the hull is relatively flat, the shores have to be perpendicular to the local hull curvature, and the shores will be at too great an angle, more than 45°. At angles greater than 45° the shores provide very little resultant force in the transverse direction and will tend to trip out. If the shores are too high above the turn of the bilge, they become too long and will not support the column strength. If the point has to be high on the hull to overcome the overturning moments, towers may have to be used.

M_o is created by the transverse dynamic force working through the ship's (i.e. COLE) center of gravity. (See Appendix Figure P-5)

M_o = (displacement) (a_y)(L_o)

Where displacement = 8,886 tons

a_y = 0.435 from motion analysis

L_o = distance between the ship's CG and the position of the shores on the hull in the vertical direction. = (ship's CG above its keel (KG) + Keel block height (H_{kb})) - shore average height (H_s) = 15.54'

M_o = (8,886) (0.435)(15.54) = 60,068 ft-tons

The righting moment is developed by the resultant force that the spur shores can create in the transverse direction against the hull. From the motion analysis, in a dynamic environment, the weight of the ship is more when the heavy lift ship pitches up and less when the heavy lift ship pitches down. An example of this is when the heavy lift ship pitches down and rolls off the top of a wave into a trough. The dynamic load factor in the vertical direction is a_z. When the heavy lift ship pitches up, a_z increases the loading on the blocking system, (displacement x a_z). When the heavy lift ship pitches down, a_z decreases the loading on the blocking (displacement x (2-a_z). The resultant of this force in the transverse direction is the loading on the blocking times the cosine of the angle of roll.

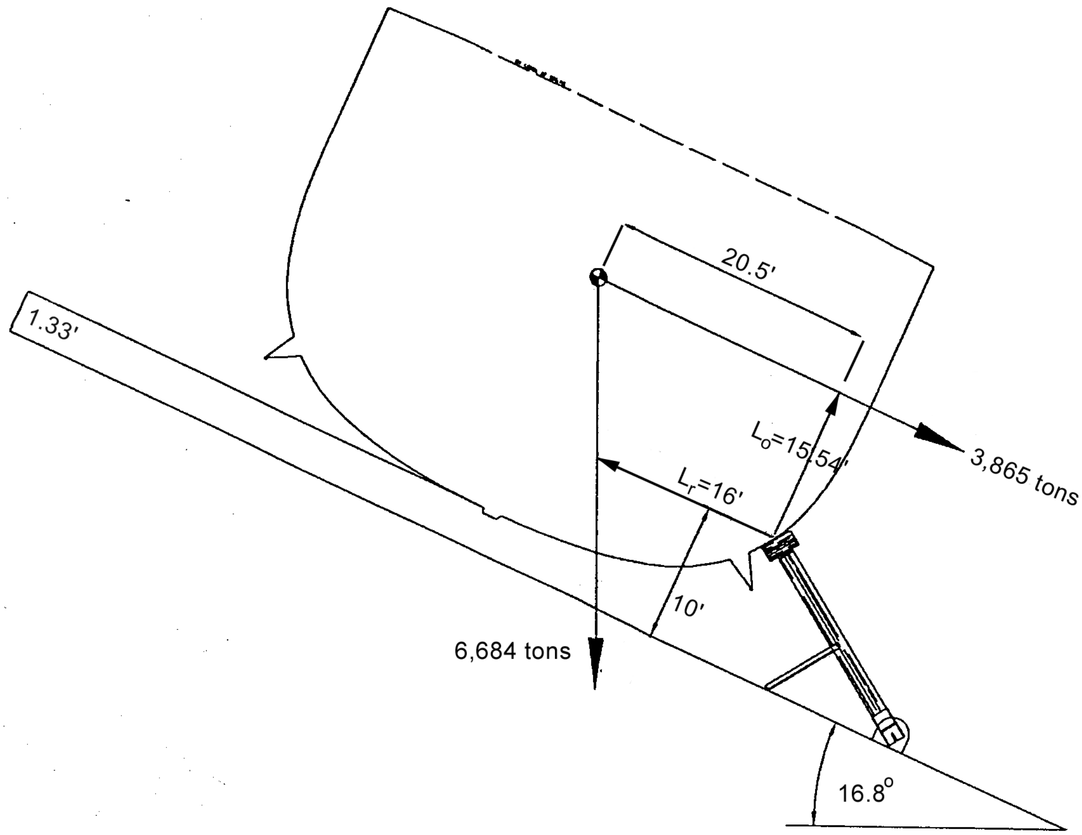
The lever arm L_r is the distance between the line of action of the downward force through the CG of the ship and the position of the shore on the hull in the transverse direction.

L_r = 20.5' - (sin 16.8°)((24.21' + 1.33') - 10')))

M_r = (displacement) (2-a_z) (cos 16.8°) L_r

M_r = (8886)(2-1.214)(cos 16.8°)(20.5 - 15.54 sin 16.8°) = 107,047 ft-tons

The righting moment is greater than the overturning moment, therefore this is an acceptable shore height. Next you look at the ship's structure to make sure that where the shores are positioned on the hull aligns with back up structure such as a bulkhead, a web frame or a deck. When these positions are met, the final consideration determines the orientation of the shore. As noted in the first paragraph above, the shore has to be perpendicular to the local hull curvature. Where the shore is located on the hull curvature to the cargo deck determines the angle of the shore. A good mix of angles between 20° and 45° is recommended with at least two at each angle.



Appendix Figure P-5. Overturning Moment.

Appendix Q - CHECKLIST FOR PREPARING AN ASSET FOR HEAVY LIFT

The following checklist is designed to help the crew of a ship or other preparing activity prepare a vessel to be heavy lifted. It lists general requirements, most of which must be completed before the asset is delivered to the float-on site. If the preparing activity has questions concerning this checklist or preparations required to ready the asset for heavy lift, it should communicate these concerns as early as possible to ensure a timely departure. The preparing activity should fully complete this checklist in time for the preloading conference. Items that are not applicable or cannot be accomplished must be cleared through the Loadmaster and Docking Observer.

The Docking Observer should conduct a preliminary inspection as soon as possible (prior to the float-on date) to preclude misunderstandings and rework. In special situations, the standards reflected in this checklist can be “relaxed” if operational factors dictate that greater risk is acceptable and if all parties agree. Any deviations from this checklist must be accompanied by an appropriate justification from the preparing activity.

The Docking Observer should conduct a final inspection of the asset, accompanied by a representative of the preparing activity or the as-set as well as the Loadmaster and Independent Marine Surveyor. Upon satisfactory completion of this inspection, condition ZEBRA should be set on the asset.

NOTE
For more information on preparing a vessel for heavy lift, refer to Chapter 8.

ASSET INSPECTION CHECKLIST

Asset Name ________________________________ Hull Number______________________________

Owner _____________________________________ P.O.C. and 24 Hour # ______________________

Departure Port _____________________________ Arrival Port ______________________________

Receiving Activity Port ________________________ P.O.C. and 24 Hour # ______________________

Heavy Lift Vessel Name _______________________ P.O.C. and 24 Hour # ______________________

Asset Characteristics Upon Arrival at Float-On Site

Length:	Beam:	Displacement:
Draft fwd:	Draft aft:	Mean draft:
Freeboard fwd:	Freeboard aft:	Freeboard mid:
MTI:	TPI:	KG:
GM:	Maximum Ht above WL:	
Maximum Navigational Draft (include underwater appendages; i.e., sonar domes, propellers, etc.):		

Has the asset been prepared and is it authorized to be heavy lifted in accordance with requirements set forth in this manual?

____

Provide rationale for accepting asset with items not accomplished

____

____

____

____

Use separate sheet if additional space is needed.

The asset described above is seaworthy in all respects. The material condition is noted.

Representative of command having prepared the asset for lift Date

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1. SHIP INFORMATION					
		Reference	**N/A**	**Yes**	**No**
a.	Is the booklet of general plans available? If yes, provide location:				
b.	Is damage control book, curves of forms, or other stability data available? If yes, provide location:				
c.	Are liquid load diagrams and damage control flooding plates available on board? If yes, provide location:				
d.	Are instructions posted in after steering for lining up hydraulic steering systems to hand pump?				
e.	Are plans and date of the last drydocking available? If yes, provide location: Date of last drydocking: ***Note**: A copy should be provided to the heavy lift ship as early as possible. An extra copy should be brought to the preloading conference.*				
f.	Has a list of equipage been prepared? ***Note:** The preparing activity is responsible for providing a list of equipage assigned to the craft that is pilferable and must be on board at destination. Provide list on separate sheet.*				
g.	List remaining HAZMAT on board (include all fuel and ammo):				

2. RIDING CREW					
		Reference	**N/A**	**Yes**	**No**
a.	Will a riding crew be employed? If so, attach a copy of the directive (message, letter, etc.) and proceed with the following checks.				
b.	Authority that authorized a riding crew:				
c.	Number of crew members:				
d.	Has a list of the riding crew been provided to the heavy lift vessel? **Note**: *A list of the riding crew is entered in towing ship's diary (name, rate, SSN, and NOK; address and phone number of rider and NOK for civilians).*				
e.	Are enough life rafts on board the heavy lift ship with emergency rations and water for the riding crew in the event that they have to abandon ship? Location of life rafts:				
f.	Date life rafts were last tested/inspected:				
g.	Are a sufficient quantity of life jackets and life rings on board? Number, type, and location:				
h.	Means of communication between the docked asset: and the heavy lift ship: **Note:** *Must be provided if riding crew is to live aboard asset.*				
i.	Has the riding crew been trained in damage control and support systems? **Note:** *The preparing activity is normally responsible for such training.*				
j.	Is habitability and sustenance sufficient from on-board the heavy lift ship or asset? **Note:** *Habitability and sustenance should be available on the asset if the riding crew is to live aboard.*				

3. SEAWORTHINESS					
		Reference	**N/A**	**Yes**	**No**
a.	Draft after craft is in proper trim: Forward: _______________ Aft: ___________________ Max. navigational draft:	8-5.2.2 8-3.6.1			
b.	GM after craft is in proper trim:				
c.	KG after craft is in proper trim:				
d.	If GM is not known, “sally ship” to establish period of roll: Normally T = 2 $\sqrt{\text{Beam(ft)}}$ T (observed):	5-7.3			
e.	Displacement:				
f.	Provide a list of all tank soundings.				
g.	Has any temporary ballast been installed? Type and location of ballast:	8-3.6.1			
h.	If not, will craft require additional ballast?	8-3.6.1			
i.	Type of ballast required:				
j.	Describe where ballast will be placed and how much:				

SEAWORTHINESS (cont.)					
		Reference	**N/A**	**Yes**	**No**
k.	Is condition ZEBRA set throughout the tow? If the answer is Unsatisfactory, list exceptions on separate sheet.				
l.	Are all sea valves secured and tagged out?	8-3.6			
m.	Is a list of sea valves attached?	8-3.6			
n.	Are all sounding tubes capped?	8-3.6			
o.	Is there a list of all sounding tubes attached? (Required)	8-3.6			
p.	Are all between-tank sluice valves closed?	8-3.6			
q.	Are all normally dry compartments dry?	8-3.6			
r.	Are all bilges free of oil and water?	8-3.6			
s.	Have all compartments been inspected for loose equipment?	8-3.6			
t.	Has steel wire or cable been used to secure all equipment to prevent any movement in heavy weather? **Note**: *All moveable equipment must be secured in place with wire or by welding. No fiber rope or line will be accepted.*	8-3.6 5-7			
u.	Are all rudders secured? **Note:** *The rudders should be secured to ensure that there will be no movement during rolling on the heavy lift ship.*	8-3.6			
v.	Type of securing device used:				
w.	Are all portholes secured for heavy weather?				
x.	Are all watertight boundaries secured?	8-3.6			
y.	Are all hatches, scuttles, doors, and other watertight closures provided with pliable gaskets?	8-3.6 5-7.9			
z.	Have weather decks and main transverse bulkhead watertight closures been chalk tested?				

SEAWORTHINESS (cont.)						
			Reference	**N/A**	**Yes**	**No**
aa.	Are all dogs on watertight closures operable and functioning as designed?					
bb.	For LST-type assets, all of the following must be answered Satisfactory, or the vessel will not be accepted for lift:					
	i.	Do the bow doors have hydraulic rams connected?				
	ii.	Are mud flaps at the bottom of the doors secured?				
	iii.	Are all dogs, heavy weather shackles, ratchet-type turnbuckles and strongbacks in place, tight and secure so that they cannot work free?				
	iv.	Are bow ramp operating instructions posted in the hydraulic control room?				
cc.	If asset is equipped with a bow or stern ramp, all normal securing devices (i.e., ramp chains, dogs, and turnbuckles) must be in place and in good mechanical order.					
dd.	Are all lifelines in place and in good condition?					
ee.	Are there two means of egress for the asset? **Note:** *One egress must be a well constructed stair-type access. The second egress may be a temporary access such as a jacob's ladder.*		8-4.5			
ff.	Are damage control inspection routes marked by paint/diagrams and/or reflective tape?		5-8.4			
gg.	Is interior access sufficiently marked for DC teams?					

4. ELECTRICAL POWER					
		Reference	N/A	Yes	No
a.	If power is to be supplied by the heavy lift ship, has the power cable connection been inspected to ensure compatibility? **Note:** *To ensure an adequate connection, a visual inspection should be conducted.*				
b.	If the assets generators are to be run have the following items been accomplished?				
	i. Has provisions for cooling water been made?				
	ii. Have cooling water pumps been demonstrated to have sufficient suction lift and discharge head?				
	iii. . Is sufficient fuel available on board the asset for the entire transit?				
	iv. Is there sufficient ventilation for the riding crew to run the generators?				
c.	Has a grounding cable of sufficient length and size been provided and have attachment points on the asset and heavy lift ship been identified?				

5. FIRE FIGHTING						
			Reference	N/A	Yes	No
a.	Has adequate fire fighting capability been provided?					
b.	If provided from the asset:					
	i.	Have pumps been demonstrated to have sufficient suction lift and discharge head?	5-8.2			
	ii.	Are at least two P-100s or operating fire pumps and all other necessary fire fighting equipment on board?	5-8.2			
	iii.	Is there enough P-100 fuel on board?	5-8.2			
	iv.	Are there sufficient starting cartridge spares? Note: 4 recommended.	5-8.2			
	v.	Is means for storage of fuel adequate?	5-8.2			
c.	If provided from the ship:					
	i.	Has the connection on board the heavy lift vessel been inspected and been shown to be compatible? **Note:** *To ensure an adequate connection, a visual inspection should be conducted.*	8-9.6			
	ii.	Is adequate fire hose available to reach from the proposed connection point to the asset's connection point?				
	iii.	Is all hose protected against chafing?				
	iv.	Is all hose secured for heavy weather?				

6. NAVIGATION					
		Reference	**N/A**	**Yes**	**No**
a.	Have all required navigation lights been installed? **Note:** *Previous lifts have required a mast light due to increased height.*				
b.	Is each light rigged with two bulbs, so that if one burns out the craft still complies with the COLREGS?	5-7.7			
c.	Is all wiring well-secured and protected from damage by the elements?	5-7.7			
d.	Is the light equipped with a solar switch or time switch?				
e.	Are the batteries secured for heavy weather? **Note:** *If topside, batteries must be in a watertight box. The location should be carefully selected and secured from heavy seas. If possible, batteries should be inside the asset*.				
f.	Is battery ventilation adequate?				
g.	Are the batteries charged with sufficient amperage available to keep the lights burning brightly for the duration of the trip?	5-7.7			
h.	Total ampere capacity of the bank: Sufficient amperage must be calculated and available to cover the following:	Table 5-4			
	(1) Wattage of the bulbs serviced				
	(2) Distance of bulbs from battery source (wiring losses)				
	(3) Duration of transit (taking into consideration the solar/time switch and length of the period of darkness).				
i.	Are day shapes rigged in accordance with COLREGS?				

7. CARGO					
		Reference	**N/A**	**Yes**	**No**
a.	Is any ship equipment to be included as separate cargo on board the deck of the heavy lift ship?				
b.	If so, has a list of this equipment been prepared? Is this list attached?				
c.	Is this cargo properly stowed for sea in it's container?				
d.	Has the removal of this equipment been included in all weight and stability calculations?				

8. OTHER CONSIDERATIONS					
		Reference	**N/A**	**Yes**	**No**
a.	Are safety nets provided around access brows?				
b.	Are sufficient mooring lines available for tug operations?				
c.	Is sufficient fendering available for tug operations and for contact with alignment columns?	8-4.1			
d.	Have provisions been made to extend scuppers and overboard discharges to beyond the deck of the heavy lift vessel (gray water, CHT, etc.)				

9. REMARKS:

SAMPLE CERTIFICATE OF DELIVERY LETTER

FIRST ENDORSEMENT

1. Upon inspection of the asset described above, the following unsatisfactory conditions were found, which render the asset not ready for heavy lift (if none, so state).

    a.

    b.

    c.

    d.

2. (Cross out the statement which is not applicable).

    a. I find the asset described above in a condition satisfactory for heavy lift, and hereby assume responsibility for delivery to the port of destination prescribed in my sailing orders.

    b. I find the asset described above in an unsatisfactory condition and will not accept the vessel for heavy lift until these discrepancies are corrected.

______________________________	______________________________
Representative of command having Cognizance of lifted asset.	Date

Appendix R - SITREP TEMPLATE

NAME OF ASSET(s) HEAVY LIFT
SITREP 01
(DD Month YYYY)

PERSONNEL ON-SITE:

- Onsite: List onsite SUPSALV/MSC/IMS personnel (role)
- Inbound: List inbound SUPSALV/MSC/IMS personnel (role)
- Outbound: List outbound SUPSALV/MSC/IMS personnel

LAST 24:

- Bullet list of key activities and meetings for the operation
- Include if this is the last SITREP for the operation

NEXT 24-72:

- Bullet list of upcoming key activities, meetings and any expected decisions
- Include any vessel movement of asset or heavy lift vessel

UPCOMING EVENTS/MILESTONES:

- DD MMM overview of events and milestones

ISSUES:

- A separate section to call additional attention and explanation to highlight technical or logistical issues
- Include the path to resolution or who the issues was escalated to that will assist with resolution
- If no issues to note then list “None” in this section

CONCERNS

- Include items that may not have turned into an issue but are a concern for the HLPO and team to monitor
- If no concerns to note then list “None” in this section

Template Note (delete before use): The SITREP shall be issued by the HLPO via email daily to the key stakeholders in SUPSALV 00C. The HLPO may modify the distribution list as appropriate for the operation.

Appendix S - SCHEDULE TEMPLATE

Heavy Lift FLO/FLO Schedule – Location

Asset Onload/Offload – Heavy Lift Vessel

Completed: Green Cell
In Progress: Blue Cell
Projected: Uncolored
* Changes to Timeline reflected in red

Onload Schedule Template

NOTE: All template notes are italicized and can be deleted when the schedule is developed. All pre-populated notional timing and milestone/activities are for guidance and additional detail will be added.

Notional Timing	Date	Time	Milestone/Event/Activity	Notes
Relative timing	*Planned or actual date*	*Include time when relevant*	*Include key milestones, any activities necessary to achieve the milestones and events that may impact the milestones*	*Timing may be set according to departure date or onload date as determined by HLPO*
D-18 to D-15			Heavy Lift Project Team arrives on site	*Ideal arrival is 7-10 days before the onload but operational considerations may make this longer or shorter*
D-15			Coordinate with port and base authorities	*This may include a series of meetings with the various stakeholders or be combined with the Pre-Load Conference*
D-15			Pre-Load Conference with all stakeholders	
D-15 to D-12			Arrival of heavy lift vessel at onload port	
D-15 to D-12			Commence block build	
D-11			Tug inspection (if previously unassessed tugs are necessary for the operation)	
D-10			Block build verification walkthrough	
D-10			Diver walkthrough	
D-9			Final confirmation of asset load conditions	
D-9			Appendix H and Appendix R checklists complete and signed off	
D-9			Go/No-Go Meeting	
D-8			Float-on of asset	*As the operation develops include additional timeline detail to capture logistics and services necessary for onload*

			Onload operational timing	*Planned timing for ballasting, asset positioning, divers, draft at landing, draft at instability, deballasting, deck clear.*
D-7			Post onload deck walkdown	
D-6			Seafastening installation (this may take less than 6 days)	
D-1			Seafastening verification and certification	
D			Departure for transit	

Completed: Green Cell
In Progress: Blue Cell
Projected: Uncolored
* Changes to Timeline reflected in red

Offload Schedule Template

NOTE: All template notes are italicized and can be deleted when the schedule is developed. All pre-populated notional timing and milestone/activities are for guidance and additional detail will be added.

Notional Timing	Date	Time	Milestone/Event/Activity	Notes
Relative timing	*Planned or actual date*	*Include time when relevant*	*Include key milestones, any activities necessary to achieve the milestones and events that may impact the milesontes*	*Timing may be set according to arrival date or offload date as determined by HLPO*
A-4			Arrival of Heavy Lift Project Team	*Ideal arrival is 3-5 days before the onload but operational considerations may make this longer or shorter*
A-3			Review seafastening removal plan, off-load procedure, pumping plan, and any required logistics	*This may be adhoc or at a Pre-Arrival Conference*
A-3			Coordinate with port and base authorities	*This may include a series of meetings with the various stakeholders or be combined with the Pre-Offload Conference*
A-2			Pre Offload conference with all stakeholders	
A			Arrival of heavy lift vessel and Post Voyage Walk-down	
A+1			Appendix H and R Asset Preparations, Coordination with Ships Force, Asset Inspections	
A+1			Commence sea fastening removal	
A+2			Conduct walkthrough with divers (if using)	
A+2			Go/No-Go Meeting	
A+3			Float off	*As the operation develops include additional timeline detail to capture logistics and services necessary for offload*
			Offload Operational Timing	*Planned timing for ballasting, desk submerged, water on hull, hull integrity checkpoint, draft at float off, asset offload, deballasting, deck clear.*
A+3			Delivery of asset	