U.S. Navy General Specification for Diving and Manned Hyperbaric Systems

REVISION 2

NAVSEA
NAVAL SEA SYSTEMS COMMAND
Supervisor of Salvage & Diving

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
SUPERVISOR OF DIVING
AND SALVAGE
WASHINGTON, DC 20376

SUPERSEDES NAVSEA TS500-AU-SPN-010, Dated August 23, 2006, Which Shall Be Destroyed In Accordance With Applicable Security Regulations.

TECHNICAL MANUAL CERTIFICATION SHEET

CERTIFICATION APPLIES TO:	NEW MANUALS ☐	REVISION X	CHANGE ☐

APPLICABLE TMINS/PUB_ NO.	PUBLICATION DATE (day, month, year)	READING GRADE LEVEL (RGL)
TS500-AU-SPN-010	10,Feb,2023	

TITLE

U.S. Navy General Specification for Diving and Manned Hyperbaric Systems, Revision 2

TMCR/TMSR/SPECIFICATION NUMBER

CHANGES AND REVISIONS:

PURPOSE

Complete rewrite of the manual.

EQUIPMENT ALTERATION NUMBERS INCORPORATED

N/A

TMDER/ACN NUMBERS INCORPORATED

N/A

Continued on additional pages as needed.

CERTIFICATION STATEMENT

This is to certify that responsible Navy activities have reviewed the above identified document for acquisition compliance, technical coverage and reproduction quality. This form is for Internal Government management use only and does not imply contractual approval or acceptance 01 the technical manual by Government nor does it relieve the contractor of any responsibilities for delivering the technical manual in accordance with the contract requirements.

	NAME	SIGNATURE	ORGANIZATION	CODE	DATE
ACQUISITION APPROVAL	Brian A. Borchardt	RCHARDT.BRIANA DREW.1175866732	NAVSEA	00C41	2/10/23
TECHNICAL APPROVAL	Richard A. Schoenwiseni'		NAVSEA	00C3	2/22/23
TM MANAGER APPROVAL	Daniel T. Neverosky		NAVSEA	00CB	3/27/23

THIS PAGE INTENTIONALLY LEFT BLANK

FORWARD

The express purpose of Revision 2 of this technical publication is to authoritatively establish technical requirements for design, fabrication and repair of U.S. Navy (USN) diving and hyperbaric systems.

Unlike the previous issue of this document, a cursory review of this revision will reveal a complete and comprehensive re-organization. Technical and editorial changes have been made throughout and reviewers are encouraged to read this document in its entirety. Every effort has been made to ensure all referenced support documents are correct and current as of the date of this issue. However, despite these best efforts, reviewers are encouraged to always be on the look-out for changes. Requirements change as technology evolves and the ability to improve designs continues to mature and change. Given this fact, the collection of comments for future revisions starts with the date of issue of this revision.

Those who review and use this manual are not to interpret the requirements contained within. Questions and comments regarding the contents of this manual, or the design, fabrication and repair process in general, should be submitted by email to Naval Sea Systems Command (NAVSEA) at usn.washington.comnavseasyscomdc.mbx.sea-00c3@us.navy.mil. Certification related questions can be sent to usn.washington.comnavseasyscomdc.mbx.sea-00c4@us.navy.mil.

SCHOENWIESNER.RICHARD.ALAN.1028296807 Digitally signed by SCHOENWIESNER.RICHARD.ALAN.1028296807 Date: 2023.02.10 11:50:05 -05'00'

Richard Schoenwiesner
Director, Diving Division
(SEA 00C3)

SUAREZ.SALVADOR.M.1032172390 Digitally signed by SUAREZ.SALVADOR.M.1032172390 Date: 2023.03.01 09:06:45 -05'00'

Sal M. Suarez, CAPT, USN
Supervisor of Salvage & Diving, USN
Director of Ocean Engineering

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

FIGURES

TABLES

PART 1 INTRODUCTION

1-1 PURPOSE

The purpose of this specification is to establish the technical requirements for the design, fabrication and repair of diving and hyperbaric systems for use in the USN. It provides an overview of how a divers life support system (DLSS) shall be developed. Information in this specification is from various sources, including both commercial & government/military references.

1-2 SCOPE

This design specification applies to all USN diving and manned hyperbaric systems under the Technical Authority (TA) of the Supervisor of Salvage and Diving (SUPSALV), NAVSEA 00C. USN diving and manned hyperbaric systems include all surface-supplied DLSSs, saturation DLSSs, manned recompression chamber systems, diving bells, and handling systems used for maneuvering DLSSs or personnel during manned operations. Throughout this document, where the term "DLSS" is used, it is meant to include manned hyperbaric systems. This document is not intended to impose rigid procedures for design, nor discourage initiative and innovation in the use of new methods, components or materials.

1-3 BIBLIOGRAPHY

References that may be useful in DLSS design are listed in Appendix A. Unless otherwise indicated, the most recent issue or revision of each shall be used.

1-4 DEFINITIONS

Definitions applicable to this document are provided in Appendix B.

1-5 ABBREVIATIONS

Abbreviations used in this document are provided in Appendix C.

1-6 ROLES AND RESPONSIBILITIES

1-6.1 ACQUISITION/PROGRAM MANAGER (PM)

The Acquisition/Program Manager (PM) is a government employee who is the designated individual with the responsibility for and authority to accomplish the project objectives for the development, production, and sustainment to meet the user's operational needs. The PM is accountable for the overall cost, schedule, and performance of the project. They exercise the decision-making powers and oversight throughout the project.

1-6.2 TECHNICAL WARRANT HOLDER (TWH)

The Technical Warrant Holder (TWH) is the USN engineer and recognized technical expert in their field across specific technical domains. The TWH is the independent technical conscience for the USN to make sure systems being designed, produced and delivered to the fleet are as technically sound and as safe as possible. The TWH supports the PM, providing best value engineering and technical products.

1-6.3 SYSTEM CERTIFICATION AUTHORITY (SCA)

The System Certification Authority (SCA) provides an objective, third-party review of the design, fabrication, testing, and operating and maintenance (O&M) procedures of all USN owned or operated manned diving and hyperbaric systems. The SCA is designated via Office of the Chief of Naval Operations Instruction (OPNAVINST) 3150.27, *U.S. Navy Diving Program*. Certification of DLSSs under the cognizance of the SCA is conducted in accordance with (IAW) NAVSEA SS521-AA-MAN-010, *U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual*. The PM works with the SCA to ensure detailed technical reviews of the system design are conducted and formally documented.

1-6.4 DESIGNER

An individual or organization responsible for the design of the DLSS. The designer is responsible and liable for the safe design of the DLSS that, meets or exceeds contract specifications.

1-6.5 BUILDER

An individual or organization responsible for the fabrication and assembly of a DLSS IAW with the design specifications. The builder is responsible and liable for the safe delivery of a complete DLSS that meets contract specifications and is certifiable by the SCA.

1-6.6 DEPOT MAINTENANCE FACILITY

Facility that has the infrastructure to perform major overhauls or a complete rebuild of parts, assemblies, subassemblies, and end items, including the manufacture of parts, modification, testing, and reclamation, as required.

1-6.7 IN-SERVICE ENGINEERING AGENT (ISEA)

Provide technical services to the PM, the TWH and the Fleet. In-Service Engineering Agents (ISEAs) provide analysis, develop technical alternatives and assess performance and risk mitigations. They are available to assist the design and certification of systems, construction, production or integration for in-service systems.

1-6.8 SYSTEMS ENGINEER (SE)

The Systems Engineer (SE) refers to the Program Lead SE, the Chief Engineer or Lead Engineer responsible for SE processes and who plan, conduct and/or manage SE activities in the program. The SE balances the conflicting design constraints of cost, schedule, and performance while maintaining an acceptable level of risk. The SE should possess the skills, instincts and critical thinking ability to identify and focus efforts on the activities needed to enhance the overall system effectiveness, suitability, survivability and sustainability.

PART 2 DESIGN

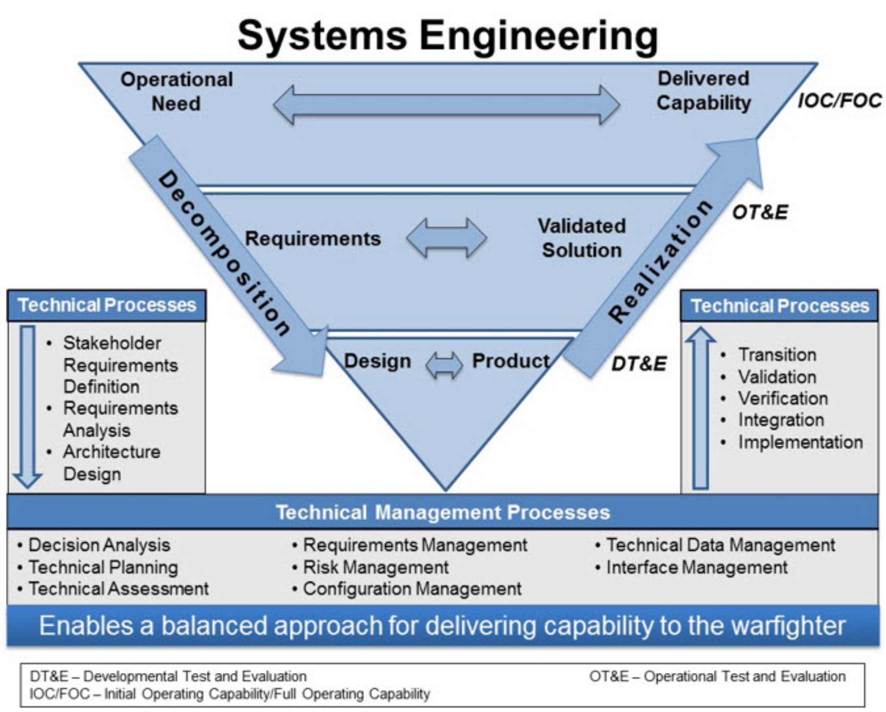
Part 2 provides guidance, rules and requirements for use by experienced engineers to design a DLSS for USN use. The overarching purpose of a DLSS is to safely take personnel to a specified depth, maintain life, and safely return the personnel to the surface. Missions that involve diving operations may take hours or, if saturation diving is involved, days or weeks. It is imperative that any DLSS designer must understand the special hazards associated with diving and hyperbaric environments. Ultimately, the final responsibility for all aspects of a safe design lies with the DLSS designer and cannot be delegated to any manual or textbook.

2-1 DESIGN PROCESS

2-1.1 SYSTEMS ENGINEERING PLAN (SEP)

Systems engineering ensures the effective development and delivery of capability through the implementation of a balanced approach with respect to cost, schedule, performance and risk, using integrated, disciplined and consistent activities and processes (see Figure 1). IAW the Defense Acquisition Guidebook (DAG), the PM and SE should develop a tailored Systems Engineering Plan (SEP) which identifies the most effective and efficient path to deliver a capability, from identifying user needs and concepts through delivery and sustainment.

Figure 1: Systems Engineering



The SEP is a living document that details the execution, management, and control of the technical aspects of a DLSS acquisition from conception to disposal. Event-driven technical reviews and audits, as described later in this section, assess program maturity and determine the status of the technical risks associated with cost, schedule and performance goals. The SEP is updated as needed to reflect technical progress achieved and to reflect changes in the technical approaches stemming from the findings and results of the technical reviews, program reviews, acquisition milestones, or other program decision points.

Depending on the complexity of the DLSS an effective SE may require the development of the following key documents:

a. Initial Capabilities Document (ICD).

b. Capability Development Document (CDD).

c. Concept of Operations (CONOPS).

d. Acquisition Strategy.

e. Risk Management Plan (RMP).

f. Configuration Management Plan (CMP).

g. Integrated Master Plan (IMP).

h. Integrated Master Schedule (IMS).

i. Test and Evaluation Master Plan (TEMP).

j. Draft System Specifications.

As the program’s blueprint for the conduct, management and control of all technical activities, the SEP fosters comprehensive decision making during the technical planning process and communicates objectives and guidance to program personnel and other stakeholders. As the system matures and issues arise, the PM and SE should consistently look for root cause(s) and implement corrective actions in order to enable programmatic and technical success. Modifications to the SE processes and SEP may be required because of root cause and corrective action analysis and implementation.

The PM may opt to provide the SEP with the Request for Proposal (RFP) and require the contractor deliver a Systems Engineering Management Plan (SEMP) that is consistent with the SEP. The SEMP is the contractor-developed plan for the conduct, management and control of the integrated engineering effort. The SEMP should define the contractor technical planning and how it is accomplished from the contractor perspective, and articulates details of their processes, tools and organization.

2-1.2 CONFIGURATION MANAGEMENT

Configuration Management (CM) is defined as a management process for establishing and maintaining consistency of a product's performance, functional, and physical attributes with its requirements, design and operational information throughout its life. CM contains the documentation that describes what is supposed to be designed, what is being designed, what has been designed, and what modifications have been made to what was designed.

A CM program ensures that designs are traceable to requirements, that change is controlled and documented, that interfaces are defined and understood, and that there is consistency between the product and its supporting documentation. The objectives of CM are to identify and document the characteristics of a Configuration Item (CI); to control changes to these characteristics; to provide information on the status of change action; and to audit and review the item for compliance with contractual and identification requirements.

CM comprises four interrelated efforts: Identification, Control, Status Accounting, and Audits as described in the following sections. NSW S13-CMP-01, *Fleet Diving Systems CMP* provides organizational and managerial guidance and direction to all Fleet DLSS contractors and government agencies in meeting CM procedures and authorizations unique to the Fleet DLSS equipment. If alternative CMPs are required, the designer shall provide a copy of the applicable CMP for approval to the PM at the preliminary design review (PDR).

2-1.2.1 *Identification of Configuration Baselines and Specifications*

Configuration Identification consists of the documentation of the formally approved baselines and specifications. The configuration baselines are fixed reference configurations established by defining and recording the approved configuration documentation for a System or CI at a milestone event or at a specified time. Major configuration baselines known as the functional baselines (FBL), allocated baselines (ABL), and product baselines (PBL) as well as the developmental configuration, are associated with milestones in the life cycle of a CI. Each of these major configuration baselines is designated when the given level of the CI's configuration documentation is deemed to be complete and correct, and needs to be formally protected from unwarranted and uncontrolled change from that point forward in its life cycle.

Configuration documentation identifies the functional and physical characteristics of the CIs. It is developed, approved, and maintained through the evolutionary baselines of the DLSS design.

2-1.2.1.1 ***Functional Baseline (FBL)***

The FBL consists of the initial documentation describing a system's functional, interoperability, and interface requirements and the verification required to demonstrate the achievement of those specified characteristics. The FBL consists of the initially approved technical documentation for a system or top level CI as set forth in the system specification prescribing:

a. All necessary functional characteristics.

b. The verification/tests required to demonstrate achievement of the specified functional characteristics.

c. The necessary interface and inter-operability characteristics with associated CIs, other system elements, and other systems.

d. Identification of lower level CIs, if any, and the configuration documentation for items (such as items separately developed or currently in the inventory) which are to be integrated or interfaced with the CI.

e. Design constraints, such as envelope dimensions, component standardization, use of inventory items and integrated logistics support policies.

f. Specific designation of the functional characteristics of key CIs.

The FBL is established after the System Requirements Review (SRR) and controlled by the PM. From a contractor's point of view, a FBL, whether formally established or not, is always in place at the inception of the design and is represented by whatever documentation is included or referenced by the contract to define the technical/performance requirements that the contractor's product is obligated by the contract to meet.

2-1.2.1.2 ***Allocated Baseline (ABL)***

The ABL is the currently approved documentation describing a CI's functional, interoperability, and interface requirements and the verification required to demonstrate the achievement of those specified characteristics. The ABL consists of the current approved performance oriented documentation governing the development of a CI, in which each specification:

a. Defines the functional and interface characteristics that are allocated from those of the system or higher level CI.

b. Establishes the verification required to demonstrate achievement of its functional characteristics.

c. Delineates necessary interface requirements with other associated CIs.

d. Establishes design constraints, if any, such as component standardization, use of inventory items, and integrated logistics support requirements.

The ABL is established after the PDR and is controlled by the designer. The requirements in the specification are the basis for the contractor's design of the CI; the quality assurance (QA) provisions in the specification form the framework for the qualification-testing program for the CI. The ABL for each CI is documented in an item performance (or detail) specification, generally referred to as a development specification.

2-1.2.1.3 *Development Configuration*

The Development Configuration is the contractor's design and associated technical documentation that defines the contractor's evolving design solution during development of a CI. The developmental configuration for a CI consists of that contractor internally released technical documentation for hardware and software design that is under the developing contractor's configuration control until the establishment of the PBL.

Contractor implementation of the FBL and ABL requirements involves the creation, and release of engineering documentation that incrementally defines the configuration of the specific product. The developmental configuration represents the contractors detailed design solution. It may or may not include a detail specification for the product. The contractor is responsible for the configuration control of the developmental configuration and may iteratively design, release, prototype and test until the functional and allocated requirements are satisfied.

The developmental configuration will ultimately include the complete set of released and approved engineering design documents, such as the engineering drawings and associated lists for hardware and the software, interface and database design documents for software. By reference within this documentation, it also includes test and verification documents.

When establishing a CM program, the designer should follow the guidance in NAVSEAINST 4130.12, *Configuration Management Policy and Guidance*. Other useful references that may also be consulted are American National Standards Institute (ANSI)/Electronics Industries Alliance (EIA)-649, *National Consensus Standard for Configuration*

Management, MIL-HDBK-61, *Configuration Management Guidance*, International Organization for Standards (ISO) 10007, *Quality Management Systems – Guidelines for Configuration Management* and Secretary of the Navy Instruction (SECNAVINST) 4130.2, *Department of the Navy Configuration Management Policy*.

2-1.2.1.4 ***Product Baseline (PBL)***

The PBL is the initially approved documentation describing all of the necessary functional and physical characteristics of the CI. It also describes the selected functional and physical characteristics designated for production acceptance testing and tests necessary for support of the CI.

The PBL documentation includes the complete set of released and approved engineering design documents including engineering models, engineering drawings and associated lists for hardware. The software, interface and database design documents for software should also be included in the PBL. The PBL may include the 2-D or 3-D engineering model of a hardware product. For software the PBL should include a representation of the source code. It also includes, by reference, the material and process specifications invoked by the engineering documentation.

The PBL is established after the Critical Design Review (CDR) and controlled by the PM.

2-1.2.2 *Configuration Control*

Configuration control is how the DLSS's (and its associated CIs) change control process is executed and managed after the formal establishment of its baseline. It consists primarily of a change process that formalizes documentation and provides a management structure for change approval. NSW S13-CMP-01 provides organizational and managerial guidance and direction to all Fleet DLSS contractors and government agencies in meeting CM procedures and authorizations unique to the Fleet DLSS equipment.

2-1.2.3 *Configuration Status Accounting (CSA)*

Configuration Status Accounting (CSA) is the recording and reporting of the information that is needed to manage the configuration effectively, including a list of approved documentation, status of proposed changes, and the configuration of all the system. IAW MIL-HDBK-61 and ANSI/EIA-649, a CSA system shall be established and maintained throughout the life-cycle of a CI, and related technical and logistics support products. This information is essential for providing a unique and positive identification of a CI and for entering in all technical and logistics documents related to it. CSA is the method used to track and record changes to the configuration baseline and is the management tool for ensuring that all related tasks resulting from baseline changes are accomplished.

The designer is encouraged to use commercial electronic engineering document management software that allows transfer and access to configuration documentation. The use of MIL-STD-974, *Contractor Integrated Technical Information Services (CITIS); Defense Acquisition Deskbook, Section 3.7*, Computer-aided Acquisition and Logistic Support; and appropriate Integrated Digital Environment to provide the USN online access to or delivery of programmatic and technical data in digital form is required unless waived by the PM. The Defense Acquisition Deskbook is an automated repository of information that consists of an electronic desk reference set, a tool catalogue, and a forum for the exchange of information.

2-1.2.4 *Configuration Audits*

Verification of the functional and physical requirements called out in the specifications is an integral part of CM. Configuration Audits are used to verify a system and its components' conformance to their configuration documentation. Functional Configuration Audits (FCA) are used to verify that the actual performance of the CI meets the specification requirements. Physical Configuration Audits (PCA) is a formal examination of a production representative unit against the PBL. These types of audits are normally performed during the Fabrication phase of the DLSS (see Part 3).

2-1.3 TECHNICAL REVIEWS

The design progress and maturity is assessed at technical reviews, which are key event-driven points, conducted after certain levels of development have been achieved. The design is compared to pre-established exit criteria for the particular event to determine if the appropriate level of maturity has been achieved. They are utilized to check design maturity, review technical risk and determine whether to proceed to the next development level. Formal technical reviews are to verify that problems have been solved and are not considered a problem solving event.

The reviews briefly summarized below are based on a complex DLSS project, requiring significant technical evaluation. There may be a need to tailor the design assessment activities as appropriate for a particular DLSS. There may be cases where system technical maturity is more advanced than typical (i.e., based on a previous program) which may allow for the merging or elimination of certain events. The technical baseline (including the FBL, ABL, and PBL) established at the conclusion of certain technical reviews inform all other program activities. The designer and the PM shall agree upon the tailoring of these events, however baselines must be developed sequentially as they must build on each other.

Details on roles and responsibilities, entrance/exit criteria and products of the following events are found in the DAG and should be outlined and tailored for the design in the SEP and SEMP.

2-1.3.1 *System Requirements Review (SRR)*

This review determines the adequacy of the designer's efforts in translating the PM's requirements into system specific technical requirements in order to meet the performance requirements and the standards of the DLSS. Risks shall be well understood and mitigation plans shall be in place. The following documentation should be included to assist in a successful review:

a. System Operations Requirements.

b. Draft System Specification and draft Performance Item Specifications.

c. Functional Analysis (top level block diagrams).

d. Feasibility Analysis (technology assessments as required).

e. System Maintenance Concept.

f. Overall System Design Criteria (reliability, logistics, etc.).

g. SEP.

h. TEMP.

i. Draft Top-Level Technical Performance Measurements.

j. System design documentation (layout, conceptual drawings, selected suppliers, etc.).

k. Trade Studies.

The SRR confirms that the system-level requirements are sufficiently well understood to permit the designer to establish an initial system level FBL. Once the FBL is established, the functional, performance and physical attributes of the items below system level can be defined and allocated to the physical subsystems or CIs that will perform the functions.

2-1.3.2 *System Functional Review (SFR)*

This review determines the adequacy of the designer's engineering efforts in defining and optimizing the major subsystems or CIs, with associated functionality and performance requirements, that compose the system. This review shall result in two major products which will define the FBL and the draft ABL: the final System Performance Specifications and the draft Performance Specifications for the subsystems or CIs. This review signifies the that the system has passed from concept to a well-defined system design. The system functional review (SFR) shall include the assessment of the following items:

a. Verification that the System Specification reflects the PM's requirements.
b. Functional Analysis and allocation of requirements to subsystems/CIs.
c. Draft CI Performance Specifications.
d. Design data that defines the overall system.
e. Verification that the risks associated with the system design are at acceptable levels for engineering development.
f. Verification that the design selections have been optimized.
g. Any supporting Analyses and Plans are complete where appropriate (logistics, human systems integration (HSI), etc.).
h. Technical Performance Measurement data and analyses.
i. Plans for evolutionary design and development are in place and that the system design is modular and open.

During the SFR the system level FBL must be approved by the PM as the governing technical requirement before proceeding to further technical development, which allows for the engineering design and development of the CIs. The PM will take control and manage the system FBL following the completion of the SFR. Once the FBL is established, the functional, performance and physical attributes of the items below system level can be defined and allocated to the physical subsystems or CIs that will perform the functions.

Work then proceeds to complete the definition of the subsystems or CIs in terms of function, performance, and interface requirements. Reviews may be held for the design requirements at the subsystem levels in order to verify that the lower level design requirements will result in an acceptable detailed design of the system. The establishment of the CI design requirements represents the ABL for the system.

2-1.3.3 *Preliminary Design Review (PDR)*

This is a formal technical review of the basic design approach and is typically held when 15% of the production drawings are released. Using the FBL as a governing requirement, a preliminary design is expressed in terms of design requirements for subsystems and CIs of the DLSS. This preliminary design sets forth the functions, performance, and interface requirements that will govern design of the items below system level. The PDR shall include the assessment of the following items:

a. Subsystem/CI Performance Specifications.

b. Draft Item Detail, Process, and Material Specifications.

c. CMP.

d. Scope of Certification (SOC) boundaries (must be approved by the PM).

e. Design data defining major subsystems, equipment, software, and other system elements.

f. Analyses, reports, maintenance and reliability analyses, trade studies, logistics support analysis data, and design documentation.

g. Technical Performance Measurement data and analysis.

h. Engineering breadboards, laboratory models, test models, mockups, and prototypes used to support the design.

i. Supplier data describing specific components.

The SOC boundaries must be reviewed and approved by the NAVSEA 00C3 PM and NAVSEA 00C4 SCA prior to or at the PDR (see section 2-1.5). Following the PDR, the preliminary design and ABL, will be put under formal configuration control. Current Department of Defense (DoD) practice is for contractors to maintain configuration control over the CI performance specifications, while the government exercises requirements control at the system level.

2-1.3.4 *Critical Design Review (CDR)*

This is a formal technical review that is conducted prior to fabrication and production of the DLSS in order to ensure that the detailed design calculations, analyses, and engineering drawings satisfy the performance requirements and standards of the DLSS. This review is used to evaluate and verify that the draft PBL, or the “build to” documentation, is sufficient to start initial manufacturing. At the CDR, 85% of the manufacturing quality drawings shall be complete. All drawings submitted for CDR shall be under formal configuration control unless otherwise permitted by the PM.

The CDR includes the evaluation of all CIs before release of the design for fabrication. Additionally, test plans are reviewed to assess if test efforts are developing sufficiently to indicate the system testing program (see section 3-6.2) will be successful. The approved detail design serves as the basis for final production planning.

Certification design reviews using NAVSEA SS521-AA-MAN-010 will normally be conducted concurrent with the PDR and CDR.

2-1.4 SYSTEM SAFETY PROGRAM

System safety applies engineering and management principles, criteria, and techniques to achieve acceptable mishap risk, within the constraints of operational effectiveness, time, and cost, throughout the system design. It draws upon professional knowledge and specialized skills in the mathematical, physical, and scientific disciplines as well as principles and methods of engineering design and analysis, to specify and evaluate the environmental, safety, and health mishap risk associated with a system. Experience indicates that the degree of safety achieved in a system is directly dependent upon the emphasis given. A safe design is a prerequisite for safe operations, with the goal being to produce an inherently safe product that will have the minimum safety-imposed operational restrictions. The PM shall assure that the System Safety Program meets the requirements of NAVSEAINST 5100.12, *System Safety Engineering Policy*.

System safety interfaces with other aspects in the overall engineering design process including human engineering; reliability, maintainability and availability (RM&A); operability, survivability, and environmental, safety, and occupational health.

2-1.4.1 *System Safety Program Plan*

The designer shall document system safety engineering approach. This documentation shall:

a. Describe the program's overall system safety plan and implementation including milestones, definitions of hazard severity and probability of hazards, and a detailed risk level matrix (severity and probability). Include identification of each hazard analysis and mishap risk assessment process used.

b. Include information on system safety integration into the overall system engineering process.

c. Include the following safety analyses: health hazard assessment, system hazard analysis (see section 2-1.4.2), component level hazard analysis, system level hazard analysis (see section 2-1.4.2) and failure mode, and effects analysis (FMEA) (see section 2-1.7.2.1).

d. Define how hazards and residual mishap risk are communicated to and accepted by the appropriate risk acceptance authority and how hazards and residual mishap risk will be tracked.

e. Include a Hazard Tracking and Closeout Plan. This plan shall maintain a tracking system that includes hazards, their closure actions, and residual mishap risk throughout the design. The designer shall keep the PM advised of the hazards and residual mishap risk.

2-1.4.2 *Hazard Analysis*

As part of the design process for a DLSS, a hazard analysis shall be developed and submitted to the PM for approval to evaluate the effects of all possible failures (see Appendix D). Both a component level hazard analysis and a system level hazard analysis shall be performed. The component level hazard analysis is typically performed assuming that only one failure occurs in any one subsystem. The system level hazard analysis shall account for the multiple effects to a system due to any number of single failures. The hazard analysis shall describe the possible effects of a hardware failure (mechanical, electrical), software failure or operator error for each component or subsystem. Those hazards that could affect the safety or recoverability of personnel shall clearly detail what features, warnings or procedures have been incorporated into the design, operation and maintenance of the system to preclude or minimize the probability of failure. It is the responsibility of the designer to ensure that the conditions, identified as significant safety hazards are eliminated or reduced to the lowest practical level.

Hazards are not always the result of equipment failure, but may be attributed to human error when responding to a routine command, while addressing a minor problem, or from the operation of a control function at the wrong time. Operating and emergency procedures (OPs/EPs) must be specific, clear and concise in order to avoid confusion. The hazard analysis shall show that the possibility of human error has been considered in the design and that safeguards have been taken to reduce the likelihood of such an occurrence.

MIL-STD-882, *System Safety Program Requirements,* provides an acceptable set of guidelines to conduct proper hazard analyses. The application and tailoring guidelines given in MIL-STD-882 should be carefully followed in order to make the hazard analysis no more complex than is necessary in order to prove the safety of the design. The System Safety Society's System Safety Analysis Handbook provides expanded guidance on implementation of a System Safety Program as described in MIL-STD-882, including step-by-step instruction for completing required analyses. The PM is responsible for assuring that the risk assessment meets the requirements of NAVSEAINST 5000.8, *Naval Systems Command Risk Management Policy*.

Components of a hazard analysis include hazard identification, hazard assessment, and hazard mitigation as discussed below.

2-1.4.2.1 *Hazard Identification*

Hazards are identified through a systematic hazard analysis process encompassing detailed analysis of system hardware and software, the operational environment, and the intended use or application. Historical hazard and mishap data shall be considered and utilized, including lessons learned from other systems. The identification of hazards is the responsibility of all program members. During hazard identification, consider hazards that could occur over the system life cycle.

2-1.4.2.1.1 *Hazard Analysis Tools and Techniques*

The safety analyst may use a broad range of well documented tools with associated techniques, depending upon the complexity of the system and as found acceptable by the PM. The safety analyst may introduce different methods and new methods, not identified here, as long as found acceptable to the PM, all prior to implementation.

Many analysis techniques are available for evaluating systems safety and reliability. Usually several techniques are employed in combination to produce an integrated, methodical analysis approach, for identification of high-risk concerns. A single technique may, in some instances, be most prudent given time and schedule restraints, system complexity, and other factors.

Qualitative versus Quantitative Analysis – For DLSSs, the qualitative approach, with emphasis upon tasking an appropriate DLSS experienced safety analyst, is the prudent approach. The quantitative approach considers the complexity and uniqueness of components, systems and sub-systems associated with DLSS, to completing a robust quantitative analysis of the entire system. The following suggestive techniques have been proven effective in both unique and complex DLSS for decades, not requiring performing a quantitative analysis.

a. **Preliminary Hazard Analysis (PHA)** – This procedure is used to quickly review, document and initially identify all potentially hazardous conditions within a system. Within the scope of the PHA are operational, equipment, total system, and system interface hazards. The purpose of a PHA is to identify and evaluate hazards, then to identify issues requiring further in-depth analysis. The PHA qualitatively assesses undesirable or potentially hazardous conditions; it normally augments a more rigorous descriptive narrative analysis (DNA); it does not normally stand alone. The PHAs objectives are to identify potential hazards, evaluate their impact upon safety and reliability and specify, if necessary, methods of analysis used during further investigations, such as fault tree analyses (FTA), or DNAs.

b. **DNA** – DNAs are used to present a detailed risk analysis in narrative format. DNAs are free form narratives which substantiate risk assessments generally disclosed in the hazard analysis. DNAs are a forum for discussing component/system failure histories, hazard scenarios, relevant technical facts, and known mitigating factors i.e., design changes, testing, calculations, etc. Complex component interactions can be discussed with respect to system diagrams, fault tree diagrams, or failure mode tables. The DNA format is very flexible, allowing the analyst to focus on the most probable and/or severe system failures and to develop the analysis rationale for any desired level of detail. Where PHA methodology is insufficient to provide the proper level of detail needed for risk assessment, the PHA can be supplemented by an associated DNA. The risk assessments disclosed by the DNA are a combined evaluation of hazard severity and frequency of occurrence.

c. **FTA and Success Tree Analysis (STA)** – A deductive procedure for identifying possible modes of failure which would cause a specified undesired event in a given system. FTAs may be quantitative or qualitative and may be used to analyze complex systems for both safety and reliability. FTA logic can be inverted to produce an STA if a different perspective is desired. For quantitative FTAs/STAs, relative values of failures are assigned to provide the relative probability of the top event's occurrence computed from the relative probability of the end event's occurrence. This also reveals the relative importance of a system's various features and functions. If values are not assigned appropriately, failure importance may be distorted or masked by other failures. As substantive data becomes available on failure rates, this information can be substituted for the relative values and an improved system safety/reliability model can be constructed. Qualitative FTAs/STAs may be performed without statistical analysis. This method applies to systems which benefit from the mapping of fault events and does not require a formal statistical analysis. Often the resultant map (tree) can, upon inspection, reveal paths to system failure which are most likely to occur. For more information reference NRC NUREG-0492, *Fault Tree Handbook*.

d. **Toxic/Flammability Safety Analysis** – Safety studies which disclose increased risks to personnel resulting from the introduction of new, non-metallic materials into closed space DLSS/Chamber areas and oxygen (O_2) enriched environments. Like all other analysis types, the Toxic/Flammability safety analysis utilizes standard analysis methods (PHAs, DNAs, STAs, etc.) and summarizes overall risk impacts based on the hazard risk assessment matrix. These safety analyses are normally supported by development of Toxic/Flammability composite databases which exhaustively catalog all non-metallic materials in the DLSS. While the databases must be maintained accurately for the life of the project, they need not be contained within a single document. Toxic/Flammability safety analyses are PM approval documents.

2-1.4.2.2 ***Hazard Assessment***

The severity and probability of the risk associated with each identified hazard shall be assessed by determining the potential negative impact of the hazard on personnel, facilities, equipment, operations, the public, and the environment, as well as on the system itself.

2-1.4.2.3 ***Hazard Mitigation***

The hazard analysis shall identify potential risk mitigation alternatives and the expected effectiveness of each alternative or method. Risk mitigation is an iterative process that culminates when the residual risk has been reduced to an acceptable level as deemed by the PM. The system safety design order of precedence for mitigating identified hazards is:

a. Eliminate hazards through design selection. If unable to eliminate an identified hazard, reduce the associated mishap risk to an acceptable level through design selection.

b. Incorporate safety devices. If unable to reduce the associated mishap risk through design selection, reduce the mishap risk to an acceptable level using protective safety features or devices.

c. Provide warning devices. If safety devices do not adequately lower the risk of the hazard, include a detection and warning system to alert personnel to the particular hazard.

d. Develop procedures and training. Where it is impractical to eliminate hazards through design selection or to reduce the associated risk to an acceptable level with safety and warning devices, special procedures and training shall be developed. Procedures shall identify the use of personal protective equipment (PPE). For hazards assigned catastrophic or critical mishap severity categories, avoid using warning, caution, or other written advisory as the only risk reduction method.

2-1.5 SCOPE OF CERTIFICATION (SOC) DEFINITION

Defining the SOC is part of the certification process defined in NAVSEA SS521-AA-MAN-010. SOC consists of all portions of the DLSS and its ancillary equipment that is required to ensure personnel safety. The initial SOC boundaries shall be submitted by the designer and approved by the PM at the PDR. The designer must show justification for the limits on the SOC boundaries through engineering criteria and supporting documentation. Systems and components, not initially shown to be within the SOC by the designer, shall be reviewed by the PM for their contributions to the overall safety of design. The PM is responsible for obtaining NAVSEA 00C4 SCA approval of the SOC boundaries IAW NAVSEA SS521-AA-MAN-010.

2-1.5.1 *Scope of Certification (SOC)*

The designer should use a hazard analysis to assist in the development of SOC boundaries. Systems, components, procedures and documentation that must be included in the SOC are those:

a. Where failure creates an immediate hazard that may result in severe injury or death.

b. Where malfunction or failure could prevent the safe return of the operators, divers, or occupants to the surface.

c. That keep operators, divers, or occupants safely on the surface following an ascent.

d. Used to rescue personnel from the DLSS and return them to the surface, support platform, or, in the case of hyperbaric chambers, to ambient conditions outside the chamber.

e. Associated with temporary test equipment affecting trim and stability conditions, both surfaced and submerged, that could threaten safe recovery of personnel.

f. Written operating procedures (OP), including pre-dive and post-dive procedures, and emergency procedures (EP),

g. Maintenance procedures for systems, subsystems, and components within the SOC including the O&M manuals and preventative maintenance packages.

h. Drawings required in the fabrication, operation, and maintenance of the system.

The PM will provide the designer with guidance on how to display the SOC boundaries in system documentation. Items included or excluded in the SOC boundary may change as the design matures and possibly even after CDR, into system fabrication. It is the responsibility of the PM to ensure SOC boundaries are finalized, approved by the NAVSEA SCA, and captured in system documentation IAW NAVSEA SS521-AA-MAN-010 prior to initial certification.

2-1.6 HUMAN SYSTEMS INTEGRATION (HSI)

The designer should consider personnel, training, environment, safety and occupational health, habitability, human factors, and personnel survivability into the design process.

2-1.6.1 *Personnel and Training*

The PM shall determine the knowledge, skills, and abilities (KSA) of system operators, maintainers, and support personnel and provide that information to the designer. The goal is to design a system for use by the USN diving community without having to modify or create new Navy Enlisted Classifications (NEC) or provide additional training requirements. The designer should consider process improvements, design options, or other initiatives to reduce manpower and improve the efficiency or effectiveness of support services.

2-1.6.2 *Personnel Survivability and Habitability.*

In the design analysis the designer shall address special equipment, gear or services needed to sustain maximum personnel effectiveness in the operational environment and anticipated working conditions.

2-1.6.3 *Human Factors Engineering (HFE)*

HSI encompasses the human engineering and manning determinations, and is part of the DLSS's design and development. HSI data influences system, component, or equipment design to achieve effective user-system interaction. Examples of human factors engineering (HFE) include:

a. Physical human factors, which addresses physical attributes of the human body such as height, weight, arm reach, center of gravity, etc. The designer shall consider documenting, in the design analysis, physical human factors based on the 5th percentile female and 95th percentile male, per Naval Submarine Medical Research Laboratory (NSMRL) TR 2006-1249, *A Review and Comparison of Anthropometric Indices Applicable to the U.S. Navy Submariner Population* unless otherwise specified.

b. Physiological human factors, which addresses visual acuity, tolerance to extreme temperatures, and frequency range of human hearing, etc.

c. Psychological or behavioral human factors, which addresses mental reaction time to various stimuli, capabilities and limitations of short term memory, and "expectancy" as an element of perception.

The design analysis shall document accommodation, compatibility, operability, and maintainability by the user population. Physical accommodation is defined as having adequate reach, strength, and endurance necessary to perform all physical tasks. There shall be adequate clearance for movement, to ingress/egress the work area, and to perform all required tasks. There shall be adequate internal and external visibility to perform all required operations and adequate fit of PPE to successfully perform all mission duties while receiving optimal protection from adverse environmental threats and conditions. The designer should refer to MIL-STD-1472, *Human Factors Engineering Report*, and other non-government standards for human engineering guidance criteria for the design of the DLSS.

Design shall reflect applicable system and personnel safety factors, including minimizing potential human error in the operation and maintenance of the system, particularly under emergency or non-routine conditions, as well as consider mitigations to reduce or eliminate repetitive motion injuries. Design of non-military-unique workplaces and equipment shall conform to 29 Code of Federal Regulation (CFR) Part 1910, *Occupational Safety and Health Standards*, unless military applications require more stringent limits. The PM may direct the designer to validate some human factors through mockups.

2-1.6.3.1 *Sound*

The designer should consider the effect of sound levels on the system occupants IAW the guidelines and calculations provided in OPNAVINST 5100.23H, Chapter 18, *Navy Safety and Occupational Health Manual*, and MIL-STD-1474, *Noise Limits*. When considering time-weighted averages of sound levels in decibels (dB) on an A-weighted scale (dBA) for frequencies of 20 to 16,000 hertz (Hz), the systems covered in this manual can be divided into two categories: manned hyperbaric facilities/underwater habitats and diving helmets.

a. For manned hyperbaric facilities and underwater habitats, the following permissible exposure limits are applicable (see OPNAVINST 5100.23H, Chapter 18):

b. During work periods (not to exceed 16 hours in any 24-hour period), the noise level shall not exceed 82 dBA.

When an intermittent noise greater than 70 dBA exists, the maximum permissible exposure limit must be recalculated using the following formula.

$$T = 8 \times 2^{\left(\frac{85-L}{3}\right)}$$

Where:
T = time in hours (decimal).
L = effective sound level in dBA.

For impact/impulse noises the maximum sound pressure level is 140 dB peak.

When two or more periods of noise exposure of different levels comprise the daily noise exposure, their combined effect must be considered. If the sum of the following expression exceeds unity (i.e., >1), then the mixed exposure exceeds the permissible exposure limit.

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots. \frac{C_n}{T_n}$$

Where:
C = the total time of exposure at a specified noise level.
T = the time of exposure permitted at that level
n = the number of periods.

During sleep/rest periods (a minimum of eight hours in any 24-hour period), the noise level shall not exceed 70 dBA.

c. For diving helmets also follow the guidance in section 2-1.6.3.1 above.

The designer should minimize the ambient noise level to the extent feasible through effective sound reduction or attenuation to meet the ambient sound levels above. See MIL-STD-1474 for further guidance on equipment noise acceptance criteria in meeting sound level thresholds. For safe diving distances from transmitting sonar see Appendix 1A of NAVSEA SS521-AG-PRO-010, *U.S. Navy Diving Manual*. For other active sound sources, contact NAVSEA 00C3. The active sound source will need to be properly characterized to determine a safe diving distance. For guidelines on how to characterize such sources, see NSMRL/F1203/MR-2020-1339, *Guidelines for Characterization of Sounds Produced by Underwater Active Acoustic Technologies for Human Exposure*.

2-1.6.3.2 ***Vibration***

The following recommendations apply to whole body vibration, as defined by ISO 2041, *Mechanical Vibration, Shock, and Condition Monitoring - Vocabulary,* and ISO 5805, *Mechanical Vibration and Shock - Human Exposure - Vocabulary*, where the vibratory motions are limited to those transmitted to the human body as a whole through supporting surfaces. This includes the feet for the standing occupant, the buttocks, back, and feet for the seated occupant, and the supporting surface of the occupant lying on his or her back. The applicable frequency range is defined as 0.1 to 0.5 Hz for motion sickness and 0.5 to 80 Hz for health, comfort, and perception.

Evaluation of vibration and its possible effects on health, comfort, and perception, and motion sickness should conform to ISO 2631-1, *Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-body Vibration - Part I: General Requirements*, as described below:

a. Health – To minimize the effects of whole-body vibration on health, the root-mean square (RMS) value of the frequency-weighted translation accelerations should not exceed the health guidance caution zones for the expected daily exposures defined by ISO 2631-1, Annex B. If possible, exposure within the health guidance caution zone should be avoided. Frequencies below 20 Hz should be avoided. Evaluation of environments where the vibration crest factor is above nine, or for environments containing occasional shocks of transient vibration, should conform to paragraph 6.3 of ISO 2631-1.

b. Performance – The RMS value of the frequency-weighted translation acceleration should fall below the health guidance caution zone for the expected daily exposures defined in ISO 2631-1, Annex B. Whole body vibration should also be minimized in the frequency range below 20 Hz where major body resonance occurs. To preclude impairment of visual tasks, vibration between 20 and 70 Hz should be minimized. The transmission of higher frequency vibration through the seating system should also be minimized, especially where transmission of vehicle vibration to the head at such higher frequencies that can occur for seating conditions in which the body or head come in contact with the seatback or a headrest.

c. Comfort – Where specific levels of comfort are listed in ISO 2631-1, Annex C must be maintained; the applicable overall vibration RMS values indicated therein should not be exceeded.

d. Motion sickness – The weighted RMS acceleration in the z-axis (between 0.1 and 0.5 Hz) should be sufficiently low to preclude or minimize motion sickness as assessed by the methods and assessment guidance specified by ISO 2631-1, Annex D.

e. Equipment vibration only – where whole-body vibration of the human operator or parts of the body is not a factor, equipment oscillations should not impair required manual control or visual performance.

2-1.7 RELIABILITY AND MAINTAINABILITY

2-1.7.1 *Reliability*

The DLSS should perform reliably under worst-case conditions. The reliability performance objective should be in terms of mean time between failures (MTBF). MTBF must be longer than the longest operational mission profile. All failures should be given design consideration since a large number of non-critical failures will become a burden and drive up total ownership cost (TOC). See MIL-HDBK-470, *Designing and Developing Maintainable Products and Systems*, Volume I and Volume II. Also reference Society of Automotive Engineers (SAE) M-102*, Reliability, Maintainability, and Supportability Guidebook*, and the Reliability Analysis Center website, *http://rac.alionscience.com*, for guidance.

2-1.7.2 *Maintainability*

The designer should follow the guidance of MIL-HDBK-470 for determining the maintainability and reliability of the DLSS. Commonly used maintainability analyses include, but are not limited to, FMEA and Reliability-Centered Maintenance (RCM) Analysis. The depth and scope of any analysis will vary with the design detail available and the complexity of the equipment.

2-1.7.2.1 ***Failure Mode, and Effects Analysis (FMEA)***

The designer shall, if directed by the PM, perform an FMEA to identify mission or safety critical single point failures and the steps to mitigate them (i.e., elimination through design or making the design robust through redundancy, graceful degradation, or insensitivity to the cause of the failure). See MIL-HDBK-470. Other notable references include the SAE J-1739, *Potential Failure Mode And Effects Analysis in (Design FMEA) and Failure Mode And Effects Analysis in Manufacturing and Assembly Processes (Process FMEA)*, and the Automotive Industries Action Group (AIAG), *Potential Failure Mode and Effects Analysis (FMEA) Manual*.

2-1.7.2.2 ***Reliability-Centered Maintenance (RCM)***

The designer shall, if directed by the PM, use the RCM process of MIL-STD-3034, *Reliability-Centered Maintenance Process*, in the development of preventative and corrective maintenance procedures. Other programs such as Naval Air Systems Command (NAVAIR) 00-25-403, Management Manual: *Guidelines for the Naval Aviation RCM Process*, or non-government RCM processes may be considered and will require approval by the PM. The RCM analysis shall show that the design permits rapid positive identification of malfunctions, and rapid isolation and repair of these items by system personnel.

2-1.8 COMMAND AND CONTROL (C2)

2-1.8.1 *General Definition*

Command and control (C2) is the set of organizational and technical attributes and processes by which an enterprise marshals and employs human, physical, and information resources to solve problems and accomplish missions. The communication systems (COMMS) and monitoring systems are key elements. For DLSS, C2 can become life critical, especially for the larger more complex systems (Submarine Rescue Diving & Recompression System (SRDRS), Ocean Simulation Facility (OSF), Saturation Fly Away Dive System (SAT-FADS), etc.). For smaller DLSS, some level of C2 is always required to accomplish even simple missions.

2-1.8.1.1 ***Concept of Operations (CONOPS) and Command and Control (C2)***

The CONOPS, as provided to the designer by the PM, is a document or graphic describing the characteristics of a proposed system from the viewpoint of an individual who will use that system. It is designed to give the overall picture of the operations and describes how a system will be used from the viewpoints of the various stakeholders. The CONOPS needs to identify enough information such that the designer can determine the architecture of C2. This will be determined by the complexity of the system and intended mission. As identified for smaller DLSS, like a surface supplied diving system (SSDS) or a recompression chamber system, the designer shall consider simple elements such as lighting, COMMS, and monitoring. Larger systems require a more in-depth approach. It is unacceptable to arrange a system that requires monitoring critical instrumentation at a location that is not integrated with C2.

2-1.8.1.2 ***Command and Control (C2) Documentation***

The designer shall create C2 documentation, such as Functional Block Diagrams, drawings and OPs/EPs, in order to support design reviews, hazard analyses and determination of the SOC boundaries. See SUPPLIMENTAL DOCUMENT for complex examples of C2.

2-1.9 DESIGN PARAMETERS

Design parameters include qualitative and quantitative aspects of physical and functional characteristics of a system that are input to its design process. Design parameters determine cost, design, and risk tradeoffs in the item's development. For a DLSS, design parameters on a simple level, include schematics, flows, pressures, and/or temperatures. The designer shall document the system design parameters and insure that they are implemented in the design. A design verification and validation matrix is the recommended method to track that design requirements are fulfilled by the design.

For a list of general design parameters see section 2-5.1.

2-1.10 INTEROPERABILITY

Interoperability is a characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, present or future, in either implementation or access, without any restrictions. While the term was initially defined for information technology or systems engineering, it has grown and is now used in many applications beyond software. For a DLSS, interoperability can be as simple as connecting a hose to hard pipe or ensuring the correct hose end fittings are installed to ensure the wrong connections cannot be made (i.e. low-pressure air hose cannot be connected to high-pressure O_2, which is an example of anti-interoperability). The ability to mate one chamber with another using the North Atlantic Treaty Organization (NATO) Flange, mating a diving bell with the habitat or the ability to mate the Pressurized Rescue Module with the submarine decompression chamber (SDC), are all examples of interoperability. The designer and/or the PM shall identify interoperability requirements and then ensure proper implementation. One tool that can be used is an interface control drawing, showing areas of interoperability concern.

2-2 GENERAL DESIGN REQUIREMENTS

The requirements of this section are applicable to ALL systems and components fabricated IAW with this specification. Requirements peculiar or supplemental to a specific type of system are covered by the section governing that system (see section 2-3). Where supplemental or differing requirements are specified in the section governing the system, the system section requirements take precedence.

2-2.1 DIVERS LIFE SUPPORT SYSTEM (DLSS)

2-2.1.1 *General Requirements*

The DLSS shall be designed to provide a safe, controlled atmosphere to all personnel during all normal and emergency design operating conditions. The designer shall address the requirements for the system's breathing gas and the environmental control system (ECS), to include monitoring of both types of systems, based on expected CONOPS and environmental conditions.

The designer shall provide detailed calculations to show that the breathing gas supply will provide gas at the required flow rate and pressure to meet the conditions of the highest expected demands that may be placed on the system (highest demands), including emergencies. For DLSS, the gas requirements specified in NAVSEA SS521-AG-PRO-010 must be met for each type of equipment used. The DLSS shall provide a secondary and emergency gas supply (EGS), to return personnel to a safe haven in the event of a failure of the primary DLSS where required by NAVSEA SS521-AG-PRO-010. The hazard analysis (see section 2-1.4.2 and section 2-5.7) shall verify that the DLSS can recover from a single point failure during operations. The breathing gas supply and the ECS shall be designed so that it can be monitored by operators.

2-2.1.1.1 ***Types of Gas Supply Systems***

Enough gas must be available to compress to the maximum depth, maintain depth for as long as required and return the divers to the surface, including decompression and emergency treatment. The designer must also determine whether additional gas is needed for upward excursions and/or for lock runs based on the operational requirements of the system.

2-2.1.1.2 ***Oxygen (O_2)***

In the closed environment of a DLSS, the occupants will consume O_2 as part of their normal metabolic process typically between 0.33 and 4.0 liters per minute (L/m) standard temperature and pressure, dry (STPD). Refer to NAVSEA SS521-AG-PRO-010 for typical O_2 consumption rates during various activities.

Air contains a partial pressure of oxygen (PP_{O2}) of 0.21 atmospheres, absolute (ata) at the surface. A drop to 0.14 ata will cause the onset of symptoms related to O_2 deficiency, or hypoxia. Most diving operations should use a PP_{O2} of 0.30 ata as the lower limit at the working depth. Table 1 shows the allowable PP_{O2} by system type. High-pressure O_2 poisoning, or central nervous system (CNS) O_2 toxicity, is most likely to occur when divers are exposed to more than 1.6 ata O_2. The design of the system shall be such that the diver is protected from hypoxia and CNS. To prevent the onset of CNS O_2 toxicity, the design of the DLSS shall be such that PP_{O2} delivered to the user shall typically be at 1.3 ata or below. Closed-system O_2 rebreathing systems may require lower partial pressures, while surface supplied helium-oxygen (HeO_2) systems usually permit higher PP_{O2}. The designer shall reference NAVSEA SS521-AG-PRO-010*,* for the PP_{O2} permissible exposure times for closed and semi-closed, self-contained underwater breathing apparatus (SCUBA), surface supplied underwater breathing apparatuses (UBAs), saturation diving, and recompression therapy. The USN normally maintains PP_{O2} between 0.44 to 0.48 ata during saturation dives. The exact upper and lower PP_{O2} limit requires knowledge of the DLSS mission as well as the expected dive duration.

Table 1: Allowable Oxygen Partial Pressure (*PP_{O2}*) by System Type

System Type	Allowable *PP_{O2}*
Open Circuit Air & Nitrogen-Oxygen (NITROX) Diving	1.4 ata (max)(1)
Open Circuit Helium-Oxygen (HELIOX) Diving (Surface Supplied)	1.3 ata (max, on-bottom)(2)
Open Circuit HELIOX Diving (Saturation)	1.25 ata (max, for excursion dives)(3)
Closed Circuit O_2 Diving	Limits shall be provided by the PM in terms of depth and allowable exposure time rather than PP_{O2}. The diver will have no knowledge of the PP_{O2} in the breathing mix and can only operate on the basis of depth and time.
Closed Circuit Constant PP_{O2} Diving	1.3 ata (time weighted average)(3)
Semi-closed Circuit NITROX Diving	Variable depending on flow rate, O_2 percentage, workload, rig kinetics, and work rest timing cycles.

(1) Dives with higher PP_{O2} are allowed but with restricted exposure times.
(2) Brief exposures to PP_{O2} as high as 1.9 ata are allowed during decompression.
(3) 1.9 ata max during compression and 1.3 ata minimum during decompression. The PP_{O2} limits are the same for NITROX and HELIOX diving.

If the designer has a question on what the limits for PP_{O2} should be, they are responsible for requesting the information from the PM.

2-2.1.1.3 ***Carbon Dioxide (CO_2)***

Respiration accounts for most of the carbon dioxide (CO_2) generated in a DLSS. The ratio of volume of CO_2 produced to the volume of O_2 consumed is termed respiratory quotient (RQ) and varies from 0.7 to 1.1, depending on the individuals balance of dietary fats and carbohydrates, level of exertion, and other factors. At rest, the RQ is on average around 0.85. During moderate to hard work, the RQ approaches 1.

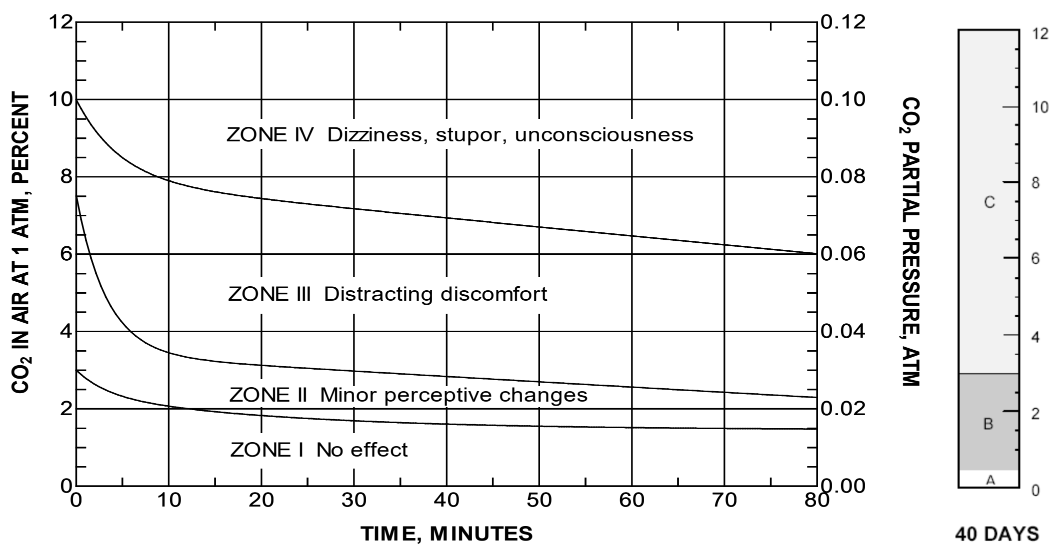
The average resting O_2 consumption is approximately 0.44 L/min (STPD) or 1.0 cubic foot per hour (ft^3/hr) (STPD) per man, and the corresponding average CO_2 generation rate has been observed to lie between 0.352 and 0.374 L/min (STPD) or 0.80 and 0.85 ft^3/hr (STPD). This amounts to about 46 gram (g) or 0.1 pound (lb) per man-hour. Therefore the average resting RQ should be about:

$$RQ = \frac{V_{CO_2}}{V_{O_2}} = \frac{0.374L(STPD)/\min.}{0.44L(STPD)/\min.} = 0.85$$

Excessive amounts of CO_2 in the breathing gas results in toxic effects, the severity of which depends upon exposure time and the partial pressure of carbon dioxide (PP_{CO2}).

Figure 2 shows the relation of physiological effects of CO_2 for different concentrations and exposure periods at 1 ata. The bar graph at the right, for exposure of 40 days, shows that PP_{CO2} in air of less than 0.005 atmospheres (atm) partial pressure (Zone A) causes no biochemical or other effects. PP_{CO2} between 0.005 and 0.03 atm partial pressure (Zone B) cause adaptive biochemical changes, which may be considered a mild physiological strain. Partial pressures above 0.03 atm partial pressure (Zone C) cause pathological changes in basic physiological functions. For saturation diving or any long exposure the PP_{CO2} shall be controlled to an upper limit of .005 ata with allowable short peaks up to .008 ata. For ventilated chambers or open-circuit diving apparatus, an upper limit of .02 ata is acceptable for durations of several hours.

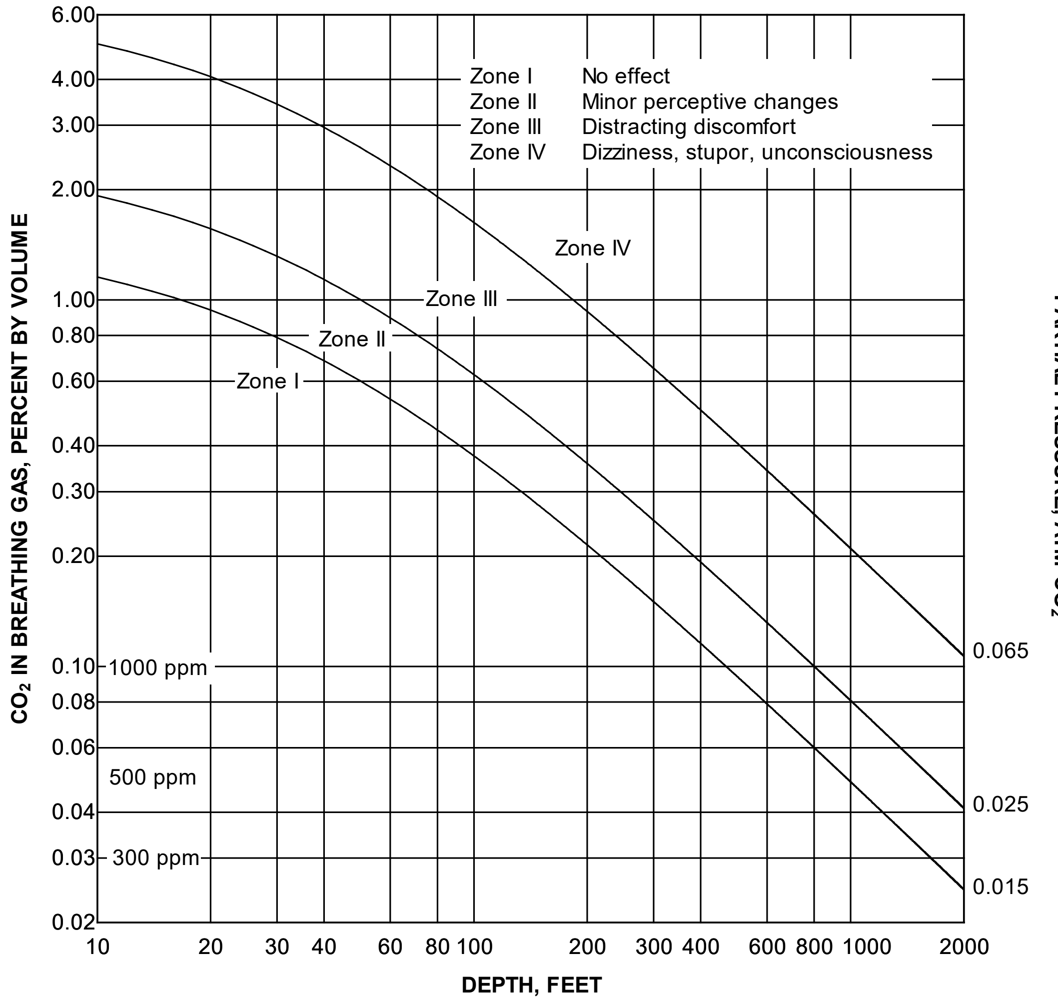
Figure 2: Relation of Physiological Effects of Carbon Dioxide (CO_2) Concentration and Exposure Period



The PP_{CO2} shown in the right hand bar graph should be multiplied by 0.01.

Figure 3 shows CO_2 tolerance zones as a function of CO_2 percentage and depth for a 1-hour exposure period. The percentage of CO_2 that can be tolerated in the breathing gas decreases with increasing depth, because the partial pressure governs the biological effects.

Figure 3: Relation of Physiological Effects of Carbon Dioxide (CO_2) Concentration and Exposure Period



The sources for Figure 2 & Figure 3 are the Naval Coastal Systems Center (NCSC) Technical Manual 4110-1-83*, Design Guidelines for CO_2 Scrubbers*; National Aeronautics and Space Administration (NASA)-SP-118*, Space Cabin Part IV Engineering Tradeoffs*.

The designer shall develop a design solution to remove CO_2 from the DLSS. In the closed environment of a DLSS, CO_2 is usually removed by a material that absorbs it chemically, such as calcium hydroxide or soda lime. In ventilated systems, fresh gas is used to dilute CO_2.

Calculations and/or test data shall be provided to the PM to document the adequacy of the CO_2 removal system. If ventilation is the method of removal, the designer shall determine the amount of gas required to ventilate the DLSS throughout the most rigorous operational requirement (most personnel, longest time, deepest depth).

2-2.1.2 *Breathing Gas Supply*

The following are general requirements for breathing gas supplies of DLSS (except UBAs):

a. Open circuit breathing gas systems that do not incorporate separate emergency breathing systems (EBS) shall have not less than two independent sources of breathing gas; one of which must be from a stored supply. For these designs, acceptable configurations are either two stored breathing gas sources or one breathing gas compressor and one stored gas supply. A volume tank is required for direct compressor operations. If a system would be improved using compressors to provide both primary and secondary gas, the designer shall request written approval from the PM to develop the system in this way. If approval is granted, the compressors shall be independently powered.

b. DLSS with closed circuit normal breathing designs shall include an EBS (see section 2-2.1.2.4).

c. Breathing gas systems shall be designed to permit cleaning IAW MIL-STD-1330, *Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen, Nitrogen, and Hydrogen Systems*, MIL-STD-1622, *Department of Defense Standard Practice for Cleaning of Shipboard Compressed Air Systems*, or other PM approved cleaning procedures.

d. Any breathing gas pressure control subassembly provided in the form of a variable volume gas reservoir (e.g., a breathable bag) shall have the following considerations documented in the design documentation:

    1) Puncture and tear resistant under worst case operational conditions.

    2) Mold and fungus resistant under worst case operational conditions.

    3) Configured to permit accessibility to other components.

    4) Easily removable for cleaning and drying.

e. System design shall permit sampling of gas supplies at appropriate locations which may, for example, include at the source and at the point of use.

f. O_2 and CO_2 levels shall be monitored and controlled in closed loop and closed environment systems.

g. Automatic transfer to reserve breathing gas supply, if provided, shall actuate a warning signal, both audible and visual. Provision may be made for turning off the warning device once it has been activated. Consideration should be given to providing automatic reactivation of the warning after a specified time.

2-2.1.2.1 ***Stored Breathing Gas/Diluent Gas***

Breathing and diluent gas storage systems may be used to provide air, helium (He), nitrogen (N_2), mixed gas or O_2 to the DLSS. When stored breathing gas is used, the minimum storage pressure must be stated in system drawings. The minimum storage pressure is that necessary to provide adequate pressure for satisfactory system operation throughout the longest planned mission.

When breathing gas storage systems are installed in a DLSS, the following items shall be considered:

a. The capacity of the primary supply must exceed the requirement for the consumption rate of the designated number of divers for the full duration of the dive (bottom time plus decompression time). The maximum depth of the dive, the number of divers, and the equipment to be used must be taken into account when sizing the supply.

b. All DLSS shall be equipped with separate primary and secondary breathing gas supplies.

   The primary and secondary gas supplies shall be separated such that they include separate gas banks, piping and pressure regulators. The separation shall be maintained from the storage flasks, all the way to the diver's manifold (surface supplied or saturation DLSS) or pressurization manifold (recompression chamber). If approved by the PM, the secondary breathing gas supply can cross-connect with the primary breathing gas supply, provided there are suitable isolation valves or other devices installed to prevent inadvertent operation.

c. Suitable valve protection shall be provided to prevent inadvertent depressurization of the containers. For flasks that are permanently installed and recharged in place, double valve protection shall be provided on fill lines.

d. Gas storage flasks shall meet the requirements of section 2-2.6.1.

e. Gas storage systems shall be secured to prevent their accidental detachment. They shall also be supported or restrained to prevent the imposition of a load on other components that are not designed as supports.

f. Primary and secondary breathing stored gas supplies shall have self-powered instrumentation to monitor pressure at a minimum (e.g., mechanical gauges).

2-2.1.2.2 ***Primary Breathing Gas Supply***

The primary system shall be capable of sustaining all DLSS personnel for the duration of the longest planned mission. If stored gas is to be used as the supply for the primary breathing gas, the gas storage flasks shall provide sufficient gas for the most demanding mission for which the DLSS is designed. The designer shall justify the gas storage system capacity by calculations. Leakage rates and environmental temperature fluctuations should be taken into consideration'.

For DLSSs that use a gas blender as a primary breathing gas supply, the system must be equipped with a volume tank immediately downstream of the gas blender and a gas analyzer for real time monitoring of PP_{O2} prior to the blended gas being directed to divers or gas storage. If blending more than two gasses you may consider monitoring additional constituents.

When the system breathing gas is air, either an air compressor or stored compressed air may be used as the primary supply. When an air compressor is to be used to support diving operations, a volume tank is required to eliminate pulsations in the compressor discharge and act as a storage tank, allowing the compressor to shut down during periods of light loads. Verification of adequate flow rate shall be required and annotated in system specification or drawings.

2-2.1.2.3 ***Secondary Breathing Gas Supply***

A secondary breathing supply system shall be provided for use in case of a failure of the primary gas supply. Secondary gas supply shall not be used during normal system operations. The secondary supply must be separate, distinct and totally independent from the primary breathing supply.

The secondary supply must be capable of immediately providing proper breathing mixtures at the correct pressure and flow rate in the event of failure of the primary system. The secondary supply must be sized to be able to support recovery of all divers to the surface (or a safe haven) if the primary supply sustains a casualty at the worst-case time (for example, immediately prior to completion of planned bottom time of maximum dive depth, when decompression obligation is greatest). The basis for the capacity of the secondary supply shall be reviewed and approved by the PM during the formal system design reviews (SDR). The adequacy of the secondary supply capacity shall be justified by calculations.

2-2.1.2.4 ***Emergency Gas Supply (EGS)***

An EGS system shall be provided IAW NAVSEA SS521-AG-PRO-010. Not all systems require an EGS.

2-2.1.2.5 ***Emergency Breathing System (EBS)***

An EBS shall be provided IAW NAVSEA SS521-AG-PRO-010. Not all systems require an EBS.

2-2.1.3 *Diving Gases – Purity Standards*

The following are the purity requirements for gases used in DLSS and recompression chambers:

a. Diver's air shall meet the standards outlined in NAVSEA SS521-AG-PRO-010, specifically:

   1) O_2 quality shall meet MIL-PRF-27210, *Oxygen, Aviator's Breathing, Liquid and Gas*, (series) Type I and must be verified as to purity by the supplier.

   2) He quality shall meet MIL-PRF-27407, *Propellant Pressurizing Agent, Helium*, Type I, Grade B and must be verified as to purity by the supplier.

   3) N_2 quality shall meet FED-SPEC-A-A-59155, *Nitrogen, High Purity, Special Purpose*, Type I Grade and must be verified as to purity by the supplier.

The air provided by ships' low-pressure air compressors for general shipboard use is not suitable for use as breathing air unless specifically tested and certified according to OPNAVINST 5100.19, *Navy Safety and Occupational Health Program Manual for Forces Afloat*. Additionally, air taken from machinery spaces or from downwind of the exhaust of an engine or boiler may contain excessive concentrations of CO_2, carbon monoxide (CO), and other toxic contaminants and therefore is unacceptable for divers breathing air. Normal atmospheric air may contain small concentrations of toxic gases, including sulfur dioxide, oxides of N_2 and gaseous hydrocarbons, and particulates. The source of these is usually from the exhaust of internal-combustion engines or other high-pressure, high-temperature combustion. For permanently installed systems, care should be taken in selecting a suitable location for air compressor inlets to ensure that they are upwind of exhaust stacks and similar areas where noxious or toxic gases may accumulate.

2-2.1.4 *Divers Life Support System (DLSS) Instrumentation*

Instrumentation for DLSSs shall be provided to warn personnel of unsafe conditions. It shall be sufficiently accurate and shall operate satisfactorily within the range of the DLSS environmental and section 2-1.9 for design parameters. Suitable redundant instrumentation shall be provided and designed to operate in the event of normal power failure. Instrumentation shall be reliable and easy to calibrate (preferably in place). Calibration should be able to be accomplished while the instrument is in-place.

Instrumentation requirements in a DLSS will vary widely depending upon depth and exposure times. For complex systems, especially saturation DLSSs, substantial instrumentation may be necessary. Instrumentation may include, but not be limited to, the following:

a. CO_2 sensors.

b. O_2 sensors.

c. Gas flow sensors.

d. Gas source pressure indicators/sensors.

e. Physiological sensors.

f. Heated suit sensors.

g. Temperature sensors of DLSSs interior.

h. Respirator gas temperature sensors.

i. Low and high level/pressure warning devices.

j. Pressure/depth indicators.

k. Fire detection devices.

l. Humidity sensors.

m. Electrical defect sensors (ground detectors).

n. Ammeter(s) and voltmeter(s).

Any automatic transfer to secondary or emergency breathing gas supply, if provided, shall actuate a warning signal, both audible and visual. Provisions shall be made for turning off the audible warning device after it has been activated. The visual warning device shall remain activated until system parameters are again within acceptable limits. Consideration shall be given to providing automatic reactivation of the audible warning after a specified time.

Test data, which establishes the ability of the measuring devices to meet the accuracy requirements in the intended environment, must be furnished. The design shall utilize a backup means for providing measurements of critical functions (e.g., O_2 and CO_2 monitors). Failure of one measuring device must not impair the function of the other.

Electronic sensors shall meet the requirements of section 2-2.8.

2-2.2 DESIGN CALCULATIONS

Design calculations as well as acceptance criteria are mandated by recognized industry codes and standards. The designer shall request written approval from the PM on the proposed codes and standards to be used in the design of the system prior to conducting calculations.

Design calculations shall be provided to the PM for approval and clearly stating all design assumptions and load conditions. The most conservative load condition needs to be analyzed and it is like likely that multiple conditions need to be analyzed depending on the use of the part/component/system. These loading conditions need to be defined and approved by the PM.

Calculations shall be in a format that can be confirmed and replicated by the PM. The calculations shall be in standard engineering data sheet format that clearly indicates the design, as depicted in the drawings, is fully satisfactory and meets all design requirements of the applicable code or standard. All design assumptions shall be clearly defined and the engineering data sheet must be signed by the design engineer.

For calculations completed before drawings are placed under CM, they must later be validated as applicable to the configuration baseline drawing. All calculations affecting SOC parts must be traceable to respective production drawings.

2-2.2.1 *Minimum Calculation Requirements*

Calculations by the designer must demonstrate the adequacy of the design in terms of the design parameters of the DLSS as defined in the program baseline. All the design assumptions and load conditions must be clearly stated. Components, equipment and systems shall be designed to properly operate at the highest demand specified design conditions. Design calculations shall use highest demanding material dimensions. The designer shall produce documentation with sufficient detail to permit an independent analysis of the design. Calculations should provide, at a minimum, the following information:

a. Design calculations for pressure vessels for human occupancy (PVHO) shall clearly show the design meets all requirements of American Society of Mechanical Engineers (ASME) PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy,* or alternative pressure vessel design codes may be proposed by the designer but must be approved by the PM.

b. Structural design calculations shall show the effect of fabricating to worst case material dimensions. Potential effects of corrosion caused by oxidation, pitting, galvanic interaction of dissimilar metals, stress corrosion cracking (SCC) and embrittlement must be considered. Design calculations shall reference applicable test data, codes, design standards, safety standards and operating experience when used to support a calculation technique.

c. Design calculations for piping and mechanical systems, loads, power supplies, etc. shall have calculations to show the capability of the system to perform its intended function. This includes system flow characteristics (e.g., velocity, flow rates, pressure, and storage and/or air bank capacity) where applicable. Flow rates and storage capacities shall be based on the highest demanding cases, including emergency situations where the system may see service.

d. Due to the nonlinearity of gas properties at high-pressures, calculations of high-pressure gas volumes and densities shall use gas the use the gas properties identified in NAVSEA 0994-LP-003-7010, *U.S. Navy Diving-Gas Manual*.

e. Design calculations for electrical equipment and systems will contain as a minimum:

   1) Electrical load and power analysis.

   2) Maximum heat generated by the equipment, and the maximum anticipated temperature.

   3) Voltage-drop calculations including fault current analysis and coordination of protective devices analysis.

   4) Where available, information obtained from the manufacturers of the electrical/electronic equipment may be used in lieu of actual calculations provided that technical justification to support the manufacturer’s information is provided.

2-2.2.2 *Stress Analysis*

The designer shall verify the adequacy of the design by performing detailed stress analyses and conducting the tests, as described in this section. Applicable sections and provisions of pressure vessel and piping design codes shall be applied. The test program shall consider all ramifications of the stress analyses. Stress analyses and test reports shall also consider the most critical loading case which shall include the cumulative detrimental effects of design allowances, dimensional variations, and tolerances. The designer may request that specific designs, utilizing standard materials or components, be exempted from stress analysis as based on technical justification. In cases where the pressure boundary is a unique and complex shape, destructive testing can be accomplished. The PM will make a determination of those materials and systems that do not require stress analyses. If performing a finite element analysis (FEA) the designer can consider Appendix L Examples of loads to be considered are:

a. Weight of water used for hydrostatic testing.

b. Added mass considerations for acceleration/deceleration of fluid in the system.

c. Forces encountered while transporting, securing, removing, or handling the system or its components.

d. Static loads imposed by the clamping or securing devices used to secure the system.

e. Maximum operating pressure (MOP) of gas within the system.

f. Thermal stresses due to the maximum operating temperature range of the system.

g. Reactions due to differential thermal expansion between the system and the structure to which it shall be fixed or due to elastic expansion of the system caused by internal pressure.

h. Vibration transmitted from the shipping platform transporting the components of the system.

i. Shock, including accidental blows.

j. Vertical and horizontal loads on foundations.

k. Forces developed by shipboard accelerations, ship vibrations or imposed by ship motions.

l. Dynamic loads, such as those encountered:

    1) When launching, retrieving, or handling the DLSS.

    2) In normal or casualty operations such as explosively jettisoning external equipment.

    3) From collapse of any non-pressure compensated elements.

m. Fatigue load life of the pressure resisting components and piping for a specified number of cycles in a cold water environment.

n. Effects of corrosion.

2-2.2.3 *Fatigue*

Applicable fatigue analysis shall be submitted to the PM for approval for all piping systems, pressure vessels and hard structures IAW requirements of the specific code that was used for the design. This fatigue analysis may be based on specimen and/or model tests. Prior to conducting the analysis, technical justification for the basis of the fatigue analysis shall be provided to and approved by the PM. Suitable fatigue strength reduction factors shall be applied to the specimen or model test results to account for variations in properties, scatter in the test results and the uncertainties involved in applying specimen and model fatigue data to fabricated full-scale structures. The fatigue analysis must consider at least the following design parameters:

a. Magnitude and nature of peak stresses – stress concentration factors used in the calculation of peak stresses shall be based on experimental data on similar structures.

b. Material properties and method of fabrication.

c. Maximum deviation in material thickness, assembly techniques and allowable flaws.

d. Geometry of the structure and details of penetrations and attachments.

e. Previous fabrication, stress-loading, and operating history of the material.

f. Effects of residual stresses, thermal stresses and strain rate.

g. Type and method of loading and environmental effects such as corrosion/erosion.

h. Maximum anticipated number of load cycles.

2-2.3 DRAWINGS

2-2.3.1 *Drawing Requirements and Standards.*

All DLSS drawings shall meet the requirements of MIL-STD-31000, *Technical Data Packages*. Drawing requirements shall be defined during the Requirements Analysis of the design process and adhered to throughout the design.

For each component or item on a drawing, the manufacturer's model or type number, part number, material, vendor identification, applicable military specification, and federal specification or standard as appropriate shall be identified. The drawings shall specify any special material control requirements. Each component that provides a control, sensing or similar essential function that impacts the operation of the system (valves, gauges, pressure regulators, etc.) shall have a unique identifier made up of a system designation and a number as a minimum. While a unique identifier is the minimum requirement, it is preferred to use nomenclature that provides the maximum information in the minimum space for not only use on the drawings, but also for application on the component identification label plates.

These unique identifiers shall be shown on the drawings and shall be used in the OPs/EPs and the system hazard analysis.

Table F 1 and Table F 2 provide common component, system and locator nomenclature that can be used to derive unique component nomenclature. Using this convention is useful for large complex DLSSs, such as saturation DLSSs. The nomenclature can be tailored and customized to meet and/or exceed the minimum unique identifier requirement. Any convention that is decided upon by the designer shall be approved by the PM prior to implementation.

The required dimensional inspection points, such as the minimum and maximum tolerances shall be identified on drawings for all machined and forged components.

Drawings must completely identify the pressure vessel(s) and all the appurtenances (foundations, penetrations, attachments, etc.). All welds and the inspection requirements shall be detailed and identified. All components shall be fully specified on the Bill of Material (BOM) and notes shall fully explain or define processes, specifications, procedures and special instructions. Pressure vessel(s) weight, internal (floodable) volume and cycle life (as required) shall be stated on the top assembly drawing for each vessel. When cycle life is defined, cyclic requirements (inspections, tests) shall also be stated.

All fabrication drawings shall contain all the manufacturing, assembly, cleaning and testing information necessary to permit operators to maintain the DLSS after its fabrication. Each component and welded or mechanical joint within the SOC shall have a unique identification number on the joint identification drawing (JID), which will be used for documentation and traceability throughout fabrication. See Appendix G for examples of typical drawings notes found on various fabrication drawings for diving and hyperbaric system drawings built to this standard.

2-2.3.2 *Joint Identification Drawing (JID)*

The designer shall develop JID for the DLSS and welded pressure vessels of any diving or hyperbaric system designed IAW this specification. JIDs are used not only during the fabrication of the system, but also throughout the life of the equipment for maintenance and record keeping. It is imperative that these drawings are complete and accurate and are updated during design and fabrication to ensure accuracy.

The purpose of the JID is to provide documentation to verify actual installation, identity, and specific location of each element within the SOC.

JIDs are a schematic and parts list of the piping systems, pressure vessels, and components. The schematics shall show all piping, tubing, fittings, valves, gauges, and joints. The JID may also list the minimum wall thickness required (after bending) for piping and tubing, but it is a requirement to list that information in the drawing specification for the proper fabrication of pipe and tubing bends. An example of a JID is shown in Appendix F.

Each component and welded or mechanical joint within the SOC shall have a unique identification number on the JID which will be used for documentation and traceability throughout fabrication.

Prior to beginning fabrication, the JID shall be submitted to the PM for approval. An example of a JID fitting designations is shown in SUPPLEMANTAL DOCUMENT.

2-2.3.3 *Scope of Certification (SOC) Boundaries*

All drawings will clearly and completely reflect SOC boundaries as appropriate to the components/subsystems that are reflected on the drawing. Additionally all SOC components will be identified on the BOM.

2-2.3.4 *Cleaning Requirements*

The drawings shall provide cleaning requirements for DLSS piping and PVHOs IAW with section 3-5.6.

2-2.3.5 *Revisions*

ASME Y14.35, *Revisions of Engineering Drawings and Associated Documents*, shall be used to define the practices for revising drawings and associated documentation and to establish the methods for identification and recording revisions. Once the PM approves the design after the CDR and the PBL is established, all drawing revisions shall be formally documented. The PM must approve all revisions.

2-2.4 MATERIALS

Selection of the proper material to be used in the design and manufacture of DLSSs is a critical factor affecting system safety. The specific end use of each component must be evaluated on the basis of its operating environment (particularly when used in combination with other materials), loading conditions, and life expectancy. The use of an inappropriate material in a DLSS may result in a catastrophic failure, causing critical or fatal injury to personnel.

The designer must be able to justify the use of materials and intended applications as proposed in the design of the DLSS within the expected service environments. All of the materials shall be identified in system drawings.

Consideration should be given to environmental exposure and location, as well as compatibility of one material with other adjacent materials for given environmental extremes.

Materials should conform to a recognized code or standard applicable to the design of the component or system (i.e. if the recompression chamber is designed to ASME PVHO-1 then materials of construction should be selected based on the allowable materials IAW with ASME PVHO-1).

Appendix M lists typical DLSS materials and/or components with their application. The specifications listed are representative of requirements for the material identified and are provided for guidance. Note that untested or unusual configurations or applications of these materials and/or components would require justification to the PM. Also, exposure to unusual environmental conditions such as unusually high or low operating temperatures has to be considered.

The designer must submit justification to the PM for approval. The following are examples of the type of information that may be required depending on the type of material or application:

a. The applicable military, federal, or commercial specification with a detailed list of exceptions or additions.

b. Material properties of the base metal in the condition it will be used and, if the material is to be welded, of the weld metal and the material in the heat affected zone.

c. Tensile properties for the material at its service environment temperature, including but not limited to tensile strength, creep behavior, yield point, percent elongation, reduction of area, elastic modulus, and stress-strain curves (tension and compression). The material specimens tested should represent any defects and variations in material properties introduced by manufacturing and fabrication processes. Should the preparation of specimens with intentional defects or property variations prove unfeasible, the designer may fabricate a first article and conduct inspections and destructive testing.

If the first article is satisfactory, all follow-on production articles that meet or exceed the quality of the first article will satisfy this part of the requirement.

d. Impact and fracture toughness properties over the material temperature range for the intended service environment (e.g., transition temperature and shelf energy values). Desirable tests include Charpy V-notch transition curves and dynamic tear as well as drop-weight tests per American Society for Testing and Materials (ASTM) procedures, and/or explosive bulge tests. Where appropriate, the designer should show that the material's fracture toughness properties in the applicable environment are adequate for its intended use. In this regard, a fracture mechanics type of test is useful to study the effect of seawater on fracture resistance.

e. Proof of weldability and machinability IAW the testing requirements of NAVSEA T9074-AD-GIB-010/1688, *Requirements for Fabrication, Welding, and Inspection of Submarine Structure*, or approved industrial standard. These test results shall include tensile and impact properties of both weld metal and heat affected base metal. A list of specific applications should also be provided. Specific considerations include quantities and thickness of material, welding processes used, inspection standards used, manufacturer's name and fabrication experience, history of component service environment and length of service, pre-weld and post-weld heat treatments (if any), and the type of requirements and inspections required of the material supplier in the material purchase specifications.

f. Fatigue data, preferably data in the low-cycle range (below 10,000 cycles), which considers the effect of the environment. Testing must include loads equivalent to the peak stress encountered during operation at maximum design depth.

g. Basic process to be used in producing the material. If the fabrication process involves welding, the types of electrodes shall be included. The basic process to be used in producing the material, including sufficient information to demonstrate that the procedures ensure that repeatable material properties are obtainable.

h. Data over a sufficient time period to justify the adequacy of the materials with respect to general corrosion and to SCC in its intended environment.

i. Nondestructive examination (NDE) requirements to be applied to base material and weld joints, as appropriate.

j. The material's chemical properties.

k. The material's mechanical properties, including changes to properties as a result of material forming (i.e., proportional limit stress).

l. Data that illustrates the material and structural performance when subjected to dynamic shock from explosively jettisoning external equipment and from the implosion of a flotation sphere or any other air-backed component or equipment mounted on or transported by the DLSS. This paragraph establishes performance criteria (must survive) for the candidate material under the conditions of explosively jettisoning external equipment, but does not impose pass/fail criteria for material performance during implosion shock loading. It is not required to demonstrate that the material would survive the shock, but rather to demonstrate how the material actually performs. The resulting data will be used to conduct the evaluation of implodable and explodable volumes specified in Appendix J and Appendix K.

m. The effects of flaws, such as cracks or defects, on material performance.

n. The effects of temperature on material performance and resistance to crack propagation.

o. The results of destructive testing performed on fabricated sample material and comparison of these results with the design basis predictions of the failure point. These include implosion and/or rupture test of scale models of the proposed structure (as applicable).

p. Data that covers an extended time period, establishing the adequacy of the material with respect to general corrosion and to SCC in the applicable service environment.

q. Fabrication characteristics, including data verifying the repeatability of results.

r. Hazards involved in fabrication or use of material with respect to toxicity or flammability.

The following subsections contain additional requirements and design consideration that provide assurance of adequate material performance for DLSSs built IAW this specification.

2-2.4.1 *Toxicity*

Non-metallic materials or components, which could cause occupational illness or release noxious/toxic fumes at temperatures below 200°F (93.33°C), shall not be used within pressure vessels or surfaces exposed to breathing gasses unless approved by the PM. Examples of these materials and components include paints, insulations, sealants, adhesives, plastics, lubricants, fabrics, and fittings. This requirement applies to paints, sealants, or adhesives after drying or curing.

The designer should look to utilize materials that have been proven for use in hyperbaric environments but if new materials are selected, they will need to be off-gas tested (see section 3-6.10 for requirements). Mercury, asbestos, cadmium, magnesium and beryllium are examples of materials that shall not be used in a DLSS without adequate protection and justification.

The designer shall compile a toxic and flammable data list of all potentially toxic materials used inside closed environments, such as recompression chambers, and submit this to the PM for review and approval.

2-2.4.2 *Flammable/Combustible Materials*

Every effort shall be made to eliminate, or at least minimize, flammable material in the DLSS. Flammable materials are those that will ignite or explode from an electric spark or when heated and will continue burning in the presence of air or in a potential DLSS atmosphere. In O_2-enriched atmospheres, considered by NAVSEA 00C3 to be greater than 25% IAW MIL-STD-1330, the reactivity of O_2 increases the risk of ignition of materials and fire propagation. This means that materials which DO NOT normally burn in air may burn energetically in an O_2-rich environment with a much hotter flame and propagate at a much greater speed. Due to the potential for O_2 concentration to exceed 25% in diving and hyperbaric chambers, the designer is strongly urged to follow the guidance found in ASTM G88, *Standard Guide for Designing Systems for Oxygen Service*. Due to the potential for O_2 concentration to exceed 25% in O_2 and mixed-gas DLSS, as well as inside hyperbaric chambers, the designer is strongly urged to follow the guidance found in ASTM G88.

The designer shall compile a toxic and flammable data list that includes all potentially flammable materials used inside the PVHO and breathing systems which includes sufficient information to permit an independent evaluation of the suitability and adequacy of the materials to be used.

The designer must address the following characteristics of the material in its intended application:

a. Probability of ignition.

b. Ease of ignition.

c. Potential to involve other material.

d. Hazardous effect to the system.

e. Function and performance.

f. Ability to satisfy its intended function.

If flammability testing of a complete equipment assembly will lead to its destruction, the following alternative analysis is recommended:

a. If possible, identify types and amounts of all materials used in the assembly. If available, evaluate commercial flammability data for these materials.

b. If the equipment is energized when operating, it must be built IAW a recognized government or commercial specification.

c. If the equipment is energized when operating, perform a 24 hour "burn in bench test" to determine the maximum temperature the energized unit reaches. Identify any local hot spots.

d. Determine if the assembly is mounted next to any other installed heat sources. This should be avoided if possible, but if this is not feasible then address how the assembly will be protected from these heat sources (e.g., insulated with a nonflammable material such as NOMEX®) and assess the impact of co-location.

e. Determine if the assembly is a heat source itself. If so, address how surrounding areas will be protected.

f. If the assembly is energized, operators must be able to de-energize the hardware quickly to secure power to the ignition source.

DLSS stationary furniture, such as bunks and chairs, shall be made of a conducting material to minimize the possibility of the accumulation of a static electric charge. Bare aluminum is conductive; however, most aluminum used for furniture is anodized. This anodized finish is highly insulating and blocks the desired electrical discharge path. In this case, provisions shall be made to ground the furniture and have conductive resistance of less than 1 megaohm (MΩ).

Magnesium and alloys containing significant amounts of Magnesium shall not be used in DLSSs because of their high combustibility. Materials that are nonflammable at atmospheric pressures may be highly flammable when subjected to increased O_2 concentrations and/or elevated pressure. The designer should also be familiar with ASTM G63, *Standard Guide for Evaluating Non-metallic Materials for Oxygen Service*, and ASTM G94, *Standard Guide for Evaluating Metals for Oxygen Service*, when selecting materials to be used in elevated O_2 environments and piping systems.

2-2.4.3 *Acceptable Material for Oxygen (O_2) Atmospheres*

Materials, both metallic and non-metallic as well as oils and lubricants, used in a system where the concentration of O_2 is greater than 25% by volume shall be evaluated for their ability to resist burning using a recognized standard such as ASTM G63 (for non-metallic) and ASTM G94 (for metals).

Improper selection of materials in an O_2 enriched environment can significantly increase the risk of a fire and therefore all materials used in these systems or environments shall be approved by the PM. For further guidance on flammability analysis see section 2-2.4.2.

Fluorocarbon plastics, elastomers, greases and high viscosity oils are typically used in USN systems. The tables below provide a list of some of these types of materials that have been approved for use.

Table 2: Seals

Material	Manufacturer	Item Name
Polytetrafluoroethylene (PTFE)	DuPont	Teflon®
Polychlorotrifluoroethylene (PCTFE)	Diakin 3M	Neoflon M-400H Kel-F® (no longer manufactured)
Vinylidene fluoride (VDF) and hexafluoropropylene (HFP) combined are designated in the category Fluorocarbon Rubber (FKM) IAW ASTM D1418, *Standard Practice for Rubber and Rubber Latices – Nomenclature*	DuPont	Viton®
polyimide	DuPont	Vespel® SP21

Table 3: Lubricating Greases and Oils

Material	Manufacturer	Item Name	MIL-SPEC
Perfluoropolyether (PFPE)	DuPont	Krytox 240AC®	MIL-PRF-27617, *Grease, Aircraft and Instrument, Fuel and Oxidizer Resistant*
PCTFE	Halocarbon Products Co.	Halocarbon 25-5S	N/A
Chlorotrifluoroethylene (CTFE)[1]	Gabriel Performance Products	Fluorolube® GR362	N/A
Silicone	Dow Silicones Corporation Polysi Technologies, Inc.	DC-4 PST-525	SAE AMS8660, *Silicone Compound NATO Code Number S-736*[2]
(1) CTFE is not compatible with aluminum alloys (2) Mechanical components in recompression chambers may be lubricated with grease conforming to this specification.			

For further information on lubricants, see Naval Ships' Technical Manual (NSTM) Chapter 262, *Lubricating Oils, Greases, Specialty Lubricants, and Lubrication Systems*.

See sections 2-2.4.4 and 2-2.5.5.4.1 for materials acceptable for piping and seals, respectively.

2-2.4.4 *Corrosion*

2-2.4.4.1 ***Environment; Design for the Worst Case***

The designer shall consider corrosion during the initial selection of system materials and throughout the design process. This requires practical real world experience with corrosion, as well as a formal and working knowledge of corrosion engineering. This especially requires the designer to know and understand the hyperbaric system mission environment. The duration of exposure to seawater or humid air and the need for using measures to control corrosion shall be considered in the design. Some hyperbaric systems, such as treatment chambers, are operated in benign, dry, environmentally controlled buildings, yet they experience unforeseen corrosion events. Some systems, such as Free Ascent Towers and other land-based aquatic training facilities, are continuously exposed to high concentrations of chlorine vapors and chlorine water. Corrosion engineering is a consideration when pursuing the addition of hydrogen (H_2) as a dilutant breathing gas – H_2 embrittlement. Most portable systems will be operated in harsh seawater environments that place systems in a saltwater spray surrounding. Given the fresh continuous mixing of O_2 and seawater, this can become the worst of all environments. The designer shall identify and consider the worst case environment when designing corrosion mitigations.

2-2.4.4.2 ***System of Systems; Design for all Integrated Components***

Corrosion of pressure containing components, such as pipe, piping components and associated structures such as pressure vessels, electrical penetrations, hatches, and viewport window seats, all must be considered as a system of systems during the corrosion design process. One metallic material next to another in the right/wrong environment can become a significant problem. The designer shall also consider overall ancillary system corrosion. This includes non-pressure containing components, such as but not limited to: pipe hangers and supports, component brackets and foundations, as well as foundations for pressure vessels. In general, all fasteners and metallic materials required to assemble the system shall be considered. Most of the time, electrical systems naturally receive corrosion protection by coincident protection from operator electrocution hazards. Following the National Fire Protection Agency (NFPA) standards, as well as the use of electrical equipment and components that meet requirements of recognized commercial standards such as Underwriters Laboratory (UL), and National Electrical Manufacturers Association (NEMA) for enclosures, is required unless otherwise specified. Corrosion of handling systems, specifically wire rope and other like items is addressed via handling system design and more specifically maintenance and integrity testing.

2-2.4.4.3 ***Comprehensive Analysis; System Corrosion Analysis***

When both the system design and operational environment are complex systems such as SAT-FADS or SRDRS, the designer shall conduct and document a system corrosion analysis. Unless otherwise deemed acceptable by the PM, system corrosion analysis shall be performed by a corrosion specialist, certified by the National Association of Corrosion Engineers (NACE) or equivalent recognized association, such as the British Institute of Corrosion. The scope and size of a formal corrosion analysis shall be approved by the PM prior to conduct. Typical types of corrosion that shall be considered:

a. Electrolytic corrosion: The most common form of corrosion in the marine environment, which occurs through oxidation and reduction. Electrons pass from the site of oxidation (corrosion) to the site of reduction. The site of oxidation (corrosion) is the anode. The site of reduction is the cathode. The electrolytic path for the electron flow can be supplied or supplemented by a seawater environment and cab become driven by outside electrical sources. The path also occurs in other diving environments such as freshwater environments and the previously mentioned chlorine water environments. The following are various types of electrolytic corrosion:

    1) General/pitting corrosion.

    2) Crevice corrosion.

    3) De-alloying corrosion.

    4) Galvanic corrosion.

b. SCC: Certain alloys (e.g., silicon aluminum bronze (SAB)) are susceptible to SCC. This can occur when the material is exposed to a corrosive environment while under tensile stress. There are numerous examples of SCC failures found in high-pressure fittings (most commonly union nuts), where nickel aluminum bronze (NAB) should have been installed, but SAB got erroneously installed. Amines, found in enclosed submarine scrubber environments (Nuclear Submarine Environment) and other forms of ammonia in the environment (biological waste – (urine/dung)) can accelerate this type of corrosion.

c. Biofouling and Microbiologically Influenced Corrosion (MIC): an electrochemical process where the participation of microorganisms is able to initiate, facilitate, or accelerate the corrosion reaction without changing its electrochemical nature. The three pressurized fire suppression water storage tanks located at David Grant United States Air Force (USAF) Hyperbaric Medical Center, CA, Duke Center for Hyperbaric Medicine and Environmental Physiology, and USAF Wound Care Medical Center, Wright-Patterson Air Force Base, OH, all experienced MIC. Here the city water was the likely source and the problem was never conclusively determined. However, like some other examples, flowing well oxygenated fresh water, allowing introduction of the microorganism was the likely cause. Mitigation included killing the microorganism with chlorine treatment. MIC has also occurred in the seawater and other environments. This includes a rare case in the deep ocean environment where a submersible operating near thermal ocean vents found living organisms to be a cause of stainless steel MIC corrosion. Freshwater and seawater MIC has been found attacking various materials – stainless steel including pressure vessels, copper-nickel fittings; and K-Monel SUBSAFE Hull Studs.

2-2.4.4.4 ***Corrosion Coating Protection***

Some of the traditional methods of protection against corrosion, such as waterproof grease, are not to be used in DLSSs unless approved by the PM. Painting, anodizing and plating are all common and cost-effective methods of corrosion protection. However, these processes provide only a thin layer protection. When this surface protection is scratched, the exposed bare metal is subject to accelerated local corrosion. All non-metallic protection processes require evaluation and approval by the PM due to divers exposure to toxins, off-gas and control of breathing spaces, such as chambers and habitats.

There are no requirements to coat the interior of steel flasks used in divers air systems. In the past, NAVSEA S650-AH-INS-010, *Powdered Fluropolymer Coating*, and NAVSEA S650-AB-MMD-010, *Phosphate coating of High-Pressure Flask Interiors*, were issued to address interior corrosion concerns. Problems were encountered with implementation of these specifications. Given today's improved dryer packages, corrosion concerns have been mitigated and interior coatings are not recommended.

2-2.4.5 *Coatings*

2-2.4.5.1 ***Passivation***

Stainless steel pipe, tube and fittings shall be passivated IAW ASTM A967, *Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts*, unless otherwise specified on the fabrication drawing.

2-2.4.5.2 *Paint on Pressure Vessels for Human Occupants (PVHO)*

The following paint systems are currently approved for use by the USN:

a. Prime coat with NSN 8010-01-302-3608 and finish coat with white NSN 8010-01-302-3606 (inside or outside); or finish coat with grey NSN 8010-01-302-6838 (outside only).

b. Carboguard 890H (part A & B) manufactured by Carboline of St. Louis, MO (314)644-1000, *www.carboline.com*.

If either of the above paint systems are used, the PM will provide a list of contaminants and their allowable limits to the designer to include in testing (see section 3-6.9).

If the designer chooses an alternate paint system, the designer must qualify the paint procedure IAW section 3-5.2.2.1.2.

Aluminum recompression chambers shall not be painted.

2-2.4.5.3 *Metal Coatings*

A consideration when using coatings is maintaining its integrity over its intended lifetime. Small faults in the film, such as pin holes or leading edges, allow corrosion to occur in the base metal under the film, causing intensified pitting and progressive destruction of the coating and the substrate by galvanic attack. The use of coatings, particularly inert metallic coatings, is not a recommended procedure to be used alone to prevent corrosion in long-time exposure situations. Regular and frequent inspection and maintenance practices are necessary to protect the coatings employed.

The designer must obtain approval by PM of the use of metal applied as a surface finish, coating or cladding by validating that it does not present an unacceptable corrosion potential, toxic or flammability hazard. Metal applied as a surface finish, coating, or cladding shall be lower on the electrochemical scale than the metal to which it is applied.

For more guidance on galvanic corrosion protection see MIL-STD-889, *Dissimilar Metals*.

2-2.4.6 *Piping Systems/Divers Life Support System (DLSS) Materials*

Piping system materials shall be selected IAW MIL-STD-777, *Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships,* or ASME B31.1, *Power Piping.* Other standards may be used with PM approval. Consideration should be given to eliminate contact between dissimilar metals where galvanic effects of corrosion may occur. The PM must approve the use of nonmetallic piping and piping components. See sections 2-2.4.1 and 2-2.4.2 for additional requirements.

2-2.4.7 *O-rings*

Refer to NSTM Chapter 078, *Volume 1: Seals,* for acceptable O-ring materials. Unless otherwise permitted by the PM, FKM O-rings are required for DLSS piping systems. See section 2-2.5.5.4.1.

2-2.4.8 *Lubricants/Sealants*

Only lubricants IAW NSTM Chapter 262, may be used on any component in contact with the diver's breathing gas. Do not mix lubricants used on a component unless approved by the PM. Installation and operational lubrication requirements shall be identified on the applicable drawings.

NOTE: Never mix halocarbon and fluorocarbon lubricants unless approved by the PM.

Unless otherwise permitted by the PM, only virgin white Teflon tape that meets the requirements of A-A-58092, Commercial Item Description*, Tape, Anti-Seize, Polytetrafluorethylene*, shall be used as thread sealant on any component in contact with the divers' breathing gas.

2-2.4.9 *Floatation/Ballast Materials*

For flotation and ballast materials, at minimum, information covering the following points shall be submitted to the PM:

a. The applicable military, federal, or commercial specifications.

b. Data demonstrating that the material presents no toxicity hazards to the DLSS personnel due to its application and location.

c. Specific gravity as a function of pressure and temperature.

d. Sustained hydrostatic collapse load, creep behavior, moisture absorption, and cyclic fatigue life of solid buoyant materials in a seawater environment.

e. Information establishing that material is nonflammable under the conditions of use or, if flammable, that suitable precautions have been taken in its application and location.

f. Information to establish that the material can perform satisfactorily as a buoyancy or ballast material in the proposed applications. Items considered should include the long-term storage of the material including cyclic temperature effects in an air environment, exposure to the environmental factors (pressure, temperature, humidity, etc.), and compatibility with both seawater and any containment or protective materials.

2-2.4.10 *Fairing and Miscellaneous Nonstructural Materials*

For fairing and nonstructural materials, as a minimum, the designer will provide the following information:

a. The applicable military, federal, or commercial specifications.

b. Information covering resistance to deterioration in seawater, compatibility with mating structural materials, and resistance to dynamic loads such as wave slap and loads encountered in operating, handling, or docking the DLSS.

2-2.4.11 *Hydraulic System Fluids*

For hydraulic system fluids, as a minimum, the designer shall submit the following:

a. The applicable military, federal, or commercial specifications.

b. Information covering resistance to deterioration, flammability, and compatibility with selected hydraulic system components.

c. Information relating to possible toxicological hazards from the fluid, based on its application and location. This data shall be included in the system toxic and flammable data list.

2-2.4.12 *Electrical/Electronic Systems*

For fabrication guidance the builder should refer to MIL-HDBK-454B, *General Guidelines for Electronic Equipment*, or NFPA 70, *National Electrical Code*.

NOTE: During DLSS fabrication, installed cables shall be protected against mechanical damage, burning by welders' torches and contact with oils and solvents.

The builder shall make every effort to comply with the following:

a. Cleaning: After fabrication, parts and assembled equipment should be cleaned of smudges; loose, spattered, or excess solder; weld metal; metal chips and mold release agents; or any other foreign material which might detract from the intended operation, function, or appearance of the equipment.

b. Threaded Parts or Devices: Screws, nuts, and bolts should show no evidence of cross threading, mutilation, or detrimental or hazardous burrs, and should be firmly secured.

c. Bearing Assemblies: Bearing assemblies should be free of rust, discoloration, and imperfections of ground, honed, or lapped surfaces. Contacting surfaces should be free of tool marks, gouge marks, nicks, or other surface type defects. There should be no detrimental interference, binding, or galling.

d. Wiring: Wires and cables should be positioned or protected to avoid contact with rough or irregular surfaces and sharp edges and to avoid damage to conductors or adjacent parts.

e. Shielding: Shielding on wires and cables should be secured in a manner that will prevent it from contacting or shorting exposed current-carrying parts. The ends of the shielding or braid should be secured to prevent fraying.

f. Containment: The harness and cable that form containment means should be neat in appearance, uniformly applied, and positioned to retain critical form factors and breakout locations. The containment means, (lacing, ties, tie-down straps, etc.) should not cause the wire or cable insulation to deform so that performance characteristics are adversely affected.

g. Insulation: There should be no evidence of burns, abrading, or pinch marks in the insulation that could cause short circuits or leakage.

h. Clearance: The clearance between wires or cables and heat generating parts should be sufficient to minimize deterioration of the wires or cables.

2-2.4.13 *Threaded Fasteners*

Threaded fasteners within the SOC, including bolts, studs and nuts shall meet the requirements of MIL-DTL-1222, *General Specification for Studs, Bolts, Screws and Nuts for Applications Where a High Degree of Reliability is Required*, or SAE J429, *Mechanical and Material Requirements for Externally Threaded Fasteners*, or SAE J995, *Mechanical and Material Requirements for Steel Nuts*. Material, number, type, size, and method of tightening should be IAW recognized design code. Studs and bolts should be of sufficient length so that, when nuts are tightened to their appropriate torque values, at least one thread is exposed. Where practicable, the number of threads exposed shall not exceed five; however, in no case shall the thread exposure exceed 10 threads.

2-2.4.14 *Locking Devices for Critical Fasteners*

The need for locking devices on mechanical fasteners shall be evaluated by the designer where the loss of the fastener would cause a critical failure. Generally, a locking device should provide a positive locking action, be simple to install, and should lend itself to easy inspection without disturbing the locking feature. If the locking device does not meet the above guidance, or is unique in design, the designer shall furnish sufficient information to justify the safety and integrity of the device. The justification shall include recommended inspection procedures and acceptance standards. If locking devices are not practical, critical fasteners shall be marked with a "torque stripe" identifying the relative locations of parts under proper torque. For further design guidance on fastening devices, refer to MIL-DTL-1222.

2-2.5 PIPING SYSTEM AND COMPONENTS

Piping, piping system components and the piping system itself shall be designed IAW ASME B31.1, and MIL-STD-777 except where otherwise stated in this specification or approved by the PM. Component types and materials shall either be chosen from IAW MIL-STD-777 or ASME B31.1, section 2-2.4.3 or section 2-2.4.4 of this document.

The designer shall evaluate structural adequacy and fatigue life of the piping system and consider all anticipated in-service conditions such as:

a. There shall be adequate joints for disassembly, cleaning and inspection. Single lengths of piping shall not exceed 30-feet between unions.

b. Piping shall be sized to a maximum gas velocity of 0.8-mach or less.

c. Weight of pipe fittings, valves and other components including cleaning or testing fluids.

d. Internal or external pressure, both static and cyclic.

e. Dynamic effects of shipboard motion, deflections and rotations of structure and equipment at points of pipe attachment.

f. Handling loads, especially in transportable systems.

g. Restraint of hangers and supports.

h. Thermal expansion and contraction.

i. Shock, impact, vibration and water hammer.

j. Mechanical loads caused by operation of the system.

k. Effects of the corrosive seawater and salt air environment.

Typically the above are considerations not required for piping sized ½” or less unless otherwise required by the PM. Piping which, if ruptured, would depressurize the DLSS shall be protected against damage, which may be accomplished by suitable routing, shielding, etc.

The breathing gas supply lines in the DLSS shall be constructed of corrosion resistant, seamless wall, rigid piping where possible. Flexible hose may be used to connect the rigid piping to components that move or vibrate during operation or transportation of the system. Primary design requirements are adequate strength & size (to permit required flow rates and pressure) and compatibility with breathing gas mixtures.

Only seamless piping or tubing is authorized in USN DLSSs. Both piping and tubing are used in DLSS gas and liquids systems and the terms are sometimes used interchangeably. Piping is circular in shape and is sized based on needed carrying capacity. Piping is typically ordered using a nominal pipe standard and specifying a nominal diameter and wall thickness (schedule). Tubing can be circular, square, rectangular or oval in shape and is generally used for instrumentation systems or where precise outside diameters is needed (tubing is manufactured to tighter tolerances). Tubing is typically ordered by specifying outside diameter and wall thickness. Piping is generally used when larger diameters are required and tubing is generally used when diameters ½” or less are needed.

Consideration shall be given to material type, wall thickness, minimum bend radius, back-wall thinning allowance and inner radius wrinkling when specifying the method of piping system fabrication. See section 2-2.5.6 for specifics on bending for pipping and tubing.

Piping connections shall be designed and arranged so that it is physically impossible to inadvertently connect a system of one pressure or service to a system of a different pressure or service. In cases where different gases may share a common line (e.g., O_2 and NITROX in a built-in breathing system (BIBS)), those gases shall be kept separate through use of block and bleed valves or similar methods to ensure that both gases are never connected to the common header at the same time.

Piping subject to external pressure shall be designed for the maximum differential pressure that can exist in either direction during operating, shutdown or test conditions; suitable overpressure protection shall be provided.

Where possible, normal and emergency breathing gas supply lines should be arranged separate from each other, and away from possible ignition or contamination sources.

All piping and components including fittings shall be identified in sufficient detail on the system drawings (e.g., description, material, part number, pressure rating) to permit replacement with the same part. All piping, hoses, valves, pressure vessels, gauges, filters, etc., must be marked or labeled to indicate function, content and direction of flow on the drawings.

All piping and piping system components used for the transmission or monitoring of liquid or breathing gas within a system shall be marked and color-coded to identify the specific gas or liquid contained and the direction of flow. Where piping is located behind a panel, an accurate color-coded schematic shall be permanently attached to the panel face. A labeling system shall be used to identify each component by type of gas or liquid, by color and by word or letter symbol. The hand wheel or operating lever of all system valves shall be color coded also. All material used for color-coding components (e.g., paint or plastisol) located inside a closed breathing environment must meet toxicity and flammability requirements. Color codes shall be IAW Table 4.

Table 4: Color Code and Component Designation for DLSSs

System	Designation	Color Code
He	HE	Buff
O_2	OX	Green
HeO_2	HEOX	Buff & Green
N_2	NIT	Light Gray
Nitrogen-Oxygen	NITROX	Light Gray & Green
Air (Low-Pressure)	ALP	Black
Air (High-Pressure)	AHP	Black
Exhaust	EXH	Silver
Potable Water	PW	Blue
Chilled Water	CW	Blue & White
Hot Water	HW	Red & White
Fire Protection	FP	Red

Piping system components must have a standardized labeling scheme throughout, with unique component identifiers that match the system drawings and system OPs/EPs. Such standardization is important for approval of OPs/EPs, continuity of system manuals and personnel training.

2-2.5.1 *Piping Systems Components Structural Design Considerations*

The designer shall perform a stress analysis of each piping system component IAW ASME B31.1 or shall be able to verify manufacturers documentation that prove the adequacy of the component. This analysis shall document all anticipated loading conditions including the loads calculated in the piping flexibility analysis discussed in section 2-2.5.3. These calculations shall be provided to the PM for review and acceptance at the PDR, the CDR, and at final delivery.

Pressure ratings for all piping and components shall be equal to or greater than the MOP of the system or line of which they are a part.

The structural design requirements used for externally pressurized components shall not be less than the requirements for the pressure hull and hard structure.

Peak stresses, including effects of local stress concentrations, must be limited by fatigue considerations, as discussed in section 2-2.2.3.

Consideration of the following should be included in the analysis:

a. Erosion/corrosion allowances.

b. Mechanical strength to accommodate fabrication processes.

c. Item identification marking (vibro-etch, etc.).

For components whose geometry is not amenable to analytical evaluation, and when considered appropriate by the designer, the structural adequacy of piping system components may be verified experimentally. In this case, an experimental stress analysis and burst test such as specified in ASME Boiler and Pressure Vessel Code (BPVC) Section VIII-2, Annex 5.F, may be performed in lieu of an analytical stress analysis. This approach should be detailed and approved by the PM prior to use as an acceptance method.

2-2.5.2 *Design of Piping Systems and Components*

The piping system shall incorporate redundancy safety features, remote and emergency operations as determined by the hazard analysis IAW section 2-1.4.2. All piping components shall be designed or selected to meet the maximum flow that is required for the mission conditions expected for the DLSS. These conditions shall be specified when justifying the design or selection.

a. Where practical, manually operated piping components shall be readily accessible and easily operated under normal and emergency conditions.

b. Unless directed otherwise, pressure-reducing valves (see section 2-2.5.9.1.4 for specific guidance) shall be provided with inlet and outlet isolation valves and a bypass valve. The flow capacity of the pressure-reducing valve bypass shall be no greater than the flow capacity of the downstream relief valve.

c. A relief valve (see section 2-2.5.9.1.3 for specific guidance) immediately downstream from the pressure reducing valve. Any piping components downstream of the pressure reducing valve but upstream of the relief valve must be designed and tested to the pressure at the inlet of the pressure reducing valve.

d. A redundancy shall be provided in any system where the ability to maintain uninterrupted service is required.

e. A check valve or "non-return" valve is required in any system where two-way flow is possible but one-way flow is required for the safety of the DLSS personnel or for normal operation of the equipment.

f. Flareless, mechanical friction, compression or bite-type connections shall not be used on piping components whose failure could cause uncontrolled depressurization or flooding of pressure vessels, DLSS, ballast tanks, electrical assemblies, or other life-critical components. These connections shall not be used in high-pressure O_2 systems that are near hot electrical or hydraulic machinery, unless approved by the PM. The use of such connections in control and monitoring systems must be approved by the PM.

g. Lines which are routinely disconnected must be provided with suitable closure devices for each exposed connection to prevent entrance of foreign materials and debris when the system pressure boundary is broken. Routine disconnections are those associated with inspections, overhauls, and the normal DLSS setup, operation, and takedown. Both male and female connections shall be so protected. Caps that introduce moisture and tapes that leave adhesive deposits shall not be used for this purpose. When not in use, closure devices should be stored in a way that prevents contamination.

h. Vent lines shall be independent of each other and of other lines. All vent lines shall exhaust outside the system, and shall be so configured and capped to prevent ingress of weather or debris. They shall be designed to provide lightning protection.

i. Chamber Vent Piping – Vent piping immediately downstream of the chamber vent throttle valves shall be increased to a minimum of two diameters larger than the piping upstream of the valve (i.e., 2” upstream – 4” downstream). Use a 316L Schedule 10 piping is acceptable. This pipe shall be insulated for sound isolation. The vent system length shall be kept to a minimum, changes in vent flow (90’s and 45’s) shall be kept to a minimum, and all changes in direction shall use long radius bends or fittings.

2-2.5.3 *Piping Flexibility*

Piping shall be designed to have sufficient flexibility to prevent failures resulting from the conditions listed in section 2-2.5 a – k. Piping shall be designed to have sufficient system flexibility to prevent premature failures and/or prevent:

a. Overstressing of the piping.

b. Leakage of mechanical joints.

c. Excessive force and moments translated to connected equipment and structures which exceed the limits specified or allowed, or renders them inoperable.

The structural adequacy of the piping system shall be demonstrated by the designer for all anticipated service loadings. In addition, the designer shall show that fatigue life of the piping system is adequate by performing a fatigue analysis.

In certain cases (i.e., saturation DLSSs), piping flexibility calculations are required as a further measure of assurance prior to system fabrication. Where required, calculations shall show maximum stresses and their location in each section of piping under examination. Detailed sketches of piping under examination shall be required with the calculation report. Calculations shall be submitted in sufficient detail to allow easy review and shall include statements delineating the following:

a. Theoretical basis of the calculations.

b. Method of performing the calculations.

c. Simplifying assumptions.

d. Sign and symbol conventions.

e. Assumed material and dimensional data.

f. Other pertinent information such as hull deflections.

g. Fatigue reduction factors.

h. Stress intensification factors.

i. Allowable stress range.

j. Miscellaneous pertinent information (e.g., support/hanger deflections).

The piping flexibility analysis shall also address the flexibility of piping components. Flexibility factors shall be IAW ASME B31.1, code for pressure piping. Piping components for which there are no flexibility factors listed in ASME B31.1 shall be considered rigid, unless the designer can justify the use of added flexibility. The piping flexibility analysis shall include calculations of the bending moments, twisting moments, and reaction forces imposed on each critical component in the piping system. Flexibility analysis is not required for pipe up to and including 3/8 inch NPS or for tubing up to and including 1/2 inch OD. Additional information on the flexibility analysis can be found in ASME B-31.1.

2-2.5.4 *Special Considerations for Oxygen (O_2) Systems*

The designer should follow the guidance found in ASTM G88, NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres*, and Compressed Gas Association (CGA) Pamphlet G-4.4, *Industrial Practices for Gaseous Oxygen Transmission and Distribution Systems*. When selecting materials to be used in elevated O_2 environments and piping systems. The designer should be familiar with ASTM Manual 36, *Safe Use of Oxygen and Oxygen Systems*: *Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation*, ASTM G63, and ASTM G94. See SUPPLEMENTAL DOCUMENT for piping systems and components with special considerations for O_2.

A diving life support O_2 system is one that contains a gas mixture where the fraction of oxygen (F_{O2}) is >25% by volume. The designer shall give special consideration and analysis to the use of O_2 in the specific DLSS design. An O_2 leak may be a contributor to a fire hazard and may also be toxic to DLSS personnel under pressure. Every attempt shall be made to design O_2 piping systems to eliminate the possibility of leaks. Use of seamless copper or nickel alloy (Monel®) piping/tubing is preferred in high-pressure O_2 systems although austenitic seamless 300 series (304L, 316L) stainless steel with a minimum of 1/8-inch wall thickness may be used, provided that the designer has taken all precautions to limit the flow velocity in the pipe and has incorporated sufficient filtration to eliminate particulate that may cause spark ignition. It should be remembered that 300 series stainless steel has lower ignition temperature-pressure and will have increased burn propagation once ignition has occurred.

High-pressure portions of the O_2 system piping shall be welded, vice using mechanical fittings, wherever possible. When used, O_2 system mechanical joints shall not be located where leakage or failure could ignite surrounding material (i.e., next to a hydraulic system or electrical components with heated surfaces). Where arrangement cannot eliminate all reasonable hazards, and the joints cannot be moved, flame shields or other appropriate means should be used.

NOTE: Pipe threads shall not be used in stainless steel piping systems because of the possibility of particulates being shed in the joining process.

Quick-opening valves shall not be used in high-pressure O_2 systems and should not be used in low-pressure O_2 systems except in cases where the valve is used for emergency shutoff (e.g., chamber hull stops).

Metallic materials wetted by O_2 shall not propagate a flame, shall not burn, and shall be impact resistant with O_2 at the MOP of the system IAW ASTM G94. Non-metallic material wetted by O_2 shall be resistant to auto-ignition, shall be resistant to impact ignition, and shall have the lowest possible heat of combustion IAW ASTM G63. Additionally, where non-metallic material is installed, the design shall minimize the surface area and volume exposed to O_2. See section 2-2.4.3 for additional requirements for material to be used in O_2 systems.

Electrical equipment, which may spark while in use, shall not be installed in the vicinity of O_2 flasks or interconnected hoses that are to be stored and operated in an enclosed space. Signs shall be posted in the space to state that smoking or open flames shall not be permitted due to O_2 being in use. In addition, an O_2 monitor, with visual and audible alarm, shall be installed in the immediate vicinity of the O_2 flasks. O_2 flasks shall not be located inside the DLSS (e.g., recompression chamber or diving bell) without technical justification from the designer and approval from the PM.

2-2.5.5 *Pipe Joints*

Only pipe joint designs that are fabricated, assembled and tested IAW this specification shall be used (e.g., butt welds, socket welds, mechanically formed and bolted flange connections and O-ring faced fittings) in DLSS. Other joint designs (e.g., bite type, flared, compression fittings and NPT threaded joints) must be approved by the PM.

The number of mechanical pipe joints shall be kept to a minimum and shall be accessible for inspection. Wherever possible, bending of the pipe shall be used. See section 2-2.5.6 for pipe and tube bending requirements. All pipe and tube fittings shall only be used at temperatures and pressures not exceeding the manufacturer's rating recommendations.

Lines, which must be connected and disconnected during system operation, shall be equipped with appropriate pressure venting capabilities.

2-2.5.5.1 ***Welded Pipe Joints***

Welding is the preferred method of joining pipe that will not require disassembly for system repair or maintenance. The welding process melts the base metal to form a joint that is often as strong as the surrounding piping and resists cracking due to piping flexure. Welded joints 2.5” pipe size and smaller may be socket or butt welded. Welded joints over 2.5” pipe size shall be butt welded. Shipboard and portable DLSS welded pipe joints shall meet the requirements of NAVSEA S9074-AR-GIB-010/278, *Requirements for Fabrication Welding and Inspection, and Casting Inspection, and Repair for Machinery, Piping, and Pressure Vessels*, ASME B31.1 or as approved by the PM.

2-2.5.5.2 ***Brazed Pipe Joints***

Brazed joints are not permitted in new DLSS designs. Brazed pipe joints are used to permanently join piping material that is not weldable. Brazed joints are not as strong as welded joints because the process only melts the soft filler metal and not the base metal.

2-2.5.5.3 ***Mechanically Attached Fittings (MAF)***

Mechanically Attached Fittings (MAF) are permanent pipe fittings that cannot be removed after installation without deforming the pipe or fitting. These fittings are not reusable and considered permanent. MAF include elastic strain preload (ESP), swaged Puget Sound Naval Shipyard (PSNS) Uniform Industrial Process Instruction (UIPI) 5050-913, *Grip-Type MAF (Swagelok)* and shape memory alloy (SMA) types. These fittings are not authorized for use in DLSSs without PM approval.

2-2.5.5.4 ***O-ring and Flanged Pipe Joints***

Mechanical piping unions and flanges include a wide variety of designs that rely on a mechanical action (i.e., torque of bolts or nuts) to compress a soft seal. Flange fittings are most often used in designs for large diameter shore-based liquid or steam system piping. The use of face seal O-ring unions is recommended over bolted flanges. Due to pipe flexure in shipboard and portable systems, flange fittings are far more prone to leakage than are face seal O-ring fittings. For some shipboard O_2 systems located below the main deck, it is required to remove the O-ring or gasket material and to seal weld the union nut. Military Standard (MS) boss fittings with O-ring seals are preferred over threaded pipe joints because the threads are not relied upon to form the seal and galling of the threads is less likely. For bolted flanges and blanks, additional design requirements and all alignment and assembly requirements for mechanical joints shall be IAW NSTM Chapter 505 or ASME B31.1. Bolted flanged joints shall not be used in piping that is subjected to submerged environments or high stresses without PM approval.

Mechanically formed face seal flanges have been approved for use in portable systems (e.g., flange seal fittings - Parker Parflange). The procedures and equipment for manufacturing these joints must be approved by the PM prior to fabrication.

2-2.5.5.4.1 ***Seals***

Sealing materials and techniques must be shown to be adequate for the range of pressures, temperatures, gas mixtures, vibrations, lubricants, and atmospheric environments specified for the system. Captive O-ring designs (e.g., dovetail), where the capture is in the direction of differential pressure, are preferred. Seals shall not be subject to failure due to the effects of a non-lethal extinguishable fire inside or outside the system, attack by the fire extinguishing agents used by the system, or by thermal shock caused by the application of extinguishing agents. The effects of ultraviolet light, pressure cycling, stress concentrations, differential thermal expansion, differences in moduli of elasticity, tolerances and aging shall be considered when designing seals.

It is essential that all seals, gaskets and O-rings in DLSSs be fabricated from the proper material. In systems capable of containing elevated O_2 concentrations, only O_2 compatible materials shall be used. Because of their superior compatibility, fluorocarbon seals per MIL-R-83248A, *Rubber Fluorocarbon Elastomer, High Temperature, Fluid, and Compression Set Resistance* are preferred for DLSSs. Because MIL-R-83248 is cancelled, NSTM Chapter 078 provides cross references to SAE specifications. Asbestos-containing gasket material shall not be used. Additional guidance concerning seal, gasket and O-ring material is provided in NSTM Chapter 078, NSTM Chapter 505, MIL-STD-777, and ASME PVHO-1.

Table 5: O-Ring Cross Reference Table

Cancelled Document	Types and Classes	Specifications	Document Description
MIL-R-83248	Type I, Class I	AMS 7276	Rings, Sealing, FKM, High-Temperature-Fluid Resistant, Low Compression, Set 70-80
MIL-R-83248	Type I, Class 2	AMS 7259	Rings, Sealing, FKM, High-Temperature-Fluid Resistant, Low Compression, Set 85-95

MIL-R-83248	Type II, Class 1	AMS 3216	FKM, High-Temperature-Fluid Resistant, Low Compression, Set 70-80
MIL-R-83248	Type II, Class 2	AMS 3218	FKM, High-Temperature-Fluid Resistant, Low Compression, Set 85-95

2-2.5.5.5 ***Threaded Pipe Joints***

Pipe threads are typically not allowed in DLSS or systems subjected to external pressure without specific PM approval. Experience has shown that pipe thread connections are susceptible to corrosion, shock and vibration damage, and leakage. Consideration must be given to pressure limitations due to the reduction in wall thickness of the pipe at the tapered threads. Should a component only be procurable with pipe threaded end fittings, a means must be provided to permit its removal without disturbing the threaded joints if periodic removal of the component is necessary for the system maintenance (i.e. relief valves, filters or gauges). Any compound (e.g., anti-seize thread tape) or lubricant used in threaded joints shall be suitable for the service conditions and shall not react unfavorably with the service fluid or piping materials. Where pipe threads are to be used between stainless steel components, there should be a hardness difference between the two components of at least 5 Rockwell C.

CTFE greases such as Halocarbon Products Halocarbon 25-5S® and Hooker Chemical Fluorolube® GR362 are not compatible with aluminum alloys. For further information on lubricants, see NSTM Chapter 262.

NOTE: Halocarbon oils and greases shall not be mixed.

2-2.5.5.6 ***Flared Pipe Fittings***

Flared pipe fittings and their joints shall conform to the range of wall thicknesses and methods of assembly recommended by the manufacturer. Care should be taken with cutting and flaring tools so as to not induce work hardening of the tube end, which can make the material more susceptible to brittle fracture. Flared fittings shall not be used without technical justification from the designer and approval from the PM.

2-2.5.5.7 ***Flareless Pipe Fittings***

Flareless, mechanical friction or bite-type connections shall not be used on piping components where failure could cause uncontrolled depressurization or flooding of pressure vessels, DLSS, electrical assemblies or other life-critical components. The use of such fittings may be permitted if the component can be quickly isolated from the rest of the system in case of failure and a redundant means of providing the control and monitoring functions is available.

Flareless and non-standard fittings, including proprietary fittings, shall not be used without specific PM approval. Approval for joint design shall be based on past experience and/or tests that demonstrate that the joint is safe for the operating conditions.

2-2.5.6 *Pipe/Tubing Bends*

All piping shall be bent IAW MIL-STD-1627, *Bending of Pipe or Tube for Ship Piping Systems*, or ASME B31.1 (see also section 3-5.1.4). The drawings shall list the minimum bend radius and the minimum wall thickness (after bending) for all piping and tubing. When specifying piping products, the designer shall document what the minimum bend radius of each section of pipe will be. Table 6 provides a recommended minimum thickness prior to bending for different bend radii. The bend radius of piping shall be limited to 5 nominal diameters. Bending less than 5 nominal diameters requires justification to the PM.

2-2.5.6.1 *Minimum Wall Thickness/Bend Radius*

The minimum wall thickness for piping or tubing extrados (back wall) after bending shall not be less than the minimum wall thickness required for straight piping or tubing. In addition to specifying the piping and tubing products to use in the drawings, the designer shall also list the minimum wall thickness.

Table 6: Recommended Thickness of Piping Prior to Bending

Radius of Bends	Min. Thickness Recommended Prior to Bending(1)
6 pipe diameters(2) or greater	1.06tm(3)
5 pipe diameters	1.08tm
4 pipe diameters	1.14tm
3 pipe diameters	1.25tm

(1) Interpolation is permissible for bending to intermediate radii.
(2) Pipe diameter is the outside diameter (OD) of the pipe/tube.
(3) t_m is the minimum wall thickness required for straight pipe/tube.

2-2.5.7 *Pipe Hanger Requirements*

Arrangement and design of pipe hangers shall be carefully considered as a basic element of the piping design. Pipe hanger spacing requirements for various pipe and tube sizes are provided in Table 7. For additional guidance on hanger design, refer to NAVSEA drawing

804-1385781 for surface ships, NAVSEA 5000-S4823-1385782 for submarines, and NSTM Chapter 505 or ASME B31.1.

Piping and tubing should be supported as close to bends as possible. Piping shall not be used as the sole support for relatively heavy components (e.g., large valves, moisture separators or filter housings). Components shall be supported so that the force required to operate them (or other normal operational loads) does not cause visible deflection, rotation or vibration. One line shall not be used to support another, although clamp blocks may be used to support two or more adjacent lines as long as the blocks are attached to non-piping structural members.

Piping and tubing shall not be used as support for heavy components such as regular line valves, relief valves, check valves, strainers, or filters. One pipe line shall not be used to support another. Block-type hangers may be used to support two or more pipe lines with the assembly-type hangers attached to suitable structural members.

Table 7: Pipe Support Spacing

Pipe Support Spacing		
Nominal Pipe Size (in)	Span (in)	
	Gas Service	Liquid Service
1/8	24-28	18-24
1/4	38-44	30-36
3/8	50-60	40-46
1/2	60-70	50-56
3/4	85-95	65-75
1	95-110	85-100
1-1/4	120-140	110-120
1-1/2	120-140	110-120
2	120-140	110-120
2-1/2	120-140	110-120
3	120-140	110-120
Tubing Support Spacing		
Normal Tubing Size (in)	Span (in)	
	Gas & Liquid Service	
1/8	18-24	
1/4	24-30	
5/16	30-40	
3/8	40-50	
1/2	50-60	
3/4	60-70	

1	70-80

2-2.5.8 *Flexible Hoses*

All hoses must meet the requirements of this specification and those in NAVSEA S6430-AE-TED-010, *Piping Devices, Flexible Hose Assemblies, Volume 1*, which also includes information on determining the criticality of application for hoses.

The use of flexible hoses shall be limited to applications where excessive flexing or vibration of rigid piping dictates its use. Additionally, flexible hose shall be used in portable systems where elements must be assembled and disassembled on a regular basis for operation or maintenance. When a flexible hose assembly is to be subjected to considerable vibration or flexing, sufficient slack shall be provided to avoid mechanical loading. Sharp bends or twisting shall be avoided. Bend radii shall not be less than the manufacturer's recommended minimum bend radius. Kinked hoses shall be immediately discarded because there is no way to determine the extent of damage done to the thin hose liner. All hoses shall have a rated working pressure equal to or greater than the system design pressure in which they are used. A pressure safety factor of 4 times the hose rated working pressure to burst pressure shall be the minimum used for flexible hose. Flexible hose material shall be compatible with the intended service and shall not give off noxious or toxic gasses or vapors. Cleaning solutions must be compatible with the hose materials and must be able to clean the hose to the same level as the system in which it is used.

When hoses and connectors are used in applications where they may be subjected to mechanical loading, they shall be provided with strain relief devices. These devices shall be designed to prevent damage to the hoses and connectors as well as to prevent accidental disconnection of the hoses if they are pulled. Provisions shall be made to connect the strain relief device to a nearby structural member. The most common form of strain relief is a small diameter wire cable (1/8”-3/8” stainless steel) with eyes at each end to which shackles are attached. The strain relief shall be attached to the hose by marlin at regular intervals (no greater than 36 inches). All high-pressure hoses are required to have this strain relief device, except those that are permanently installed in an area where personnel will not be injured if a failure occur.

Where hand-held fire hoses are provided inside a DLSS, they shall be electrically conductive and grounded to reduce the risk of electrical shock to the user in case they should be inadvertently used on live electrical equipment.

The safe working life for each flexible hose used in the DLSS shall be specified. The use of rubber hoses in DLSSs is discouraged due to the life span limitations of the material.

The information needed to identify hoses is the manufacturer's part number and the size or dash number (dash number is the nominal inside diameter (I.D.) in sixteenths of an inch). Hoses built to military specification requirements will contain the specification number, the class of hose (where applicable), the quarter and year of manufacture, and the manufacturer's trademark. This information is molded or otherwise permanently repeated at regular intervals on the hose cover (sometimes referred to as the "lay line marking") or provided on a hose tag. For interpretations of commercial lay line markings, refer to the appropriate manufacturer's catalog (see section 2-2.5.8.2).

All flexible hoses, which are not permanently installed, shall be provided with suitable end caps that protect the hose end fittings from mechanical damage and prevent contamination when not connected for use.

In general, flexible hose fittings shall meet the same design requirements as those for pipe fittings. Additionally, all flexible hose end fittings shall be designed so they cannot be connected into the wrong system. This can be done by size selection, key fitting, or end fitting type. Color coding or identification alone is not generally considered sufficient to ensure that hoses are not connected to the wrong system. Devices used for alignment or prevention of incorrect connection shall be sturdy enough to resist normal handling damage and manual override of any keying devices. Other fitting considerations are material compatibility, corrosion resistance, flammability, ease of operation/connection and sealing tightness. Fittings must be identified by the manufacturer's part number, the size of the end connection that joins to the piping system, and the dash number to show the size of the hose to which it mates. For interpretation of manufacturers' markings, consult the appropriate manufacturer's catalog. Fittings that meet military specification requirements will have the specification number, class of fitting (where applicable), type, size and manufacturer's trademark clearly indicated.

Quick disconnect fittings used on flexible hoses shall be readily accessible and capable of being disconnected under pressure in case of an emergency. Provisions shall be made to prevent accidental disconnection, such as a positive locking mechanism that requires more than one mechanical action to disconnect. Quick disconnect fittings shall not be used in high-pressure compressed gas systems unless specifically approved by the PM.

Hoses used in O_2 systems shall have a liner made of PTFE, which is one of the best ignition resistant plastic materials in O_2.

2-2.5.8.1 ***Umbilicals***

Umbilical assemblies shall be fabricated IAW NAVSEA SS521-AH-PRO-010, *Diving Umbilical Description, Material and Assembly* or submitted to the PM for approval. Umbilicals shall be designed to include complete identification of the hoses by a metal tag on each.

Umbilical hoses must meet all the requirements for flexible hoses. Umbilicals are made up of hoses and cables that tether a DLSS or a diver to a supply source for breathing gas, fluids, electrical power, communications and mechanical strength. They shall be resistant to abrasion; impact damage, cracking and deterioration under the conditions of the mission profile and retain sufficient flexibility for free movement. Umbilicals must possess adequate tensile strength for their design use, adequate flexibility to withstand coiling for storage and reeving over sheaves, and adequate burst strength (4 times the rated working pressure). Occasionally, hoses are subjected to external seawater pressure that is greater than internal pressure. In these applications, it must be demonstrated that the hose has sufficient reserve crush resistance for the intended service. New diver umbilical assembly designs shall be fabricated and tested using guidance per EN 15333, *Open Circuit Umbilical Supplied Compressed Gas Diving Apparatus*, which provides loading requirements for the umbilical specific to the strength member and follow on inspection criteria to qualify the design.

All umbilical connections shall be provided with suitable end caps/plugs that protect the hose end fitting from mechanical damage and prevent entrance of contamination when not connected for use. Fittings on the dive system connections shall be similarly protected.

2-2.5.8.2 ***Hose Tags***

Tags have to conform to the requirements of NAVSEA S6430-AE-TED-010 unless approved by the PM.

A tag containing the information listed below shall be attached to all hose assemblies:

a. Hose number.

b. Proof test activity.

c. Date installed.

d. MOP.

e. Proof pressure.

f. Date tested.

The tags shall be made of a material that does not tarnish or rust and should be readable from a distance of 2 to 3 feet. Tags may be attached to the hose assembly using plastic tie wraps or corrosion resistant wire and should be in a place where they are easy to read. For umbilicals and pneumofathometer hoses, tags should be attached away from the diver, where the hose meets a bulkhead or console.

2-2.5.9 *Piping System Components*

Care must be exercised when designing piping components for the DLSS to ensure that gas or liquid flow is in the proper direction through the component. Most components have a designed direction for flow and this should be observed. Where components permit bi-directional flow, they shall be installed to take best advantage of the design. For example, valves serving as both inlet and outlet on high-pressure flasks shall be installed so that when they are closed the flask pressure acts from below the seat and not on the valve stem packing. Piping components shall always be installed IAW the manufacturers' recommendations, unless a deviation is approved by the PM.

All piping system components shall be selected to permit adequate flow for the highest demanding mission conditions expected for the DLSS. These conditions shall be specified when justifying the selection of a component.

Adequate stop valve and/or check valve protection shall be provided to prevent loss of control of the system. Isolation valves shall be provided for all gauges and regulating valves and double valve protection shall be provided on fill and drain lines for all gas flasks. Double valve protection shall consist of one isolation valve for each flask bank and isolation valves for each flask in the bank. Hull and back-up valves are required on PVHOs to prevent uncontrolled depressurization or flooding unless otherwise approved by the PM.

2-2.5.9.1 ***Valves***

For guidance on the selection of valves for a particular application refer to MIL-STD-777, NSTM Chapter 505, ASME B31.1, ASME/ANSI B16.34, *Valves – Flanged, Threaded, and Welded End*, or MIL-STD-438, *Schedule of Piping, Valves, Fittings, and Associated Piping Components for Submarines Service*. Valves utilizing a soft seat design are preferable to those employing a metal-to-metal seat design. Pressure boundary hydrostatic and seat tightness testing of valves shall be IAW section 3-6.4.4 and section 3-6.6.

See SUPPLEMANTAL DOCUMENT for a list of valve symbols.

2-2.5.9.1.1 ***Stop Valves***

Stop valves are the most common component in a piping system. These valves provide positive control of system fluid flow. Stop valves are generally hand operated, although they may be fitted with remote operators in special instances.

The term "stop valve" applies to globe, needle, ball and plug valves that are able to completely stop the flow through a piping system. Globe and needle valves are designed to permit throttling of system flow (e.g., a pressure regulator bypass valve) as well. Ball and plug valves, on the other hand, are not designed for precise throttling flow control, but rather as quick-opening/quick-closing valves. Because of the inherent dangers of O_2, quick-opening valves (e.g., plug or ball valves) shall not be used in high-pressure O_2 systems without prior PM approval.

Stop valves are required on all high-pressure gas flasks, on all piping penetrations to a pressure vessel and at the boundary between primary and secondary systems. The previously listed examples are not meant to encompass all areas where stop valves may be required as based on a specific system design. For instance, a hazard analysis performed on a specific system may generate a requirement for additional stop valves to isolate specific components in case of failure.

2.2.5.9.1.1.1 ***Throttle Valves***

All valves that regulate flow (other than on-off function), O_2 service valves, and high-pressure valves (except for those remotely actuated) are considered throttle valves. They shall be globe or needle valves unless otherwise approved by the PM.

2.2.5.9.1.1.2 ***Shutoff Valves***

All hand operated valves, other than throttling valves, shall be ball valves. They shall be two-way (bi-directional) flow, three piece, with a swing out construction, valves conforming to ASME/ANSI B16.34 and utilizing a soft sealing surface. On panels, in which the direction in which the valve handles point indicates the open or closed position, the direction shall be the same for all valves on the panel.

2-2.5.9.1.2 ***Check Valves***

Check valves are used in piping systems when one-way flow is required for the safety of the DLSS personnel or for normal operation of the equipment. Check valves shall be installed such that their orientation ensures proper operation of the valve. While check valves offer additional system safety to prevent reverse flow, they shall not be used to replace positive acting stop valves in DLSS without the written approval of the PM. Check valves should be used downstream of the charging connection at charging stations to prevent backflow through the connection. Check valves should also be installed in the discharge piping of air compressors to prevent backflow through the compressor after it shuts down. All check valves on gas systems shall utilize a soft seat sealing surface poppet or disc and spring unless otherwise approved by the PM.

2-2.5.9.1.3 ***Pressure Relief Valves/Devices***

Piping systems and pressure vessels shall be provided with overpressure relief devices capable of relieving system pressure at not more than 110% of the MOP. If there's an unusual application where 110% relief pressure is not appropriate, it shall be specifically addressed, justified and approved by the PM. When a single pressure relief device is used for a pressure vessel, the relief pressure setting shall not exceed the system design pressure. When fully open, relief valves shall be capable of relieving maximum system flow without pressure build up. Relief valves must reseat above the MOP of the system.

Relief valves installed on PVHO's and on ASME air storage flasks shall conform to and be marked and stamped IAW ASME BPVC Section VIII, Division 1, *Rules for Construction of Pressure Vessels*. Non-ASME coded relief valves may be installed on systems other than PVHO's and ASME storage flasks. All non-ASME coded relief valves shall be adjustable-type relief valves. Relief valve discharge shall be directed away from personnel to reduce possible injury.

Relief valves shall be installed at the discharge of all air compressors, gas transfer pumps, receivers/volume tanks, the low-pressure side of pressure-reducing valves, and at external charging stations where piping/components downstream require protection from upstream pressure. Relief valves shall be located so that they cannot be isolated from the system or component they protect from over-pressurization. Hyperbaric chamber relief valves are the exception to this requirement. Relief valves on hyperbaric chambers shall be equipped with a quick acting, ball-type gag valve located between the chamber pressure hull and each relief valve. This gag valve shall be safety wired in the open position with frangible wire. Relief valves shall not exhaust inside of a

PVHO. If a relief valve is installed inside a manned pressure vessel or an enclosed space, unless otherwise approved by the PM, the exhaust shall be piped to the outside.

Fusible/frangible burst discs are often used to protect Department of Transportation (DOT) and ASME gas flasks. Fusible discs protect against expansion due to rising temperatures. Frangible discs protect against excessive pressure. Unlike pressure relief valves, burst discs cannot reseat and, therefore, only operate once before requiring replacement. Frangible discs shall be carefully selected, taking into account the effects of disc corrosion.

Should the pressure relief valves or burst discs be actuated by a malfunction or pressure spike, they shall not present a hazard of rapid decompression to operators, divers, or occupants. Relief valve discharge shall be directed away from personnel to reduce possible injury. Relief valves used in O_2 systems that are located in enclosed spaces must have outlets piped to the weather.

Inlet piping connecting the pressure vessel, main, or other component being protected, to the relief valve shall be as short and direct as possible.

Where relief valve discharge piping is to be provided, it shall be arranged and sized so that back pressure does not cause unsatisfactory relief valve operation, either from a stability or capacity standpoint. Back pressure build-up shall be based on the maximum capacity of the installed relief valve rather than the minimum required relief valve flow rate based on source flow. The two types of backpressure mentioned herein are superimposed backpressure and total backpressure. Superimposed backpressure is defined as pressure at the discharge of a relief valve prior to the opening of that relief valve. Superimposed backpressure can exist where a relief valve discharges into a common line shared with other relief valves, or discharges into a pressurized or closed system. Total backpressure is defined as the total pressure that can exist at the discharge of a relief valve, and can comprise the combination of any superimposed backpressure plus the built-up backpressure created by the discharge flow of the relief valve. Where a total backpressure in excess of 10% of the set pressure of the relief valve can exist, a relief valve of balanced design shall be used. Label plates will at a minimum contain the component part number, serial number, manufacturer, and test and relief pressures.

Figure 4: Relief Valve Tag Example

2-2.5.9.1.4 ***Pressure Reducing/Regulating Valves***

Pressure reducers/regulators shall be designed to maintain outlet pressure within the required limits despite the varying inlet pressures. When set to the required outlet pressure, pressure regulation shall not be affected by position, motion, activity, or ambient temperature. Pressure must be maintained satisfactorily within the system design operating range. Gauges, indicating upstream and downstream pressures, shall be located adjacent to the regulating valve or in the vicinity of the system control console. In this instance, the designer must prove, by testing, that the regulator bypass valve can adequately control the system pressure and flow rates during operation.

If a bypass valve is installed around the pressure reducing/regulating valve, either a non-isolatable relief valve protection shall be provided to protect downstream piping from over pressure or all piping on the downstream/low-pressure side of a pressure reducing valve shall be designed to withstand the upstream MOP. The bypass shall be capable of manually regulating pressure and passing the required design flow rate. Appropriate isolation valves and relief valves shall be installed to support maintenance and protect downstream components.

Suitable filtration shall be installed upstream of the pressure regulator to remove particulate, moisture, and gaseous contamination.

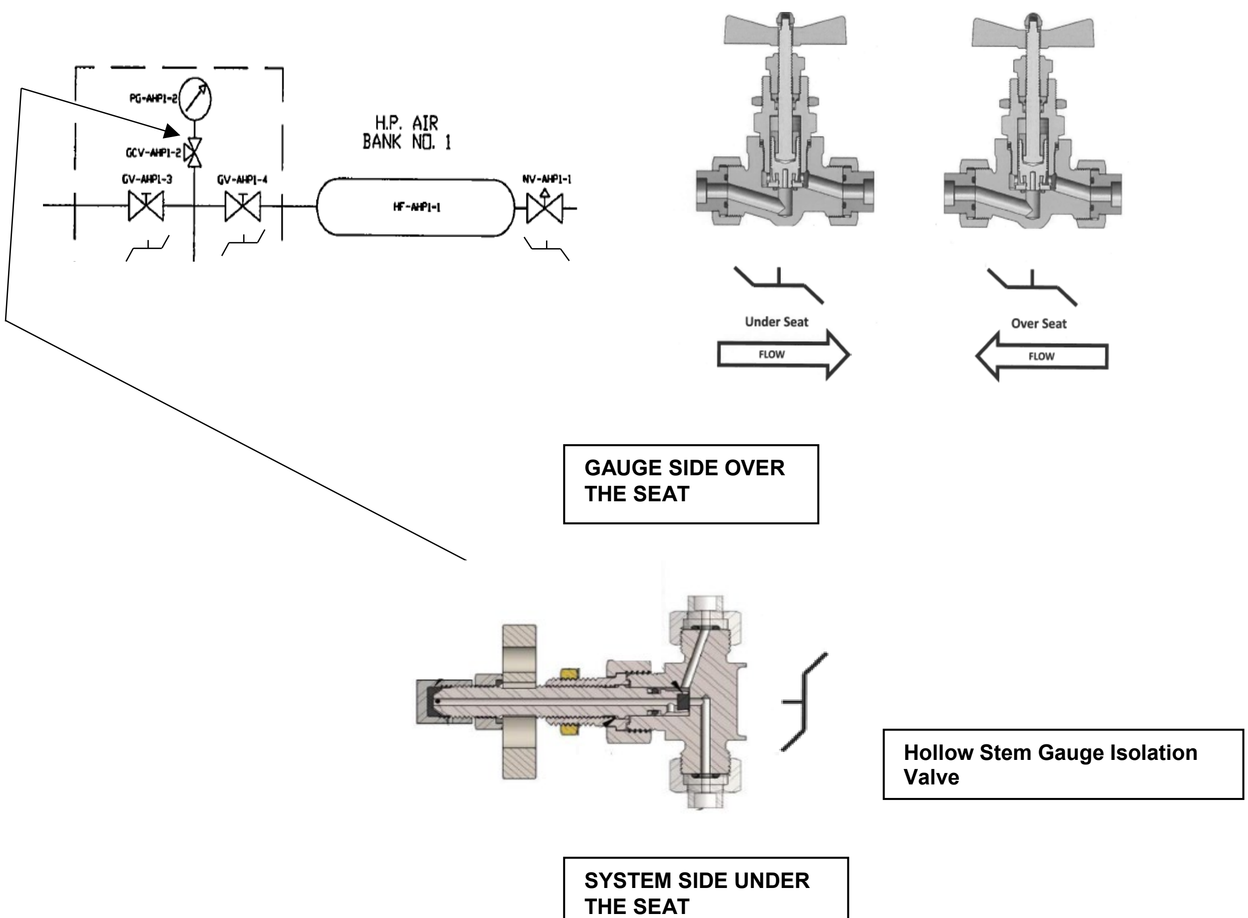
2-2.5.9.1.5 ***Flow Control Valves***

Flow control valves are used in systems when a constant flow must be maintained or as a method of providing protection from high flow rates. If a flow-control component is adjustable, it shall provide smooth, even flow changes as it is operated. If orifices are used to control flow, the orifice size shall be easily identifiable on the component and on the drawings. Filtration should be provided upstream of orifices. Calculations shall be provided to the PM to allow for size/fit verification of filter elements. Provisions shall be made for clearing or bypassing clogged orifices during use.

2-2.5.9.1.6 ***Correct Valve Installation***

It is important that the system designer identifies normal flow direction and that the flow through each valve is correct. The direction of flow through a valve is usually illustrated by an arrow on the body of the valve. Another method is to use bridge-wall marks. Bridge-wall marks can also be applied to system diagrams to identify which position the valve shall be installed.

Figure 5: Correct Valve Installation



The designer shall ensure pressure from the upstream source will be flow through under the seat. Example – flask shutoff valves are installed on the flask head such that the flask storage is on the under the seat side of the valve. Figure 5 illustrates under the seat and over the seat flow. Identification of the proper orientation of a hollow stem gauge calibration valve is required. If this type of valve is installed backwards, when the calibration fluid is applied, it will flow into the system and not towards the gauge, which negates the purpose of this type of valve. This figure also illustrates how a bridge-wall mark can be applied to a system drawing or a flushing diagram. This is important to aid in determination of the number and types of flush plugs required to clean a system.

2-2.5.9.2 ***Filters***

Breathing gas supplies shall be filtered at the compressor intake, the compressor discharge, and between the supply gas and first regulator. Additional in-line filtration shall be installed to remove particulate, moisture, oil mist, and gaseous contamination if warranted. Filtration shall be at a maximum 50 – 60 microns (μm) nominal in air systems and 10 – 15 μm absolute in O_2, He, and mixed gas systems. Filters in breathing gas systems must be sized so that gas flow is not restricted. In-line filter elements shall be made of a material that is compatible with the breathing gas. Stainless steel filter elements are satisfactory for air systems. For any gas system where the O_2 concentration could exceed 25% by volume, the designer shall take into consideration all conditions of system flow and pressure when deciding upon materials, especially the type and form of material used for the filter element. Previously, the theory was that filter elements made from O_2 favorable materials (mesh or sintered) such as brass, bronze, and nickel alloys such as Nickel 200 and nickel-copper (Ni-Cu) (Monel) were all acceptable. As a result of rigorous high-pressure and high velocity ASTM testing, it is now known that the final form of the element and how it was manufactured is critical to its ability to pass testing. For filter elements installed in high-pressure O_2 systems, where the likelihood of gas flow is high, only sintered bronze filters that have passed ASTM testing shall be used. For more information, see ASTM G175, *Standard Test Method for Evaluating the Ignition Sensitivity and Fault Tolerance of Oxygen Pressure Regulators Used for Medical and Emergency Applications*, and Journal of ASTM International, Vol. 6, No. 8 (Paper ID JAI102300), *Promoted Ignition Testing of Metallic Filters in High-Pressure Oxygen*.

Requirements pertaining to compressor inlet and outlet filters shall be obtained from the compressor original equipment manufacturer (OEM).

For O_2 booster pumps, all filters shall be sintered bronze unless otherwise approved by the PM.

2-2.5.9.3 ***Pressure Gauges***

Unless otherwise permitted by the PM, pressure gauges shall meet the requirements of this specification and ASME B40.100, *Pressure Gauges and Gauge Attachments*, which contains ASME B40.7 *Gauges: Pressure Digital Indicating*. In DLSSs, the requirement for accurate, reliable, readable pressure gauges is essential. All diver depth and recompression gauges shall be pneumatically powered direct drive gauges.

Sufficient gauges shall be provided to allow operators to monitor critical gas pressures which must include the following locations:

a. Pneumofathometers.

b. Diver's manifold.

c. Volume tanks.

d. High-pressure bank manifold.

e. Upstream and downstream of reducing valves and regulators.

f. On each compressor stage and at the outlet.

g. For recompression chambers, there shall be two completely independent gauges on each occupied lock and one on the medical lock.

h. Recompression chamber pressurization supply manifold.

i. Recompression chamber O_2 BIBS manifold.

j. Differential pressure.

Select a gauge whose full-scale reading approximates 130% to 160% of the MOP of the system. For example, if the MOP for a system was 3000 pounds per square inch (psi), a gauge with a full-scale reading of 4,000 psi or 5,000 psi would be satisfactory for installation.

Selecting gauge accuracy and precision should be based on the type of system and how the gauge will be used. For example, a high level of precision is not required on air bank pressure gauges where only relative values are necessary to determine how much air is left in the bank or when to shut down the charging compressor. However, considerable accuracy (0.25% of full scale for saturation diving operations and 1% of full scale for surface supplied operations) is required for gauges that read diver depth (pneumofathometers and chamber depth gauges). Depth gauge accuracy is critical to selecting the proper decompression or treatment table. Table 8 lists types of gauges and their required accuracy.

Table 8: Divers Life Support System (DLSS) Gauge Accuracy Requirements

Gauge Type	Accuracy Grade (1)
Recompression Chamber Depth (Primary and Secondary)	1A
SSDS Pneumofathometer to 190 Feet of Seawater (fsw)	1A
SSDS Pneumofathometer 190-300 fsw	3A
Saturation DLSS Pneumofathometer	3A
Saturation DLSS Deck Decompression Chamber (DDC) Depth (Primary and Secondary)	3A
Saturation DLSS Personnel Transfer Capsule (PTC) Depth (Internal)	3A
Saturation DLSS PTC Depth (External)	1A
High-pressure Gas Manifold	A
Diver's Manifold	A
Upstream/Downstream of Regulators	1A
Volume Tank Pressure	A
Recompression Chamber Medical Lock Depth	D
Compressor Stage Pressure	D
Compressor Outlet Pressure	A
Air/O_2/NITROX/HELIOX BIBS Manifold	A
(1) See Table 9 for additional information on Accuracy Grades.	

Table 9: Gauge Accuracy Grades

Accuracy Grade	Permissible Error (% Percent of Span, excluding friction)			Maximum Friction (% of Span)[2]
	Lower 1/4 of Scale	Middle 1/2 of Scale	Upper 1/4 of Scale	
4A	0.10	0.10	0.10	See Note 1
3A	0.25	0.25	0.25	0.25
2A	0.50	0.50	0.50	0.50
1A	1.0	1.0	1.0	1.0
A	2.0	1.0	2.0	1.0
B	3.0	2.0	3.0	2.0
C	4.0	3.0	4.0	3.0
D	5.0	5.0	5.0	3.0

(1) Grade 4A gauges must remain within specified tolerance before and after being lightly tapped.
(2) During gauge testing/calibration, at each test point, the gauge shall be read, lightly tapped, and then read again. The difference of the readings is the Friction Error.
(3) See ASME B40.100 for more information on gauge accuracy.

Unless specifically exempted by the PM, each gauge shall be provided with a gauge isolation valve that is readily accessible and shall be closed to isolate a defective gauge from the system. Valves that meet the requirements of MIL-DTL-24578, *Valves, Globe Pressure Instrument, Stem Test Connection, Union End*, that act as both isolation valves and calibration connection ports are recommended.

All pressure gauges must be securely mounted in a location that permits easy reading of the dial and access for removal. Considerations shall be given for allowance of in place gauge calibration. Gauges must be protected from mechanical vibration, shock and inadvertent mechanical damage. All pressure gauges shall be equipped with a pressure blow-out plug (usually located on the back of the case) to prevent the gauge face from blowing out in case of a tubing rupture inside the gauge. Care must be taken when mounting gauges not to obstruct or block the operation of the "blow-out" plug. Fluid-filled gauges are not permitted in breathing gas systems unless specifically authorized by the PM. If authorized, only halocarbon oil may be used in a fluid filled gauge. Pressure gauges shall be mounted in the orientation as recommended by the OEM. If the gauge is intended to be oriented differently, system drawings shall identify specific calibration position(s) in which the gauge must be tested.

2-2.5.10 *Remote Control Systems*

The designer shall furnish detailed design information for all remote control systems and components. These systems provide remote operation capabilities for the DLSS (e.g., the actuation of hull stops). Information provided to the PM must clearly discuss the capability of the system to function in the intended environment (i.e., temperature, pressure, humidity). Descriptions must be furnished for all remote control systems. The descriptions shall include an analysis of the consequences of a failure or loss of normal mode and also describe automatic and manual backup control features available for emergency recovery or surfacing procedures. Design information and test data must be in sufficient detail to permit an independent evaluation of the adequacy of the controls in their environment, under all normal and emergency operating conditions.

2-2.5.10.1 ***Remote Control Power Systems***

Remote control power supplies shall be manual, mechanical, pneumatic, hydraulic, or electrical. The choice shall be based on reliability in the environment in which the power supply must function. The designer shall furnish information, based on previous use of the power supply or based on tests, that substantiates the reliability of the power supply in the intended environment.

All remote controls must have two independent sources of power or be fail-safe unless otherwise approved by the PM.

2-2.5.10.2 *Remote Control Monitoring Systems*

Remote control systems shall contain devices that monitor system status and responses. Indicators for malfunctions or failures in a control actuator must be provided to the operator or diver. The designer shall define the level of monitoring required based on the criticality of the system. The monitoring system design shall be submitted to the PM for concurrence.

2-2.5.10.3 *Remote Control Actuators*

A remote control actuator is any device or group of devices used to accomplish a desired control function. The design shall ensure that the control actuator is resistant to false alarms or extraneous signals that produce undesired responses. Switches and controls that are used to manually energize a control actuator must be located so that they are not inadvertently energized.

Remote control actuators shall be designed to be failsafe. Failure of any portion of a control actuator shall not in any way prevent the ability of the DLSS to return to the surface.

Individual remote control actuators shall be capable of being isolated from other remote control actuators that share a common power supply. For electrical remote control actuators, this requires either fuses or circuit breakers on all lines that connect each remote control actuator to the power supply. For hydraulic or pneumatic remote control actuators, this requires appropriate check valves or isolation valves on all lines that connect the power supply to the remote control actuator.

Remote-operating control actuators that are used to operate system valves from control stations may be mechanical, hydraulic, pneumatic, or electric. Local overrides shall be required for all remotely operated valves. Failure modes for remotely operated valves shall be evaluated during the system hazard analysis. For additional information, see section 2-1.4.2.

Where a remote control actuator normally operates automatically, provisions shall be made to allow the operator or diver to manually override the automatic control. The manual control shall bypass as much of the automatic control system as is practical.

2-2.5.10.4 ***Remote Computer Control and IV & V***

When the designer is employing automated computer controls, software independent verification and validation (IV&V) is required. Even if the computer is only monitoring gas, such as O_2 dosage delivered to the diver. IV&V requirements and guidance can be found in Institute of Electrical and Electronic Engineers (IEEE)-STD-1012, *Standard for System, Software, and Hardware Verification and Validation*. Computer controlled systems shall be included in a hazard analysis IAW MIL-STD-882.

2-2.6 PRESSURE VESSELS

2-2.6.1 *Gas Storage Cylinders*

Gas storage cylinders shall meet the requirements of MIL-DTL-22606, *Flask Compressed Gas and End Plugs for Air, Oxygen, and Nitrogen*, ASME BPVC Section VIII or U.S. DOT regulations governing cylinders contained in 49 CFR, *Transportation*. If another code is deemed advantageous by the designer, they may submit a written request to the PM for approval.

Each gas flask shall have a readily accessible isolation valve to stop gas flow to the system. The flask isolation valve must be able to withstand full flask pressure. The flask valve shall be installed so that the pressure in the flask is under the seat.

Each gas flask containing divers' air shall be equipped with a drain line and a drain valve unless approved by the PM. The drain line outlet shall be visible during draining operations so the operator can see when the moisture is drained. Drains are not required on O_2, He, N_2, or mixed gas flasks. Lightweight portable flasks, such as SCUBA bottles or chamber air & oxygen system (CAOS) flasks, do not require drains as long as provisions are made to permit the flasks to be inverted to be periodically drained.

Gas storage cylinders used in transportable systems shall meet the requirements and be stamped or marked IAW the U.S. DOT or MIL-DTL-22606.

Gas flasks or cylinders should normally be located outside of a manned pressurized space. The designer must justify locating compressed gas flasks in a manned pressurized space and approval must be received from the PM. If gas flasks or cylinders are located inside a manned pressure vessel, the designer shall provide a readily-accessible valve to stop the flow of gas from the flask. The designer must also perform calculations showing that inadvertent release of stored contents of these flasks will not increase the pressure inside the chamber by more than 1 atm over ambient or exceed the limits of a safe breathing atmosphere.

2-2.6.2 *Receivers and Volume Tanks*

Receivers and volume tanks shall be fabricated using the approved specifications for pressure vessels described in section 2-2.6.1. In general, receivers and volume tanks are fabricated IAW ASME BPVC Section VIII. All receivers and volume tanks shall be equipped with pressure gauges, drain valves and relief valves. More information on receivers and volume tanks can be found in NSTM Chapter 551, *Compressed Air Plants and Systems*.

2-2.6.3 *Pressure Vessels for Human Occupancy (PVHO)*

PVHOs shall be designed IAW the most current version of ASME PVHO-1. This includes the design of viewports and penetrations. Piping systems shall also be designed IAW section 2-2.5.

2-2.6.4 *Design of Internally Loaded Pressure Vessels/Hard Structures*

NOTE: Pressure hulls/vessels, hard structures, and components which are subjected to both external and internal pressure shall be designed to withstand the highest loadings both internally and externally.

Internally loaded pressure vessels include hyperbaric/recompression chambers, diving bells, air receivers, and gas storage flasks. The designer shall demonstrate the structural integrity of the pressure vessel under loading conditions representative of those expected in service. As such, the design must take into consideration the effects of temperature, cyclic loading, creep, ductility, and anisotropy. Examples of pertinent variables include pressure, temperature, number of load cycles, material reproducibility, fabrication flaws and defects, design tolerances, local stress concentrations, fatigue, vessel openings, intersection of different shells of revolution, reinforcements, residual fabrication stresses, corrosion rates, and deviations from nominal geometry.

2-2.6.4.1 *Stress Analysis*

The designer shall perform a complete stress analysis of the vessel or hard structure to demonstrate that all stresses are within the design criteria for the DLSS and that its fatigue life is adequate for the intended service life.

2-2.6.4.2 *Verification of Calculated Design Operating Pressure*

For designs implementing new geometries, new materials, or known materials not typical for this application, the PM may require verification of design by model testing.

The calculated failure pressure may be verified by performing either full or reduced scale destructive model tests. When such testing is performed, the structural model shall be sufficiently large to contain representative prototype geometries, material properties and fabrication process restraints, tolerances, and residual stresses.

If testing is required, a detailed test procedure shall be developed by the designer and submitted to the PM for review and approval prior to testing. The test shall be of sufficient duration to demonstrate that sustained loading does not produce permanent deformation or damage in the structure at MOP and temperature. The test procedure shall include a detailed strain gauge plan which specifies the number, type and location of all gauges. The test procedure shall duplicate the loading conditions expected in service and shall allow the mode of failure to be identifiable where applicable. Upon completion of testing, the recorded strain gauge data shall be used to verify the calculated performance of the structure. The complete test report shall be provided to the PM for review and approval.

2-2.6.5 *Design of Externally Loaded Pressure Vessels/Hard Structures*

NOTE: Pressure hulls/vessels, hard structures, and components which are subjected to both external and internal pressure shall be designed to withstand the highest loadings both internally and externally.

For pressure vessels and hard structure of the DLSS that is subjected to greater external pressure than internal pressure, the designer shall provide evidence that the structure has sufficient collapse strength to withstand MOP (including a factor of safety (FS)).

In general, the modes of failure in a pressure vessel subjected to external pressure are caused by either elastic or inelastic instability. The designer shall demonstrate that the collapse pressure of the hull and hard structure is at least 1.5 times the maximum system pressure under loading conditions (environment, loading rate, and duration) that are representative of those expected in service. Exceptions to this criteria require PM approval.

The collapse pressure is defined as the lowest pressure at which any one of a series of nominally identical hull structures would collapse. The design collapse pressure (analytical or experimental) must take into consideration the effect of basic material characteristics (i.e., creep, ductility, anisotropy) and must account for statistical fabrication & geometrical variations to assure adequate reproducibility. Examples of pertinent variables include in-service material reproducibility, fabrication flaws & defects, hull openings, intersections of different shells of revolution & attendant reinforcement(s), residual fabrication stresses, and deviations from the nominal geometry (i.e., flat spots, mismatch, frame tilt, out-of-roundness, out-of-fairness, out-of-sphericity). Out-of-roundness, out-of-sphericity deviations, and material discontinuities are of major concern in the design and fabrication of externally loaded pressure vessels. Even small deviations in a sphere or cylinder's geometry will significantly weaken a pressure vessel.

The designer must bear in mind that seawater corrosion must be taken into account when the pressure vessel is to be submerged. The sections that follow give the requirements that shall be met in order to accomplish this objective.

2-2.6.5.1 ***Inelastic Stability***

For known materials (see section 2-2.4) used in stable pressure vessels and hard structures (i.e., stiffened or unstiffened shells which permit the level of load-induced membrane stresses to approach the material yield point at collapse pressure), the collapse pressure must be no less than 1.5 times the MOP. In determining the pressure at which collapse occurs, all fabrication and design-induced restraint and geometrical variables must be considered since the strength of moderately stable structures can be detrimentally affected by such variables.

For new materials or use of known materials not typical for this application, an appropriate ratio of collapse to operating pressure shall be justified by the designer and submitted to the PM for approval.

2-2.6.5.2 ***Elastic Stability***

For stiffened or unstiffened hull structures fabricated from either known materials (see section 2-2.4) material and having a propensity for failure in an elastic instability mode (i.e., collapse occurring at actual stress levels appreciably below the material yield point), the collapse pressure at which failure due to instability occurs must be no less than 1.5 times the MOP.

For new materials or use of known materials not typical for this application, an appropriate ratio of collapse to operating pressure shall be justified by the designer and submitted to the PM for approval.

2-2.6.5.3 *Stress Analysis*

The designer shall perform a complete stress analysis of the pressure vessels and hard structures to submit to the PM for approval. The analysis shall demonstrate that all stresses are within the design criteria and that its fatigue life is adequate for the intended life of the DLSS. The static stress levels shall be limited to the values below.

a. The average shell membrane stress at MOP shall be limited to 2/3 of the minimum specified yield strength of the material.

b. The highest combined value of the average shell membrane stress and bending stress, excluding effects of local stress concentrations, at MOP shall be limited to 3/4 of the minimum specified yield strength of the material. The effect of all loading conditions, transitions, and stiffener-to-shell connections must be considered.

c. The maximum peak stress at any point in the hull, including effects of local stress concentrations, shall be limited to the minimum specified yield strength of the material and shall take into account all fatigue considerations (see section 2-2.6.6).

To ensure an adequate fatigue resistance for some designs it may be necessary to reduce the level of allowable stress as given in paragraphs a, b, and c above.

The designer shall calculate stresses in the pressure vessel and hard structure by means of recognized stress formulas or proven computer programs. The validity of the stress analysis methods used shall be demonstrated by experimental results, manually obtained predictions, and prior experience with similar structures.

For hulls and hard structures constructed of new materials or use of known materials not typical for this application, the foregoing design requirements and guidelines may not be appropriate or adequate. However, the design basis used must be comprehensive and at least as conservative.

2-2.6.5.4 *Verification of Calculated Collapse Pressure*

NOTE: The requirements of this section only apply to the prototype of each design. All IDENTICAL reproductions of a prototype shall be tested to the requirements of 3-6.11, unless otherwise required by the PM.

For pressure vessels, hard structures, and penetration fittings made of known materials (see section 2-2.4), the calculated collapse pressure must be verified by model testing or use of existing destructive and/or nondestructive tests. There are three alternative methods which can be used. The method chosen shall have PM concurrence.

a. When comparable hull geometries and identical materials have been successfully tested to a pressure at least 1.5 times the maximum system pressure of the structure, use of this test data can be substituted for destructive testing of the structure under review. In instances when this method is applicable, and when even minor differences exist between the hull structure tested and that requiring verification, the differences must be analyzed and submitted to the PM for approval.

b. For new designs that do not fall within the parameters described in paragraph a, the calculated collapse pressure may be verified by performing representative destructive model tests, either full or reduced scale. When such testing is performed, the structural model shall be sufficiently large to contain representative prototype geometries, material properties and fabrication process restraints, tolerances, and residual stresses.

c. Testing of the actual hull structure to 1.5 times the MOP will be accepted as verification of the calculations. When this option is chosen, the calculated collapse pressure must be greater than 1.5 times MOP by a margin sufficient to preclude damaging the structure during the test. PM approval of the safety margin shall be obtained prior to the test.

For designs implementing new materials, or known materials not typical for this application the ratio of the collapse pressure to MOP may need to be greater than 1.5, depending on the material characteristics. Additionally, the calculated collapse pressure and the reproducibility of this collapse pressure shall be verified by destructive model tests and/or appropriate destructive tests of a duplicate prototype hull. For a destructive model test to be acceptable, it must be performed on a model which incorporates all the structural details of the full-scale structure and whose scale is such that the mechanical properties of the material are identical or differ by a known factor or magnitude from those in the full-scale structure built from the same material. The designer shall submit the FS and all test parameters to the PM for approval.

2-2.6.5.4.1 ***Testing Procedures/Test Instrumentation***

Prior to testing, a detailed test procedure for all structures shall be developed and provided to the PM for review and approval. The testing shall be conducted at a pressure which is at least 1.5 times MOP (or by the approved FS) and shall be of sufficient duration to demonstrate that sustained loading does not produce permanent deformation or damage in the structure at MOP. The test procedure shall include a detailed strain gauge plan which specifies the number, type and location of all gauges. The test procedure shall duplicate the loading conditions expected in service and shall allow the mode of failure to be identifiable where applicable. For instance, the tested structure should be filled with liquid and vented to prevent total disintegration of the structure during collapse. Upon completion of testing, the recorded strain gauge data shall be used to verify the calculated performance of the structure. Subsequent to testing, pressure boundary weld NDE may be specified or required by the PM. The complete test report (including post-test NDE) shall be provided to the PM for review and approval.

2-2.6.6 *Fatigue Evaluation*

A fatigue analysis shall be conducted IAW section 2-2.2.3.

When designing a pressure vessel to comply with the requirements of either division of the ASME BPVC Section VIII a fatigue evaluation shall be performed. The evaluation for fatigue is made based on the number of anticipated cycles of a stress or strain range at a point in the vessel. The allowable number of cycles should be adequate for the specified number of cycles as given in the User Design Specification.

Unless otherwise approved by the PM the screening criteria are provided in paragraph 5.5.2 of ASME BPVC Section VIII, Division 2, Article 4.5, *Design Rules for Openings in Shells and Heads*, shall be used to determine if fatigue analysis is required as part of a design. If the vessel or vessel component does not satisfy the screening criteria, a fatigue evaluation shall be performed using the techniques in paragraphs 5.5.3, 5.5.4 or 5.5.5 of ASME Section VIII, Division 2.

When a pressure vessel or hard structure are constructed of new materials or known materials not typical for this application (see section 2-2.4), sufficient destructive fatigue tests of full scale prototypes or models must be performed to experimentally determine the fatigue life of the design, unless deemed unnecessary by the PM. Prior to the start of testing, a fatigue test plan shall be submitted by the designer to the PM for review and approval.

2-2.6.7 *Fracture Toughness*

The designer shall ensure that the materials used to fabricate pressure vessels, hard structures, or any pressure boundary components exhibit adequate resistance to fracture. Specifically, the design analysis submitted to the PM and code inspector or classification society surveyor shall demonstrate that brittle fracture is not a possible mode of failure by considering at least the following:

a. Magnitude, nature and rate of stresses (both applied and residual).

b. Maximum temperature range to which the structure shall be subjected in service.

c. Size, location and density of flaws initially present in the material and those that occur as a result of cyclic operations.

d. Environmental effects such as corrosion and/or erosion. Specifically, the environmental effects on crack initiation and propagation (e.g., SCC) must be evaluated, especially when the structure will be immersed in an electrolyte such as saltwater.

e. Effects of creep and strain rate on fracture toughness.

f. Localized effects due to penetrations, attachments and other vessel or component restraints (i.e., stress risers).

g. Effects of fabrication processes and heat treatments on the fracture characteristics of the material. For welded fabrication in particular, the properties of the weld filler and base metal within the heat-affected zone and resultant induced internal stresses shall be considered.

h. Material thickness.

The material properties used by the designer in the fracture analysis must be verified for the material used for actual fabrication by requiring appropriate tests such as tensile and compressive strength tests, fracture toughness (KIc) tests, stress corrosion cracking (KIscc) tests, Charpy V-notch impact tests, dynamic tear tests, drop-weight tests and explosion bulge tests. Where appropriate design fracture toughness data is not available for the applicable material then fracture mechanics-type tests shall be conducted to establish appropriate requirements for that material. The design analysis must consider possible variations in material properties and the effect of material thickness on fracture characteristics in particular. The structural design basis used by the designer for the analysis of brittle fracture shall be verified by destructive testing of the pressure hulls and component models and structures, or by reference to existing information and service experience where possible.

The designer shall specify in fabrication requirements that all plates, parts and components are verified to have adequate strength and toughness over the range of the design operating temperature.

Toughness characteristics of ferrous materials shall be referenced to the Nil Ductility Transition Temperature (NDTT).

2-2.6.8 *Penetrations*

Design of openings in the pressure vessel shall be IAW the specified code/standard to which the vessel is designed. ASME BPVC Section VIII Division 2, provides design criteria for penetrations, including the opening shape, area replacement, and distribution. Article 4.5 does not satisfy the requirements of a fatigue analysis nor does it include piping loads that may be imposed on the nozzle and/or shell portion and that may be added to the pressure loading. The designer must carefully consider such additional loadings and make provisions for them. ASME PVHO-1, Non-mandatory Appendix C also includes recommendations for the design of through pressure-boundary penetrations and should be utilized when possible. Sufficient additional penetrators should be considered during the design phase for addition of future components.

2-2.6.8.1 *Piping Penetrations*

Piping penetrations in the pressure vessel shall be located and arranged so that in the event of an emergency, such as flooding or loss of atmosphere, a maximum amount of atmosphere will become entrapped in the DLSS. Emergency shutoff capability shall be provided to protect the internal breathing atmosphere from exhaust, full flooding, or contamination. Hull stop and/or check valves should be located as close as possible to the penetrator.

2-2.6.8.2 *Electrical Penetrations*

See section 2-2.8.7.2.

2-2.6.9 *Viewports*

Viewport designs shall conform to ASME PVHO-1 unless prior written authorization from the PM has been obtained.

The designer shall show that the viewport design is adequate for the system pressure and temperature range, environmental conditions, and expected number of pressure cycles. Each port's field of view within the DLSS shall be shown on the system drawings. Resistance to stresses applied continuously over a long period and cyclic stresses must be properly considered. Full specification must be made of the materials used, including their composition, the required thermal/chemical/physical treatment, dimensions, tolerances, and renewal/replacement criteria. Where necessary, windows shall be protected from accidental impact or other mechanical abuse.

2-2.6.10 *Hatches/Closures*

The design of all hatches/closures must permit safe operation under all specified ship motions and operating conditions. The ease and speed with which a closure can be opened or closed and whether tools are required to do so, are design considerations. The reasoning behind the design of a hatch/closure shall be documented in the design calculations for the DLSS.

All closures (including hatches for personnel or materials, port covers/deadlights, and caps or plugs for openings) shall have a demonstrated FS at least as stringent as that used for the design of the pressure hull. Hydrostatic testing of all hatches, covers, caps, and plugs shall be to 1.5 times the MOP of the pressure vessel or as required by the design code.

For designs implementing new geometries, new material, or known materials not typical for this application, the criteria stated above may not be appropriate or adequate. Therefore, the designer may apply an alternative criteria which demonstrates at least the same degree of conservatism. Corrosion protection must be provided. This criteria must be approved by the PM.

Hatches should be designed such that they seat in the same direction as the system differential pressure. Where hatches are required to seal against differential pressure, an interlock is required to ensure that the hatch cannot be opened until the pressure on both sides are equal. The mating flanges of all hatches shall be integral to the pressure vessel shell.

For hatches/doors, the hinging, closing, locking, and sealing elements must be made resistant to or be protected from abuse from rough handling or to possible accidents (e.g., impact from a PTC which is being attached to the DLSS in rough weather). Hatch assembly seating surfaces shall also be resistant to corrosion. The preferred method to achieve corrosion resistance is to manufacture the entire forging and the door/hatch from corrosion resistant material, but clad welding of these surfaces generally provides acceptable corrosion protection.

2-2.6.11 *Vacuum in Manned Pressure Vessels*

All hyperbaric PVHO shall be designed to prevent the possibility of unintentionally causing pressure of less than one atmosphere (i.e., drawing a vacuum) while the chambers are occupied. Design features such as vacuum breakers shall be sized for the highest flow rate possible.

All suction, drain, and exhaust lines in hyperbaric manned compartments must be equipped with an anti-suction device to prevent injury from personnel being sucked into the inlet.

2-2.7 WELD DESIGN

Weld design shall be IAW the applicable design code or MIL-STD-22, *Welded Joint Design*, unless otherwise directed in this specification.

2-2.8 ELECTRICAL SYSTEMS

Consideration must be given to the electrical requirements for all DLSSs and supporting equipment. A wide range of electrical and electronic equipment from heavy machinery such as pumps, compressors and handling equipment to precise instrumentation for monitoring, control, communications and data acquisition are used in DLSSs.

Although electrical hazards cannot always be eliminated, electrical components exposed to high O_2 concentrations inside a pressure hull are potentially hazardous to personnel. The designer shall justify their use and address the potential for fire and other personnel hazards in a hazard analysis IAW section 2-1.4.2.

2-2.8.1 *Power Requirements*

Unless provided by the PM, the designer shall determine the power requirements, both normal and emergency, to support the DLSS. The designer shall show how much power is required from the support platform/facility and how much of the DLSS is self-supporting.

Where the electrical system is required for the operation of equipment within the SOC boundaries, separate primary and emergency power is required. The exception to this requirement is when the back-up for a primary system is not electrically powered. The preferred method to prevent power interruption in the case of a primary power system failure is an automatic bus transfer system. The emergency power supply shall be capable of powering vital equipment that provide life support and safety for returning the occupants from the maximum system operating depth to the surface.

2-2.8.2 *Material Selection*

See Table N 4 in Appendix M for selection of typical materials for electrical and electronic systems. Additional requirements for electrical/electronic materials selection are provided in section 2-2.4.12.

2-2.8.3 *Ungrounded System*

Except for systems that are only intended to operate from shore-based grounded power sources, all electrical power distribution circuits shall be supplied from an ungrounded electrical system to minimize electrical shock hazards and ensure continuity of service. Alternating current (AC) power shall be fed from isolation transformers. Direct current (DC) power shall be fed using isolated power supplies or converters. All equipment designed to employ chassis grounds as part of the electrical circuitry shall be isolated from the electric power system by a transformer or by isolating the chassis from the DLSS structure and personnel. The hull/support platform of a DLSS shall not be used as an electrical conductor or as a common reference in order to minimize corrosion due to electrolysis.

2-2.8.4 *Batteries*

The American Bureau of Shipping (ABS) Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities, provides the guidelines and requirements that should be considered and taken under advisement during design and specification development for DLSS batteries.

The system hazard analysis outlined in section 2-1.3 shall specifically address the DLSS battery systems including, chemistry, installation, removal, charging, discharging, off gas, maintenance and any control or monitoring systems used.

High energy density systems, such as lithium-ion or fuel cells, may present unique dangers when used within the confines of a DLSS. The use of lithium batteries shall be IAW NAVSEAINST 9310.1, *Naval Lithium Battery Safety Program*. Any large, high-density energy sources used in a DLSS to be operated on or from a USN facility or platform shall require a platform hazard assessment IAW NAVSEA SG270-BV-SAF-010, *High Energy Storage System Safety Manual*.

2-2.8.5 *Electrical Shock Hazards*

All electrically powered equipment and/or electrical equipment enclosures shall be adequately grounded to prevent shock hazards to personnel, with the following exceptions:

a. Equipment or equipment enclosures that are non-conductive.

b. Portable equipment powered by an internal battery (for example, flash lights, a hand-held navigation unit or a lap top computer need not be grounded).

For guidance see MIL-STD-1310, *Shipboard Bonding, Grounding, and other Techniques for Electromagnetic Compatibility, Electromagnetic Pulse Mitigation, and Safety*, and International Marine Contractors Association (IMCA) specification D 045, *Code of Practice for The Safe Use of Electricity Under Water*.

The environment for electrical components (e.g., cabling, connectors, protective devices, motors, power supplies) that are used on DLSSs may differ markedly from normal shipboard conditions. The components may be oil-immersed, subject to full sea pressure, operate at low temperatures, or be subject to high vibration and high humidity. The designer shall furnish specific documentation that verifies the ability of the electrical component to function in the intended environment for its design life and over the design range of pressures, temperatures, humidity, voltages etc. Documentation may be in the form of a certificate of compliance (CoC) or test report for the specified electrical component.

Materials used in electrical equipment shall be shown, by test and/or experience, to be resistant to deterioration by the in-service operating environment.

2-2.8.5.1 *Electrical Shock Prevention Requirements*

Unless otherwise approved by the PM, ground fault detectors (GFD), insulation resistance (IR) monitoring and/or ground fault circuit interrupters (GFCI) shall be provided for all DLSS circuits utilizing voltages in excess of 30 volts DC or 7.5 volts AC unless the designer can justify not using them. Protection shall meet the requirements for safe body currents as given in the IMCA D 045.

2-2.8.5.2 *Fault Current Protection*

Each current carrying conductor shall be electrically protected. The devices shall be adequate for the environment, proof tested, and technically justified for their intended application.

A load analysis shall be performed to show that fault current protection devices operate correctly under normal and maximum load demands. DDS-310-1, *Electric Power Load Analysis for Surface Ships*, provides guidance on performing a load analysis.

A short circuit analysis shall be performed to show that fault current protection devices protect the conductors and underwater penetrators under worst case fault conditions.

A protective device coordination study shall be completed to minimize impact to critical systems by clearing faults as close to the source as possible. IEEE-242, *Recommended Practice for Protection and*

Coordination of Industrial and Commercial Power Systems, provides guidance on performing short circuit studies and protective device coordination studies.

Fault current protection devices shall be provided for each unit of electric generating equipment or power supply and for each unit of power consuming equipment connected to the distribution system.

When mounted internal to the DLSS, these devices shall be installed in purged (with inert gas) explosion-proof enclosures, proof-tested and technically justified for their intended application.

Circuit breakers shall meet approved national or international requirements and be tested or certified by a nationally recognized independent testing laboratory as suitable for shipboard applications. Circuit protection should be selected IAW with MIL-DTL-917, *Electric Power Equipment, Basic Requirements,* (see Table II-5-1). Fuses and thermal devices are prohibited in HeO_2 environments; fault current protective devices of magnetic design shall be utilized.

Fuses and other thermal devices to be used in oil-filled, compensated enclosures shall be specifically designed for that environment.

2-2.8.5.3 ***Electrical Insulation/Isolation***

Electrical insulating materials shall be selected on the basis of their ability to insulate the DLSS equipment and to provide the proper functional and mechanical characteristics. Examples of electrical functional characteristics are dielectric strength, and IR. Mechanical characteristics include impact strength, tensile strength, elongation, flexibility, adhesion, and abrasion resistance.

Electrical insulating materials shall be nonflammable and nontoxic (see MIL-DTL-917 for guidance).

Conductors within cables shall be electrically insulated from each other, from the DLSS, and from operators and occupants. All wiring used in a DLSS shall only have low smoke insulation (ANSI/UL 2043-2208, *Standard for Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces*, or equivalent) and meet the requirements of MIL-DTL-917, MIL-DTL-24643, *Cables, Electric, Low Smoke Halogen-Free, For Shipboard Use*, or NFPA 70, Article 504 and section 2-2.8.5. Teflon-coated wire or kapton polymide film over fluorinated ethylene propylene (FEP)-type insulation is generally preferred for DLSS applications.

The minimum allowable IR of wire used in a DLSS shall be 1 MΩ if not subject to sea pressure and 10 MΩ if the wire is subject to sea pressure. Refer to electrical testing subsection for IR testing requirements.

2-2.8.6 *Wiring Methods.*

Installation of cables, enclosures and electrical equipment in a DLSS shall be IAW the requirements of MIL-STD-2003, *Electrical Plant Installation, Standard Methods for Surface Ships and Submarines*, and this manual unless otherwise justified and approved by the PM. For shore based systems, installation of electrical equipment shall be IAW NFPA 70 and local jurisdictional authority.

Cables subjected to external hyperbaric or sea pressure shall be either pressure compensated or a solid core construction. Other cable construction methods proposed for use shall be technically justified for the intended application and approved by the PM.

Pressure compensated cable shall not be used in the interior of the DLSS due to the possibility of contamination by the compensating fluid.

Cable runs shall be designed so that the effect of any fire damage due to a fault will be minimized with respect to damaging other cabling in the distribution system. Cables shall be installed and supported to avoid undue stress, excessive bending and chafing. Cable support edges that come in contact with cables shall be rounded, smooth and burrs removed.

Cables shall be protected against damage from accidental contact, crushing, shearing or use as a step or handhold. Cable and wire housed inside a DLSS shall be arranged so as to avoid interference with personnel movement.

Particular care shall be taken in the case of portable electrical equipment to protect conductors from excessive flexure, kinking, tension, being caught between movable objects, or being stepped on. Regardless of protection, conductors shall be resistant to such abuse.

Conductors shall be flexible and easy to handle. Sufficient slack shall be provided in the conductor at penetrators to permit plug-in and disconnect operations without excessively stressing the cable. A means of support shall be provided at the cable/plug interface to minimize bending during DLSS operation. Support conductors where possible.

Underwater cables shall be non-wicking and capable of withstanding an external hydrostatic test of 1.5 times the maximum system depth IAW section 3-6.4.2 without damage or changing the insulation and conductivity characteristics

Cables and connectors subjected to pressure (wet or dry) shall be free of voids and air pockets. Voids have been known to burst during rapid depressurization (especially in an He environment), causing a safety hazard.

Conventional switches, outlets and other wiring devices that may cause a spark are prohibited inside the DLSS unless specifically approved by the PM. Electrical energy is a potential hazard in an O_2-enriched environment because it is the chief source of ignition of flammable materials. Special considerations shall be taken when designing electrical systems for a DLSS that has the potential for O_2-enriched environments. Electrical devices designed for O_2-enriched environments shall be utilized. Devices used inside the DLSS and/or in the O_2-enriched environment shall be intrinsically safe or technically justified for their intended application (see NSTM Chapter 300, *Electric Pant – General*, and NFPA 70).

2-2.8.7 *Electrical Connectors and Penetrators*

Electrical connectors and individual hull penetrator designs shall meet the requirements of MIL-STD-2003 and this manual unless otherwise justified and approved for the intended application by the PM.

The bodies of electrical connectors and penetrators exposed to salt spray or seawater shall be made of corrosion resistant material. Provisions shall be made to protect the DLSS pressure hull from corrosion in the gasket areas of the penetrators. Electrical connectors and individual hull penetrator designs shall be technically justified for their intended applications.

2-2.8.7.1 ***Electrical Connectors***

Connector design shall permit the DLSS operator or diver to readily disconnect the umbilical and any other electrical conductor while minimizing the chances of receiving an electric shock. System O&M procedures shall not allow disconnecting connectors when the circuit is energized.

All cables terminating in pressure-type connectors shall have connectors attached in such a manner as to exclude all voids from the cable connector assemblies and to impose no undue mechanical stresses on conductors or connectors.

Electrical connectors shall be sealed against water intrusion at maximum operating or rated pressure.

Connector pins and sockets shall be of corrosion resistant material or plated to prevent corrosion and electrical discontinuities.

System designs shall provide electrical penetrators subject to sea pressure with adequate protection against the hazards associated with a short circuit at the connector (see section 2-2.8.5.3 for short circuit analysis).

The materials and methods used to join connectors and fittings to umbilical cables and hoses shall provide a strong bond capable of withstanding severe handling and operating conditions.

Electrical connectors shall be designed to prevent incorrect connection and accidental disconnection. Size selection, key fitting, or other means shall accomplish this. Color coding or other visual identification alone is insufficient unless specifically authorized by the PM for individual connections.

2-2.8.7.2 *Electrical Penetrators*

Pressure vessel electrical cable penetrators shall provide a high-pressure, gas tight, water barrier at the hull to prevent flooding of the DLSS in the event of failure or disconnection of the external cable. Stuffing tube-type penetrators into pressure vessels and non-compensated hard structures are not acceptable and shall not be permitted in new construction. Pin-type connections for cable entrances into compensated enclosures are preferred; however, terminal tube entrances may be acceptable provided evidence of compatibility of the cable jacket and insulation with the compensating medium is provided.

Electrical hull penetrations in the pressure hull are part of the primary pressure boundary and shall be gas/water tight to the full rated depth of the DLSS. Pressure test data shall be provided to assure that its hydraulic life is defined in relation to the design life of the hull and thermal shock to the connector.

The electrical penetrators must be rated for the maximum system pressure of the vessel and pressure tested to 1.5 times the maximum system pressure in the medium to which it is subject (see section 3-6.4.2).

To the maximum extent possible both positive and negative leads shall not be contained within the same electrical penetrator without prior approval of the PM. This applies to power supply and return leads only. This requirement does not apply to signal connections.

2-2.8.8 *Lighting Systems*

DLSSs should be equipped with both normal and emergency lighting systems operated from separate power supplies, unless otherwise approved by the PM. Emergency or auxiliary portable lighting should be provided for operator use, in the immediate vicinity of critical controls, unless otherwise approved by the PM. When applicable, the designer shall address and make provisions for operating deckplate/exterior operating stations, especially when diving at night.

When lights are installed inside a pressurized space, the housings shall be adequately designed so as not to explode or implode, and the wiring to the fixture sufficiently rugged to withstand inadvertent impact and mechanical loads without causing a fire or shock hazard.

2-2.8.8.1 ***PVHO Personnel Lighting Requirements***

The desired illumination level per unit floor area at various locations in a hyperbaric complex, and resulting power consumption, will be determined primarily by personnel requirements. The detailed design of interior lighting installations is quite complex and depends on many variables. This subsection provides overall guidance to the designer and does not establish absolute requirements, as those design requirements can only be detailed for each specifically designed PVHO. Interior geometry and the reflectivity of white interior paint will directly influence the design – a small amount of basic information for the designer is provided here:

a. Illumination – Surface illumination is commonly measured in foot-candles. A foot-candle equals one lumen per square foot. Using the metric system, a lumen is measured by a square meter or a lux. Thus, a foot-candle is equivalent to approximately 10 lux or 10.57 lux.

b. Illumination recommendations in foot-candles, for various grades of tasks, provided by Table 10.

c. Illumination Realization – To obtain the desired illumination level at the work area, the characteristics of both the type of light, lamp and the fixture, or luminaire, must be considered. Generally, light levels inside the chamber at work area should be between 25 and 50 foot-candles for personnel comfort. Consideration should be given to provide a means of varying the light intensity, especially if the PVHO contains a berthing lock.

Table 10: Recommended Illumination Levels for Various Task Grades

Task Description	Illumination, Foot-candles	Source
Performance of visual tasks of extremely fine detail under poor contrast conditions for long periods of time.	100 or more[1]	UFC 4-159-01N (DM-39), *Design: Hyperbaric Facilities*.

Performance of visual task of fine detail under medium contrast conditions.	50 – 100	UFC 4-159-01N (DM-39)
Performance of visual tasks of moderately fine detail under better than average contrast for intermittent time periods.	25 – 50[2]	UFC 4-159-01N (DM-39)
Performance of visual task of simple orientation for short temporary durations.	5 – 10	UFC 4-159-01N (DM-39)
1. Note – As identified in the Bright White Light Inspection section of MIL-STD-1330; a standard 2-D Cell Flashlight is considered equivalent to 100 Foot-candles. That was added in 1996. Today, LED flashlights far exceed this minimum surface inspection requirement. There are many hyperbaric options. 2. Note – Guidelines from DOD-HDBK-289, *Lighting on Naval Ships*, for medical and dental spaces, shipboard, calls out minimum 28 foot-candles with an exception for spaces such as laboratories and medical treatment rooms called out as 42 foot-candles. Naval Facilities Engineering Command (NAVFAC) Military Medical Facilities (UFC 4-510-01, *Design: Military Medical Facilities*) call out 28 – 46 foot-candles for an examining room.		

2-2.8.9 *Instrumentation/Data Acquisition*

Instrumentation/data acquisition devices shall be electrically isolated from the DLSS personnel, but not located in a manner that might subject it to erroneous readout. Electrical failure of one instrument/device shall not impair the use of another. All instrumentation/data acquisition shall be compatible with its intended environment and not create a fire, electrical or toxic hazard (see sections 2-2.4.1 and 2-2.4.2).

2-2.9 COMMUNICATION SYSTEMS (COMMS)

In all operating conditions of a DLSS, except when using SCUBA, there shall be a primary and a backup communication method. The backup COMMS between operator stations shall provide redundancy in all modes of operation. The systems shall be designed such that they operate independent of each other and the failure of one system shall not impair the use, or result in the loss of the other.

The electronic COMMS may be supplemented as necessary by visual COMMS, such as lights and message boards. The backup communication method between operating stations within the DLSS may be visual.

A primary voice COMMS such as intercom, telephone or radio equipment shall be provided to permit DLSS occupants and divers to communicate with support personnel. An underwater telephone (UQC) and radiotelephone shall be provided for DLSSs for both submerged and surfaced communications. The backup or emergency communications shall capable of being powered separately from the primary COMMS.

The PM shall specify the range and water conditions for which these systems are required to be effective.

Other COMMS, which may be required in a DLSS, include He speech unscramblers, through-water communicators and closed circuit TV monitoring systems. All equipment shall be compatible with the environment and not create a fire, electrical or toxic hazard.

2-2.10 ENVIRONMENTAL CONDITIONING

Diver heating/cooling and hyperbaric chamber heating/cooling systems are required where environmental conditions dictate. The system needs to be designed to maintain the temperature and humidity ranges that are designated in the original contract by the PM. Any deviation from this will require permission from the technical, programmatic and certification representatives for the system.

The electrical components of heating/cooling systems shall be located outside the DLSS pressure hull whenever possible. Heated/cooled gas or water may flow through the pressure hull or the hull itself may be heated/cooled. All electrical heating equipment must be compatible with the environment and must not create a fire, electrical or toxic hazard. Heating/cooling components internal to the DLSS or those that are exposed to the breathing atmosphere of the DLSS personnel must not produce toxic or noxious fumes.

The designer shall pay particular attention to the arrangement of equipment in close proximity to the heater. This is necessary in order to preclude possible off gassing due to local elevated temperatures. All equipment must be installed IAW the manufacturer's instructions.

The designer shall consider whether electrical heating/cooling systems should be provided with emergency power for use in the event of main power failure.

All diver heating systems shall incorporate a high temperature shutdown that will activate when the heat source to the diver exceeds acceptable temperature limits.

2-2.10.1 *Environmental Control and Monitoring*

The DLSS shall incorporate control and monitoring sub-systems to provide adjustment of environmental conditions during dive operations. Environmental limits are further discussed in NAVSEA SS521-AG-PRO-010.

Circulation of gases within larger hyperbaric chambers and complexes is necessary to prevent pocketing or layering of gases such as O_2, CO_2 and He. Placement of the gas inlets and outlets shall be chosen to ensure maximum atmosphere circulation. Inadequate atmosphere circulation can affect the efficiency of CO_2 scrubbers.

Gauges and thermometers shall be installed to indicate pressures, temperatures, liquid levels, and flow rates, as necessary for the safe operation, control, and troubleshooting of systems, machinery, tanks, and equipment.

2-2.10.1.1 ***Atmospheric Contaminants***

Saturation DLSSs and other DLSSs where the diver might be expected to stay for some time shall employ means to remove volatile contaminants. Typically, chemical absorbents are used to remove these contaminants. Activated charcoal or activated alumina (Purafil) is commonly used for this purpose. Most volatile contaminants are introduced into the closed chamber environment through normal bodily functions and items that may be brought into the chamber from outside.

The level of atmospheric contaminants in a DLSS can affect the maximum depth at which a diving complex can be safely used. If atmospheric contamination originates from volatile contaminants in the supply gas, the partial pressure exposure by divers to these contaminants will be directly dependent on depth. For atmosphere contamination arising from the chamber complex itself, the off gassing rate may be independent of depth, therefore there may be no influence of depth on the level of diver exposure to these contaminants.

Purification and filtration components shall be capable of limiting the harmful gaseous and particulate contaminants to the levels outlined in NAVSEA SS521-AG-PRO-010.

The build-up and control of other personnel generated contaminants such as CO, methane, ethanol, H_2, ammonia, hydrogen sulfide and amino-based hydrocarbon compounds needs to be addressed during the design of the DLSS ECS. Factors such as number of personnel, mission duration, occupied space volume, human waste stowage, and breathing gas exchange shall be used to determine if control of these contaminants is necessary. The simplest form of control includes passive methods such as:

a. Activated carbon, which can absorb high molecular weight hydrocarbons, alcohols, ketones, aldehydes, and organic acids.

When impregnated with phosphoric acid, it can also remove ammonia and other organic bases.

b. Purafil (activated alumina impregnated with potassium permanganate), which adsorbs a number of acid and alkaline gases. It will also oxidize many unsaturated hydrocarbon compounds.

c. Unheated Hopcalite (a mixture of oxides of manganese, copper, cobalt and silver), which will remove CO (and to a lesser extent, H_2) via catalytic oxidation. Unheated Hopcalite is often used on diesel driven and/or oil lubricated compressors providing breathing air.

With the exception of saturation DLSS, control of gaseous contaminants, other than CO_2, is not typically required due to the short mission durations.

2-2.10.1.2 *Carbon Dioxide (CO_2) Control and Monitoring*

The CO_2 removal subsystem shall be sized IAW the calculated maximum CO_2 production rate. Formulas for calculating CO_2 production rates are provided in section 2-2.1.1.3. The CO_2 level must be controlled and monitored when the primary and secondary breathing gas supplies are recirculated to the DLSS or to the diver, with the exception that closed and semi-closed UBAs do not monitor CO_2 levels. CO_2 monitors shall provide high-level alarms that should be visual as well as audible.

Most CO_2 control systems operate by passing expired gas through a canister containing CO_2 absorbent material. Only NAVSEA-approved CO_2 absorbent material shall be used in DLSSs. CO_2 control systems must maintain the PP_{CO2} in the breathing gas below the specified allowable level for the duration of the longest mission for which the system is designed. In the event of a failure of the primary CO_2 absorbers, there shall be a back-up CO_2 control method capable of maintaining acceptable CO_2 levels. The back-up method may include absorbers, a method to ventilate the system, a method to operate the system in an open circuit mode, or a combination of these. Closed circuit UBAs do not require a back-up method to control and maintain acceptable CO_2 levels.

The designer shall provide data showing the expected length of time that the CO_2 absorbent will maintain CO_2 below the specified limits. The designer must also supply calculations that show the absorbent requirements for the longest designed mission of the system. CO_2 absorbents are not depth dependent, therefore this shall be done at the maximum and minimum operating temperatures and at the maximum calculated CO_2 production rate.

All hydroxide-type absorbents are caustic, and contact may be harmful to personnel as well as damaging to equipment. Therefore, canister designs must incorporate filter elements or other appropriate means to ensure that particles of the absorbent do not escape the canister. The use of lithium-hydroxide absorbents is prohibited due to its extremely caustic nature.

CO_2 absorber canister materials must also be highly resistant to caustic attack and seawater corrosion. CO_2 absorber canisters must be capable of being easily refilled and replaced during system operation, with the exception of UBAs. Sufficient absorbent must be available to permit completion of the longest anticipated mission at the lowest expected operational temperature plus a 50% additional allowance. The time required to isolate, replace, and restore the absorber to operation shall not result in an unsafe level of CO_2 build-up in the DLSS.

The absorber design must provide a means to remove moisture produced from the CO_2 absorbent reactions. This moisture may fog the DLSS viewports or the diver's faceplate, accumulate in breathing gas passages, increase resistance to gas flow through the absorbent, and decrease the effectiveness of the absorbent.

CO_2 scrubber designs should include the following features:

a. Minimum flow resistance.

b. Maximum utilization of absorbent.

c. Neutral buoyancy in closed or semi-closed circuit UBAs.

d. Minimum gas-flow channeling that severely restricts mission duration by reducing absorbent utilization.

e. Minimum heat transfer in cold water for closed or semi-closed circuit UBAs.

f. Filtration to prevent CO_2 absorbent from entering the gas stream beyond the absorber canister.

Additional information regarding CO_2 scrubber design may be found in NCSC Technical Manual 4110-1-83.

2-2.10.1.3 *Oxygen (O_2) Supply, Control, and Monitoring*

The primary O_2 supply system capacity shall be based on providing, as a minimum, sufficient O_2 to meet the human O_2 consumption rates given in section 2-2.1.1.2. A secondary O_2 supply system is required in case of failure of the primary O_2 supply system, unless exempted by the PM.

O_2 monitoring equipment shall be provided, shall be capable of easy calibration before each use, and shall incorporate high and low partial pressure or percent level alarms. For air systems, the alarms shall be both visual and audible. For a standard recompression chamber, alarm set points shall be 18% and 23%. When the breathing gas is closed loop or semi-closed loop in design, the designer shall incorporate a method of maintaining the proper PP_{O2}, with the exception of closed circuit UBAs and semi-closed systems that are constantly mass supplied. SSDS systems are exempt from O_2 monitoring.

2-2.10.1.4 ***Carbon Monoxide (CO)***

A common example of an atmospheric contaminant is CO, which is produced at very low rates by normal metabolism. If no other source of CO is present, CO will normally not rise to levels of concern.

Concentrations of CO higher than those noted above can be tolerated with levels of discomfort in emergencies. For example, breathing air containing 150 to 250 parts per million (ppm) of CO at one atmosphere for many hours will result in a severe headache. On the other hand, breathing air containing 1600 ppm of CO at one atmosphere for one hour will cause confusion and ultimate collapse. In current DLSS design, the only way to remove CO is by ventilation, although some compressor purification systems are capable of converting CO to CO_2.

2-2.10.1.5 ***Gas Purification and Filtering Systems***

The designer shall provide adequate purification and filtration to protect DLSS personnel and equipment from harmful contaminants (both gaseous and particulate) in the breathing gas. The designer shall justify the extent to which DLSS provides personnel protection from H_2, CO, toxins and noxious odors.

During system design, the designer shall identify all likely gaseous and particulate contaminants that might enter the DLSS. Purification and filtration components shall be capable of limiting the harmful gaseous and particulate contaminants to the levels outlined in NAVSEA SS521-AG-PRO-010. Actual sampling and analysis shall be verified during the DLSS prototype/first article tests. (See section 3-6.9).

2-2.10.1.6 ***Humidity Control and Monitoring***

Humidity control is required for hyperbaric chambers used for saturation diving. The relative humidity (RH) shall be maintained between 50% and 80% unless otherwise approved by the PM. Maintaining RH levels of 50% to 80% is desirable for divers' comfort.

2-2.11 FIRE SAFETY/SUPPRESSION REQUIREMENTS

The designer shall address provisions for effectively fighting fires that may occur in the interior of a diving chamber or interior of a DLSS. The designer shall also address provisions for protecting the exterior of the DLSS & ancillary equipment and for the protection of the operators & support personnel from fire.

Materials that are noncombustible or nonflammable under normal atmospheric conditions may become combustible in a hyperbaric environment. When a chamber is pressurized with air or an O_2/inert gas mixture, the PP_{O2} is directly proportional to the increase in ata which increases the fire hazard even though the percent of O_2 remains the same.

When a chamber is at surface pressure, the ata is 14.7 pounds per square inch, absolute (psia) or 1 ata. At 1 ata, the PP_{O2} is 3.09 psia or 0.21 ata and the F_{O2} is 0.21 or 21%. When the chamber is pressurized with air to 33 fsw, the pressure in the chamber will be 29.4 psia. At this pressure, PP_{O2} will increase to 6.18 psia or 0.42 ata. Although the F_{O2} is still .21, the increased PP_{O2} that now has a surface equivalent value (SEV) of 42% has increased the fire hazard. This increased fire hazard due to the increase in atmosphere pressure is usually referred to as the fire zone.

As a chamber is pressurized on air or O_2/inert gas mixture, the fire hazard increases as pressure increases. At a predetermined depth, chamber pressurization will be done using 100% He, which will reduce the PP_{O2} and reduce the ability of the chamber atmosphere to support combustion will decrease. Although the PP_{O2} will remain constant, the F_{O2} will eventually fall below 0.06 or 6%, which is generally accepted as the value where combustion cannot take place.

See NAVSEA SS521-AG-PRO-010, for further discussion on the fire zone and for precautions to be taken to minimize fire hazard. See NFPA 53 for further information on fire hazards in O_2-enriched atmospheres.

Fire and explosive hazard warning signs shall be provided at the entrances of the PVHO.

2-2.11.1 *Fire Protection Considerations*

DLSSs that are located on the deck or enclosed space of a platform may require conformance to the fire safety requirements imposed by the jurisdictional authority for which the platform is governed.

Compliance with commercial or other government fire safety requirements based on the system operating parameters may be required at the discretion of the PM.

2-2.11.1.1 ***Personnel Protection***

All watch standers critical to keeping occupants within the DLSS safe while aborting diving operations and/or evacuating the divers (diving supervisor, console/rack operator, handling system operator, life support operator, tenders) shall be provided with a portable emergency breathing capability that provides the same duration that would be required for the chamber occupants. Each chamber occupant shall be provided with suitable method to be provided a breathing mixture independent of the chamber.

2-2.11.1.2 ***System Arrangement and Structural Considerations***

Support-platform-installed DLSSs, including hyperbaric chamber(s) and ancillary equipment, shall be located in compartments or on deck where explosive gas-air mixtures will not occur (e.g., not located over or adjacent to fuel tanks or fuel feed machinery spaces, in the vicinity of ventilation openings from machinery spaces, engine/gas turbine or boiler exhausts, or ventilation outlets from galleys).

DLSSs within enclosed shipboard compartments shall be separated from adjacent spaces by means of A-60 class bulkheads and decks IAW Safety of Life at Sea (SOLAS). Piping and cables essential for operation of the DLSS should be laid in separate structural ducts that are insulated to the A-60 class standard.

NOTE: Class A-60 bulkheads and decks are insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 284°F (140°C) above the original temperature, nor will the temperature at any one point, including any joint, rise more than 356°F (180°C) above the original temperature, within 60 minutes. They are so constructed to be capable of preventing the passage of smoke and flame to the end of the one-hour standard fire test.

Enclosed control and support stations (e.g., Standard Navy Double Lock (SNDL) recompression chamber system, containerized DLSSs, saturation control van, auxiliary equipment van, shipboard control, chamber and equipment compartments) shall have two means of access located as remote from each other as practicable. Any glass windows shall be shatter-resistant. Controls for the firefighting system(s) shall be located in or as close as possible to the DLSS control station. USCG 16714 CG-ENG Policy Letter No. 01-16 of April

29, 2016, addresses several requirements for fire protection that may be identified by the PM in the system requirement documentation.

Efforts should be made to keep O_2 flasks and interconnecting hoses away from heat and sources of potential arcing (e.g., electrical outlets, light switches, and electric motors). Where high-pressure flasks and hoses are installed in an enclosed environment, an O_2 monitor with visual and audible alarms shall be placed in the vicinity of the flasks.

2-2.11.1.3 *Detection*

The DLSS operators, divers, occupants and support personnel can detect a fire quickly. If an automatic fire detection system is desired, it shall respond within 1 second after flame origination. Total response time of an automatic system from detection to activation of deluge systems shall not exceed 3 seconds. Automatic detectors must have proven reliability to activate the system when an actual flame is detected and not respond to false alarms which would needlessly drench occupants and equipment. A fire suppression system (FSS) must provide a visual and audible indication of system activation at the operator’s station, disconnect all ungrounded electrical circuits, and activate emergency lighting & communications.

2-2.11.1.4 *Extinguishing*

Each compartment of the PVHO shall be equipped with a suitable means of extinguishing a fire. The type and complexity of fire extinguishing method will depend on the size and complexity of the system. Fire extinguishing methods range from portable hyperbaric fire extinguishers or even wet towels in the case of small portable systems, to remote actuated deluge systems in the case of larger saturation diving complexes. Only fire extinguishers on the Authorized for Navy Use (ANU) list are to be used.

If a fixed fire extinguishing system is to be installed it shall meet the following requirements:

a. The system shall be capable of providing rapid and efficient distribution of the extinguishing agent to any part of the compartment under all foreseeable conditions.

b. The system shall be manually actuated. Means are to be provided to actuate the system from within and outside the PVHOs. Suitable safeguards are to be provided to prevent inadvertent actuation.

c. The extinguishing agent shall be fresh water only unless otherwise approved by the PM. Use of other extinguishing agents may require justification IAW section 2-2.4.1.

d. The system shall have the capability to discharge less than the total supply of the extinguishing agent.

2-2.12 COMPRESSORS

When selecting a compressor to supply breathing air, the output flow rate, pressure, and air purity are the primary considerations. For DLSSs, fixed and portable standalone compressor system manufacturers shall be selected from the ANU list IAW NAVSEAINST 10560.2, *Diving Equipment Authorized for Navy Use*, or approved by the PM.

It is the intent of the following sections to provide for the selection of high-pressure air compressor systems, ranging from 3,000 – 6,000 psi, which shall be used to provide breathing air to USN DLSSs for use during U.S. military diving operations. Included in the following sections are details for the selection of compressor blocks, purification systems, prime movers and other associated components. The specific compressor system must meet all the requirements of this specification to be eligible for USN use. Other compressors may be used with prior approval from the PM.

2-2.12.1 *General Considerations*

The compressor system shall provide sufficient gas to support the greatest demand. Compressors shall be designed and built to continuously provide air that meets the compressed air breathing requirements from NAVSEA SS521-AG-PRO-010. After fabrication, compressors shall have an air sample taken and tested by the manufacturer to ensure it meets the requirements of NAVSEA SS521-AG-PRO-010. Testing documentation shall be delivered along with the compressor. Following the initial sample done by the manufacturer, air samples shall be taken every six months and shall meet the requirements of NAVSEA SS521-AG-PRO-010.

The air compressor system shall be operable in ambient temperatures that are appropriate for the application for which the system is intended. For U.S. military diving operations, air compressor systems may be required to operate in extreme temperatures, which may range from 0°F (-17.78°C) to 115°F (46.11°C), therefore the operating environment should be taken into consideration when selecting system components. The assembled air compressor system shall be capable of operating in a marine environment, which entails being subject to harsh weather, salt spray and shipboard pitching and rolling of up to 15°.

All equipment components, including piping and tubing, shall be properly supported and protected to prevent damage from vibration during shipment, operation, or maintenance. All equipment components, including tubing and fittings, shall be installed in a neat and orderly arrangement, adapting to the contours of the system. All tubing and fittings shall be 316 or 304 series stainless steel; welded tubing and fittings shall be low carbon. Cadmium, magnesium or zinc plated components are not allowed to be used in components containing breathing air. Aluminum equipment and components shall be hard anodized to protect them from the salt air environment.

If oil lubricated, the compressor shall be fully lubricated with an appropriate system for the compressor size. Oil lubricated compressors should conform to MIL-PRF-17331 (2190TEP), *Lubricating Oil, Steam Turbine and Gear, Moderate Service*, for normal operations or MIL-PRF-17672, *Hydraulic Fluid, Petroleum, Inhibited,* (2135TH) for cold weather operations. Where a compressor manufacturer specifically recommends the use of a synthetic base oil in their compressor for production of breathing air, that manufacturer recommended synthetic base oil may be used in lieu of MIL-PRF-17331 or MIL-PRF-17672 oil. Manufacturers that require the use of specific synthetic compressor lubricating oil shall provide the Material Specification Data Sheet (MSDS) for the oil, showing that the lubricating oil will not volatilize, under normal operating conditions, into compounds that are noxious or toxic. A sight glass shall be provided to check the oil level and the oil drain for the compressor shall be piped to the outside of the frame.

Compressors generally supply output air at temperatures that are too high for breathing purposes. High temperatures associated with high-pressure air compressors may cause compressor lubricants to break down. Interstage coolers and aftercoolers may be required to bring the compressor discharge temperatures down to an acceptable level. Compressor blocks may be air or water cooled. During the cooling process, water vapor is condensed out of the air into condensate collectors. There shall be a method, either manual or automatic, to drain the condensate periodically during operation of the compressor.

High-pressure air compressors shall be equipped with a backpressure regulator located downstream of the moisture separator. Backpressure regulators shall be designed to maintain a specified minimum operating pressure (normally 1000 pounds per square inch, gauge (psig) or greater IAW the compressor manufacturer's requirements) at the compressor outlet. The backpressure regulator is used to seat the compressor piston rings and prevent excessive compressor lubricating oil from entering the system piping. Backpressure regulators should be located downstream of the moisture separator and upstream of the outlet filter. For compressors equipped with filtration tower packages, the backpressure regulator shall be installed downstream of the filtration package. Some compressor systems may additionally require a downstream pressure regulating valve to keep a set minimum backpressure on the compressor during operation and the manufacturer should specify if one is required.

The compressor air inlet system shall not restrict the flow of air to the compressor and shall be constructed of non-off gassing and breathing-compatible materials IAW this specification. The compressor shall be equipped with an intake filter with replaceable particulate element. This element shall be a dry-type, non-shedding type. Oil bath filters are not authorized in breathing gas systems. Consideration shall be given to the location of the compressor inlet in regards to possible contamination from machinery exhaust fumes or other airborne contaminants. The intake shall be diverted away from the engine on diesel driven systems.

2-2.12.2 *Purification Systems*

The purification system shall be equipped to purify air to a quality that meets or exceeds the requirements NAVSEA SS521-AG-PRO-010. Purification shall be achieved by moisture separation, dehumidification, and filters/cartridges. Such methods of purification include: mechanical separation of condensed oil and water droplets, removal of vaporous water by a desiccant or refrigeration, adsorption of oil vapor and elimination of noxious odors by activated carbon and conversion of CO to breathable levels of CO_2 by catalyst. It is recommended that a CO detector/alarm/shutdown device and automatic condensate drains be installed on compressors used to provide breathing air.

2-2.12.2.1 ***Moisture Separators***

All high-pressure air compressors require moisture separators to remove liquid contaminants from the compressed air. The moisture separator capacity is selected according to compressor output flow rate, output temperature, and the anticipated environment that the compressor will be used in. Separators shall be located downstream of any after coolers to trap the condensation resulting from the air cooling process and compressor oil that may enter the outlet gas stream. All separators must be provided with drain valves to remove collected liquid.

2-2.12.2.2 *Dehumidifiers*

The air purification system should provide a means of removing water vapor from the breathing air. Dehumidification is accomplished through the use of a desiccant or refrigeration.

2-2.12.2.3 *Filters/Cartridges*

All air or gas shall be filtered before reaching the diver. Compressor outlet filters are to be located downstream of the moisture separator and backpressure regulator and upstream of the divers gas distribution piping and components. For compressors equipped with filtration tower (air purification) packages, the filtration tower shall be installed upstream of the backpressure regulator. Bypass piping around filters is not permitted.

The air purification packages shall have a minimum working pressure equal to or greater than the pressure capability of the compressor. The purification system shall utilize replaceable cartridges and shall be designed such that replacement of the cartridges can be accomplished without disconnecting system piping. The design of the purification cartridge housings will be required to preclude the possibility of operating the system without cartridges installed or with improperly installed cartridges. A bleed valve shall be provided to vent the purification system and facilitate replacing the cartridges. A pressure maintaining valve and a check valve shall be installed immediately downstream of the purification system to increase the efficiency of the system by maintaining a positive back pressure. A check valve shall be supplied between the coalescing separator on the compressor's discharge line and the purification system to maintain the positive pressure in the purification system when the compressor shuts down. A relief valve shall be installed immediately downstream of the compressor outlet.

Air purification systems on compressors are required. An electronic purification monitor with warning light indicator, which activates prior to cartridge exhaustion and automatically shuts down the compressor when the cartridge is exhausted is strongly recommended.

2-2.12.3 *Prime Movers*

The compressor system shall be supplied with an electric motor or diesel engine of size suitable to ensure that the compressor can operate at its advertised maximum rated capacity. For electric driven units, motor voltage, phase and frequency shall be specified by the designer.

The compressor and prime mover shall be mounted on a common base with stationary units being vibration isolated from the system's main frame. The engine exhaust must be diverted away from the compressor intake. Units shall be supplied with a sliding base to facilitate tightening the drive belts manually. The belt drive shall be suitably guarded and rotation arrows shall be affixed in a conspicuous place on the compressor.

2-2.12.4 *Electrical Control and Instrument Panel*

Instrument and control panels shall include the following:

a. On/off selector switch.

b. Emergency stop.

c. Non-resettable hour meter.

d. Final discharge pressure gauge.

e. High-pressure shut down/alarm/indicator.

f. High temperature shutdown/alarm/indicator.

g. Final air temperature gauge.

h. Oil pressure gauge.

i. Low oil pressure shutdown/alarm/indicator.

j. UL listed panel.

A non-resettable hour meter shall be installed in the instrument panel to record the compressor's operating hours. The instrument panel shall also include a pressure gauge to monitor the compressor's oil pressure. An oil pressure failure switch should be visible and accessible. The compressor shall shut down and a fault light will illuminate should the compressor's oil pressure drop below the factory preset value during operation. The oil pressure switch is to be by-passed during start-up to permit the oil pump to achieve the normal operating pressure.

A temperature switch should be supplied on the discharge line of the final stage of compression; the compressor is to shut down and a fault light illuminate should the final stage discharge temperature exceed the tamper-proof set point during operation. A final discharge air temperature gauge, high temperature alarm (set to 25°F (-3.89°C) less than the high temperature shutdown), temperature shut down (set to the manufacturer's recommended maximum temperature) and fault light should be installed to ensure that volatized toxic/noxious material will not become entrapped in the air provided to the DLSS. All pressure gauges should meet the requirements of this specification.

Warning and alarm indicator lights should have a lamp test function built in. All fault lights should be red in color and installed on the instrument panel with each fault light being labeled with an engraved nameplate. All instrument panel mounted pressure gauges are to be 2 ½" diameter and be liquid filled. Gauges should also be labeled with an engraved nameplate.

2-2.12.5 *Frame and Cabinet Assembly*

The entire compressor system shall be mounted on a steel or aluminum frame that is sufficiently sized to adequately accommodate all of the system's components and also designed to withstand the static and dynamic loads of the system. The frame is required to adequately support the system for all reasonable transportation loads. If necessary, the system shall be enclosed in a suitable cabinet design. At a minimum, the compressor shall be protected by a frame when a weather resistant box is not installed.

A fork lift slot and lifting eyes shall be installed if the compressor weighs more than 200 lbs. For compressors weighing less than 200 lbs a handle shall be incorporated into the frame design for portability.

Frames shall have adequate corrosion protection to protect them from the salt air environment. All welded frame components shall have continuous fillet or butt welds to prevent salt water intrusion and accelerated corrosion. The arrangement of components on the frame or in the enclosure shall permit unrestricted cooling air flow to the compressor and prime mover, while also providing access for operation, inspection and maintenance. The purification system shall be mounted to the same frame assembly as the compressor.

2-3 DESIGN REQUIREMENTS FOR SPECIFIC TYPES OF SYSTEMS

2-3.1 BREATHING APPARATUS

2-3.1.1 *General*

Diver breathing apparatus provides a breathable atmosphere directly to a diver via a mouthpiece, mask, hood, or helmet while either in the water or in a dry hyperbaric environment. The breathing gases delivered to the diver may vary from air, O_2 or a mixture of gases depending on the application requirements. The breathing apparatus may be a sub-system or component part of larger DLSS or be a stand-alone self-contained system. The complexity of the diver breathing apparatus vary from simple air supplied ventilated breathing masks to complex, electronically controlled closed-circuit mixed gas UBA designs. Regardless of a diver's breathing apparatus application, type, or complexity all must provide a safe and reliable supply of the proper breathing gas to the user.

Some existing breathing apparatus have been approved for USN operational use by being officially ANU IAW NAVSEAINST 10560.2. ANU apparatus have undergone design safety reviews, test and evaluation to ensure diver safety. In cases where a new diving or hyperbaric system design is planned to use an existing ANU apparatus as a component part, the application of the ANU apparatus shall be verified to be within the approved scope of use and limitations or additional analysis/testing shall verify the apparatuses expanded requirements for the new application.

2-3.1.2 *Requirements*

2-3.1.2.1 ***General Requirements***

For new breathing apparatus designs or new applications of existing apparatus, the PM shall provide the designer with the specific performance requirements which shall be documented in the breathing apparatus design parameters. If requirements are not provided or if additional information is required, the designer shall request the information from the PM. The requirements set a foundation for the operating conditions that the design shall meet. Design parameters shall addresses the following as applicable:

a. Worst-case dive profile system including maximum depth, maximum duration, maximum work rates.

b. Environmental temperature range (including operational & storage).

c. Required breathing gas including diluent.

d. Removal of CO_2.

e. Interface specifications with gas supplied and/or charging system such as min/max pressures, float/charging rate rates.

f. Communication Interface.

g. Max/min weight and buoyancy and trim.

h. Work of breathing/Static lung loading/peak inhalation/exhalation pressure. Refer to Navy Experimental Diving Unit (NEDU) TM 15-01, *U.S. Navy Unmanned Test Methods and Performance Limits for Underwater Breathing Apparatus*.

i. Applicable gas supply and gas concertation status display/alarms.

j. Back-up gas supply.

k. Vision.

l. Thermal protection requirements.

m. User comfort.

n. Protection against hazardous atmosphere/contaminates.

o. Reliability requirements.

p. Maintenance, serviceability and operation requirements.

q. Face or head seal considerations for range of individuals.

The hazard assessment of breathing apparatus shall be used to identify/develop additional requirements and safety mitigations.

2-3.1.2.2 ***Open Circuit Systems***

Open circuit systems are a type of DLSS which the user breathes in a gas mixture from a fresh gas supply and then exhales expelled gas to the surrounding environment without recycling the exhaled breathing gas. Typically fresh gas is supplied to the diver from a reservoir through a regulator, such as SCUBA regulators or a recompression chamber's BIBs masks. Diver gas consumption is the main controlling factor for sizing gas supply requirements. Gas supplies supporting open circuit systems shall be designed for the most demanding mission. System design shall account for diver metabolic rate, oxygen and diluent consumption, depth profile and duration (normal and emergency), environmental conditions, ventilation rates and estimated system leakage and design margins. Analyses and/or calculations shall be provided to the program manager for approval.

For some open circuit DLSS, carbon dioxide production becomes a driving system design consideration. Inspired CO2 levels in small volume systems, such as UBAs, can rise rapidly with exertion. Adequate flow shall be available at all times to keep the partial pressure of CO2 below 15.2 Torr (15.2 millimeter of mercury (mmHg), 2.0 kPa) with a CO2 production rate of up to 2.5 L (STPD)/min for each diver. Historical systems have demonstrated that a continuous flow of 170 actual L/m, STPD (6 actual cubic feet per minute (ACFM)) per diver can adequately reduce CO2 levels with more flow needed if intermittent ventilation is used. Analyses and/or calculations shall be provided to the program manager for approval.

2-3.1.2.3 ***Closed and Semi-Closed Circuit Systems***

Closed and semi-closed circuit systems are a type of DLSS where either all or a portion of the exhaled gas is scrubbed and re-circulated back to the diver on inhalation. Closed and semi-closed circuit systems require the use of CO_2 scrubbers to remove CO_2 from the expired gas. In closed systems, all gas is scrubbed prior to being returned to the diver along with makeup oxygen and diluent gases as necessary. In semi-closed systems, most of the diver's breathing gas is recirculated while injecting a small percentage of the total circuit flow with a fresh gas supply. Gas supplies and CO_2 scrubbers supporting closed and semi-closed circuit systems shall be designed for the most demanding mission. System design shall account for diver metabolic rate and CO_2 production, oxygen and diluent consumption, depth profile and duration (normal and emergency), environmental conditions, ventilation rates, CO_2 scrubbing capability (e.g., canister duration) and estimated system leakage and design margins. Analyses and/or calculations shall be provided to the program manager for approval.

2-3.1.2.3.1 ***Closed Circuit Systems Oxygen (O_2) Requirements***

Closed circuit DLSS shall provide enough oxygen and flow rate to support the most demanding mission and shall, at a minimum, account for diver metabolic rate, depth profile and duration, system leakage, injection rate and design margins. The DLSS shall maintain partial pressure of oxygen within an acceptable range and with minimal overshoot or transient. Analyses and/or calculations shall be provided to the program manager for approval. Historical systems calculations of O_2 consumption may assist in informing an initial estimate: consumption was estimated by adding the volume consumed for each anticipated level of exertion or estimated by assuming a mean value of 2.0 L/min (STPD) per diver for missions of less than 12 hours and 1.0 L/min (STPD) per diver for longer missions.

2-3.1.2.3.2 ***Semi-Closed Circuit Oxygen (O_2) Requirements***

Semi-closed circuit DLSS shall provide enough oxygen and flow rate to support the most demanding mission and shall, at a minimum, account for diver metabolic rate, depth profile and duration, system leakage, injection rate and design margins. Throughout a dive, the DLSS shall maintain partial pressure of oxygen within an acceptable range and with minimal overshoot or transient. Analyses and/or calculations shall be provided to the program manager for approval.

2-3.1.2.3.3 ***Diluent Gas Requirements***

Some DLSS or UBAs require the use of a diluent gas. A diluent is that gas which is used to maintain gas volume or system pressure in the breathing loop and not depleted by metabolic consumption. Nitrogen and helium are the most common diluents used. Diluents are generally needed on descent to increase system pressure or at depth to offset loss due to leakage while maintaining a set metabolic oxygen partial pressure. Diluent gas storage capacity shall be able to support all design parameters to include number of personnel, mission duration, depth and temperature, number of descents, estimated system leakage and design margins. Storage capacity analyses and/or calculations shall be provided to the program manager for approval.

2-3.1.2.4 ***Automated Gas Control Requirements***

If automated computer control is used to directly or indirectly control to breathing gas supply in a breathing apparatus then the requirements of section 2-2.5.10.4 for software IV&V is required.

2-3.1.3 *Testing*

Due to the performance factors of breathing apparatus being both very complex and extremely sensitive to small fabrication details, modeling and calculations predicting of breathing apparatus performance are not consider sufficient to assess design suitability. Testing of production representative prototype or actual production apparatus is required to verify performance requirements. The testing for breathing apparatus shall be documented and conducted IAW a test plan approved by the PM.

Breathing apparatus testing will generally include using a breathing machine, which can provide standardized respiratory volume, and breathing rate challenges and generate breathing data. Requirements such as user interface and comfort are generally evaluated with approved manned tests.

2-3.2 SURFACE SUPPLIED DIVING SYSTEM (SSDS)

SSDS are designed to provide air and/or mixed gas from a gas source above the water surface, via an umbilical, to a diver in the water column. The breathing gas must be provided at sufficient pressure to overcome the water pressure at the maximum depth of the system (over bottom pressure) and the pressure losses due to flow through the diving hose and system piping. SSDS shall include independent primary and secondary gas supplies. The breathing gas supply requirements depend upon specific factors of each dive such as depth, duration, level of work, number of divers, and type of DLSS being used. The PM should provide the designer with the number of divers, the UBA that will be utilized and the worst case dive profile including the concept of operation and environmental conditions that the system will have to support. If this information is not provided or if additional information is required, the designer shall request the information from the PM in writing.

2-3.2.1 *Umbilical Requirements*

See section 2-2.5.8.1.

2-3.2.2 *Breathing Gas Supply Pressure and Flow Requirements*

Different SSDS require different flow rates and over bottom pressures. An open-circuit gas supply system must have a flow capacity (in ACFM) that provides sufficient ventilation at depth to maintain acceptable CO_2 levels in the mask or helmet. CO_2 levels must be kept within safe limits during normal work, heavy work, and emergencies. In order to supply the diver with an adequate gas flow, the breathing gas source must deliver at sufficient pressure to overcome the bottom seawater pressure and the pressure drop through the system hoses and valves.

Unless free flow is required, the SSDS should be designed with consideration to the demand peak flow of the required UBA. It is the responsibility of the designer to ensure that the flow rate and pressure requirements are met.

2-3.2.2.1 *Mixed Gas Surface Supplied Diving System (SSDS) Supply Requirements*

For mixed-gas SSDS, the gas supply system for the divers shall be designed so that gas mixtures (HeO_2, NITROX, O_2, air, etc.) can be supplied to the divers as required. All mixed-gas SSDS require a primary and secondary source of breathing gas that consists of required mixed gases in cylinder banks and an emergency supply of air from compressors or high-pressure flasks. Each system must be able to support the gas flow and pressure requirements of the specified equipment. A CONOPS is a document describing the characteristics of a proposed system from the viewpoint of an individual who will use that system.

The primary gas supply must be sized to meet the consumption rate of the designated number of divers, including the standby diver, for the duration of the dive. The secondary gas supply must be able to support recovery operations of all divers and equipment if the primary system fails during the worst-case time (e.g., immediately prior to completing the planned bottom time at maximum depth when decompression obligations are the greatest).

2-3.2.2.2 *Standby Diver Air Requirements*

For USN diving operations, a standby diver with a tender is required for all diving operations. The primary and secondary air requirements (pressure, flow, and volume) for the standby diver shall be the same as those for in water divers. Gas supply requirements shall be based on all divers including standby for the planned mission and including emergency considerations.

2-3.3 RECOMPRESSION CHAMBER

All recompression chambers, as defined in ASME PVHO-1, shall be designed and built to conform with ASME PVHO-1 and this specification. Chambers shall be designed to provide the amount and mixture of gases required by the USN Treatment Tables unless otherwise specified in the User Design Specification.

2-3.3.1 *Gas Supply*

2-3.3.1.1 *Air Supply*

A recompression chamber system must have separate primary and secondary air supply systems that satisfy NAVSEA SS521-AG-PRO-010, Table 18-3. The purpose of this requirement is to ensure that the recompression chamber system at a minimum, is capable of conducting a USN Treatment Table 6A (TT6A) with all extensions (for information on treatment tables see NAVSEA SS521-AG-PRO-010). If the system is to be used for a more extensive or rigorous treatment protocol, the designer shall request that the PM provide the most demanding treatment protocol that the system is to be designed for. Calculations shall be provided to the PM that clearly explain the rationale used in determining the required air volumes.

The basic rules for ventilation are presented below. These rules permit rapid computation of the ACFM required under different conditions as measured at chamber pressure. The rules are designed to ensure that the effective concentration of CO_2 will not exceed 1.5% (11.4 mmHg) and that when O_2 is being used, the percentage of O_2 in the chamber will not exceed 25%.

a. When air is breathed, provide 2 ACFM for a diver at rest and 4 ACFM for a diver who is not at rest (i.e., a tender actively taking care of a patient).

b. When O_2 is breathed from the BIBS, provide 12.5 ACFM for a diver at rest and 25 ACFM for a diver who is not at rest. When these ventilation rates are used, no additional ventilation is required for personnel breathing air. These ventilation rates only apply to the number of people breathing O_2 and are only used when no BIBS dump system is installed.

c. If a BIBS dump system is used for O_2 breathing, the ventilation rate for air breathing may be used.

d. If portable or installed O_2 and CO_2 monitoring systems are available, ventilation may be adjusted to maintain the O_2 level below 25% by volume and the CO_2 level below 1.5% SEV.

These rules assume that there is good circulation of air in the chamber during ventilation. If circulation is poor, the rules may be inadequate. It is the responsibility of the designer to ensure that ventilation of the chamber is adequate. Locating the inlet near one end of the chamber and the outlet near the other end improves ventilation.

2-3.3.1.2 ***Oxygen (O_2) Supply***

See section 2-2.1.1.2.

2-3.3.1.3 ***Pressurization and Ventilation Rate Requirements***

Pressurization rate, also known as descent rate, is the rate of a chamber's internal pressure increases and is normally expressed in units of fsw/min. The chamber's pressurization rate is a function of chamber volume, gas supply pressure/volume, piping/valve/component sizes and should be calculated using the minimum required gas supply pressure.

The chamber ventilation rate is the rate of chamber gas exchanged into and out of the chamber at a constant chamber depth. Chamber ventilation allows for refreshing the chamber's atmosphere suppling clean gas and exhausting gas with excess CO_2 or O_2 as well as providing cooling.

Unless otherwise specified by the PM the pressurization and ventilation rates shall meet the requirements of NAVSEA SS521-AG-PRO-010 or specific mission requirements approved by the PM.

2-3.3.1.4 ***In estimating the total gas requirement when using ventilation to control CO_2, assume a CO_2 production rate of 1.8 L/min (STPD) per diver for short missions, and 0.9 L/min (STPD) per diver for missions longer than 12 hours. Short bursts of activity will not significantly raise chamber CO_2. Environmental Control System (ECS)***

Typical ECS for recompression chambers other than a saturation DLSS consists of a CO_2 scrubber installed within the chamber which circulates chamber atmosphere through the scrubber by venturi (pneumatically driven) or an electric fan. In addition to the scrubber, an air conditioning unit is recommended to be installed to help maintain the chamber atmosphere at comfortable levels. Though an ECS is not required for recompression chamber operations, it may be beneficial in order to reduce the amount of stored gas required to operate the chamber. If an ECS is to be installed, the designer should consider sizing the CO_2 scrubber to maximize the mean time between canister break-through while minimizing the amount of space required within the chamber to house the unit. The internal components of the air conditioning unit (if provided) should be appropriately sized to maximize their efficiency at maintaining temperature and humidity at comfortable levels; as well as controlling the buildup of condensate (i.e. a drip pan installed, or ability to drain condensate to the external). If a CO_2 scrubber is installed, then the chamber must be fitted within instrumentation for monitoring CO_2; the ability to monitor temperature and humidity is also recommended.

2-3.4 SATURATION DIVERS LIFE SUPPORT SYSTEM (DLSS)

For design of a saturation DLSS, in addition to the general requirements herein, the PM will provide the designer with a detailed document to outline system technical and performance requirements. An example of such a document is SAT-PGDM-001S-01, *System Requirements for the Saturation Fly Away Diving System (SAT-FADS)*.

To the maximum extent practical the saturation system design should leverage off of commercial classification society rules.

2-3.5 HANDLING SYSTEMS

Handling systems include any weight handling systems that are used to launch and recover divers through the air/sea interface from a support platform. These systems may consist of a simple block and tackle arrangement, using a davit and capstan to raise and lower a diver stage, or may consist of a complex A-frame system that is used to launch and recover manned tethered underwater vehicles, such as a saturation diving bell.

DLSS handling equipment includes, but is not limited to, cranes, booms, davits, and A-frames as well as their associated winching and rigging components. Hydraulic, electrical, and pneumatic subsystems are also considered part of the handling system.

The typical handling system for launching divers today consists of an A-frame structure pinned to a foundation structure to allow rotation and controlled by hydraulic rams for booming inboard and outboard. A lift wire winch mounted to the foundation with winch wire reeved through a sheave on center of the A-frame cross-beam to connect to the diver stage or open bell, and a guide wire winch mounted to the foundation with winch wire that is double reeved through a clump weight below the stage/bell and dead ended to the A-frame cross-beam. The rams and winches are supplied power from a hydraulic power unit (HPU) fed through a common control console. More complex designs may incorporate powered sheaves, umbilical winch (if using a diving bell), twin baskets, or heave compensation. The A-frame design may not suit every diving mission, but is preferred to a stage from a single davit because of the added stability and control provided by the guide wire running on both sides of the stage/bell.

2-3.5.1 *Design Criteria and Guidelines*

This section provides guidelines and criteria for the design and analysis of handling system components and associated structures. Alternatively, the USN may elect to impose commercial design criteria administered by a commercial classification society (i.e., ABS, Det Norske Veritas-Germanischer Lloyd (DNV-GL), etc.)

2-3.5.1.1 ***Types of Loads***

The initial step in designing any handling system is to determine the design load that the system will encounter. The design load is derived from a combination of forces under worst-case operating conditions. Components should be sized according to the greatest design load, or combination of loadings that will be encountered. The following loads and forces should be considered when designing handling systems:

a. Asymmetric loads. When sizing structural members for handling systems that employ more than one load-carrying member to support their payload, consideration should be given to factors that might cause asymmetric loading. Such factors affecting the DLSS that would result in asymmetric loading include, but are not limited to, the following: external water, free surface effects in the internal tanks, a shift in ballast, and external payloads.

b. Dynamic loads. In addition to the load generated by lifting the normal rated capacity of the handling system, dynamic forces due to wave-induced motions on the support platform must also be considered. Analysis should be conducted IAW DOD-STD-1399 (NAVY), *Interface Standard for Shipboard Systems, Section 301A Ship Motion and Attitude (Metric),* or equivalent, unless support platform motions are known. If support platform motions have been measured at sea, or have been determined through the application of proven computer programs, the results can be used in lieu of DOD-STD-1399 (NAVY), Section 301A.

c. Dead loads. The minimum dead load consists of the weight of the structural parts of the handling system and materials permanently attached to the structure.

d. Wind forces. The wind loads on the projected area of the handling system structure and on the DLSS, appropriate to the design conditions, are to be considered.

e. Heave added mass, damping and drag. The added mass damping coefficients for the structure being moved through the water column, and sensitivity to lowering and raising speed and heave compensation should be considered.

f. Maximum forces. Structural members are to be sized using the appropriate loads and FS. The general requirements in applying FS to all USN weight handling systems that perform manned lifts are presented in section 2-3.5.2.1.2.

2-3.5.1.2 ***Environmental Considerations***

Handling systems are subjected to extremely harsh and powerful environmental factors that significantly impact the operational and maintenance characteristics of the system. Environmental factors which should be considered in the system design parameters are: sea state, air temperature, water temperature, precipitation (rain and snow), ice, wind velocity, currents, and the corrosive effects of the salt water environment.

2-3.5.1.2.1 ***Sea State***

For the sea state specified in Table 12 (see section 2-4.1.3.1), the uppermost value for the wave heights of the significant wave or the 1/10th highest wave should be taken as the design wave. The period of maximum energy of the sea spectrum should be chosen as the design period (see section 2-4.1.3.1). The effect of wave slap to components exposed to the sea must be considered (see section 2-4.1.3.3).

2-3.5.1.2.2 ***Air and Water Temperature***

The maximum and minimum design operating temperatures of both the air and water must be taken into account during handling system design. This is particularly important for hydraulic systems where hydraulic fluid may become too viscous in extreme cold or lose its lubricating properties in extreme heat. Additionally, extremely cold air temperatures may affect the ductility of some metals and render structural members unsafe if not adequately designed.

2-3.5.1.2.3 ***Precipitation***

The effect of rain and snow can be dramatic on topside equipment not designed for it. Electrical connectors, junction boxes and motors not rated for harsh outside environments often fail in shipboard service. All pivoting or sliding load bearing surfaces should either be sealed from the weather or be designed to permit thorough inspections and be provided with an adequate number of lubrication fittings. Waterproof grease is required for these applications. Also, steels must have a protective coating of paint designed for a salt spray environment.

2-3.5.1.2.4 ***Wind Velocity and Wave Slap***

Side loads may be induced in the handling system by high winds and wave slap. This loading may be significant if either the DLSS or the handling system itself has a large surface area. The designer shall account for possible wind related and wave slap effects in the system design.

2-3.5.1.2.5 ***Ocean Currents***

In the same manner that wind affects the handling system topside, ocean currents affect any submerged components of the DLSS. Drag effects caused by ocean currents may be significant depending on the geometry of the DLSS and/or any submerged portions of the handling system. Drag effects shall be taken into account in the design of the handling system.

2-3.5.1.3 ***System Considerations***

The operation of the handling system is an integral part of the total DLSS, and as such, is limited by the coordination of personnel on deck and interface of the DLSS, handling system, and support vessel. For safe and efficient launch and recovery evolutions, the following items must be addressed when developing a handling system:

a. Positive control. The motion of the DLSS during launch and recovery operations must be under positive control at all times.

b. Fail-safe. A provision designed to automatically stop or safely control any motion when a hydraulic or electrical failure occurs. The handling system shall be provided with interlocks, safety devices, and protective devices so that it will be fail-safe. (i.e. spring actuated, hydraulic release disc brakes, hydraulic counter balance valves, end of travel limit switches or hard stops, etc.).

c. Motion effects. The physical location of the handling system on board the support ship should be such that the effects of the ship's motions on the DLSS during handling evolutions are minimized.

d. Weight. The weight of the handling system should be minimized to limit the weight added to the support vessel and the adverse effects on its sea keeping ability.

e. Shock mitigation. Dynamic motions of the support ship at-sea can cause shock loads to the DLSS and its personnel through the handling system. Motion compensating devices shall be considered to minimize these shock loads.

f. Environmental effects. The handling system shall be adequately designed and maintained to withstand the elements and dynamic loads imposed by heavy weather.

g. Recovery speed. The ability of the handling system to control the equipment through the air-sea interface at sufficient speed to avoid excessive wave action.

h. Mating. For PTCs (diving bells) there shall be a method of restraining the movement of the PTC during mating to the DDC.

2-3.5.1.4 ***Human Engineering and Operational Design Considerations***

Handling systems are designed to transport personnel in a restricted and hazardous environment under the direct supervision and control of support personnel. A human engineering evaluation should be conducted to ensure the ability of support personnel to control and supervise the safe and coordinated movement of the DLSS. The following are some critical areas that should be addressed in the evaluation (see section 2-1.6):

a. Hazardous exposure. Due to the nature of handling system operations, some evolutions will be inherently hazardous. However, hazards should be eliminated whenever possible. There should be a minimum of support personnel exposed to hazardous operations during handling evolutions

b. Coordination and control. Safe and timely operation of handling systems requires precise control and coordination of all personnel involved. The system arrangement should be simple and require minimal supervision. In addition, there must be clear communications between the handling support personnel, the support ship personnel responsible for maneuvering the ship, and the diving supervisor.

c. Monitoring equipment status. Control and support personnel responsible for the operation of the handling system should have access to monitoring devices to enable them to evaluate the status of the equipment. This is to ensure the system is operating within its capability limits (e.g., speed, load, pressure, temperature). These factors, along with the observed sea state, can then be evaluated to determine their effect on the operating parameters of the DLSS. Video monitoring should be considered when necessary to eliminate blind spots and provide full field of view of launch and recovery evolutions at the control station.

d. Manning. Minimizing the number of personnel required to operate and maintain the system should be considered.

2-3.5.1.5 ***Emergency Conditions and Reduced Operating Capability***

The handling system shall be designed to minimize the effects of component failures. To identify and define the failures, and to determine how to resolve them, a hazard analysis shall be performed (see section 2-1.4.2). The hazard analysis can also be used to evaluate the system's capability to continue to operate and safely recover DLSS personnel. All handling system components shall be operable in sea states specified by the mission profile. In the event of a control console failure, an alternate or backup means of system operation is required.

2-3.5.2 *Design Requirements*

Load bearing component requirements are discussed in section 2-3.5.2.1 and cover structural, rigging, and machinery component criteria; hydraulic and pneumatic system requirements are discussed in section 2-3.5.2.2; and power requirements and controls are discussed in section 2-3.5.2.3. Design analyses for handling systems must be based on recognized engineering analytical methods and standards. Loads imposed by the environmental conditions specified in the requirements documentation must be included in the analyses. The design of all load bearing and load controlling elements must be submitted to the PM for review and approval.

2-3.5.2.1 ***Load Bearing Component Requirements***

All elements of the handling system that support the weight of the DLSS when occupied by personnel shall be designed, fabricated, and maintained IAW the following sections.

2-3.5.2.1.1 ***Load Bearing Component Design***

Design analyses must indicate forces, loads, shears, and moments for all structural members, welds, and connections including interaction forces with the supporting deck and ropes. Components shall be analyzed considering tensile, compressive, bending, shear, torsional, and cyclical loadings. Structural members subject to pure compression shall be evaluated IAW DDS-100-4, *Strength of Structural Members*, or AISC 325-11, *Steel Construction Manual*. The allowable stresses and safety factors used shall be revised as required to meet the safety factors specified in section 2-3.5.2.1.2. Analyses for rigging gear must also be included in the design documentation.

Calculations shall take into account the wet and dry weight of the DLSS, entrained water weight, added mass effects (if applicable), crew and payload weights, the dynamic affects due to the motion of the support ship and DLSS at sea, and the effects of the wind and wave forces. The support platform's motions shall be analyzed for the maximum operating sea conditions, sea state or swells specified in the requirements documentation.

The worst-case loading due to heave, roll, pitch, or any combination thereof, shall be used in the calculations.

2-3.5.2.1.2 ***Design Factors***

Design factors for handling systems are based on USN engineering practices, and are related to the material used and the conditions of the operating environment conditions. Relatively high design factors are necessary, even though the materials and their properties are well known, because they are used in uncertain environments and are subjected to uncertain stresses. Material justification will be required IAW section 2-2.4 to certify handling system components within the SOC, even when the design meets the requirements of this section. Items requiring material justification will be identified by the PM during the conceptual design phase and during design reviews.

a. Structural and machinery components. The design factor for all structural and machinery components shall be 3 on material yield strength, or 5 on material ultimate tensile strength, whichever is greater. The design factor shall be based on the design load of the component.

b. Rigging and Fittings.

Design factors for wire and synthetic rope are given in Table 11. These factors shall be based on the design load of the handling system and the specified nominal breaking strength for wire rope or average breaking strength for synthetic rope.

Table 11: Design Factors for Rigging

Material Application	Critical Component	Non-critical Component	D/d Ratio[1]
Wire rope standing rigging	5	5	-
Wire rope running rigging	6	5	18:1
Rotation resistant wire rope - standard construction	7[2]	6	34:1
Rotation resistant wire rope - formed through a die	6	5	18:1
Synthetic rope[3] - Braided	7	5	8:1
Synthetic rope[3] - Twisted/Plaited	7	5	10:1
Synthetic rope[3] - Aramid (Kevlar®)	6	5	20:1

(1) Ratio of sheave or drum diameter (D) to wire rope or synthetic line diameter (d). The ratios provided are for guidance only. It is strongly recommended to consult with the rope manufactures for determining the minimum sheave or drum diameter for the size of rope selected.
(2) This FS is for rotation resistant wire rope supporting a free hanging load. If a guideline system is used that does not allow the load to rotate, this FS can be reduced to six. Under no circumstances shall the for wire FS ropes be less than six for manned lift systems.
(3) When wet, the safety factor for nylon rope shall be applied to the breaking strength minus 15% unless a suitable marine overlay finish is used.

c. If galvanized wire rope is used, reduce the nominal breaking strength by 10% to account for the effects of galvanizing.

NOTE: If drawn galvanized wire is used, no reduction in breaking strength is necessary.

d. For wire or synthetic rope end fittings:

1) Design factor for fittings shall be equal to or greater than the commercial rating for the DLSS design load.

2) End fittings shall be constructed of carbon or stainless steel only, unless otherwise approved by the PM.

3) Reduce the nominal breaking strength of the wire based on the joint efficiency of the end termination used.

2-3.5.2.1.3 ***Submission of Drawings and Calculations for Load Bearing Components***

If the handling system is certified to a commercial classification society standard (i.e. ABS, DNV-GL, etc.), submission of documentation required by class rules will satisfy the requirements sited below. As a minimum, the following documentation shall be submitted:

a. Design analyses and calculations that provide the basis for the system design, including all assumptions governing the design. The analyses must include the following when results of computer calculations are submitted: input data, summaries of input and program assumptions, output data, and summaries of conclusions drawn from the output data.

b. General arrangements showing equipment locations and the rated capacity of the system.

c. Details showing sizes, sections, and locations of all structural members.

d. Details of all reeving components showing sizes, safe working loads, materials, manufacturer, and part number.

e. For synthetic rope assembly: length, size, nominal diameter, material, construction, average breaking strength, manufacturer, and specification (if applicable); and end termination type, manufacturer and material(s).

f. For wire rope assembly: length, size, nominal diameter, construction, minimum breaking strength, preformed or non-preformed, lay, finish, grade (improved plow steel (IPS), extra improved plow steel (EIPS), or traction steel), core type, lubrication, manufacturer, end termination type, manufacturer and material(s).

g. Foundation and support arrangements.

h. Structural material specifications.

i. Drawings must show all welding proposed for the principal parts of the structure. The welding process, filler metal, and joint designs are to be shown on detail drawings or in separate specifications.

j. The areas to be nondestructively inspected and methods of inspection are to be shown on the drawings, or in separate specifications.

k. Winch drum and flange details.

l. Type and size of bolts.

m. Reeving diagram.

n. Testing requirements and procedures.

o. List of all materials and fittings, for all components.

p. The components within the SOC must be identified.

2-3.5.2.2 ***Hydraulic and Pneumatic System Requirements***

Hydraulic systems shall be designed and tested IAW the requirements of this subsection. These requirements can also pertain to pneumatic systems; however, it is recommended the designer discuss any unique requirements with the PM prior to initial design efforts.

2-3.5.2.2.1 ***Hydraulic and Pneumatic System Design***

Hydraulic and pneumatic systems and components shall be designed to operate the rated load at the rated speed when the differential pressure across the actuator is not more than two-thirds of the MOP. This will ensure the handling system will operate efficiently under dynamic conditions at sea as well as when undergoing load testing.

Hydraulic and pneumatic systems and components shall be designed IAW MIL-STD-2193, *Hydraulic System Components, Ship*; with piping, valves, fittings and gasket material selected from MIL-STD-777, (or MIL-STD-438 for submarine applications), ASME B31.1 or an approved industrial standard. NSTM Chapter 556, *Hydraulic Equipment (Power Transmission and Control)*; NSTM Chapter 505; or NSTM Chapter 551 can be used as guidance.

Hydraulic and pneumatic systems and components shall be designed such that they are fail-safe and the brake on any winches, traction machines, cranes, or elevators shall set and stop motion if there is a loss of power.

The USN may also elect to design the handling system IAW the requirements of 46 CFR, Chapter 1, Subchapter F, *Marine Engineering*, or an approved industrial standard. However, applicable parts and subparts of the commercial specification must be defined by the designer and PM prior to initiating the design.

The following requirements shall also be met:

a. The MOP shall not exceed pump or compressor and motor manufacturer's continuous ratings.

b. Pump or compressor drive electric motor current shall not exceed nameplate rating at the design load.

If the handling system is certified to a commercial classification society standard (i.e. ABS, DNV-GL, etc.), submission of documentation required by class rules, will satisfy the requirements sited below. As a minimum, the following documentation shall be submitted:

a. Design analyses and calculations that provide the basis for the system design, including all assumptions governing the design. The analyses must include the following when results of computer calculations are submitted: input data, summaries of input and program assumptions, output data, and summaries of conclusions drawn from the output data.

b. Plan showing manufacturer's ratings, braking capabilities and power drive requirements for hydraulic equipment.

c. Plan showing details on emergency source of power.

d. Hydraulic schematic that shows:

    1) Relief valve settings.

    2) Material specifications, size, and pressure ratings of all pipe fittings, valves, flexible hoses, pumps, filters, and accumulators.

    3) Testing and cleaning requirements.

e. Drawings and design calculations, or a technical data sheet from the manufacturer is required for each hydraulic or pneumatic cylinder to identify its burst pressure.

f. Testing procedures.

g. The components within the SOC must be identified.

2-3.5.2.3 *Electrical Power Requirements and Controls*

Attention should be given to each component's electrical power requirements in view of the total system power drain on the support vessel or independent power source. When the design/configuration requires the DLSS to be lifted from the water in order for the DLSS operator(s) to disembark, two separate and independent power sources shall be provided to support operation of the handling system.

2-3.5.2.3.1 *Electrical System Design*

Design and installation of the handling system electrical power distribution system shall be IAW the requirements of 46 CFR, Chapter 1, Subchapter J, *Electrical Engineering*, or an approved industrial standard.

Electrical systems and components shall be designed such that they are fail-safe and the brake on any winches, traction machines, cranes, or elevators shall set and stop motion if there is a loss of power.

The controls shall be service-proven, and meet U.S. Coast Guard regulations or other authoritative specification.

a. All controls used during the normal handling system operating cycle shall be located within easy reach of the operator while at the operator's station.

Control levers shall return automatically to their center (neutral) position when released.

Control operations and functions shall be clearly marked and easily visible from the operator station.

Control system plans and information submitted to the PM, for review and approval, shall be IAW 46 CFR, Chapter 1, Subchapter J, Subpart 110.25-1, as determined to be applicable by the designer. The components within the SOC must be identified.

2-4 SPECIFIC DESIGN CONSIDERATIONS

2-4.1 NAVAL ARCHITECTURE DESIGN

At minimum, the following naval architectural requirements shall be considered: static and dynamic stability (both transverse and longitudinal), the conditions of list and trim, the strength of the DLSS, and the dynamic consideration of stability and motion in a seaway. Section 301A of DOD-STD-1399 (NAVY) is the USN's standard for shipboard motion and attitude and is referenced throughout this specification. The designer may have to consider commercial classification society loading requirements if the DLSS may be used on other vessels of opportunity (VOO).

2-4.1.1 *Stability and Equilibrium*

Where applicable, the designer shall demonstrate (by both calculation and by tests) that the DLSS has adequate static and dynamic stability under the various loadings and conditions encompassed by the design (e.g., surfaced, submerged, and all possible emergency surfacing conditions). Any limiting conditions for sea state, winds, temperatures, water density variations, and so forth, must be identified. Extreme loading conditions and the resulting stability shall also be analyzed. For example, some DLSSs jettison relatively large weights to achieve buoyancy in an emergency. There is an attendant risk that significant weights might be jettisoned inadvertently while performing normal operations. The designer must show that the safety of DLSS personnel would not be jeopardized under these conditions. Detailed information on the criteria for stability and reserve buoyancy must be furnished to operating personnel to permit proper control of loading and to avoid danger of capsizing or foundering in heavy seas or swells. The designer shall also demonstrate that the DLSS is adequate to withstand such factors as wave slap and that the strength of the structure of the DLSS is adequate in the surfaced condition. Protection shall be provided against foundering.

a. If the DLSS is manned while being handled, it must remain stable while being removed from the sea to its cradled position aboard a ship or on another platform. The designer must demonstrate that the DLSS and its handling system are capable of passing through the sea/air interface without damage to the DLSS or its occupants.

b. The designer shall identify the systems and components that provide any necessary stability and buoyancy for the DLSS under operating conditions. A failure analysis shall be provided by the designer to address the consequences of a failure or loss of displacement by any of the systems and buoyancy components. The adequacy of specific materials must be justified as discussed in section 2-2.4.

c. Some DLSSs (e.g., tethered submersibles, saturation DLSSs) are operated while either permanently or temporarily mounted on a surface platform. In these cases, the surface platform shall provide sufficient stability so that the divers or occupants, while in the water, will not be endangered because support personnel on the surface are unable to provide vital functions in a seaway.

d. The designer must show that the structural strength of the DLSS in a seaway does not endanger the safety of personnel. A DLSS may also operate in close proximity to the ocean bottom, which means that there will be a hazard of striking objects, grounding, or even deliberate bottoming. There is also the hazard of bumping against or colliding with the surface support ship. The designer must show that a DLSS can withstand such incidents or demonstrate that sufficient precautions can be taken to avoid such situations.

2-4.1.1.1 *Inclining Experiments and Trim Dives for Submersibles and Submerged Habitats*

See section 3-6.17 for requirements.

2-4.1.1.2 *Additional Conditions*

The designer must demonstrate the adequacy of all unique conditions of the DLSS. Any unique condition (e.g., mating a DLSS to a DDC) must be capable of being performed under all the specified sea state conditions without endangering the embarked personnel. If the DLSS is to be secured to a host ship or other platform, it must be designed to have adequate attachment capability to withstand the sea state conditions specified by the PM.

2-4.1.2 *System Arrangement and Layout*

The designer shall identify and document the operational requirements for the system arrangement and layout. The layout of the DLSS shall ensure protection from incidental damage and personnel hazards and allow accessibility for safe operation, maintenance, and inspection. The DLSS should be located in a safe area with respect to fire, explosion, weather and sea state. The DLSS shall be located so that diving operations will not be affected by support platform propulsion or mooring.

2-4.1.3 *Loading on At-Sea Systems*

Diving support platform or submersible motion in a seaway includes roll, pitch, yaw, surge, sway and heave. Diving support platform or submersible attitude caused by loading, wind, or control surface forces includes list, trim, and heel. Diving support platform or submersible motion and ship attitude generate forces which are both static and dynamic in nature and exert a cumulative effect in terms of gravitational and dynamic acceleration. Dynamic effects vary, depending upon the location in the diving support platform or submersible, and increase with distance from the diving support platform or submersible motion axes. Static effects (e.g., permanent list) are uniform throughout the diving support platform or submersible.

These forces must be considered in their combined “worst-case” value and applied to the design of the DLSS so that when exposed to such conditions, its structure, appurtenances, systems or equipment will perform IAW design requirements. The designer should refer to Section 301A of DOD-STD-1399 (NAVY) for guidance in determining loading factors and overall design limits.

2-4.1.3.1 ***Sea State***

Sea state is a measurement of the severity of sea conditions, inclusive of wave height, period, and energy distribution with wave frequency and direction. Sea conditions generate ship motions, producing dynamic forces. These dynamic forces depend on ship motion amplitudes and periods, which depend upon the support platform’s responsiveness to the characteristics of the seaway.

The designer must show that the DLSS is safe for operation and emergency egress under the specified operating and survivability sea states. The designer shall also demonstrate that the DLSS is adequate to withstand such forces as wave slap and that the strength of the DLSS's structure is adequate in the surfaced condition. The system shall be designed to operate in specified sea state. The designer shall show that the DLSS is safe for emergency recovery/egress in the survivability condition. The sea state definitions that shall be used can be found in Section 301A of DOD-STD-1399 (NAVY) and in Table 12 below. More information can be found in the ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities.

Table 12: Sea State Definitions

Sea State	Significant Wave Height
3	0.5 – 1.25 m (1.6 – 4.1 ft)
4	1.25 – 2.5 m (4.1 – 8.2 ft)
5	2.5 – 4.0 (8.2 – 13.1 ft)
6	4.0 – 6.0 m (13.1 - 19.7 ft)
7	6.0 – 9.0 m (19.7 – 29.5 ft)
8	9.0 – 14 m (29.5 – 45.5 ft)
> 8	> 14 m (> 45.5 ft)

2-4.1.3.2 ***Survivability***

Survivability refers to a system in a sea state that is more severe than the sea states in which the system is intended to operate. The designer shall show that the DLSS is safe for emergency recovery/egress in the survivability condition. After sea conditions subside, mission essential systems should be serviceable and the DLSS is capable of continuing operations without returning to port for repairs.

2-4.1.3.3 ***Wave Slap***

All supporting structures and foundations that are directly mounted to a ship's deck and exposed directly to the waves, shall be designed to withstand a wave slap loading of 500 pounds per square foot. Structures that are not directly deck mounted or not directly exposed to the waves (including control and auxiliary equipment vans, external doors, panels, and appurtenances) shall be designed to withstand wave slap loads of 200 pounds per square foot. All equipment exposed to the air/water interface shall be designed to withstand a wave slap loading of 1,000 pounds per square foot.

2-4.1.3.4 *Ships Motion*

Unless otherwise specified, the DLSS shall be capable of operating under the following conditions:

a. When the support platform is permanently trimmed down by the bow or stern as much as 5° from the normal horizontal plane.

b. When the support platform is permanently listed up to 15° from normal vertical plane.

c. When the support platform is pitching 10° up or down from its normal horizontal plane.

d. When the support platform is rolling up to 45° to either side of the vertical plane.

2-4.2 TRANSPORTABILITY

The designer shall demonstrate, through the use of appropriate design calculations, that the DLSS meets transportability requirements to be used as specified in the system performance specification (e.g., types of trucks, cargo aircraft and VOOs). At a minimum, portable DLSSs should meet the following specification for the desired modes of transportability:

a. The DLSS shall be designed and equipped to provide all necessary handling and shipping equipment, rigging, and mechanisms necessary to interface with air/ground transports and associated handling equipment.

b. The DLSS shall be designed to withstand vibration loading as shown in Figures 514.6C-1 (*US Highway Truck)*, 514.6C-6 (*Jet Aircraft Cargo)* and 514.6D-9 (*Shipboard Random*) of MIL-STD-810, *Test Method Standard for Environmental Engineering Considerations and Laboratory Tests*.

c. For sea transportation, the DLSS must be configured for shipping by either containerizing or by direct attachment or tie down to the deck. The system in the transport mode should meet the requirements of sections 2-4.1.3, 2-4.1.3.1, 2-4.1.3.3, 2-4.1.3.4, and 2-4.2, when exposed to the environmental conditions.

d. For ground transportation, the DLSS must be capable of being re-configured into modules sized for shipping by U.S. over-the-road truck transport, without the need for special permits or routes on public roads rated for truck transport IAW 23 CFR Part 658, *Truck Size and Weight Regulations*.

e. For air transportation, the DLSS must be capable of being re-configured to air transport pallets or other suitable means compatible with the U.S. Air Force 463L Air Cargo System, using MIL-STD-1791, *Design for Internal Aerial Delivery in Fixed Wing Aircraft*, for guidance. All gas storage flasks (storage vessels) requiring pressurization during transport shall be designed and fabricated to permit gas cylinders to be flown while charged IAW the DOT under 49 CFR and using MIL-STD-1791 for guidance. The system and its components as well as the aircraft itself shall not be damaged, nor shall subsequent operational performance be degraded as a result of being subjected to the following loads (see MIL-STD-1791) applied independently when in the Transport Mode:

1) Forward 3.0 g.
2) Aft 1.5 g.
3) Lateral 1.5 g.
4) Up 2.0 g.
5) Down 4.5 g.

2-5 DESIGN DOCUMENTATION

The subsections herein are intended to summarize the guidance and requirements on submission of design documentation which correspond to sections 2-1 and section 2-2. Communication between the PM and the designer is paramount to ensuring the information is appropriately captured in the design data package. The PM shall not dictate how this information is formatted, but they should ensure that the content of the submissions contains sufficient detail to support an independent design review.

2-5.1 DESIGN PARAMETERS

Design parameters shall set a foundation for the operating conditions that the design shall meet. Design parameters shall be documented and submitted to the PM at the PDR that addresses the following as applicable:

a. System safety engineering approach including:
   1) PHA/identification of anticipated hazards.
   2) Design safety factors.
b. Depth/pressure limitations.
c. Type of life-support equipment.
d. System/sub-system descriptions.
e. Manning requirements.
f. Design life and service period (usual life, number of cycles, etc.).

g. Ambient operating and storage conditions (temperature, humidity, wind, etc.).
h. Transportation requirements (mechanical shock, vibrations, etc.).
i. Reliability and maintainability requirements.
j. Limits for breathing gas composition, pressure, flow, temperature, and humidity.
k. Specification and justification of breathing gas contamination limits.
l. Personnel temperature limits for both normal and emergency operating conditions.
m. Physiological considerations of occupants/divers/operators.
n. Emergency equipment requirements and capabilities.
o. Communications requirements.
p. Applicable industry design codes and standards.
q. Special design considerations.

2-5.2 DESIGN ANALYSIS

A complete and thorough design analysis shall be provided to the PM for approval concurrence. The design analysis shall consist of formal design calculations and a complete stress analysis as explained below. The design analysis must also correlate the highest demands (depth, time, number of occupants, current, sea state, temperature, etc.) with the design requirements. The analysis should address:

a. Hydrostatic test loads.
b. Transport and handling.
c. Static stresses.
d. Operating pressures.
e. Thermal stress.
f. Shock, impact, and vibration.
g. Dynamic loads.
h. Fatigue analysis.
i. Piping systems.
j. Human factors.
k. Noise abatement.
l. Environmental loads.

m. Corrosion.

n. Electrical.

If design qualification testing is required, a detailed test procedure and a complete test report documenting the test data, any variance to the original test plan, any outstanding issues, and a test summary to assist stakeholders to take a decision.

2-5.3 DESIGN CALCULATIONS

Calculations will be submitted to the PM for approval that demonstrate the adequacy of design in terms of the design parameters of the diving or hyperbaric system, and with all assumptions clearly stated. Components, equipment and systems shall be designed to properly operate at the highest demanding design conditions. Information will be submitted in sufficient detail to permit independent analysis of the design. Documentation shall be tabulated to ensure that the information completely covers the design. A Design Package, based on the design calculations required IAW section 2-2.2, shall be submitted as directed.

2-5.4 SYSTEM DRAWINGS

a. Drawings shall be provided according to the project schedule that are adequate to support technical design reviews. The level of drawing detail shall reflect the level of design maturity that has been attained at the time of each design review. The number and type of drawings required for an adequate technical design review will be determined by the function and complexity of the subsystem being reviewed. In addition to showing system and subsystem configuration, drawings normally required to support a technical design review, must have adequate detail to show material, fabrication, cleaning, testing and special assembly requirements. In most cases where electrical systems are being reviewed, system schematic diagrams with the above information are acceptable. All piping subsystems shall utilize JIDs as the primary subsystem fabrication drawings as detailed in section 2-2.3.2 and are required for review of the final piping subsystem design. Where critical equipment such as recompression chambers are being evaluated, assembly drawings are required for the final design review. The following list outlines the drawings required at minimum as part of the design documentation package: For large complex systems with many drawings a drawing tree may be required.

b. Structural, mechanical and electrical fabrication drawings, including BOM.

c. Weld maps and JIDs.

d. Assembly and arrangement drawings.

e. Schematic drawings with sufficient detail to be used when developing and performing OPs/EPs. These drawings are required to support development of SOC Boundaries. These types of drawings shall include:

   1) For piping – system and subsystem schematics with sufficient detail to support design reviews, flow and capacity calculations, hazard analysis, fabrication, testing, and any special assembly requirements. Necessary details include valve and component nomenclature, material, flow arrows, direction of component installation, relief valve set points, regulator settings, test pressures and cleanliness levels are all required. Sufficient detail is required to support in-kind component replacement, as well as to document as-built condition. Schematics shall include applicable drawing notes and a mechanical component legends with symbols and nomenclature unless provided by separate drawing or reference.

   2) For electrical – system and subsystem schematics with sufficient detail to support design reviews, power/load calculations, hazard analysis, fabrication, testing, special assembly requirements. Sufficient detail is required to support in-kind component replacement, as well as to document as-built condition. Schematics shall include breaker trip points and other electrical component rating details. Schematics shall include applicable drawing notes and an electrical component legend with symbols and nomenclature unless provided by separate drawing or reference.

2-5.5 JUSTIFICATION OF MATERIALS AND NEW APPLICATIONS

When material justification is required IAW section 2-2.4, it is the responsibility of the PM to provide guidance to the designer on how the information should be submitted, which will be dependent on the complexity and application of the system, and the quantity and type(s) of qualification testing required to prove out the design.

2-5.6 TOXIC AND FLAMMABLE SAFETY ANALYSIS

A list of all potentially toxic and/or flammable materials to be used during construction, or to be installed or used in operating and maintaining the DLSS shall be submitted to the PM for approval. Toxic materials may be paints, insulation, adhesives, sealants, gaskets, bedding, clothing, lubricants, equipment, instruments, fittings or other items that could give off noxious fumes at operating pressures and temperatures or at any temperature below 200°F (93.33°C). Flammable materials are those which will ignite or explode from an electric spark or when heated and will continue burning in the presence of air or in any O_2-enriched atmosphere.

Flammable materials shall be evaluated under both normal and emergency atmospheric conditions. More information on toxicity and flammability can be found in 0.

2-5.7 HAZARD ANALYSIS

A hazard analysis that thoroughly evaluates the effects of all possible failures shall be submitted to the PM for approval. MIL-STD-882, provides an acceptable set of guidelines for the conduct of hazard analyses. The application and tailoring guidelines given in MIL-STD-882 should be carefully followed in order to make the hazard analysis no more complex than is necessary to prove the safety of the design. The hazard analysis is typically performed assuming that only one failure occurs at a time – not multiple failures occurring at the same time.

2-5.8 OPERATION AND EMERGENCY PROCEDURES (OPS/EP)

OPs/EPs shall be developed by the designer in a preliminary state to capture system functionality to satisfy system design requirements.

2-5.9 DESIGN VERIFICATION AND VALIDATION

Verification and Validation (V&V) are steps to determine if a system or component satisfies its operational and system-level requirements. The purpose of V&V is to provide direct evidence of progress toward ultimately meeting the system requirements. The V&V results ensure that the product will pass the system technical and performance criteria. Eventually, these results prove that the product performs as specified and indicate how well it will satisfy its operational needs. The main difference between verification and validation is that Verification is focused on making sure system-level requirements are met, while Validation focuses on making sure the system is performing the way it was designed and intended. The Verification Process confirms that a system element meets design-to or build-to specifications. Throughout the system’s life cycle, design solutions at all levels of the physical architecture are verified through a cost-effective combination of analysis, examination, demonstration, and testing, all of which can be aided by modeling and simulation. The Validation Process answers the question of, “Is it the right solution to the problem?” As such, this process works in conjunction with the Stakeholder Requirements, Requirements Analysis, and Architecture and Design processes. It evaluates the requirements, functional and physical architectures, and implementation.

A design verification and validation matrix shall be submitted to the PM and may include the following as agreed upon between the PM and designer:

a. Verification documentation as agreed upon with the PM.

b. Notes and other such evidence of completion of PDR and CDR.

c. Drawing approval.

d. CMP IAW section 2-1.2.

2-5.10 COMMAND AND CONTROL (C2) DOCUMENTATION

Design C2 documentation shall be developed as required by the PM. The C2 design documentation shall include:

a. System CONOPS.

b. A description of the control, monitoring, and COMMS.

c. A C2 functional block diagram.

PART 3 FABRICATION

Part 3 provides the fabrication specifications necessary to comply with NAVSEA standards for fabrication of USN diving and manned hyperbaric systems. Changes/revisions will be made to the document to include advances in technology of DLSS and development of new testing methods.

3-1 ADMINISTRATIVE REQUIREMENTS

The administrative requirements for the fabrication, assembly, and testing of diving or hyperbaric components and systems is described below.

3-1.1 FABRICATION REVIEWS

The builder shall prepare for and host Fabrication Review Meetings with the PM and other USN personnel. All Fabrication Reviews shall be held IAW a schedule agreed upon by the PM's and the builder. The builder shall have available all necessary data and personnel so that the reviews may be conducted in a timely and efficient manner. The primary emphasis of the Fabrication Reviews will be on cost, schedule, technical issues, and any risk areas. At a minimum, each Fabrication Review will cover the following issues:

a. Program Schedule Update to include Status of Deliverables.

b. Program Technical Update to include CM Issues.

c. Program Cost Update to include Subcontractor Management Issues.

d. QA and Certification Issues.

e. Testing Results and Related Issues.

f. Action Item Review.

g. Walk-through of the Available HW.

3-1.1.1 *Material Certification Review (MCR)*

The final fabrication review will be conducted by the USN SCA (NAVSEA 00C4) as an on-site material survey/audit IAW NAVSEA SS521-AA-MAN-010. This may be done in stages for various CIs or subsystems. Prior to acceptance of the diving or hyperbaric system by the PM, it must be certified by the SCA. When the builder is ready for final delivery (i.e., the system is completely built, applicable testing is complete and all of the paperwork is complete) they will schedule with the PM for the SCA to visit the facility and conduct the review. The SCA will conduct an in-depth inspection of the equipment and paperwork to ensure that they are in compliance with this specification, the system drawings, and any other applicable contract documents.

Any discrepancies from this specification, the drawings, or other applicable contract documents shall be reported by the SCA to the PM.

3-1.2 DEVIATIONS/CHANGES

Any deviations from this specification, the system drawings, or any other contract document relating to the fabrication of the hyperbaric or DLSS shall be approved in writing by the PM. Any changes must be requested by the builder in writing to the PM and written approval must be given to the builder prior to making the change. The deviation request must include all technical, schedule and cost implications due to the change.

3-1.3 CONFLICTS

Any conflicts between this document, the system drawings, and any other contract documents shall be brought to the attention of the PM. The PM shall resolve all conflicts and shall provide the resolution in writing to the builder.

3-2 QUALITY ASSURANCE (QA)

The builder shall submit, for approval, a QA plan that outlines the contractor’s QA program. The QA plan shall be approved by the PM prior to the start of fabrication by the builder. The contractor's QA plan shall meet the intent of ANSI/ISO/ASQ Q9000 Series, *Quality Management Standards*, or other national or international recognized standard. As a minimum content, the QA plan shall:

a. Disclose the contractor’s planned approach for fulfilling the requirements of the chosen quality standard.

b. Include a description of the organization that will fulfill the quality program requirements for this project, with a definition of the responsibility and authority of each functional element.

c. Identify all of the contractor's documented policies and procedures, which implement the quality program.

d. Summarize the objective or purpose of each policy and procedure shall be given.

e. Delineate where inspection, audit, and other controls are applied to assure compliance with the contract quality requirements.

f. Identify each Controlled Work Procedure (CWP), and inspection instruction applicable to the contract hardware and show where it is applied.

g. Describe the method by which the plan will be applied to subcontractors.

The QA plan is intended to assure that the completed DLSS has been fabricated IAW all required specifications, that traceability for all materials requiring system certification can be accomplished, and that standards of workmanship comply with requirements. The QA plan shall result in records to verify compliance with contract requirements. Records are the major forms of objective quality evidence (OQE) to verify compliance with contract requirements. Records shall be complete, signed, dated, and made available to PM for review. The builder is responsible to make arrangements for the retention, storage and retrieval of all QA records until they are delivered to the PM. Recorded data shall include, but is not limited to:

a. CM and drawing control. The contractor shall implement an internal CM system, as described in section 2-1.2, for the control of production drawings, production documentation, and production specifications related to manufacturing of the system. Production specifications include process control procedures and work instructions. The CM procedures shall include a clearly defined and documented system of change and revision.

b. Material control. The material control program shall show that materials and components installed in the system are the same as received, inspected and as specified in the system drawings.

c. Fabrication and manufacturing control. The contractor's quality program shall result in production records as required by system drawings and invoked manufacturing specifications and this specification.

d. Cleanliness control.

e. Testing and inspection control.

3-2.1 SCOPE OF CERTIFICATION (SOC)

If not provided during the design process, the builder shall submit to the PM an initial description of all portions of the system and its ancillary equipment that are expected to fall within the SOC as defined in section 2-1.5. This submittal shall be within a period agreed upon by the PM. For a list of systems and equipment typically requiring inclusion in the SOC boundary, see NAVSEA SS521-AA-MAN-010.

3-2.2 CONTROLLED WORK PROCEDURES (CWP)

CWPs must define the scope of work and provide production personnel with step-by-step instructions on how the work is to be accomplished. These instructions are required wherever fabrication, assembly, cleaning and/or testing of components or systems, within the SOC boundaries, are to be performed. When CWPs are written to accomplish repairs, maintenance or modifications, they shall state the specific reason for performing the work. CWPs shall also provide all inspection, test, and retest requirements and any warnings or cautions which must be observed while performing the work. CWPs shall be generated, reviewed and approved prior to commencing work. Where work procedures already exist (e.g., technical manuals, standard process instructions, approved drawings, preventive maintenance system (PMS)), the specific paragraphs from those documents shall be called out in the CWP. Procedures shall be signed with printed name and signature by the person responsible for completing the work, inspections and retest of the system or component. Any change to the scope of work being performed shall cause a revision to the CWP to be issued. All CWPs shall be made available to the PM for review during on-site surveys.

The fabrication and assembly of the DLSS within the scope of the certification boundaries shall be accomplished IAW the highest standards of workmanship and fabrication processes. This will entail the use of qualified mechanics, written work procedures for such processes as welding, cleaning and prefabrication of subassemblies, and assembly sequence planning.

The builder shall verify the system has been built IAW the JID. Verification shall be on the Fluid Mechanical System Installation Record form, see SUPPLIMENTAL DOCUMENT. As a minimum, the following information should be recorded:

a. Verify that the system has been installed IAW the JID (see section 2-2.3.2).

b. Inspect all mechanical joints for completeness.

c. Inspect all welded joints for completeness.

d. Inspect the surfaces of piping and components for possible damage during fabrication, such as gouges, dents, arc strikes, weld spatter, etc.

e. Inspect each component for completeness (e.g., valves for presence of handwheels).

f. Inspect the system for presence of required label plates, tags, etc.

If the system is determined to be incomplete or damaged, it is the builder’s responsibility to repair or complete the fabrication prior to the material certification review (MCR) and delivery.

3-2.3 RECORDS

The builder shall keep complete and auditable records of purchases, inspections, fabrication, and testing of the system. The records must meet the intent of data sheet examples in SUPPLEMENTAL DOCUMENT. The records shall be filed by suitable means and shall be traceable to each individual component. An access system shall be developed by which the records can be quickly obtained for inspection by the PM. The records described in the following paragraphs shall be originated and retained as documentation to support material certification of the DLSS. Two (2) copies of all records, pertaining to items contained within the SOC, are required to be submitted to the PM at the time of the MCR (section 3-2.3.5.1.1).

3-2.3.1 *Material Traceability Records*

a. Copies of purchase documents.

Vendor's certificates of material and equipment, certifying compliance with applicable specifications and containing detailed chemical, physical, and test data as required by this specification, the system drawings, and other contract documents.

NOTE: Documentation (purchase documents, vendor certificates, etc.) for consumable items used in the fabrication of the DLSS (such as filler metals for welding) must be provided with the material certification paperwork.

b. Receipt inspection records.

c. Builder-conducted chemical or physical tests on material or equipment.

d. Gauge and relief valve calibration sheets.

e. Approved waivers or deviations.

3-2.3.2 *Fabrication Records*

a. Copies of all CWPs and process instructions.

b. Welding procedure qualification records (PQR) and approval documents.

c. Welder or welder operator qualification records, including, current eye exam near field acuity record and quarterly process use record, if applicable.

d. Installation, storage, and handling procedures.

e. In-process surveillance procedures and records.

f. Welding joint history records.

g. NDE reports.

h. NDE inspector certification documents, including, method, level, date of certification, and annual eye exam record.

i. Mechanical joint fabrication records.

j. Hose logs.

k. Fluid mechanical system installation record.

l. Records of all installation checks.

3-2.3.3 *Cleanliness*

a. Cleaning procedure(s).

b. builder's cleaning data sheets (required for both MIL-STD-1330 and MIL-STD-1622 cleaning).

c. Vendor's certification of cleanliness of items supplied in a clean condition.

d. Vendor's cleaning data sheets, tags, or stickers for items supplied in a clean condition (required for both MIL-STD-1330 and MIL-STD-1622 cleaning).

e. Hose and other non-metallic off-gassing test records or documented prior history of use in a similar application.

f. Air purity testing documentation.

3-2.3.4 *Additional Systems-Level Tests*

Additional systems-level integration and operational testing shall be completed and approved prior to final acceptance or certification of the acquired system. The vendor or builder shall provide approved procedures and signed copies of testing data sheets demonstrating that testing was complete, verified and validated by appropriate technical, quality assurance and management personnel, as applicable. For additional details, see sections 3-6.2 and 3-6.3 on System Testing Program and Test Categories requirements. The following systems-level tests shall be completed unless otherwise approved by the program manager:

a. Factory Acceptance Testing (FAT)

b. Prototype First Article Testing (PFT)

c. Pre-Installation Testing (PIT)

d. Pre-Operational Testing (POT)

e. System Operational Testing (SOT)

f. System Integration Testing (SIT)

3-2.3.5 *Record Format*

Records (data sheets) used and provided by the builder shall provide the required OQE to determine that required design, fabrication, cleaning, and testing meets the specification.

Sample forms (data sheets) are provided in Appendix G and are recommended for use by the builder in compiling the Material Certification Data Book. These sheets include the information that would be required by the PM on each form. The builder may modify these forms or use their own forms as they see fit but the same information shall be required as specified throughout this document.

3-2.3.5.1 ***Material Certification Data Book***

3-2.3.5.1.1 ***Material Certification Review (MCR)***

Prior to acceptance of each new system, it will undergo a MCR. This review shall be conducted at the builder's site and must be satisfactorily completed prior to acceptance by the PM. Additional requirements and explanation of the MCR can be found in section 3-1.1.1. The PM or their representative will thoroughly review the Material Certification Data Book and inspect the equipment during this process in order to ensure that it meets the requirement of this specification, the drawings and any other applicable contract documents.

3-2.3.5.1.2 ***Material Certification Data Requirements***

This section prescribes the guidance for the presentation of documents and record keeping of the tests and procedures required by this specification. These records/documents will be made available to the government during progress meetings and other times as agreed to in the contract. They will also be completed and provided to the appropriate government representatives for the MCR and delivered with the product.

The JID serves as the MCR road map. Identification of individual components and their respective material documentation shall flow from and to the JID. Each system JID will be supported by a completed material certification package. Table 13 is a sample table of contents required to support each JID (non-PVHO). Table 14 is a sample table of contents for Material Certification Data Book (PVHO only).

NOTE: When a purchase order covers multiple components that are used in systems covered by more than one JID, copies of the purchase orders and documentation received with the goods shall be

included in each JID section (i.e., air supply, BIBS supply, exhaust, etc.).

The forms provided are pro forma and are not meant to be exclusive of other data. What is important is that the data be organized and provided in the manner set forth to demonstrate compliance with the record keeping requirements of this specification, the system drawings, and all other applicable contract documents.

Table 13: Sample Table of Contents for Material Certification Data Book (non-PVHO)

Section	Information	Supporting Documentation
1.0	System (JID #)	Approved JID
1.1	Welded Joints	Weld Joint History Record NDE Inspection Reports as required provided by Inspector Welding Procedure Welder's PQR Inspectors Qualification and Vision Test Record
1.2	Mechanical Joints	Mechanical Joint Assembly Record
1.3	Hydrostatic Test and Cleaning Data	
1.3.1	Fittings	Component Cleaning and Testing Record
1.3.2	Tubing	Component Cleaning and Testing Record
1.3.3	Gauges	Component Cleaning and Testing Record Gauge Calibration Form
1.3.4	Valves	Component Cleaning and Testing Record Relief Valve Test Data
1.3.5	O-Rings	Component Cleaning and Testing Record
1.4	System Testing	System Test Plan
1.4.1	Hydrostatic Test	Hydrostatic Test Record as appropriate
1.4.2	Pressure Drop Test	Drop Test Record as appropriate
1.4.3	Gas Analysis	Gas Analyses Certificate as appropriate
1.4.4	Electrical Component Test Data	Electrical Component Test Record as appropriate
1.5	Material Certifications	
1.5.1	Fittings	Purchase Order Receipt Inspection as appropriate A CoC can be provided for multiple issues but must reference all items it covers
1.5.2	Tubing	Same as above
1.5.3	Gauges	Same as above
1.5.4	Valves	Same as above
1.5.5	Miscellaneous	

NOTE: A purchase order and a receipt inspection shall be provided in the data book(s) for all components, materials and equipment within the SOC used in fabricating a diving or hyperbaric system.

3.2.3.5.1.2.1 ***Pressure Vessel for Human Occupants (PVHO)***

Material certification data for PVHO built IAW ASME BPVC Section VIII-1 shall be segregated from other data and submitted IAW the requirements of this section.

Table 14: Sample Table of Contents for Material Certification Data Book (PVHO only)

Section	Information	Supporting Documentation
2.1	Manufacturer Data Reports	ASME BPVC Section VIII-1 Form U-1 ASME BPVC Section VIII-1 Supplementary Form U-4 ASME BPVC Section VIII-1 Form U2 or U2A ASME PVHO-1 Form GR-1 ASME PVHO-1 Form VP-1 through VP-5
2.2	QA/Quality Control Documentation	Inspection and Test Plan (ITP) In Process (Assembly/Visual Dimension) Inspection Record Non Conformance (Head Thickness checks) Plate Edge Thickness Report
2.3	Material Certification	Purchase Orders Receipt Inspections Material Certificates Chemicals and Physicals Charpy Impact Test Records
2.4	Welding Information	Weld Map Weld Joint History Record Weld Procedures Welder Qualifications Welding Consumable Batch Certs Heat Treatment Records
2.5	Non Destructive Testing	NDE Reports (as referenced in Weld Register) Radiographs from Radiographic Inspections (RT)
2.6	Pressure Testing	Hydrostatic Test Certificates Dimensional Inspection Record Load Test Record
2.7	Design Records	Design Report Design Calculations
2.8	Drawings	

NOTE: A purchase order and a receipt inspection shall be provided in the data book(s) for all components, materials and equipment used in fabricating a diving or hyperbaric system.

3-3 PROCUREMENT

3-3.1 GENERAL

It is critical that the procurement of materials for diving and hyperbaric systems is done correctly. If the documentation of the equipment and materials is incomplete, the system will not be accepted by the PM. Builders should pay special attention when issuing purchase orders to vendors and ensure that all the documentation that is required for the specific components being ordered are explicitly requested.

3-3.2 PURCHASE DOCUMENTS

The requisition or purchase order shall specify the applicable military, federal, or commercial material/equipment specification to which the item is being procured, and shall identify each item which requires marking and traceability. The specific documentation, which must accompany the shipment, shall be described in the purchase document as follows:

a. Where material traceability is required the material must be traceable by a unique number (heat number, lot/batch number, etc.) to documentation which accompanies the shipment.

b. Chemical test: Where chemical analysis is required, the purchase document shall request a certified quantitative chemical analysis which includes the actual numerical values of every chemical element contained in the tested material.

c. Physical tests: Where physical test documentation is required, the purchase document shall request that the physical property test document include the actual numerical value for each mechanical property specified (e.g., yield, elongation).

NOTE: The material test report (MTR) documents that the chemical analysis and mechanical properties are in conformance with a specification. The following materials require an MTR: gas cylinder materials, PVHO shell materials, pressure retaining plates or penetrators used on PVHO shells, PVHO viewports and any materials that are required by the drawings or other contract documents to be supplied with an MTR.

d. Heat treatment: Where heat treatment is specified, the purchase document shall request a furnace chart and certified statement that the required heat treatment has been accomplished and shall include actual numerical value for temperature and time.

e. Cure dates: O-rings (with the exception of Viton) require the submittal of cure dates for the material, as well as composition of material.

f. Lot numbers: The paperwork shall clearly indicate which items are part of which lot number and the results of any testing done on the lot shall be traceable to the lot number.

g. Tests: Where tests such as valve seat leak tests, hydrostatic tests, operational tests, off-gassing test, etc. are required, the purchase order shall request that the certification accompanying the shipment list actual parameters such as pressure, temperature, duration, and etc. of the test, the results of those tests, test instrument calibration data, and the dated signature of the person performing the work.

h. Cleanliness: Where manufactured parts are supplied pre-cleaned, the purchase document shall request the appropriate cleaning procedure used and individual cleaning certification documentation for each item.

Descriptive language on all purchase documents shall be clear and detailed so no doubt is left regarding exactly what material is being furnished or will be used. All procurement documents shall be serialized (i.e., assigned a unique number). An example purchase order form that may be used for all purchases is given in Appendix G.

3-3.2.1 *Traceability Exclusions*

The following items are specifically excluded from traceability between the documentation and material. Any testing, cleaning, or other information that is required for the material or item is still required to be provided, but the item does not need to include any markings that specifically identify it and link it to the purchase order:

a. Packing glands (follower and retainers, integral, flanged, or separated).

b. Gaskets and similar sealing members used in conjunction with joining two pressure boundary parts.

c. Valve soft goods (see section 3-3.2.1.1).

3-3.2.1.1 ***Valve Seal Exclusions***

O-rings, seals, gaskets and other soft goods that are part of a standard (non-custom) valve from a qualified vendor, IAW the QA plan, do not require individual testing, cleanliness, or cure date documentation. Where valves are supplied for use in O_2, NITROX, or HeO_2 systems, verification of seal/soft good compatibility is required on the purchase order. The valve assembly as a whole is to be provided with testing and cleaning documentation that shall suffice for the parts of the valve. The valve as a whole is required to be traceable to all documentation that accompanies the shipment.

3-3.3 RECEIPT INSPECTION

This paragraph establishes the minimum requirements for inspection of material/equipment which is delivered by a vendor to the builder and requires traceability. The recommended form to use when conducting the receipt inspection is shown in Appendix G.

a. All material shall be inspected upon receipt for shipping damage, completeness, proper type, and for presence of all documentation (certification, etc.) required by the purchase document and that it meets the requirements set forth in the system drawing.

b. Each package in each shipment shall be inspected for proper identity, including the vendor's name or trademark, material type, material grade, nominal size, and vendor lot or traceability number.

c. Each document required by the purchase document shall be inspected to assure it is properly completed, it contains the proper information (i.e., the material specification and each chemical element and mechanical test required are reported), and that it is traceable to the material received.

d. Material/equipment received in a clean condition shall be examined upon receipt for proper packaging and seals which will prevent contamination. Where partial disassembly is required to verify that parts have been properly identified, they shall be examined under clean conditions and resealed or immediately installed. In addition, cleaning documents shall be inspected to ensure that they are correct, complete, signed and traceable to the individual component.

e. Material which has been found acceptable shall have identification affixed containing the identification number on pipe, fitting, component, etc., together with a short description (e.g., 1-inch diameter corrosion resistant steel (CRES) pipe, 1-inch globe valve), the date of inspection, and the inspector's identifying number and name. The tag shall remain with the item until final installation in the system.

f. Dimensional inspection of critical areas shall be accomplished to ensure fit-up tolerances will meet specifications.

g. Some items may require non-destructive testing (NDT) of piping and components to determine quality and acceptability of materials.

3-4 MATERIAL

3-4.1 GENERAL

All material used in the fabrication or repair of diving and hyperbaric systems shall be IAW the system drawings, specification and other contract documents. Any deviation shall be requested by the builder, in writing, and submitted to the PM. All deviations must be approved by the PM in writing prior to implementation by the builder.

3-4.2 TRACEABILITY

All items or materials within the SOC shall be marked to provide traceability from the items to the associated documentation and vice versa.

3-4.2.1 *Marking of Material*

3-4.2.1.1 ***Scope of Certification (SOC) Piping Systems***

The joint identification numbers (JIN) from the JID's shall be permanently marked on the components located within the SOC. Items, such as piping or small fittings that are not large enough to be marked, shall have tags affixed that provide the JIN. If tags are used, they shall be affixed in such a way that it is clear which joint the JIN is applicable to.

3-4.2.1.2 ***Types of Permanent Markings***

The acceptable types of permanent markings are:

a. Electrochemical etching: The electrolyte used shall be compatible with the material to be marked.

b. Raised markings: Raised identification markings that are cast or forged integrally with the part are acceptable.

c. Nameplates: The method of attaching nameplates to parts shall be indicated in applicable drawings and shall minimize stress concentrations. Nameplates, where welded, shall be welded IAW the applicable equipment specifications. Welds on or to pressure boundaries of P-1 piping systems are considered P-1 welds IAW NAVSEA S9074-AR-GIB-010/278, and are required to meet all quality requirements including inspections and pressure tests after welding label plates.

d. Die stamping: Permanent identification marking by this method shall be limited only to carbon and to ferrous and nonferrous materials except for Ni-Cu, nickel-chromium-iron, copper-nickel (CuNi), and cobalt base alloys. Only round bottom, low stress die stamps may be used and impression depths shall be limited to 0.010 inch. The wall thickness shall not be reduced below the minimum wall thickness required by the applicable drawing or specification. The marking shall be applied to a low stress area, a flange rim, or an integral pad or boss. Tube and pipe shall not be marked by this method.

e. Vibrating marking tools: The tools shall be fitted with a carbide marking point, or equivalent, and shall be adjusted to provide a legible shallow rounded impression not to exceed 0.010 inch in depth. The marking tool tip radius shall not be less than 0.005 inch.

f. Rotary grinders shall not be used for any marking application.

g. Electric arc marking pencils are acceptable for marking applications.

3-4.2.1.3 *Limitations of Permanent Markings*

The following limitations apply to all permanent marking:

a. All permanent identification markings and their locations shall be indicated on the applicable drawings or in a specification or procedure.

b. Hardened materials shall be marked only by electrochemical etching.

c. Temporary marking on the surface of hard, brittle materials, such as 17-4PH stainless steels or Haynes 25 alloy, shall be applied by ink using rubber stamps or fabric marking pens. Metallic tags used for temporary marking and the materials used to attach the tag shall be of the same material which affords cathodic protection to the material being marked.

d. Tubing or pipe is not to be permanently marked.

3-4.2.2 *Handling and Storage After Receipt Inspection*

a. Material/equipment within the SOC shall be segregated and controlled at the builder's site so that identification of such material/equipment can be maintained throughout the storage, fabrication, and assembly process and no inadvertent substitution of material can take place.

b. The builder shall require and monitor the use of procedures to prevent handling damage. Handling procedures of this type include the use of special crates, boxes, containers, and transportation vehicles.

c. Protection shall also be provided for the prevention of deterioration, contamination, and damage in storage.

3-4.2.3 *In-Process Control of Material*

The builder shall establish controls which will preclude substitution of material or improper material identification, and which will assure that traceability of material from initial receipt to final installation will not be lost. As a minimum, the following requirements shall be met:

a. Whenever pipe, tubing, or fittings are cut, machined, or worked in any manner which could remove process control identification, the identification shall be similarly indicated on the cut piece IAW section 3-4.2.1.

b. The builder shall prepare written procedures for items in storage, issue, transportation, and assembly for controls to ensure preservation of marking and/or tagging of containers and individual components.

3-4.2.4 *In-Process Inspection*

Surveillance shall be maintained during each phase of the fabrication process to include verification of cleanliness controls and nondestructive testing for material (pipe, fittings, filler metal, fasteners, etc.), components, and equipment. Any component not passing inspection shall be documented and re-cleaned until a successful examination is performed.

3-4.2.5 *Installation Checks*

Inspections shall be conducted to verify that all material used in the system are those specified, all markings are visible and legible and provide the required traceability, the equipment is installed as specified on the drawings, and the system is ready for any required cleaning and testing.

3-4.2.6 *Records*

Records must be maintained to satisfy system certification requirements for traceability. See section 3-2.3 for detailed record requirements.

3-5 FABRICATION PROCESSES

3-5.1 PIPING SYSTEM FABRICATION

3-5.1.1 *Welded Pipe/Tube*

See section 3-5.3 for welding requirements.

3-5.1.2 *Mechanical Joint Fabrication*

Assembly of each mechanical joint within the SOC boundaries shall be witnessed by a qualified inspector. Prior to joint make-up, the joint shall be inspected for fit and alignment. Joint parallelism and concentricity shall be maintained so that torque in excess of fitting manufacturer recommendations is not required for seal. At the time of the joint make-up, the witnessing inspector shall enter the following information on the Mechanical Joint Assembly Record form (see Appendix G) or equivalent.

a. JIN (from JID).

b. Joint type (flanged, threaded, union, etc.).

c. Base material type (316L CRES for pipe, etc.).

d. Type of seal used (gasket, O-ring, etc.).

e. Joint alignment inspection results.

f. Joint make-up torque (torque values listed on JID).

NOTE: Pipe threads shall not be used in stainless steel piping systems because of the possibility of particulates being shed in the joining process.

3-5.1.3 *Tube Flaring and Flanging Procedures*

All tube flaring/flanging shall be performed IAW qualified written procedures that include joint fabrication and torque requirements. Tube flaring/flanging procedures shall specify requirements and acceptance criteria for each applicable category of tube flaring/flanging material. Tube flaring/flanging procedures shall be qualified for each type of flaring/flanging equipment. Both the written procedures and qualification results shall be delivered to PM for approval prior to fabrication.

3-5.1.4 *Pipe/Tube Bending*

Piping and tubing shall be bent IAW MIL-STD 1627 or ASME B31.1. The minimum wall thickness for piping or tubing extrados (back wall) after bending shall not be less than the minimum wall thickness required for straight piping or tubing which shall be listed in the system drawings. Piping or tubing shall not be bent to a radius less than 2 times the pipe diameter. See section 2-2.5.6 for additional information on pipe bending.

3-5.1.5 *Gauges and Instrumentation*

3-5.1.5.1 *Gauge Calibration/Verification*

All installed gauges shall have their calibration and accuracy verified IAW this section. The gauges shall be verified to be within the accuracy tolerances shown on the drawings or meet the requirements of the gauge accuracy grade required by Table 8 of section 2-2.5.9.3. Caisson Gauges in the SOC (e.g., Virginia-class submarine lockout trunk) shall be calibrated using the procedures in NAVAIR TM 36303. Vendors or activities providing gauge calibration services must be approved by the PM.

3-5.1.5.2 *Gauge Cleaning*

Refer to section 3-5.6.5.

3-5.1.5.3 *Test Gauge/Instrumentation*

3-5.1.5.3.1 *Pressure Gauge*

a. A calibrated test pressure gauge shall be used that has the test pressure within the calibrated range of the gauge, with accuracy less than or equal to the required test tolerance.

b. The test pressure gauge shall have been calibrated IAW ANSI/NCSL Z540-3, *General Requirements for Calibration Laboratories and Measuring and Test Equipment*, or ISO/IEC 17025:1999, *General Requirements for the Competence of Testing and Calibration Laboratories*.

c. The master test gauge shall have nominal errors no greater than ¼ of those permitted for the gauge being tested. For example, when testing a 200 psi Grade 1A (1%) gauge, the master test gauge must have errors of no more than ¼ of 1%, or 0.5 psi. The range of the standard must be no less than that of the gauge under test but may be higher, as long as the errors do not exceed 0.5 psi. A 200 psi Grade 3A gauge, with errors of 0.25% of 200 (0.5 psi), or a 500 psi Grade 4A gauge, with errors of 0.1% of 500 (0.5 psi) or a 1000 psi digital gauge with errors of 0.05% of 1000 (0.5 psi) may be used. In addition to the requirements of this paragraph, the master test gauge must also meet the requirements of ANSI/NCSL Z540-3.

3-5.1.5.3.2 ***Test Medium***

Testing for air gauges shall be conducted using diver quality air IAW NAVSEA SS521-AG-PRO-010. Gauges in systems other than air system (i.e., O_2, HeO_2, NITROX) shall be tested using clean, dry N_2. N_2 shall meet, by vendor or laboratory statement of conformance, the requirements of FED-SPEC-A-A-59155, Grade A or B, or MIL-PRF-27401, *Propellant Pressurizing Agent, Nitrogen*, Type I, Grade B or C, or CGA G-10.1, Grade L or M. (From MIL-STD-1330D).

3-5.1.5.3.3 ***Test Gauge Alignment***

Mounting a pressure gauge in a position other than that at which it was calibrated can affect its accuracy. Verification of the calibration shall take place in such a manner that the gauge is oriented as it would be during system operation.

3-5.1.5.3.4 ***Verification Test Procedures***

The following requirements and protocols shall be used to determine compliance with the drawings and/or the accuracy grades defined in Table 15 of this document.

3.5.1.5.3.4.1 ***Reference Temperature***

A temperature of 68°F (20°C) shall be the reference standard.

3.5.1.5.3.4.2 ***Reference Barometric Pressure***

A barometric pressure of 29.92 in mercury (1.0132 E+05 Pa) shall be the reference standard. Only absolute pressure gauges with the pointer set to indicate 14.7 psia will be affected by changes in barometric pressure.

3.5.1.5.3.4.3 ***Accuracy Test***

a. Grades 3A and 4A. Before conducting the accuracy test, subject the gauge to a pressure equal to the maximum indicated pressure (or vacuum). Conduct the accuracy test within 10 minutes.

b. All Grades. Known pressure shall be applied at each test point on increasing pressure (or vacuum). At each test point the gauge shall be read, lightly tapped, and then read again. The difference in the readings is friction error. Both readings shall be recorded on the test data sheet. The same sequence shall be repeated on decreasing pressure (or vacuum). The entire set of upscale and downscale readings shall then be repeated and recorded.

Table 15: Test Accuracy

Accuracy Grade	Minimum Number of Test Points[1]
4A	10
3A, 2A, 1A, A	5
B, C, D	3
(1) The test points shall be distributed over the dial range and shall include points within 10% of the ends of the dial range.	

c. The error can be determined from the data obtained in the two pressure cycles and is equal to the maximum error at each test point, in either direction, after tapping. When expressed as a percentage of the span, the error shall not exceed the limits in Table 9 of section 2-2.5.9.3 for the applicable grade of accuracy.

3-5.1.5.4 ***Instrumentation***

3-5.1.5.4.1 ***General***

All instrumentation installed in the system such as gas monitors, temperature indicators, or flow meters shall be tested to ensure they meet the requirements set forth in the system drawings.

3-5.1.5.4.2 ***Instrumentation/Data Acquisition***

Instrumentation/data acquisition devices must be electrically isolated from the DLSS personnel, but not located in a manner that might subject it to erroneous readout. Electrical failure of one instrument/device must not impair the use of another. All instrumentation/data acquisition must be compatible with its intended environment and must not create a fire, electrical or toxic hazard.

3-5.1.5.4.3 ***Instrumentation Cleaning***

Any instrumentation component (e.g., thermal well, pressure transducer) that has direct contact with any wetted surface within a DLSS, shall be cleaned IAW section 3-5.6.5.

3-5.1.6 *Flexible Hoses*

Flexible hoses shall be fabricated as shown in the system drawings and NAVSEA S6430-AE-TED-010. After cleaning and testing, a hose tag shall be affixed to the hose assembly IAW section 2-2.5.8.2.

3-5.2 PRESSURE VESSELS

3-5.2.1 *General*

This section details the requirements for both gas supply and human occupancy pressure vessels.

3-5.2.2 *Fabrication of Pressure Vessel to Commercial Code*

Pressure vessels within the SOC shall be fabricated IAW the ASME BPVC Section VIII, or the applicable DOT regulation or specification. Pressure vessels designed for human occupancy shall also comply with the additional requirements of ASME PVHO-1 and this specification (see section 3-5.2.3).

3-5.2.2.1 ***Documentation Requirements for Pressure Vessels Built to Commercial Codes***

When using commercial codes in fabricating a pressure vessel, the delivery of documentation, as outlined in the following subsections, in addition to that which is specified in the commercial code is required to be delivered to the PM.

3-5.2.2.1.1 ***Manufacturer's Documentation***

The Manufacturer's Data Report shall be submitted for each vessel fabricated IAW ASME BPVC Section VIII. Copies of the completed and signed ASME Manufacturer's Data Reports for pressure vessels (Form U-1/U-1A) shall be submitted with applicable ASME Manufacturer's Partial Data Reports (Form U-2).

For pressure vessels designed for human occupancy, Manufacturer's Data Reports, (ASME PVHO-1 Form GR-1), shall be submitted with all applicable Forms U-1 and Forms U-2 attached.

For vessels fabricated to standards other than ASME BPVC Section VIII, all documentation required by the standard shall be delivered to the PM. This shall include records of all testing performed and the results of the tests.

A copy of the Certification of Authorization from the ASME boiler and pressure vessel committee, or the equivalent from other approved commercial code committees, authorizing the manufacturer to fabricate vessels of the designed class shall be attached to the Manufacturer's Data Report.

3-5.2.2.1.2 ***Paint Preparation and Application Procedures and Data***

When using one of the paint systems lists in section 2-2.4.5, the paint procedure shall be submitted to the PM for approval prior to painting.

If qualifying a new paint system, procedures used for the surface preparation and painting of the vessel interior and/or internal components shall be provided to the PM for approval prior to the commencement of painting. Documentation shall be provided to verify that the coating system used on the interior of the vessel is properly applied (SSPC-PA-2, *Paint Application Standard No. 2*). The off gassing test procedure (see section 3-6.9) shall be conducted on a sample of painted shell material prior to actual painting of the PVHO. This sample shall meet the acceptance criteria of the test prior to the PM giving approval for the painting procedure.

After painting of the PVHO, an air purity test shall be conducted IAW section 3-6.9. The air sample must meet the acceptance criteria for the test in order for the system to be accepted by the PM.

3-5.2.3 *Pressure Vessel for Human Occupancy (PVHO)*

PVHOs shall be constructed IAW ASME PVHO-1 and this specification.

3-5.2.3.1 ***Welding of Pressure Vessel for Human Occupancy (PVHO)***

Welding of PVHOs shall be IAW the system drawings, ASME PVHO-1, ASME BPVC Section VIII, and ASME BPVC Section IX, *Welding, Brazing, and Fusing Qualifications*. All weld procedures, PQRs, and welder qualifications shall be submitted to the PM for approval prior to welding on the PVHO. The builder will not commence welding until written approval from the PM has been granted.

3-5.2.3.2 ***Additional Documentation Required***

The following sections (3-5.2.3.2.1 through 3-5.2.3.5) describe additional documentation that is required to be provided to the PM in excess of what is already required by ASME PVHO-1, ASME BPVC Section VIII-1 and ASME BPVC Section IX.

NOTE: All documentation that is required by ASME PVHO-1, ASME BPVC Section VIII, and ASME BPVC Section IX for the welding of PVHOs

shall be provided to the PM as part of the material certification package.

3-5.2.3.2.1 ***Material Verification***

All materials comprising the pressure vessel (pressure containing material), all materials welded to the pressure vessel and weld rods shall be documented to verify compliance with the system drawings and applicable specifications. This PVHO material shall be provided with mill heat and lot numbers. In addition chemical and physical data for the material shall be provided to the PM at the MCR. These documents shall be traceable to the materials used in the system.

3-5.2.3.2.2 ***Welding Procedures***

Copies of all welding procedures required for the fabrication of the pressure vessel and attachments shall be provided to the PM prior to starting actual welding operations. Documentation verifying approval of these procedures shall also be provided.

3-5.2.3.2.3 ***Welder Qualifications***

Documentation shall be provided to the PM verifying that all welders that produce welds on the pressure vessel are qualified to the approved welding procedure for the type and position of each weld made. The document shall clearly state that the welder is qualified to perform the procedures and his qualifications are current under applicable code requirements.

3-5.2.3.2.4 ***Weld Records and Maps***

The weld records shall consist of a chamber weldment JID, or map, for each chamber pressure shell and piping system. All chamber joint weld locations shall be shown and a JIN assigned to each weld. A chamber weldment record form for each welded joint, including non-pressure retaining joints and brackets, shall be prepared and delivered to the PM as part of the material certification package. The weldment record form shall contain the following information:

a. JIN (JID).

b. Joint design type.

c. Base metal type with heat and lot number.

d. Filler metal type with heat and lot number.

e. Fit up and inspection results.

f. Welding procedure number.

g. Heat treatment if required.

h. Welder/brazer number.
i. Type of inspection and results.
j. Disposition of joint (pass/fail).
k. Any repairs of joint conducted.
l. Inspection procedure number.
m. NDE inspection number.
n. Signature and date.

3-5.2.3.2.5 ***Nondestructive Examination (NDE) Records***

Copies of all NDE records shall be provided to the PM as part of the material certification package. Nondestructive test personnel qualification records shall be maintained and provided to the PM prior to testing.

3.5.2.3.2.5.1 ***Dye Penetrant Inspection (PT)***

Records of dye penetrant inspections (PT), as specified in ASME BPVC Section VIII, shall be delivered and shall consist of:

a. Type(s) of PT tests.
b. Identification of assembly, part, etc.
c. Number of discontinuities.
d. Type(s) of discontinuities.
e. Signature and date by the assigned responsible individual verifying all specified PT inspection including PT of any required repairs has been accomplished and is satisfactory.

3.5.2.3.2.5.2 ***Magnetic Particle Inspection (MT)***

Records of magnetic particle inspection (MT) as specified in ASME BPVC Section VIII shall be delivered along with the PVHO.

3.5.2.3.2.5.3 ***Radiographic Inspection (RT)***

RT inspection data sheets as well as the radiographs themselves will be submitted to the PM. Chambers are required to have full RT of all pressure retaining butt welds (joint efficiency of 1). Records of radiographic weld inspection shall contain, as a minimum, the following:

a. Date of exposure of the radiograph.
b. Positively identified location of weld radiographed.
c. Type of material and material thickness.

d. Type of weld joint.
e. Approved procedure identification.
f. Energy source (isotopes type, intensity, kilovoltage and focal spot size of x-ray machine).
g. Type of film, screens, source-to-film distance, and exposure time.
h. Penetrameter designation.
i. Image Quality Indicator (IQI) sensitivity reading.
j. Applicable acceptance standards.
k. Flaws (unacceptable slag, porosity, or other indications).
l. Disposition (accept/reject).
m. Date of interpretation and signature of film interpreter(s).
n. Interpreter's documented qualification level shall be noted.
o. Diagram (radiograph) indicating the specific location of each radiograph coded to its unique number. Where required by contract, a copy of the actual radiographs shall be provided to the government.

3.5.2.3.2.5.4 ***Ultrasonic Inspection (UT)***

Records of ultrasonic inspection (UT), when required by ASME PVHO-1 and/or ASME BPVC Section VIII, shall contain, as a minimum, the following:

a. Date of UT.
b. Description and unique item identification, weld location and joint identification.
c. Type of material and material thickness.
d. Type of weld joint and length of weld inspected.
e. Approved procedure identification.
f. Equipment used for inspection (instrument and search unit): manufacturer and model number, transducer size and type, search beam angle, test frequency, couplant.
g. Calibration standard number.
h. Applicable acceptance standard.
i. Reference block identification.
j. Discontinuities that exceed Disregard Level (DRL).

k. Disposition (accept/reject).

l. Signature of inspection personnel and date.

m. If supplemental UT techniques are used that contribute to the final inspection results, they shall be recorded.

These records shall be delivered along with the PVHO.

3-5.2.3.3 ***Heat Treatment Procedures and Records***

Copies of the procedures and records of all heat treatments performed on the chamber shall be attached to the Manufacturer's Data Report.

3-5.2.3.4 ***Charpy Impact Test Data***

When Charpy Impact testing of materials is required, a copy of the Charpy Impact Test data shall be attached to the Manufacturer's Data Report.

3-5.2.3.5 ***Material Repair Report***

A report on repairs of any defects in the materials used for the fabrication of chambers shall be attached to the Manufacturer's Data Report.

3-5.2.3.6 ***Pressure Vessel for Human Occupancy (PVHO) Test Requirements***

3-5.2.3.6.1 ***ASME Certification Tests***

The chamber(s) shall be tested IAW this specification, the ASME BPVC Section VIII and ASME PVHO-I. Failure of any ASME test shall constitute non-conformance.

3-5.2.3.6.2 ***Hydrostatic Test***

The builder shall perform a hydrostatic strength test of the chamber(s) IAW with ASME BPVC Section VIII-1. The hydrostatic test pressure shall be 1.5 times the MOP of the PVHO. The builder shall be responsible for bracing the chamber to support the full weight of the flooded chamber without damage to any part of the system. The penetrators and viewports shall be installed and tested during this test. The contractor shall first perform the test on the inner lock (IL), followed by a test of the IL and outer lock (OL) together (if applicable). In addition, the builder shall perform the test in a manner that the pressure integrity of the complete chamber including Medlock, NATO Flange and any other pressurized ports can be determined. The builder shall inspect all welds, joints, penetrations and pressure-retaining assemblies for evidence of distortion or leaks, and record any such distortion or leakage observed. Any distortions indicating structural failure shall be immediately reported to the PM. Included in this report shall be the builder's plan to remedy the failure. Upon notifying the PM of the failure and the plan for remediation, the builder shall repair all defects and repeat the hydrostatic test.

3-5.2.3.6.3 ***Low-Pressure Leak Test***

A low-pressure leakage test of the door, hatch and viewport seals shall be conducted after the chamber(s') pressure drop test. The chamber(s) shall be pressurized with air, to 2 fsw, or a depth agreed to by the PM. All door, viewports, and hatches shall be checked for leakage by use of bubble leak detection. Any leaks found shall be documented and corrected and the leaking seal areas shall be retested. This test is necessary because defects such as weld distortion, machining flaws in sealing surfaces or door hinge misalignment may allow significant leakage at low-pressure but can often seal tightly at MOP.

3-5.2.3.6.4 ***Pressure Drop Test***

A pressure drop test shall be conducted after the chamber(s') hydrostatic strength test IAW section 3-6.8. The chamber, including all viewports and penetrators, shall be finally assembled for this test; any later disassembly shall mandate a new pressure drop test. The chamber(s) shall be pressurized with air, O_2, dry N_2, or HeO_2 as applicable to MOP and permitted to stabilize, and then isolated from the pressurization source. The chamber pressure, corrected for changes in temperature, shall not drop more than what's required in section 3-6.8 over the duration of the test. The builder shall first perform the test on the IL, followed by a test of the IL and OL together. In addition, the builder shall perform the test in a manner that the pressure integrity of the Medlock and any other pressurized ports can be determined. Any leaks found shall be eliminated and the entire chamber shall be retested.

3-5.2.3.6.5 ***Pressure Vessel Weld Testing***

All pressure vessel welds shall be tested and inspected IAW ASME PVHO-1. Written records shall be prepared and maintained for each welded joint IAW NAVSEA S9074-AR-GIB-010/278. These records shall be submitted to the PM at final delivery. The records shall include a weld JID (or "weld map") for each chamber, with all chamber joints shown, with each JID assigned. A weld record shall be prepared for each joint, including non-pressure retaining joints. The weld record shall contain the information required in section 3-5.2.3.2.4.

3-5.2.3.6.6 ***Penetrators***

Prior to final installation, hollow bolt penetrators shall be hydrostatically tested (internally) to 1.5 times the MOP separately from the chamber.

3-5.2.3.6.7 ***Strain Gauge Testing***

For PVHOs of new design, the builder shall conduct strain-gauge testing on the prototype vessel. The builder shall submit for approval, a strain-gauge test plan including as a minimum, the location and type of strain gauges. The final test report must include a comparison between calculated stress values and those obtained by strain gauges.

3-5.2.4 *Gas Cylinders*

3-5.2.4.1 ***General***

Non-PVHO gas storage cylinder and volume tanks shall be manufactured and stamped IAW all applicable DOT regulations and specifications or ASME BPVC Section VIII. Gas storage pressure vessels shall be fabricated IAW the same specification to which they are designed (e.g. if the vessel was designed IAW ASME BPVC VIII it shall also be fabricated IAW ASME BPVC Section VIII).

3-5.2.4.2 ***Testing Requirements***

Testing of gas cylinders shall be as specified in section 3-6 of this document.

3-5.2.4.3 ***Documentation Requirements***

For commercial-off-the-shelf (COTS) gas cylinders the documentation shall include records of pressure testing. For custom built cylinders (i.e., those with fabrication drawings as part of the system drawing package or those designed by a fabricator to a performance specification) the following additional documentation shall be delivered:

a. Weld map. The fabricator shall develop a map of all welds in the pressure vessel. Each weld shall have a unique JIN.
b. Weld history record (see section 3-5.3.2).
c. Pressure testing documentation (see section 3-6).
d. Records of all NDE performed.

3-5.3 WELDING

3-5.3.1 *General*

Welding of hyperbaric and DLSSs shall be accomplished IAW the provisions of either NAVSEA S9074-AR-GIB-010/278 or ASME B31.1; and with the exception of PVHO (for the welding requirements of PVHOs see section 3-5.2).

Other welding specifications and/or procedures may be utilized if prior written authorization is given by the PM.

Welding of diver handling systems shall be IAW the provisions of MIL-STD-1689, *Fabrication, Welding and Inspection of Ship's Structure*, NAVSEA S9074-AR-GIB-010/278. For diver handling systems designed to a commercial classification society standard (i.e. ABS, DNV-GL, etc.), welding and inspection shall be IAW class rules and as agreed with by the PM.

3-5.3.2 *Weld History Record*

The builder must provide traceability between the joint record and the actual welded joint for each welded pipe joint or structural weld joint. The builder shall record the following information as a minimum for all welds in diving and hyperbaric systems with the exception of class M-2 welds (see NAVSEA S9074-AR-GIB-010/278 for a description of class M-2 welds).

a. JIN (from JID).

b. Joint Design.

c. Base material type (including heat or lot identification).

d. Filler material type (including heat or lot identification).

e. Fit-up.

f. Welding procedure used.

g. Heat treatments (including any preheat, interpass, and post-weld heat treatment temperatures or controls used).

h. Welder's identification.

i. Inspection methods and results.

j. Disposition of weld.

k. Repairs to weld.

l. Inspection procedure.

m. Inspector's identification.

n. System/subsystem.

o. Serial number.

Appendix G contains a sample weld history record form.

Records of weld procedure specification (WPS) and associated PQR along with welder performance qualification and associated documentation required by the applicable specification shall be provided to the PM.

3-5.3.3 *Weld Procedure Qualification*

Each weld procedure used in welding fabrication of the system shall be qualified IAW NAVSEA S9074-AQ-GIB-010/248, *Requirements for Welding and Brazing Procedure and Performance Qualification*, if welding is to be completed IAW NAVSEA S9074-AR-GIB-010/278 or ASME BPVC Section IX if ASME B31.1 is being used.

Each welding procedure and welder employed for welding joints on PVHOs shall be qualified by demonstrating the ability to produce sound and satisfactory joints and certifying the same IAW ASME BPVC Section IX. See sections 3-5.2.3.1 through 3-5.2.3.5 for additional requirements on welding PVHOs.

Weld procedure qualification for diver handling systems shall be IAW NAVSEA S9074-AQ-GIB-010/248 or as required by commercial classification society rules and as agreed to by the PM.

All welding procedures and PQR used in fabrication of the system shall be submitted to the PM.

3-5.3.4 *Welder Performance Qualification*

Each welder employed for welding joints in the diving or hyperbaric system shall be qualified by demonstrating the ability to produce sound and satisfactory joints and certifying the same IAW NAVSEA S9074-AQ-GIB-010/248 or ASME BPV Section IX (for welding joints on PVHOs) respectively.

Welder performance qualifications for diver handling systems shall be IAW NAVSEA S9074-AQ-GIB-010/248 or as required by commercial classification society rules and as agreed to by the PM.

Welders performing structural welds on items that are outside of the SOC, do not require formal performance qualification, but shall be experienced in all material types, joints, and processes used.

All welder performance qualification records used in fabrication of the system shall be submitted to the PM.

3-5.3.5 *Welding Fabrication*

The fabrication welding for a diving or hyperbaric system shall meet requirements of NAVSEA S9074-AR-GIB-010/278, ASME B31.1, or applicable standard agreed upon by the PM. Additional requirements for fabrication of pressure vessels for gas storage and human occupancy are provided in section 3-5.2.

3-5.3.5.1 ***Piping***

All welds to piping contained within the SOC shall be Class P-1 welds as described in NAVSEA S9074-AR-GIB-010/278, ASME B31.1, or equivalent per standard agreed upon with the PM.

3-5.3.5.2 ***Filler Material***

The builder shall establish a control program which will ensure that that proper filler material is issued in the welding process. The program shall include a written procedure for the selection, identification marking, special handling, traceability, and inspection of filler material throughout the procurement, fabrication, and installation phase of the DLSS. Filler materials shall comply with NAVSEA S9074-AR-GIB-010/278, ASME B31.1, or applicable standards, including handling and storage.

3-5.3.5.3 ***Defect Rework***

Areas ground to remove rejectable defects shall be dimensionally examined. Minimum wall thickness or weld size as specified in the applicable pipe or fitting specification must not be less than acceptable levels. Where wall thickness or weld size has been ground below minimum levels, the area shall be reworked IAW initial weld procedure and examined to the same standards as the original weld. No cracks other than crater cracks may be reworked and only one cycle of rework is allowed. Rework shall be documented on the weld history record. Document excavation location and dimensions, including remaining wall thickness, prior to any weld repair.

3-5.3.6 ***Inspection***

This section contains the minimum requirements for inspection of welded joints for use in the fabrication of diving and hyperbaric systems. Additional welding requirements may be found in section 3-5.2.3.1.

3-5.3.6.1 ***Fabrication Welds***

Nondestructive testing of welds shall be IAW the requirements of NAVSEA S9074-AR-GIB-010/278 or with ASME B31.1, table 136 and the following: (1) butt welds – RT; (2) welded branch connections: 2-inch diameter and greater – RT, less than 2-inch diameter PT or MT; (3) fillet, socket welds – 5x visual inspection (VT) or PT/MT root weld and 1x VT and PT of final weld. Hydrostatic testing of welds shall be IAW the requirements of this specification, the applicable drawing, or test document.

3-5.3.6.2 *Rework to Fabrication Welds*

Prior to rework welding, mechanical removal of the defect shall be verified by repeating the inspection which originally disclosed the defect. Except for defects originally disclosed by leak tests, re-inspection may be delayed until after repair welding. Excavations requiring rewelding shall be inspected at 5x magnification VT or liquid PT. Remove minimum amount of metal to remove defect and present a suitable contour for welding. Document final excavation size (length, width, depth) and location. The repaired weld shall be inspected to the same degree as required for the original weld.

3-5.3.6.3 *Repair Welds to Wrought Base Materials*

Prior to repair welding, removal of the defect shall be verified by repeating the inspection which originally found the defect. Leak tests may be delayed until after repair welding.

On completion of repair welding, satisfactory repair shall be verified by repeating the inspection that disclosed the defect. PT inspection of the final surface of all weld repairs to piping and components is required IAW the applicable specification (this includes ½ inch of base metal beyond the toe of the repair weld). Acceptance criteria shall be based on weld or base metal requirements IAW the applicable specification.

RT of wrought base metal repair may be required on a case basis.

Hydrostatic testing of rework or repair welds shall be IAW the requirements of applicable drawings or test documents.

3-5.3.6.4 *Inspection Standards*

NDE inspections shall be performed and evaluated IAW the applicable standard, either NAVSEA S9074-AR-GIB-010/278 or ASME B31.1.

3-5.4 BRAZING

Brazed joints are typically not permitted. If a written exemption has been issued by the PM it may be allowed. In piping systems fabricated with brazed joints, all brazing shall be performed IAW written and approved brazing procedures which meet or exceed the requirements described in NAVSEA 0900-LP-001-7000, *Fabrication and Inspection of Brazed Piping Systems*. The builder shall submit the written brazing procedures and the brazer/brazing operator qualification, for PM review and approval. Any repairs to joints involving heat or brazing shall be accomplished IAW approved written requirements and subjected to the tests and inspections specified for the joint repaired.

3-5.5 ELECTICAL/ELECTRONIC SYSTEMS

During DLSS fabrication, installed cables shall be protected against mechanical damage, burning by welders' torches and contact with oils and solvents. For fabrication guidance the builder should refer to MIL-HNDBK-454 or NFPA 70.

The builder shall comply with the following:

a. Cleaning: After fabrication, parts and assembled equipment shall be cleaned of smudges; loose, spattered, or excess solder; weld metal; metal chips and mold release agents; or any other foreign material which might detract from the intended operation, function, or appearance of the equipment.

b. Threaded parts or devices: Screws, nuts, and bolts shall show no evidence of cross threading, mutilation, or detrimental or hazardous burrs, and shall be firmly secured.

c. Bearing assemblies: Bearing assemblies shall be free of rust, discoloration, and imperfections of ground, honed, or lapped surfaces. Contacting surfaces shall be free of tool marks, gouge marks, nicks, or other surface type defects. There shall be no detrimental interference, binding, or galling.

d. Wiring: Wires and cables shall be positioned or protected to avoid contact with rough or irregular surfaces and sharp edges and to avoid damage to conductors or adjacent parts.

e. Shielding: Shielding on wires and cables shall be secured in a manner that will prevent it from contacting or shorting exposed current-carrying parts. The ends of the shielding or braid shall be secured to prevent fraying.

f. Containment: The harness and cable that form containment means shall be neat in appearance, uniformly applied, and positioned to retain critical form factors and breakout locations. The containment means, (lacing, ties, tie-down straps, etc.) shall not cause the wire or cable insulation to deform so that performance characteristics are adversely affected.

g. Insulation: There shall be no evidence of burns, abrading, or pinch marks in the insulation that could cause short circuits or leakage.

h. Clearance: The clearance between wires or cables and heat generating parts shall be sufficient to minimize deterioration of the wires or cables.

3-5.6 CLEANING

3-5.6.1 *General*

All parts of the DLSS through which gas flows for delivery to the divers shall meet the cleanliness criteria stated in section 3-5.6.1.1. This includes hoses, pipe, fittings, valves, gauges, filters, air flasks, volume tank, reducers, etc.

All material/components shall be cleaned by the builder before assembly into the DLSS to the cleanliness standards in the approved specification. However, material/components received from a supplier in a clean condition IAW the requirements of section 3-5.6.1.1 need not be re-cleaned unless they have been contaminated in storage, welding, or handling. Any items that are supplied in a clean condition must have all of the appropriate documentation and that documentation must be provided to the government upon system delivery.

3-5.6.1.1 ***Divers Life Support System (DLSS) Cleanliness Requirements***

The cleaning instructions for different DLSS systems and items in those systems are outlined in Table 16.

The completed DLSS must be free of all contaminates, such as hydrocarbons and particulate matter, to ensure clean life support gas. Any piping, valve, O-ring, or other component that will be wetted with greater than 25% O_2 by volume during normal operation shall be cleaned and documented IAW MIL-STD-1330. All other piping and components that form part of the gas supply system shall be cleaned and documented IAW MIL-STD-1330 or MIL-STD-1622.

Alternative cleaning procedures (i.e. ASTM G93, or CGA G-4.1, *Cleaning of Equipment for Oxygen Service*) may be considered provided the analysis performed for the particular application is determined to be comparable to the requirements herein. All cleaning procedures for the DLSS must be approved by the PM.

Table 16: Cleaning Instructions

Applicability (Type of System/Items in System)	Cleaning Instruction	Special Requirement
Air: Piping, flasks, and components other than instruments	MIL-STD-1622, Critical	
NITROX: Piping, flasks, and components other than instruments	MIL-STD-1330, NITROX	
O_2: Piping, flasks, and components other than instruments	MIL-STD-1330, general	
He and HeO_2 (<25% O_2): Piping, flasks, and components other than instruments	MIL-STD-1330, general	
HeO_2 (>25% O_2): Piping, flasks, and components other than instruments	MIL-STD-1330, general	
Exhaust for <25% (e.g. decompression/recompression chamber exhaust): All items	MIL-STD-1622, Critical (Initial/New); Maintain chamber clean	For these systems and piping open to the chamber interior, such as chamber sensing lines, it is often reasonable to only clean and maintain cleanliness to a level that is established IAW Chapter 2 of NAVSEA SS521-AK-HBK-010, *Cleaning and Gas Analysis for Diving Applications Handbook*. Moisture can be considered a contaminant or an expected part of the system, such as the moisture generated by CO_2 scrubbing. For guidance on dew point temperature – see paragraph 3.2 of NAVSEA SS521-AK-HBK-010
Exhaust for >25% (e.g., BIBS) exhaust for O_2 or 60/40 HeO_2 mix): All items	MIL-STD-1330, general	
Life Support for air: All items	MIL-STD-1622, Critical	
Life Support for NITROX diving: All items	MIL-STD-1330, NITROX	
Life Support for HeO_2 diving: All items	MIL-STD-1330, general	
All systems: Diving helmets and masks	See Table 1-11 of NAVSEA SS521-AK-HBK-010	Disinfect per paragraph 1.7 of NAVSEA SS521-AK-HBK-010
Air: Instruments (e.g., gauges and transducers)	MIL-STD-1622, Appendix C	
He, HeO_2, NITROX, and O_2: Instruments (e.g. gauges and transducers)	NAVSEA ST700-F1-PRO-010	See paragraph 1.8 of NAVSEA SS521-AK-HBK-010 for verifying solvent removal
All systems: Very delicate components	MIL-STD-1330, critical	See paragraph 1.6 of NAVSEA SS521-AK-HBK-010 for performing particle counts
Additional requirements from other governing documents may apply when deemed necessary by the PM.		

3-5.6.1.2 *Cleaning Procedures*

Cleaning of breathing gas systems shall be performed IAW written cleaning procedures that are developed by the builder and are IAW MIL-STD-1330 and possibly MIL-STD-1622. Cleaning procedures shall include methods for sampling and criteria for acceptance. Quantitative analysis to verify system cleanliness must be performed prior to manned testing of the system. Hydrocarbon contamination is of particular concern because hydrocarbons may be both toxic and flammable. The cleaning procedure shall be submitted to the PM for approval. No cleaning shall take place until written approval of the cleaning procedure has been granted by the PM.

3-5.6.1.3 ***Hydraulic/Pneumatic Systems Cleanliness Requirements***

Cleaning, flushing and preservation of hydraulic system piping and components shall be IAW ASTM D4174, *Standard Practice for Cleaning, Flushing, and Purification of Petroleum Fluid Hydraulic Systems*, or an applicable commercial specification, subject to approval by the PM.

Cleaning and flushing of pneumatic systems shall be accomplished using best commercial practice and using compatible cleaning agents to remove all loose scale, rust, grit, filings, oil, and grease. If a pneumatic line is flushed with water, prior to installation, they must be blown dry with dry air. Filtered system fluid should normally be used for flushing.

3-5.6.2 *CLEANING CONTROLS*

3-5.6.2.1 ***Storage***

Temporary storage of cleaned equipment, piping, or components must be in an environment that will prevent contamination. The storage area shall meet the following requirements:

a. Material shall be stored in enclosed structures, free of debris and contaminants such as oil and grease.

b. Shelves shall be free of dust and other contaminants.

c. Storage building shall be locked with entry limited to authorized personnel.

d. Temperature shall be kept between 40°F (4.44°C) and 100°F (37.78°C).

3-5.6.2.2 ***Fabrication Controls***

Materials/components must remain in a clean condition when removed from storage for fabrication. The following procedures will ensure that cleanliness is maintained:

a. Prior to leaving the storage area, the packaging of all cleaned materials shall be inspected. If the outer package is torn or damaged, but the inside package is intact, replace the outer package. If the inside package is damaged and exposing the cleaned item to the ambient atmosphere, the item shall be recleaned and recertified to the applicable cleaning specification.

b. All VTs which require that a cap or seal be removed from a clean item shall be conducted in a clean area.

c. Fit-up of clean pipe and components shall be accomplished in a clean enclosure.

d. Items transported from storage to fabricating area shall be protected from damage to caps and seals and from internal contamination.

3-5.6.3 *Subassembly Cleaning*

At the option of the builder, material/components fabricated into subassemblies may be flushed of any contaminants which may have entered the subassembly prior to installation in the entire system. The flushing procedure shall be IAW MIL-STD-1330 or MIL-STD-1622 as appropriate and it shall be previously approved by the PM.

3-5.6.4 *Hose Cleaning*

All rubber hoses shall be cleaned IAW MIL-STD-1330 or MIL-STD-1622 as appropriate and pass an off-gassing test prior to acceptance. A sample off-gassing procedure is included in section 3-6.10. A hose log shall be maintained which identifies the hose, date cleaned, and cleaning process used. The same log shall be used during testing of the hose and the log shall be provided to the PM during the MCR.

3-5.6.5 *Gauge Cleaning*

Gauges used in systems wetted with greater than 25% by volume of O_2 shall be cleaned IAW MIL-STD-1330. Other gauges shall be cleaned IAW MIL-STD-1330 or MIL-STD-1622.

3-5.6.6 *Documentation*

Documentation of cleaning shall be IAW MIL-STD-1330 or MIL-STD-1622 as applicable. An example data sheet that may be used by the builder, is presented in Appendix G. This documentation shall be provided as part of the data package delivered to the PM during the MCR.

NOTE: MIL-STD-1622 does not require the use of data sheets but does require a vendor to provide a sticker or tag in the packaging with specific information. These stickers or tags from vendors must be retained by the builder and delivered as part of the documentation package with the system.

3-6 TESTING

3-6.1 GENERAL

The builder shall be responsible for developing and implementing a system testing program for the diving equipment being fabricated. All tests shall be conducted in the presence of the PM, except where such representative may authorize the builder to conduct, report, and certify the tests. A schedule and location for the testing shall be supplied by the builder to the PM no later than 4 weeks prior to the commencement of testing.

All material, labor, equipment, and instrumentation necessary to perform the tests shall be provided by the builder, unless otherwise specified. All instruments used in the conduct of the test shall be calibrated IAW ANSI/NCSL Z540-3 or ISO/IEC 17025:1999.

3-6.2 SYSTEM TESTING PROGRAM

The builder shall develop and submit a written test program, to the PM, for approval. It shall outline a comprehensive and integrated series of tests which fully demonstrates the adequacy of all systems and equipment within the SOC. The testing shall not be implemented until a written approval of the testing program has been received from the PM. The test program shall consist of the following elements:

a. A test procedure index which is a listing of all individual test procedures (test memos) with an identification number, title, latest revision number, and date of issue.

b. A test plan which indicates the sequence in which the individual test procedures are to be accomplished, thereby establishing the prerequisite(s) for each succeeding test procedure. A PERT chart or bubble chart which clearly shows all parallel and convergent paths is a useful method of presenting this information.

c. The individual test procedures which clearly show the type of testing to be performed, step by step procedures for conducting the test, required test instrumentation and acceptance criteria. The procedure must also include examples of all data sheets required to record the test results. Such procedures shall contain, as a minimum, the following information:

    1) Step-by-step procedures for conducting the test.

    2) Prerequisites or required preparations for the test.

    3) Equipment required for test including calibration data for calibrated equipment.

4) Components which must be removed from the system before testing.
5) Location of all spools, jumpers, or blanks to be installed including over the seat and under the seat and through seat flush plugs – refer to Bridgewall marks and details if applicable (see section 2-2.5.9.1).
6) Inlet and outlet points for water, N_2, air, etc.
7) Data forms for recording test results and verification signatures.
8) Valve line-up sheets showing valve line-up for test.
9) Pressure, temperature, flow rates, etc.
10) Acceptance criteria for each test.
11) Precautions to be followed, such as proper isolation of portions of system to prevent contamination of cleaned and tested system parts.

3-6.2.1 *System Testing Program Submittal*

The builder shall submit the system testing program to the PM prior to conducting the actual tests. The test program shall have written PM approval prior to execution and shall be kept current by the builder. Any changes to the test program must be submitted in writing to the PM for approval prior to implementation. It may become necessary for support facilities and/or subcontractors to assign new identification numbers, compatible with local procedures, to individual tests being performed. If so, a cross reference of test procedure index numbers shall be provided to facilitate test record verification.

3-6.2.2 *Items that Require Testing*

Items that require testing include:

a. Pressure vessel systems.
b. Flotation and buoyancy systems.
c. Mechanical systems.
d. Structural systems within the SOC.
e. Emergency de-ballasting and jettisoning systems operation.
f. Life-support systems including breathing gas purity control.
g. Handling equipment systems.
h. Electrical power, control and COMMS.
i. Instrumentation and monitoring systems.

j. Safety feature operation.

3-6.2.3 *Test Documentation*

The builder must provide written test results (data) to the PM prior to the MCR.

3-6.3 TEST CATEGORIES

The test categories, listed in sections 3-6.3.1 through 3-6.3.6 below, are all unmanned tests which must verify that the candidate system operates safely as designed. Manned testing is not covered by this specification. All manned testing, unless otherwise stated in the contract documents, shall be the responsibility of NAVSEA 00C3.

3-6.3.1 *Factory Acceptance Tests (FAT)*

This category covers testing which is performed by an equipment or component manufacturer to ensure that the material functions within specified limits. FATs should be required on all material where operation is of such a critical nature that failure to perform within the specified limits would jeopardize the safety of the divers or operators. The reason for testing of this material at the factory is, usually, that the DLSS fabricator may not have the necessary test apparatus. Syntactic foam and acrylic for viewports are examples of material which require FATs. If a FAT is required it shall be noted on the purchase documents (see section 3-3).

3-6.3.2 *Prototype First Article Testing (PFT)*

This category of test may be required to prove the design of critical components or entire systems which are developmental in nature. Performance of materials, components and systems which are unique or untried in a similar environment and are within the SOC must be demonstrated by such tests prior to manned use. PFTs will often incorporate life cycle testing to verify that a component or system will operate within design limits and will not fail prematurely.

3-6.3.3 *Pre-Installation Tests (PIT)*

Those tests which are performed on components prior to installation in a system (often referred to as bench tests). Hydrostatic and seat tightness testing of valves are examples of PITs.

3-6.3.4 *Pre-Operational Tests (POT)*

POTs are those tests performed at the system level, but prior to operating the system. IR and continuity tests and mechanical system tightness tests are examples of POT level testing. These tests shall normally be conducted on each system produced.

3-6.3.5 *System Operational Tests (SOT)*

SOTs are required to verify that separately each subsystem operates satisfactorily within its design parameters.

3-6.3.6 *System Integration Test (SIT)*

SIT are performed to verify that all subsystems can be operated concurrently, as designed. SITs are also used to verify that the system OPs can be used to operate the system safely prior to conducting manned operational testing.

3-6.4 ELECTRICAL TESTING

This section provides the minimum mandatory testing requirements for new and maintained electrical components and equipment. Electrical equipment or components may include, but are not limited to, power panels, switch panels, circuit protection panels, junction panels, cable assemblies, electrical hull fittings, battery compartments, and instrument canisters. Where the requirements of this section conflict with existing directives, specifications, or requirements, document the conflict and address it to the PM for resolution.

a. The designer shall submit test procedures designed to:

   1) Demonstrate the adequacy of electrical continuity, dielectric withholding voltage and IR of all electric cables and

   2) Demonstrate the appropriate electrical safety features of electrical and electronic devices in the SOC.

3-6.4.1 *Component Testing*

3-6.4.1.1 *Continuity*

For each cable or component in the SOC the PM shall evaluate the need for continuity testing.

3-6.4.1.2 *Dielectric Withstanding Voltage Test*

Dielectric withstand testing should not be confused with a voltage breakdown or dielectric strength test. Dielectric withstand testing is not intended to cause insulation breakdown. The test is used as a quality control check to ensure the system was constructed properly and that no manufacturing defects in insulating materials or spacings have compromised the system insulation characteristics.

a. A dielectric withstanding voltage test should be performed on all new electrical cable assemblies, electrical equipment, and electrical devices that are deemed safety critical, as a conformance test. For devices and equipment where a dielectric withstanding voltage test that meets the requirements of MIL-DTL-917 has already been performed, re-testing is not required unless damage is suspected. (see paragraph e below)

b. The voltage type (AC or DC) and the procedure used for testing shall be as required by the applicable component specification, assembly specification or equipment application. For those cases where a specification or equipment application does not define a test procedure, the test shall be performed IAW MIL-DTL-917 and MIL-STD-202, *Electronic and Electrical Component Parts*.

c. Where the standards for electrical devices other than switching or interrupting devices call for a lower test voltage, due to the possibility of the specified potential causing equipment damage, such devices may be disconnected during the dielectric withstanding voltage test and individually tested at a potential IAW the device specification or as approved by the PM. At test voltages of less than 500 volts, there is little advantage to performing this test in addition to the IR test and it can be eliminated with PM concurrence.

d. The cable dielectric withstanding voltage tests shall be performed between all conductors and the sheath and also between individual conductors. This is a go, no go criteria test.

e. For previously tested electrical cable assemblies, equipment and devices where a satisfactory dielectric withstanding voltage test has been performed, re-testing is not required unless damage is suspected. Subsequent dielectric withstanding voltage testing shall be conducted at no more than 75% of the voltage applied for the initial test.

f. Dielectric withstanding voltage tests shall always be followed by an IR test (refer to section 3-6.4.1.3).

3-6.4.1.3 *Electrical Insulation Resistance (IR) Testing*

IR measurements should not be considered the equivalent of dielectric withstanding voltage or electric breakdown tests. A clean, dry insulation may have a high IR, and yet possess a mechanical fault that would cause failure in the dielectric withstanding voltage test. Conversely, a dirty, deteriorated insulation with a low IR might not break down under a high potential.

a. All IR testing shall be with DC voltage. Measured IR values shall be corrected to 77°F (25°C) using Table 17. The DC voltage shall not be less than 500 volts and held for 1 minute for electrical cables, electrical equipment, or electric devices unless it can be shown that such a test would be detrimental to the equipment (e.g., pyrotechnic jettisoning devices). Lower voltage may be used when specified and approved by PM.

b. The IR of current carrying conductors, corrected to 77°F (25°C) shall not be less than 10 MΩ for each circuit when newly installed, and one MΩ for in-service circuits. Measured IR values shall be corrected to 77°F (25°C) IAW Table 17.

c. For those cases where a specification or equipment application does not define a test procedure, the test shall be performed IAW MIL-DTL-917 or NSTM Chapter 300.

d. IR tests shall be conducted before and after the Appendix K pressure tests.

Table 17: Insulation Resistance (IR) Correction Table

Component Temperature		Correction Factor to 25° C	Component Temperature		Correction Factor to 25° C
°C	°F		°C	°F	
10	50.0	0.35	31	87.8	1.52
11	51.8	0.38	32	89.6	1.62
12	53.6	0.41	33	91.4	1.74
13	55.4	0.44	34	93.2	1.87
14	57.2	0.47	35	95.0	2.00
15	59.0	0.50	36	96.8	2.14
16	60.8	0.54	37	98.6	2.30
17	62.6	0.57	38	100.4	2.46
18	64.4	0.62	39	102.2	2.64
19	66.2	0.66	40	104.0	2.83
20	68.0	0.71	41	105.8	3.03
21	69.8	0.76	42	107.6	3.25
22	71.6	0.81	43	109.4	3.48
23	73.4	0.87	44	111.2	3.73
24	75.2	0.93	45	113.0	4.00
25	77.0	1.00	46	114.8	4.29
26	78.8	1.07	47	116.6	4.59
27	80.6	1.15	48	118.4	4.92
28	82.4	1.23	49	120.2	5.28
29	84.2	1.32	50	122.0	5.66
30	86.0	1.41	51	123.8	6.06

Notes:

a. Beyond the table range the corrected IR at 77°F (25°C) may be determined by calculating the applicable correction factor as follows:

$$\textit{Correction factor} = 0.5^{(25-T_C)/10}$$

Where

T_C is the component temperature in °C at the time of the test.

b. Fahrenheit/Centigrade conversion formulas:

°F = (9/5)* °C + 32

°C = (°F-32)*(5/9)

NOTE: Electronic equipment (radios, cameras, instrumentation etc.) that may be damaged during IR testing must be disconnected from the circuit when performing IR testing.

NOTE: The length of a cable may be sufficiently long to preclude these readings. In such cases, with PM approval, an acceptable IR can be derived, using manufacturer's data.

3-6.4.2 *Strength Testing for Electrical Component Exposed to Ambient Pressure Greater than One Atmosphere or Seawater*

The testing contained in this subsection applies to electrical components that are newly installed and electrical components that have undergone repair that may impact the structural integrity of the electrical component. For electrical components that are critical implodable and explodable items shall instead be tested to the requirements of Appendix J or Appendix K.

3-6.4.2.1 *Hydrostatic Strength Testing*

a. Perform the test in a pressure tank filled with fresh water.

b. Conduct hydrostatic strength test of electrical components as follows:

   1) Prior to the first cycle and after the last cycle, measure the IR of the component being tested IAW section 3-6.4.1.3 and record all test data.

   2) When specified, prior to the first cycle and after the last cycle, perform continuity checks of the component being tested and record all test data.

c. Visually inspect for damage or deformation prior to and after completion of testing.

   1) 100 (+5%/-0%) psig – hold for five minutes, repeat this cycle a total of 3 times. If the MOP of the system or component is less than 100 psig then use the system MOP for this part of the hydrostatic test.

   2) 1.5 times maximum system operating pressure (+5%/-0%) – hold for a minimum of one hour, perform one cycle.

NOTE: In some cases it is impracticable to hydrostatically strength test a component by applying pressure from the outside. In these cases, the designer shall propose a suitable alternative method and submit to the PM for review and approval.

d. Document the strength testing IAW section 3-6.4.4.

3-6.4.2.2 ***Hydrostatic Strength Testing Instrumentation***

a. During conduct of hydrostatic strength testing, a separate gauge is not required for the 100 psig test provided the maximum pressure for the strength testing is 1,000 psig or less. The intent of the test is to ensure there are no imperfections in the O-ring sealing surface that can only be verified before the O-ring seats at the higher pressure. Continue to the high-pressure test following low-pressure cycling.

b. Selection of gauges shall be IAW the criteria of NSTM Chapter 504, *Pressure, Temperature, and Other Mechanical and Electromechanical Measuring Instruments*.

3-6.4.3 *Tightness Testing for Electrical Component Exposed to Ambient Pressures Greater Than One Atmosphere or Seawater.*

a. This test applies to electrical components that have been repaired and tests the watertight integrity of the component. The mechanical joint tightness testing (MJT) does not test the structural adequacy of the components. Mechanical joint testing is not a substitute for the hydrostatic test conducted in section 3-6.4.2 however if the component has passed hydrostatic strength testing IAW section 3-6.4.2, mechanical joint testing need not be performed.

b. For new electrical cables, procured from an NAVSEA S9320-AM-PRO-020/MLDG (PRO-020), *Underwater Cable Assembly and Encapsulated Components*, vendor with a PM approved procurement specification or received with cable test results approved by the PM no additional testing is required. Test results OQE IAW NAVSEA S9320-AM-PRO-020/MLDG (PRO-020) shall be provided.

3-6.4.3.1 ***Tightness Testing Instrumentation***

a. During conduct of tightness testing, a separate gauge is not required for the 100 psig test provided the maximum pressure for the tightness testing is 1,000 psig or less. The intent of the test is to ensure there are no imperfections in the O-ring sealing surface that can only be verified before the O-ring seats at the higher pressure. Continue to the high-pressure test following low-pressure cycling.

b. Selection of gauges shall be IAW the criteria of NSTM Chapter 504.

3-6.4.3.2 ***Mechanical Joint Tightness Testing (MJT)***

a. Perform the test in a pressure tank filled with fresh water.

b. Conduct the MJT as follows:

   1) 100 (+5%/-0%) psig - hold for 5 minutes, cycle three times.

   2) MOP (+5%/-0%) – hold for a minimum of 1 hour, cycle one time.

   3) No leakage is allowed.

c. Prior to the first cycle and after the last cycle, measure the IR of the component being tested IAW section 3-6.4.1.3 and record all test data.

d. When specified, prior to the first cycle and after the last cycle, perform continuity checks of the component being tested and record all test data.

NOTE: If the MOP of the system or component is less than 100 psig then use the system MOP for this part of the tightness test.

e. If it is impracticable to perform a MJT IAW this subsection then verify the watertight integrity of the electrical component with a vacuum test as follows:

   1) Evacuate the component housing to 29 (+/- 2) inches of mercury and hold for a minimum of 1 hour.

   2) No leakage is allowed.

f. Document the tightness testing IAW section 3-6.4.4.

3-6.4.4 *Test Documentation for Strength and Tightness Testing of Electrical Component Exposed to Ambient Pressures Greater Than One Atmosphere of Seawater*

a. For deep submergence systems (DSS) subject to certification IAW this manual, the minimum OQE documenting the satisfactory accomplishment of ALL required testing shall be recorded and maintained in a format suitable for review and audit. As a minimum, for components subjected to testing IAW sections 3-6.4.2 and 3-6.4.3 record the following:

   1) Platform and system tested.

   2) Serial number of components with differential pressure boundaries exposed to ambient pressures greater than one atmosphere or those components exposed to seawater.

   3) Pass/fail criteria.

   4) Type of test.

5) Actual test data, including, but not limited to, continuity before/after the hydrostatic test (if applicable) and IR before/after hydrostatic test.
6) Date test conducted.
7) Test instrumentation by manufacturer name and part number.
8) Range of test instrumentation.
9) Calibration due date & serial number of test equipment.
10) Required test pressure or vacuum.
11) Actual test pressure or vacuum.
12) Required test fluid.
13) Actual test fluid used.
14) Required duration (pressure or vacuum test).
15) Actual duration (pressure or vacuum test).
16) Test acceptance signature.

NOTE: The test acceptance signature signifies that the person signing actually performed or witnessed the test and affirms that all associated test parameters and acceptance criteria were met.

3-6.5 STRENGTH TESTING

Strength testing is recommended to be performed hydrostatically for safety purposes, other means of strength testing may be used as a replacement for hydrostatic testing upon PM approval. All pressure retaining components (e.g., piping, pressure vessels and valves) that are within the SOC whose MOP in the system is less than, or equal to, 10 times the component's design rated pressure shall be hydrostatically tested. Hydrostatic testing shall take place prior to joint tightness testing, pressure drop testing, valve seat tightness testing, and operational testing.

Strength testing is required for mechanically assembled (threaded) joints, where welding was not required for assembly. Strength testing is also required if the component was machined after vendor strength testing, unless calculations demonstrate the modified component retains a design rated pressure of 10 times the MOP in the system.

3-6.5.1 *Overpressure Protection*

a. To prevent damage to the system due to possible overpressure during testing, either the installed relief valve or a temporary self-actuating relief valve must be used.

b. The rated relieving capacity of the relief valve at test pressure shall be greater than the source being used to pressurize the system.

c. The test relief valve setting shall be 110% of MOP or as directed by the PM.

3-6.5.2 *Component Removal*

Pressure regulators, air filters, system relief valves, pressure gauges and other components may be removed and replaced with spools, jumpers, plugs, or caps during hydrostatic testing of a system where the test is required to be conducted at a pressure higher than the rated pressure of the components or if they are incompatible with the test fluid. The removed components shall be tested separately to their required test pressure.

3-6.5.3 *Test Requirements*

a. Use only Grade B water filtered through a 10 μm (maximum) filter for hydrostatic testing of the system.

b. System cleanliness shall be maintained by using test equipment that meets the cleanliness of the system or cleaning the system after testing IAW the system drawings and specifications.

c. Piping and fittings in the high-pressure portion of the system shall be hydrostatically tested to 150% MOP (±2%). The piping and fittings, including the volume tank and filter housings in the low-pressure system, shall be hydrostatically tested to 150% MOP (±2%). The flex hoses in the system shall be tested to 200% the MOP (±2%).

d. Pressure vessels shall be hydrostatically tested IAW the commercial or government specification that was used in their design and fabrication. PVHO shall be tested IAW section 3-5.2.3.

3-6.5.3.1 ***Hydrostatic Test of Piping and Piping Components***

The following test requirements are applicable to piping, valves, gauges and other similar components.

a. Hydrostatic testing, including acceptance criteria, of diving and hyperbaric system piping and piping components shall be as specified in NSTM Chapter 505 or ASME B31.1 and as specified herein when applicable.

b. Pipe and piping components whose pressure boundary is internally loaded when the system is on the surface, but is externally loaded to a pressure greater than internal pressure at depth, shall be hydrostatically tested in both the internal and external directions.

c. Pipe and piping components whose pressure boundary is externally loaded by sea pressure, but whose internal minimum operating pressure is equal to or greater than DLSS design test depth pressure, shall only require an internal hydrostatic test.

d. Pipe and piping components whose pressure boundary is externally loaded by sea pressure, but whose internal MOP is one atmosphere shall only require an external hydrostatic test.

NOTE: In the event that a required external hydrostatic test is unable to be conducted due to equipment availability, test component configuration, etc., an internal hydrostatic test at a pressure equal to 150% of the DLSS design test depth may be substituted. PM approval shall be obtained prior to substituting an internal hydrostatic test for any required external hydrostatic test. Approval will be dependent on documentation that demonstrates the ability of the pipe and/or piping component(s) to withstand the required external pressure and that sea and joint design will perform equally well when subjected to either internal or external pressure.

e. Pipe and piping components that penetrate any hull integrity boundary (tanks, spheres, skirts, etc.) where a single failure could result in internal flooding or depressurization of the diving/hyperbaric system shall be hydrostatically tested from the hull integrity boundary penetration inboard to the first isolation valve at a pressure equal to 150% of the MOP.

f. Pipe and piping components open to internally pressurized tanks and/or enclosures (including hyperbaric chambers) shall be hydrostatically tested internally from the tank and/or enclosure penetration outboard to the first isolation valve at a pressure equal to the pressure used to hydrostatically test the tank and/or enclosure.

NOTE: Incompressible fluid system mechanical joints which experience zero leakage during a hydrostatic test do not require joint tightness testing in the direction applied by the hydrostatic test. Compressed gas system mechanical joints which experience zero leakage during hydrostatic test still require joint tightness testing because the physical difference in test fluids (liquid vs. gas).

g. External hydrostatic test acceptance criteria of “no permanent deformation” for pipe shall, in addition to a complete VT, be verified by out-of-roundness measurements (defined as the difference between the major and minor outside dimensions at any one cross-section). Out-of-roundness measurements not within the pipe specification, approved drawing, or MIL-STD-1627 (for pipe bends) shall be cause for rejection of the item.

NOTE: Measurements for out-of-roundness shall be taken as close as possible to the center of the unsupported axial length. As an example, given a pipe assembly with 6 feet of pipe between two flange unions, the point of measurement would be at the midpoint of the 6 foot pipe length. Out-of-roundness measurements shall not be taken for pipe fittings.

h. A VT at test pressure shall be performed of the system to identify deformation, distortion, or leakage. There shall be no leakage across a valve seat or through a valve packing.

i. Dry the system piping and components by purging with dry N_2. A humidity of 20°F (-6.67°C) dew point shall be reached.

3-6.5.4 *Acceptance Criteria*

There shall be no leakage or permanent distortion in any pressure-containing part of the system.

3-6.5.5 *Component Replacement*

All spools, jumpers, plugs, or caps shall be removed and replaced with the components which were removed IAW section 3-6.5.2.

3-6.5.6 *Hydrostatic Retest*

A hydrostatic retest is not required after replacing valve packing, bonnet gaskets, discs, or other valve software, provided no structural modifications are made, no strength member has been deformed or otherwise modified, and a seat leakage test has been performed. Following replacement of parts, as previously noted, the unit shall be checked for leakage at normal operating pressure. A hydrostatic retest is required if repairs involve welding or structural modification in any part of the pressure-containing system.

3-6.5.7 *Hydrostatic Test Documentation*

The following information, as a minimum, shall be recorded as documentation of the hydrostatic testing:

a. Platform and system tested.

b. Date test conducted.

c. Test boundary.

d. Calibration dates and serial numbers of test equipment.

e. Test fittings, blanks and jumpers (if applicable).

f. Required test pressure.

g. Actual test pressure.

h. Test fluid used.

i. Required duration.

j. Actual duration.

k. Allowable leakage.

l. Measured leakage.

m. Results of inspections/out of roundness measurements.

n. Valve line-up for test (typically shown as a schematic).

NOTE: Valve line-ups for pressure testing shall provide the following information: Valve designator and/or valve nomenclature, required valve positions, initials and date of the Valve Positioner verifying by observation the actual valve positions, and test entry point when an external pressure source is used for an internal pressure test.

o. Test acceptance signature.

NOTE: The test acceptance signature shall be annotated as attesting that the person who actually performed or witnessed the test is verifying that all associated test parameters were met.

3-6.6 VALVE SEAT TIGHTNESS TESTING

New, refurbished, or repaired valves and regulators shall be seat tightness tested. This testing shall be performed after component cleaning and prior to operational testing.

3-6.6.1 *General*

The valve seat tightness test shall be performed IAW sections 3-6.6.4 or 3-6.6.5 below and recorded on a test data sheet. He may be used for O_2 systems if N_2 at the required pressure is not available. However, compliance with leakage requirements may prove more difficult because of the lighter (less dense) gas. All test gas shall meet MIL-STD-1330D. The tolerance on all test pressures shall be ±2% of the test pressure. See PSNS IPI 5050-916, *Ball Valve Seat Stack Height Measurement and Globe and Gate Valve Blue Check*, for more guidance.

Globe-type valve designs and poppet valves shall be tested in the direction that tends to unseat the valve. Globe-type designs and poppet valves shall also be tested in the direction that tends to seat the valve when the valve acts as a boundary closure between two distinct operating pressure systems/subsystems.

NOTE: **Valves which act as a boundary closure between two distinct pressure systems or subsystems shall have the test pressure of each port identified by a temporary tag when testing is performed in a shop or on a test bench and the ports are not to be otherwise marked or identified. The temporary tags can be removed after the valve has been installed. The purpose of the tagging is to alert personnel to the correct orientation of the valve in the system.**

Ball valves shall be tested in the direction of flow as determined by the orientation of the valve in the DLSS. Ball valves that act as a pressure boundary closure between two distinct operating pressure systems or subsystems shall be tested from both directions. Ball valves that are designated flood control closures shall, in addition to being tested at the MOP, be tested from the direction of the flooding source at a pressure of 100 psig.

NOTE: **The test pressure applied to each port shall be identified by temporary tags when testing is performed in a shop or on a test bench and the ports shall not be otherwise marked or identified. The temporary tags can be removed after a valve has been installed. The purpose of the tagging is to alert personnel to the correct orientation of the valve in the system.**

3-6.6.2 *Helium (He), Helium-Oxygen (HeO_2), Oxygen (O_2), Life Support and Exhaust Systems Only*

Pressurize each valve under the seat with a minimum of 10% He (O_2 systems with N_2) to the MOP of the system. Use the recommended procedure given in section 3-6.6.4 for verifying that there is zero seat leakage. If leakage rates are specified in the drawings for systems being tested with He, those rates take precedence.

3-6.6.3 *Air Systems*

Pressurize each valve under the seat with N_2 or diver quality air to the MOP of the system. Use the recommended procedure given in sections 3-6.6.4 and/or 3-6.6.5 for verifying that the seat leakage is zero.

3-6.6.4 *Leak Capturing Method*

Pressurize each valve, from anywhere upstream of the "under-the-seat" side of the valve to the operating pressure of the system. Attach a ¼ –inch I.D. clear Tygon tube to the first available point any distance downstream of the valve under test. Shut the next valve downstream of this test point to isolate this section of pipe so that all leakage must flow through the Tygon tubing. Mark 2 inches of the end of the Tygon tubing in ¼ –inch increments. Roll up some of the length of tubing in order to squeeze air out, then immerse the free end in a beaker of water. Unroll tubing and return it to its original shape. This action will draw some water up into the tubing. Hold the tubing vertical in the beaker and move up or down until the water level inside the tubing is lined up with the level in the beaker. Note where this level falls on the ¼-inch markings on the tubing. This will ensure that there is only one atmosphere pressure on the isolated section of piping. Wait for 1 minute then realign the water levels inside and outside the tubing. This will ensure that there is again only one atmosphere pressure on the isolated portion of the piping and any leak rate read in cc/min. regardless of the volume of the isolated portion. A ¾-inch change in level in 1 minute equals 0.6 cc/min (for air systems, the level should not change in 1 minute).

3-6.6.5 *Pressure Drop Method*

If it is not possible to capture the leakage and only as a last resort, an installed gauge upstream of the valve under test may be used for the seat tightness test with the approval of the PM. Isolate the gauge and the test valve by closing the first valve upstream of the gauge. The downstream side of the test valve shall be open to atmospheric pressure. Observe the gauge for 30 minutes minimum. The pressure should not drop.

NOTE: The acceptance leak rate of 0.6 cc/min would drop a 3000 psi test pressure 1 psi in one hour if the volume of the isolated section was 500 cc. It is therefore apparent that this is not a satisfactory method for discerning small leak rates and therefore should only be used when absolutely necessary.

3-6.6.6 *Valve Seat Tightness Test Documentation*

The following information, as a minimum, shall be recorded as documentation of the valve seat tightness testing:

a. Platform, system, and valve tested.

b. Date test conducted.

c. Test boundary.

d. Direction of the pressurization of the valve.

e. Calibration dates and serial numbers of test equipment.

f. Test fittings, blanks and jumpers (if applicable).

g. Required test pressure.

h. Actual test pressure.

i. Test fluid used.

j. Required duration.

k. Actual duration.

l. Allowable leakage.

m. Measured leakage (Leak Capture Method).

n. Initial and final gauge pressure (Pressure Drop Method).

o. Valve line-up for test (typically shown as a schematic).

NOTE: Valve line-ups for pressure testing shall provide the following information: valve designator and/or valve nomenclature, required valve positions, initials and date of the Valve Positioner verifying by observation the actual valve positions, and test entry point when an external pressure source is used for an internal pressure test.

p. Test acceptance signature.

NOTE: The test acceptance signature shall be annotated as attesting that the person who actually performed or witnessed the test is verifying that all associated test parameters were met.

3-6.7 JOINT TIGHTNESS TEST

This test subjects mechanically joined pressure containing boundaries of pipe and piping components to an internal pressure equal to 100% of MOP, and if applicable, an external pressure equal to 100% of DLSS design test depth pressure.

New, major or minor repaired pipe and piping components shall be subjected to an internal joint tightness test prior to SOTs or use. O_2 systems shall be pressurized using clean, dry N_2. Air systems may be pressurized using air or N_2. HeO_2 systems shall be pressurized using a gas mixture containing at least 10% He. All test gas shall meet MIL-STD-1330D.

Joint tightness tests conducted on components prior to installation in the system shall have a duration of at least 5 minutes. Joint tightness tests of components after installation in the system shall have a duration of at least 15 minutes followed by time to inspect each mechanical joint.

Pipe and piping components whose pressure boundary is externally loaded by sea pressure, but whose internal MOP is always equal to or greater than DLSS design test depth pressure, shall only require an internal joint tightness test.

Pipe and piping components whose pressure boundary is externally loaded by sea pressure, but whose internal minimum operating pressure is less than DLSS design test depth pressure shall require both external joint tightness testing and internal joint tightness testing.

NOTE: The ability to conduct external joint tightness testing is extremely limited. Recognizing the limitations, accomplishment of this testing may be deferred by assembling the affected joints using "controlled assembly" procedures, similar to those specified by Forces Afloat QA Manuals, and completing a controlled dive to design test depth which results in no leakage.

Pipe and piping components open to internally pressurized tanks and/or structural enclosures (including hyperbaric chambers) shall be joint tightness tested internally from the tank and/or enclosure penetration outboard to the first isolation valve at a pressure equal to 100% of the maximum internal operating pressure of the tank and/or enclosure.

Pipe and piping components that penetrate any hull integrity boundary (tanks, spheres, skirts, etc.) where a single failure could result in internal flooding of the DLSS shall be joint tightness tested from the hull integrity boundary penetration inboard to the first isolation valve at a pressure equal to 100% of DLSS design test depth pressure or 100% of system MOP, whichever is greater.

Acceptance criteria for joint tightness testing shall be zero leakage, unless He is used as a test medium. When He is used as a test medium the allowable leakage shall be 0.6 cc/min. If leakage rates are specified in the system drawings, those rates take precedence over those listed herein.

3-6.8 PRESSURE DROP TESTS

Recompression chambers, SSDS, saturation DLSSs, and gas supply and storage systems shall all be pressure drop tested. The pressure drop test(s) shall be performed following the completion of the hydrostatic, joint, and seat tightness testing and prior to operational testing. For low-pressure air systems, the duration of this test shall be 6 hours. For all other systems, the duration of this test shall be equal to the longest duration that the system is anticipated to be pressurized during operation or 24 hours, whichever is less.

3-6.8.1 *Helium (He) and Helium-Oxygen (HeO_2) Systems*

Test the system using a mixture of gasses that includes at least 10% He and following the procedures of sections 3-6.8.4 or 3-6.8.5 as appropriate. If leakage rates are specified in the drawings for systems being tested with He, those rates take precedence over those given in sections 3-6.8.4 and 3-6.8.5.

3-6.8.2 *Oxygen (O_2) Systems*

Test the system using N_2 and following the procedures of sections 3-6.8.4 or 3-6.8.5 as appropriate.

3-6.8.3 *Air Systems*

Test the system using air and following the procedures of sections 3-6.8.4 or 3-6.8.5 as appropriate.

3-6.8.4 *High-Pressure Systems*

Pressure drop tests on high-pressure systems shall be performed using the following procedure:

NOTE: All measurements shall be documented on system serialized test record.

a. Ensure isolation from low-pressure side of system by appropriate blanks.

b. Charge the system with dry, oil-free N_2 to MOP ±100 psig. High-pressure clean air may be used on air systems.

c. Record the atmospheric temperature and test pressure at the start of the test and again at the conclusion.

d. Correct the final pressure as described in section 3-6.8.6.

e. Acceptance criteria: Allowable pressure drop is 1% of the initial test pressure (corrected to atmospheric conditions at the start of the test). No leakage is allowed on O_2 systems. If the pressure drop is greater than allowed, all connections and joints shall be soap tested to determine the point of leakage. The leak shall be repaired and documented, and the system shall be retested.

3-6.8.5 *Low-Pressure Systems*

Pressure drop tests on low-pressure systems shall be performed using the following procedure:

a. Charge the low-pressure system with dry, oil-free N_2 to MOP ±5 psig. Clean pressurized air may be used on air systems.

b. Record the atmospheric temperature and test pressure at the start of the test and at the conclusion.

c. Correct the final pressure as described in section 3-6.8.6.

d. Acceptance criteria: Allowable pressure drop for air systems is 5% of the initial corrected test pressure. Allowable pressure drop for mixed gas is 1% of the initial corrected test pressure. No leakage is allowed in O_2 systems. If the pressure drop is greater than allowed, all connections and joints shall be soap tested to locate the leak. The leak shall be repaired and documented, and the system shall be retested.

3-6.8.6 *Temperature Correction*

The test pressure at the conclusion of the test must be corrected to the atmospheric conditions existing at the start of the test. The correct pressure is obtained as follows:

1. Add 14.7 psi to the initial test pressure recorded to obtain absolute pressure.
2. Add 460°/237.78° to the initial temperature (°F/°C) recorded to obtain absolute temperature.
3. Add 460°/237.78° to the final temperature (°F/°C) recorded to obtain absolute temperature.
4. Multiply the initial absolute pressure calculated in step 1 by the final absolute temperature calculated in step 3.
5. Divide the result obtained in step 4 by the initial absolute temperature calculated in step 2.
6. Subtract 14.7 psi from the result obtained in step 5. This result will be the corrected final pressure in psig.
7. Gay-Lussac's Law for systems up to 5,000 lbs., for systems above 5,000 lbs. contact 00C PM for guidance. See SUPPLEMENTAL MEMO for more information

$$(P/T)_1 = (P/T)_2$$

3-6.8.7 *Pressure Drop Test Documentation*

The following information, as a minimum, shall be recorded as documentation of the pressure drop testing:

a. Platform and system tested.

b. Date test conducted.

c. Test boundary.

d. Calibration dates and serial numbers of test equipment.
e. Test fittings, blanks and jumpers (if applicable).
f. Required test pressure.
g. Actual test pressure.
h. Test fluid used.
i. Required duration.
j. Actual duration.
k. Allowable leakage.
l. Measured leakage.
m. Temperature and pressure data supporting drop test.
n. Valve line-up for test (typically shown as a schematic).

NOTE: Valve line-ups for pressure testing shall provide the following information: valve designator and/or valve nomenclature, required valve positions, initials and date of the Valve Positioner verifying by observation the actual valve positions, and test entry point when an external pressure source is used for an internal pressure test.

o. Test acceptance signature.

NOTE: The test acceptance signature shall be annotated as attesting that the person who actually performed or witnessed the test is verifying that all associated test parameters were met.

3-6.9 AIR PURITY TEST

A gas sample from the DLSS shall be taken after fabrication has been completed to ensure that gaseous contaminants are not presenting an unacceptable atmosphere for its occupants. Both the atmosphere within the system and its compressed gas supply must be checked and evaluated for contaminants under normal operating conditions. Evaluations of closed-atmosphere systems entail three basic requirements: a valid sampling program, effective analysis techniques, and meaningful interpretation of the data obtained. Any contaminants found must be evaluated in terms of personnel safety, taking into account their toxic and corrosive hazard potentials, the durations of exposures to them, their sources, and potential methods of their removal. Contaminants may be introduced into the DLSS from a number of sources including materials of fabrication, as contaminants from compressed gases, and from other sources such as solvents used to clean the system.

Contaminants may also be introduced into the DLSS by divers or maintenance personnel.

Regardless of how thorough it may be, no analysis of gas from DLSSs can rule out all potential hazards. Nevertheless, these guidelines are based on expectations of potential contaminants in both the atmosphere of the DLSS and the supply gases. These procedures are designed to screen for a wide range of volatile organic compounds (VOCs), including hydrocarbons, and to ensure that supply gases are of high purity, (i.e., that they do not contain significant amounts of other fixed gases such as O_2, N_2, He, CO_2, or CO). The presence of VOCs, which are routinely seen in DLSSs and supply gases, should be expected in any samples taken.

The need for testing for additional volatile contaminants beyond what is described here will depend on 1) experience with each DLSS and 2) contaminants expected from specific materials and gear used in the complex. Since no testing can ensure complete safety, as a general rule any unknown odor or the observation of any aerosol (i.e., mist or smoke) associated with the DLSS should be treated as potentially hazardous until that odor or aerosol is shown otherwise.

Some potential contaminants (e.g., chlorine, hydrochloric acid, ozone, nitrogen dioxide) are very reactive and toxic. However, these chemicals readily react with metal surfaces and probably do not persist very long. Consequently, such species probably are not present in a DLSS except after an engineering casualty. Furthermore, no easy and reliable testing methods useful for DLSSs are available for these types of volatile contaminants.

3-6.9.1 *Setup*

Using standard procedures, set up the DLSS for operation. Systems shall not contain CO_2 or contaminant absorbents (e.g., Sodasorb or Purafil); any contents of charcoal filters should be removed. The system shall contain all gear and equipment (i.e., hoses, masks, bunks) that are normally inside the system during operations, so that a total systems check can be made. If the DLSS consists of two or more connected chambers, leave all inter-chamber hatches open so that the entire complex is tested.

3-6.9.2 *Hyperbaric Systems*

Prior to taking an air sample, air tightness test and valve seat tightness test of the system shall have been satisfactorily completed and the entire system assembled. The hyperbaric system should be cyclically pressurize at least 3 times between atmospheric pressure and approximately 8 ata, or its MOP, whatever is less, using hydrocarbon-free air or He. This will reduce the level of any contaminants initially inside the DLSS. The system shall be brought to the maximum operational temperature limit and pressurized to approximately 4 ata or to its MOP, whichever is less. Let the system sit at depth and at temperature, preferably for 72 hours but for at least 24 hours, to allow any off-gassing chemicals to build up. Once the test has begun, do not add any gas to maintain depth because of leakage. However, if the depth at the end of the hold period is less than 90% of the starting depth, the test must be repeated after leaks have been repaired. When practical, operate the ECS (i.e., scrubber fan), without CO_2 or contaminant adsorbent, for at least two hours before sampling the gas to ensure that the atmosphere has been well mixed within the system.

At the end of the hold period, attach a stainless steel whip to the system plumbing via a high-pressure valve and purge all hardware in the sampling line with gas at an audible flow rate for three times the volume and a minimum of 5 minutes, reducing pressure to the minimum required to pull a sample. To ensure reliable sampling, the whip's point of attachment will be as close to the actual system atmosphere as possible. Gas should contact only metal tubing and high-pressure valves that have been previously cleaned to O_2-safe specifications (MIL-STD-1330).

Following purging, draw duplicate gas samples into high-pressure stainless steel gas collection cylinders that have been previously heated and evacuated to at least 50 millitorr. To ensure an adequate volume of gas for analysis, these cylinders should have an internal volume of at least 500 ml and should be suitable for storing ppm levels of VOCs for up to one month. The cylinder shall be connected to the whip while gas is flowing from it to purge any dead space in the connection. The cylinder valve adjacent to the whip is then opened slowly and 1 minute allowed for the cylinder to equalize with system pressure before the valve is closed. Leave gas flow on as the first cylinder is disconnected from the sample line and as the second cylinder is attached.

OQE and tractability collection for the cylinder shall be as follows:

a. Date, time, and system pressure at beginning of pressure test;

b. Date, time, and system pressure at time of gas sampling;

c. System fluid;

d. Sample location, including location of whip attachment;

e. Atmospheric internal temperature within the tested system at several times during the test; and

f. Summary of test procedures.

3-6.9.3 ***All Systems – Supply Gas***

Draw duplicate gas samples from each supply gas bank header in a fashion similar to that described for hyperbaric systems. Gas sample shall be drawn from flasks and the furthest point downstream of use for breathing gas. The header shall be pressurized for at least 24 hours before sampling. A high-purity regulator (e.g., with a stainless steel diaphragm) may be needed upstream of the sample whip to allow samples to be collected at 4 ata. Again, record sampling procedures and conditions.

3-6.9.4 ***Analytical Procedures***

The laboratory performing the chemical analysis must be approved by the PM based on the laboratory's experience and professional certification.

Gas samples shall be analyzed as described below. These procedures, or alternate ones that meet or exceed the specifications listed below, must be followed. Both duplicate cylinders from each sampling exercise shall be analyzed for all constituents defined below when sufficient sample gas is available.

3-6.9.4.1 ***Volatile Organic Compounds (VOC)***

Gas samples shall be screened initially using gas chromatography (GC) with flame ionization detection (FID) or with a methodology of equivalent sensitivity and precision. To ensure detection of the most likely contaminants, GCs should be configured for detection of a wide range of VOCs including:

a. Highly volatile light compounds such as:
   1) Ethane.
   2) Propane.
b. Less volatile heavier compounds such as:
   1) Benzene.
   2) Toluene.
   3) Xylenes.
   4) Trimethyl benzenes.
c. Highly polar compounds such as:
   1) Isopropyl alcohol.

The specific chemicals listed above are representative of the three classes of VOCs that may be present in DLSSs; they do NOT comprise a list of all the individual compounds that may be expected. Gas standards of representative VOCs including those listed above, and certified by the vendor to ±5% or better and traceable to the National Institute of Standards and Technology (or equivalent national agency), shall be used for the analysis unless otherwise approved by the PM.

GCs for initial screening must be capable of detecting VOCs down to a level of 0.5 ppm or lower (depending on the specific compound being analyzed). The precision of a GC for repeat injections depends on the specific type of detector, the compound being analyzed, how good the chromatographic separation or resolution is for each compound, and what concentration level is being tested. In general, precision of VOCs analyzed at a level of 5-10 ppm should be ±5% or better.

Quantitation shall be done based upon data obtained from calibration using GC peak areas from the certified gas standards. Individual contaminants other than the actual chemicals in the calibration standards shall be quantified relative to the species in the standard closest to their GC retention times. Direct injection of specific chemical species into the GC and/or GC/mass spectrometer shall be used to identify any GC peaks estimated greater than 1 ppm. Preconcentration (e.g., on solid sorbent packing and/or by cryogenic trapping) may be necessary prior to identification when levels of contamination are low (<= 1 ppm).

3-6.9.4.2 ***Fixed Gases***

Gas supply samples shall also be analyzed for the fixed gases, O_2, N_2, He, CO_2, and CO. An analytical methodology such as GC equipped with methanization/FID or infrared spectroscopy should be used to measure CO_2 and CO. Such a method must be able to detect 5 ppm CO. GC with thermal conductivity detection should be used to analyze the other fixed gases. Precision should be at least 1% for both a 20 to 22% O_2 standard and 2,500 to 5,000 ppm CO_2 standard. Fixed gas quantitation shall be based on gas standards certified by the vendor to ±1%.

Results shall be reported as follows for each sample:

a. For VOCs (>1 ppm): identification and quantitation to the nearest 0.1 ppm.

b. For fixed gases (only gas supply samples):

    1) O_2, N_2, and He to the nearest 0.1%;

2) CO_2 to the nearest 5 ppm; and
3) CO (>5 ppm) to the nearest 1 ppm.

3-6.9.5 *Interpretation of Results*

Results from analysis of both the atmosphere samples and the supply gases shall first be examined in terms of differences between duplicate samples. Any major differences such as presence of a contaminant in one of the gas samples and its absence in the duplicate sample will necessitate that the DLSS be retested or the gas supply header be re-sampled.

Results from analysis of atmosphere samples shall then be compared to those from the VOC analysis of the actual supply gas used during the system test. Any VOCs found in the supply gas should be subtracted from the results from the system atmosphere to correct for the supply gas contribution. These modified atmosphere sample results shall then be corrected for depth by converting to SEVs. This conversion is accomplished by multiplying the reported values of any contaminant by the test depth at the time of sampling. Example: 2 ppm toluene measured using GC in gas after being collected from a chamber tested at 4 ata would have an SEV equal to 8 ppm (2 ppm x 4 ata) toluene.

A few selected contaminants that may be present in hyperbaric complexes are given in NAVSEA SS521-AG-PRO-010, with their 90-day continuous exposure limits (or 7-day limits, where a 90-day limit is unavailable). In the absence of specific guidelines for hyperbaric exposures, these limits will be used as safe limits for manned hyperbaric systems.

Where any of these chemicals are found in atmosphere samples, the calculated SEV shall be compared to the limit in NAVSEA SS521-AG-PRO-010. If the SEV exceeds this, the chamber is unsafe for use. If two or more contaminants are reported or if a limit for the reported contaminant is not listed, contact the PM for guidance.

Results from samples taken from the supply gas shall also be compared to the limits listed. When only one contaminant is reported and its limit is listed, that limit shall be divided by the reported concentration to produce the maximum safe depth in atmospheres to which the gas can be used in operating the chamber. When the supply gases contain undesired levels of other fixed gases (e.g., O_2, N_2, He, CO_2, CO), retesting should be performed to confirm findings. Corrective action may then be required to ensure the desired level of gas purity; such action may include recharging of the gas banks and/or reevaluating current gas handling procedures and hardware.

See NAVSEA SS521-AK-HBK-010. Additional advice on toxicity considerations not covered in available publications may be obtained from the Toxicology Detachment, Naval Health Research Center, Wright-Patterson Air Force Base, OH, or NEDU, Panama City, FL.

3-6.10 NON-METALLIC OFF-GAS TESTING

3-6.10.1 *General*

Non-metallic material shall be off-gas tested in accordance to Appendix F prior to installation unless there is documented historical evidence that the material is safe for use in USN DLSSs. If testing is not conducted on non-metallic components, it is the builders responsibility to provide documentation to the PM proving that the material is safe for use in the intended application. The builder shall contact the PM for guidance on off-gassing tests as required, to include the sample procedure and the chemical analysis.

3-6.11 VERIFICATION OF AS-BUILT STRENGTH (PROOF TEST) FOR EXTERNALLY LOADED PRESSURE HULLS/VESSELS AND HARD STRUCTURES

NOTE: The requirements of this section apply only to identical reproduction of a prototype which has successfully met the requirement of section 2-2.6.5.3.

A proof test to at least 1.5 times the MOP shall be conducted on all pressure vessels, hard structures, and penetration fittings that are subject to external pressure.

NOTE: "Hard structure" typically refers to DLSS components whose function is to enable the storage, transfer, or controlled movement of a working fluid at relatively low system pressure, while resisting the external force due to ambient sea pressure. For example, variable ballast tanks might be classified as hard structure. Volumes external to the pressure hull, designed to maintain a static, dry, nominally one atmosphere environment within the volume for the purpose of protecting pressure-sensitive components, are usually classified as implodables and are treated in Appendix J. Camera housings and lights are examples of implodable volumes. It is important to note also that components/volumes inside the pressure hull, which themselves may be internally exposed to ambient sea pressure, may be classified as hard structure. This explanation is provided as general guidance and does not preclude the PM from providing

justification for classifying a particular component as either hard structure or implodable.

For hull structures which have had full-scale model tests, described in section 2-2.6.5.3 b or c, IAW section 2-2.6.5.4.1, the proof test required by this section does not have to be instrumented.

For hull structures which have not had full-scale model tests described in sections 2-2.6.5.3 b or c, the proof test required by this section shall be an instrumented (strain gauge) pressure test IAW section 2-2.6.5.4.1, except that the test pressure shall be at least equal to the MOP. Subsequent to testing, pressure boundary weld NDE may be specified or required by the PM. The results of this test shall be compared to strain gauge data obtained during reduced scale model testing, similar item model testing, and/or calculations. Where multiple pressure vessels or hard structures are fabricated to identical designs, only the first item (i.e., prototype) will require instrumentation during the proof test. All items subsequent to the prototype require proof tests to at least the MOP, but need not be instrumented.

3-6.11.1 *Proof Testing Procedures/Instrumentation*

For all pressure vessels, PM approval of the proof test procedure shall be obtained prior to commencing the proof test. The proof test procedural requirements shall be similar to the model test procedural requirements of section 2-2.6.5.4.1.

3-6.12 TESTING PARAMETERS FOR PERMANENTLY OR TEMPORARILY MOUNTED EXTERNAL IMPLODABLE AND EXPLODABLE ITEMS

This section provides guidelines for ensuring that DLSSs or DLSS personnel are not subjected to underwater explosion or implosion loading, resulting from the failure of an uncompensated DLSS component. The requirements for testing and components to be tested can be found in Appendix J.

3-6.13 TESTING PARAMETERS FOR EXPLODABLE ITEMS DUE TO DECOMPRESSION

During the design process, particular attention will be given to the shrapnel effects produced by the explosion of items such as interior lights and instrument bulbs inside the DLSS and to the prevention of these occurrences. Many devices are subject to inadvertent explosion during decompression because they have been infiltrated by He or other gases during a compression cycle. These devices, in themselves, may become hazards within the DLSS and such this phenomena should have been considered during the design process. There is no known analytical method for determining the material adequacy of items within a DLSS which may explode and cause a casualty. All items that may explode due to decompression shall be evaluated IAW Appendix K.

3-6.14 TEST-GAUGES/INSTRUMENTATION

All gauges and instrumentation used for testing shall meet the requirements of section 3-5.1.5.

3-6.15 TESTING OF LIFTING POINTS AND RIGGING

3-6.15.1 *Padeyes, Lifting Lugs, and Hard Points*

All arrangements for handling and supporting weights (including weights of any personnel), all arrangements for taking heavy strains, and all parts where the safety of the system or life depend, shall be given a static load test equal to twice the specified working load unless otherwise specified in the PM approved drawings. In cases where the working load is not specified the test load shall be based on the expected duty of the arrangement. For hoisting arrangements, the static test load shall be suspended clear of all supports and held suspended for a minimum of 2 minutes (10 minutes for hoists, cranes or crane structures). After relieving the static test load, there shall be no evidence of permanent deformation of structure. PVHO lifting points shall be load tested prior to the hydrostatic test and shall be included in the post hydrostatic testing NDT. Documentation of this test shall be delivered along with the equipment.

3-6.15.2 *Rigging*

Rigging shall be tested, marked and certified IAW NAVFAC P-307, *Weight Handling Program Management*, additional testing requirements may be required by the PM. All records required by shall be delivered along with the equipment.

3-6.16 DIVER HANDLING SYSTEM TESTING REQUIREMENTS

All new diver handling systems must be tested prior to initial certification and operational use. These tests are intended to confirm the adequacy of the design, the operational characteristics, and the validity of the OPs.

Test procedures for all load tests and SOTs shall be submitted to the PM for review and approval.

The following paragraphs identify the requirements for conducting static, dynamic, and rated load tests. In addition, component level testing is also addressed post maintenance testing requirements are also addressed. For systems designed to commercial classification society standards (i.e. ABS, DNV-GL, etc.), testing shall be IAW class rules and as agreed to by the PM.

3-6.16.1 *No Load Test*

No load tests are conducted to evaluate the functioning of the diver handling system. The diver handling system shall be operated through its full range of motions and directions. Check for unusual noise, vibration, leaks, or overheating in machinery and control components. Also check for proper operation of all indicator lights, gauges and safety interlock features (if applicable).

3-6.16.2 *Static Load Test*

A static load test physically verifies the structural integrity of the fully assembled diver handling system. Test loads may be applied with certified test weights or by mechanical devices with calibrated load measuring gauges.

a. The static test load shall be equal to 200% of the rated load of the handling system, and shall be held for a minimum of 10 minutes by the brake without power to the system. No evidence of structural or rigging component deformation, or brake slippage is allowed.

b. Upon completion of the static load test, the critical load bearing components and strength welds of the handling system shall be inspected to verify there is no permanent set, deformation, cracking, or other damage to any part of the structure, foundations, machinery, and reeving components. For initial certification, or if load bearing component repair or modification work was accomplished, the level of inspection shall be as specified on the drawings or in separate specifications to include MT or PT as applicable.

c. End fittings on ropes included in the test shall be inspected for slippage and damage; none is allowed.

d. The static load test shall be conducted when the support ship is pier-side and experiencing no significant motion. The handling system shall be tested in the position of maximum loading.

e. Where static load testing of the system is not practical, component level testing may be accomplished with PM approval.

3-6.16.3 *Dynamic Load Test*

A dynamic load test demonstrates the capability of the diver handling system to operate with the rated load under the dynamic conditions of the support ship's motions at sea. The test shall demonstrate the handling system's overload capabilities throughout its complete operating range. Care must be taken to ensure specific operating limits of the components being tested are not exceeded.

a. The dynamic load test shall be equal to 150% of the rated load of the handling system. Test loads shall be moved through three complete cycles of the handling system, with all limits of its operating modes (raising, lowering, traversing, traveling, rotating, etc.) included in the test. The handling system, with the test load, shall be stopped at least three times in each direction to ensure proper brake operation. No speed is specified; however, the maximum speed attainable with the test load shall be used.

b. During the dynamic load test, the handling system shall be checked for any signs of binding, abnormal noise or vibration, and overheating. As a minimum, the following equipment parameters shall be recorded during the test: motor amperage, hydraulic fluid temperatures and pressures (including main loop, servo, and replenishing pressures), operating speeds for all modes of operations (i.e., booming out, booming in, and/or raising and lowering, etc.). In general, the following shall be verified and noted: smooth operation and proper stopping and holding of the test weight.

c. Upon completion of the dynamic load test the handling system shall be inspected for any indications of the following: warping or permanent deformation; leaking hydraulic fluid from any component or connections; wear patterns on sheaves, ropes, and gear trains; and proper drum spooling; none is allowed.

d. The dynamic load test shall be conducted when the support ship is pier-side and experiencing no significant motion.

3-6.16.4 *Rated Load Test*

A rated load test demonstrates the capability of the diver handling system to operate with its intended load at its rated speed. It also verifies that all hydraulic and electrical components operate within their specified operating limits.

The rated load test shall be equal to 100% of the rated load of the diver handling system. Test loads shall be moved completely through the handling system's full operating range, and within limits of all operating modes (raising, lowering, traversing, traveling, rotating, etc.). The system shall be capable of hoisting the DLSS at the system's rated speed when the hoist wire rope or synthetic line is on the outermost layer of the drum. The test load shall be run through at least three cycles to demonstrate proper operation. Each cycle is to be run at the specified normal operational speed of the handling system.

3-6.16.5 *Component Level Testing Requirements*

Some handling systems have unique components and may require additional or modified testing. The test documents for those tests shall be submitted to the PM for review and approval on a case basis. The system drawings/specifications should be consulted for further testing requirements. The tests specified in Table 18, and the applicable tests specified by a drawing or specification shall be conducted for each task identified. If there is a conflict between the tests specified in Table 18 and the test specified by the applicable drawing or specification, then the requirements of this document take precedence, unless specifically authorized by the PM.

NOTE: If the system is certified to a commercial classification society standard (i.e., ABS, DNV-GL) fully documented testing is still required to be submitted to the PM and retained for review by the SCA.

Table 18: Testing Requirements – Load Bearing Components

Load Bearing Component	Test Requirements
Drum or sheave (main lift wire, guide wire or umbilical)	Static load test[1], dynamic load test, rated load test.
Hook[2]	Static load test[1].
Main lift rope(s) (wire rope and synthetic line)	Pull test[3], no-load test.
Guide/Clump lift rope (wire rope or synthetic line)[4]	Pull test[3], no-load test
Umbilical strain relief	Static load test[1]
Coupling, shaft, or bearing	Dynamic load test, rated load test
Non-load bearing shaft or bearing	No-load test.
Gear (load bearing or load controlling only)	Dynamic load test, rated load test.
Gear bearing oil-seal	No-load test.
Hard structure or foundation repair, replacement or modification (i.e. boom, cross beam, foundation, etc.)	Static load test[1]

(1) If the affected component can be rigged such that the 200% test load can be applied to it only, then the test would suffice for the static load test.
(2) "Hook" in this section is a generic term for the interface device between the DLSS and the handling system.
(3) All wire rope end fitting installations must be pull tested and held for a minimum of 10 minutes to either 200% of the design load of the handling system, or to 40% of the nominal breaking strength of the wire rope. All synthetic line eye splices shall be pull tested and held for a minimum of 10 minutes to 200% of the design load of the handling system.
(4) Any winch lifting assembly (i.e. lifting wire, guide wire or umbilical) used as an alternative means of recovering divers to the surface shall be tested in the same manner as the main lift assembly wire.

3-6.16.6 *Handling System Hydraulic and Pneumatic System Test Requirements*

Hydraulic and pneumatic systems and components shall be tested IAW the requirements of this subsection. However, systems designed to the requirements of 46 CFR, Chapter 1, Subchapter F or an approved industrial standard may be tested to the requirements of those standards, providing the fabricator can show there will be no detrimental effect on system safety.

All test procedures for items within the SOC, including FAT procedures, shall be submitted to the PM for review and approval.

3-6.16.6.1 ***Hydrostatic Testing Requirements***

a. All new piping and pressure-containing components shall be hydrostatically tested. In addition, any piping, pressure-containing components, or tanks (accumulators, cylinders, etc.) that have been subject to repairs or modifications affecting its structural integrity (such as welding, brazing, or reboring) must be retested to verify the work has had no detrimental effect.

b. Hydrostatic test pressure for piping and piping components shall be 150% of MOP. The pressure used to perform the test shall be within ±3% (but no greater than ±100 psig) of the designated test pressure, unless otherwise specified.

c. The duration of hydrostatic tests for pipe and piping components, including piece parts, conducted in a shop or on a test bench shall be not less than 1 minute, plus the time required for inspection.

d. The duration of hydrostatic tests for pipe and piping components, including piece parts, conducted in the as-installed configuration shall be not less than 15 minutes, plus sufficient time for inspection of mechanical joints and components within the test boundaries.

e. Hydrostatic testing of hydraulic system piping should be performed with system fluid. However, water or other flushing fluids are permissible when accomplished IAW MIL-STD-419*, Cleaning, Protecting, and Testing Piping, Tubing, and Fittings for Hydraulic Power Transmission Equipment*, or an approved industrial standard. Hydrostatic tests of installed systems shall be conducted with system fluid only. However, hydrostatic testing of pneumatic systems should be conducted with demineralized water.

f. For flexible hoses the hydrostatic test procedure and pressure shall be IAW paragraph 8.2 of NAVSEA S6430-AE-TED-010 or an approved industrial standard.

g. Acceptance criteria for hydrostatic tests shall be no permanent deformation as determined by VT. Leakage past mechanical joints or valve seats during the test shall not be cause for rejection as long as the test pressure can be maintained. However, any leakage shall be noted in the test results section of the test procedures.

3-6.16.6.2 ***System Tightness Testing Requirements***

a. All pipe and piping components shall be subjected to a tightness test prior to operating the system.

b. The tightness test pressure shall be 100% of the MOP. The pressure used to perform the test shall be within ±3% (but no greater than ±100 psig) of the designated test pressure, unless otherwise specified.

c. The duration of tightness tests for pipe and piping components conducted in the as-installed configuration shall be not less than 15 minutes soak time at system operating pressures and temperatures, plus sufficient time for inspection of mechanical joints and components within the test boundaries.

d. Tightness testing should be conducted using system fluid.

e. Acceptance criteria shall be zero external leakage.

3-6.16.6.3 ***Handling System Relief and Counter-Balance Valve Test Requirements***

The safety of divers and DLSS operators depend on the proper operation of these valves. Relief valves are used in motion compensated circuits as well as for protecting the hydraulic system from over pressurization. Counter-balance valves are used to stop the DLSS from moving uncontrollably in the event of a sudden loss of system pressure.

All relief or counter balance valves installed in a diver handling system shall have seat tightness testing and have their cracking pressure verified.

NOTE: Seat tightness testing and cracking pressure verification may be accomplished after installation while the system is being adjusted

3-6.16.6.3.1 ***Seat Tightness Testing***

a. The duration of seat tightness tests conducted in a shop or on a test bench shall be not less than 5 minutes.

b. The duration of seat tightness tests conducted in the as-installed configuration shall be based on the time necessary for the minimum leakage to be detected at the point of observation or monitoring.

c. Acceptance criteria for seat tightness testing shall be zero leakage or that allowed in the manufacturer's specifications or approved test documents.

d. The seat tightness test shall be conducted at a pressure equal to the MOP.

e. System fluid is the preferred test medium for seat tightness testing.

3-6.16.6.3.2 ***Verification of Cracking Pressure***

a. Cracking pressures shall be verified IAW system drawings or manufacturer's specifications. The actual cracking pressure and date verified shall be etched or stamped on a metal or plastic tag and affixed to the component.

b. Operating characteristics of relief valves and counter-balance valves shall be verified by either test bench methods or when adjusting the system during installation or maintenance.

3-6.16.6.4 ***Component Level Testing Requirements***

Table 19 identifies tests required for specific hydraulic components. Some handling systems have unique components and may require additional or modified testing. The test procedures for those tests shall be submitted to the SCA for review and concurrence. The tests specified below and tests specified by drawing or specification shall be conducted for each task identified. If there is a conflict between the tests specified below and the test specified by the applicable drawing or specification, then the requirements of this manual take precedence.

Table 19: Testing Requirements – Hydraulic System Components

Hydraulic Component	Test Requirements
Hydraulic Pump or hydraulic motor	Dynamic load test, rated load test
Servo valve, High-pressure piping and components	No-load test
Hydraulic cylinder (when cylinder is used to support the weight of the DLSS)	Static load test, Dynamic load test, rated load test
All other hydraulic system components and piping	No-load test
Brakes	Static load test, dynamic load test, rated load test
Brake adjustment or alignment	Rated load test
Relief and/or counter balance valve	Static load test, Dynamic load test, rated load test

3-6.16.7 *Electrical System Testing for Divers Handling Systems*

Electrical system and component testing and inspection shall be IAW 46 CFR, Chapter 1, Subchapter J, Subpart 110.30, or equivalent industrial standard providing the fabricator can show there will be no detrimental effect on system safety.

All test procedures for items within the SOC, including FAT procedures, shall be submitted to the PM for review and approval.

As a minimum, the following tests shall be conducted after the diver handling system is installed on board a support ship:

a. Continuity and IR checks.

b. SOT and/or SIT as applicable.

3-6.16.7.1 *Component Level Testing Requirements*

Table 20 identifies the type of functional tests required for specific electrical system components. Some handling systems have unique components and may require additional or modified testing. The test procedures for these tests shall be submitted to the PM for review and approval on a case basis. The tests specified below, and the applicable tests specified by a drawing, specification or technical manual shall be conducted for each maintenance task identified in Table 20. If there is a conflict between the tests specified in Table 20 and the tests specified by the applicable drawing, specification or technical manual, then the requirements of this document take precedence.

Table 20: Testing Requirements – Electrical System Components

Electrical Component	Test Requirements
Power distribution system	Continuity checks, IR checks, voltage readings, no-load test.
Electrical control circuitry adjustment, alignments	No-load test.
Electrical motors for HPUs	IR checks, no-load test, rated load test.
Limit switch	No-load test.

3-6.17 INCLINING EXPERIMENTS AND TRIM DIVES FOR SUBMERSIBLES AND SUBMERGED HABITATS

If the DLSS is of such complex geometry that reliable curves of form cannot be readily calculated, then air, surface, and submerged inclining experiments must be performed. When the curves of form, or the pre-calculated form characteristics are available, only the surface and submerged inclining experiments are required. If the DLSS vessel is not too large, the longitudinal trimming moment can be determined by direct measurement or by a longitudinal inclining experiment. In addition, a trim dive is necessary to determine the proper weight and location of ballast, both permanent and variable, that will permit the vessel to operate under the design conditions of loading and in water of any density. The fabricator shall submit the inclining experiment and the trim dive results with the evaluation of the stability of the vessel.

3-6.18 SOFTWARE TESTING

DLSS, including UBAs may use computer software to control and monitor critical life support systems. Systems and subsystems that utilize software for life critical control or monitoring shall undergo IV&V. Prior to conducting IV&V all test plans and procedures shall be submitted and approved by the PM. Unless otherwise approved, the IV& V shall be conducted by an independent agent, not associated with the designer or manufacture and shall approved by the PM. The following, or other standards, shall be invoked by the PM, as warranted by each unique system or subsystem:

a. IEEE-STD-1228, *Standard for Software Safety Plans*.

b. IEEE-STD-1012.

c. IEEE-STD-829, *Standard for Software and System Test Documentation*.

3-7 INTEGRATED SYSTEM TESTING

3-7.1 GENERAL

After all DLSS strength, tightness, and purity tests have been satisfactorily completed, the system must demonstrate that it will operate properly and will deliver specified purity gas at the designated volume, pressure, and temperature to the divers in the various modes of operation. The tests shall simulate the intended use of the system under worst case conditions. If the specific acceptance criteria for these tests are not provided in the contract documents, the builder shall request this information from the PM prior to developing his test plan.

3-8 SHIPPING

3-8.1 GENERAL

Delivery of the system shall be as specified in the contract documents. When the builder is directed by the contract documents to deliver the system to a location other than the place of fabrication, it will be the builder’s responsibility to ensure that the equipment arrives undamaged and whole. Any damage to the system, missing components, or missing documentation are the responsibility of the builder to correct.

The builder shall develop and monitor procedures for transporting and handling DLSS components to prevent damage, contamination, or material substitution. Among the precautions to be taken are the following:

a. Personnel involved in handling material shall be trained and indoctrinated in the necessity for care in handling dive system material and components. This includes fork-lift operators, riggers, storekeepers, etc.

b. Special wrapping or lined containers to prevent chafing shall be provided for components such as pressure gauges, filters, temperature instruments, etc.

c. Special precautions shall be taken to prevent contamination when transporting material between shops and work areas by using clean, covered containers.

d. All pre-cleaned parts shall be double-bagged in heat-sealed bags. Tags shall list cleaning procedures used, clean facility, and date of cleaning.

PART 4 MAINTENANCE AND REPAIR

4-1 INTRODUCTION

4-1.1 PURPOSE

This Part provides requirements for the maintenance, repair, overhaul, and modification of hyperbaric and DLSS equipment and components.

4-2 GENERAL REQUIREMENTS

All work and testing accomplished during repair and maintenance shall be IAW the requirements of Part 3 of this specification and the USN's Standardized Diver REC Procedures IAW NAVSEA SS521-AA-MAN-010.

4-2.1 REPAIR AND MODIFICATION NOTIFICATION AND APPROVAL

Modifications, maintenance and repairs to existing or new installations shall in no manner degrade the capability of the overall system to meet performance requirements.

Repairs and modifications to existing systems shall not be accomplished without the approval of the NAVSEA PM.

4-2.2 OPERATION AND MAINTENANCE APPROVAL

Routine operation and maintenance shall be accomplished by maintaining up-to-date maintenance and OPs that are approved by the NAVSEA TWH.

4-2.2.1 *Planned Maintenance System*

All DLSSs and equipment shall be maintained IAW the OPNAVINST 4790.4, *Ship's Maintenance and Material Management (3-M) Manual*. Reference MIL-STD-3034. A suitable PMS will be established by the PM and managed or implemented as appropriate by the contractor or ISEA.

4-2.2.2 *Re-Entry Control (REC)*

Re-entry control (REC) procedures shall be established locally and approved by the PM. RECs only apply after certification by NAVSEA and are established to document and maintain the integrity, cleanliness, and safety of a DLSS.

REC procedures are required for maintenance and repair of all systems and components within the SOC to maintain system certification IAW NAVSEA SS521-AA-MAN-010.

Maintenance performed IAW PMS on non-certified systems/equipment requires documentation of work accomplished IAW PMS. REC procedures are not required.

For repair of non-certified components/systems, CWPs are required.

4-2.2.3 *Cleanliness Requirements*

Cleaning shall be accomplished IAW the requirements of Part 3.

Maintaining cleanliness shall be accomplished IAW MIL-STD-1330, MIL-STD-1622, or NAVSEA SS521-AG-PRO-010, as appropriate.

4-2.2.3.1 *Loss of Cleanliness*

Loss of cleanliness occurs when a system that has been previously cleaned becomes contaminated. Contamination may be the result of a packaging failure, loss of a purge during maintenance, or a component failure causing material to deposit within the system. Once it is established that cleanliness has been lost, contact NAVSEA SCA immediately. Depending on the system, the command shall then follow the requirements of MIL-STD-1330 or MIL-STD-1622. Additional guidance can be found by referring to Table 1-9 of NAVSEA SS521-AK-HBK-010.

4-2.2.4 *Retest Requirements*

Any system, equipment, or component disturbed during a maintenance, repair, overhaul, or modification shall be tested IAW Part 3 of this specification, with the following exceptions identified below, or PMS as appropriate.

a. When conducting spot repairs/touch-up painting to the interior of a hyperbaric chamber, if the total area painted encompasses no more than 10% of the chamber interior surface area, a gas sample is not required.

b. When conducting joint tightness or valve seat tightness testing on an O_2 system following preventative or corrective maintenance, the use of O_2 as the test gas is permitted for testing components in their installed configuration, provided the work performed restores the system to the currently approved configuration.

c. Relief valves installed on PVHO’s and ASME storage flasks that were initially stamped and marked IAW ASME shall be maintained IAW with PMS

4-2.2.5 *Documentation Requirements*

Documentation for all work, cleaning, and testing required in this Part shall be accomplished IAW the requirements of Part 3 and PMS as appropriate.

4-2.2.6 *Personnel Qualification and Training*

As a minimum, all personnel assigned to operate, perform maintenance and repair shall be trained. The USN enlisted diver Navy Enlisted Classification Job Qualification Requirement (NEC JQR) for REC Maintenance Technician shall be completed for technicians and the JQR for REC Supervisor for supervisors. For personnel working on systems that may contain greater than 25% O_2, O_2 worker training is required IAW with MIL-STD-1330.

For additional guidance on developing and conducting O_2 worker, contact the NAVSEA SCA.

4-2.3 LIFE-CYCLE MANAGEMENT

If the diving or hyperbaric system is undergoing a major overhaul or reconfiguration, the system certification may be suspended by the SCA. If the certification is suspended then the personnel or contractor performing the work shall do so IAW this Part and Part 3 of this specification. There is no need to meet the requirements of the REC Procedures. In addition to the documentation required in Part 3, the following shall be delivered to the PM prior to commencing any work on a major overhaul:

a. Results of pre-overhaul test and inspection.

b. A detailed definition of the scope of the overhaul, including a list of repairs, ship alterations (SHIPALTS) to be accomplished, components to be replaced, modifications, etc.

c. The overhaul or repair work package including appropriate drawings, description of work, tests and inspection to be accomplished and procedures to be followed.

d. QA provisions of the overhaul work package.

e. A schedule showing major overhaul milestones.

After the submittal of the required pre-work documentation package the Repair Facility shall not begin the overhaul on the system without written approval of the package from the PM.

4-2.4 SHIP ALTERATIONS (SHIPALTS)

In cases where repair or overhaul of a diving or hyperbaric system require a SHIPALT, the additional requirements of NAVSEA S9AA0-AB-GSO-010, *The General Specification for Overhaul of Surface Ships*, shall be met.

4-2.5 ENGINEERING CHANGE PROPOSAL (ECP)

An Engineering Change Proposal (ECP) is the management tool used to propose a configuration change to a CI and its government-baselined performance requirements and configuration documentation during acquisition (and during post-acquisition if the government is the current document change authority (CDCA) for the configuration documentation). For the exact process, required information and disposition for an ECP please refer to MIL-HDBK-061A, *Configuration Management Guidance*.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A: BIBLIOGRAPHY

The following bibliography contains both direct support references called out within the body of this document and references not called out. Those references not called out are annotated as, not referenced in body (NRB). There are also references annotated as "Cancelled". These remain listed in this bibliography for historical purposes.

Information for locating Department of Defense Single Stock Point (DODSSP) for military specifications, standards and related publications is available at the Defense Supply Center website http://www.dscc.dla.mil/Programs/MilSpec/ and most can be downloaded at https://quicksearch.dla.mil/. Commercial and industry specifications and standards websites are provided for assistance.

AMERICAN BUREAU OF SHIPPING (ABS)

http://ww2.eagle.org

ABS Rules for Building and Classing Steel Vessel, Part 4

ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities

ABS Rules for Conditions of Classification (NRB)

ABS Rules for Materials and Welding (NRB)

ABS Rules for Survey After Construction (NRB)

AEROSPACE MATERIAL SPECIFICATION (AMS)

http://standards.sae.org/

AMS 7259*, Rubber: Fluorocarbon (FKM), High Temperature/Fluid Resistant, Low Compression Set/ 85 to 95 Hardness, For Seals in Fuel Systems and Specific Engine Oil Systems*

AMS 7276, *Rubber: Fluorocarbon (FKM) High-Temperature-Fluid Resistant Low Compression Set for Seals in Fuel systems and Specific Engine Oil Systems*

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

http://www.netaworld.org/standards/ansi-neta-ats

ANSI/EIA-632, *Process for Engineering a System* (NRB)

ANSI/EIA-649, *National Consensus Standard for Configuration Management*

ANSI/ISO/ASQ Q9000 Series, *Quality Management Standards*

ANSI/NCSL Z540-3, *General Requirements for Calibration Laboratories and Measuring and Test Equipment*

ANSI/UL 2043-2208, *Standard for Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces*

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

http://www.asme.org/

ASME B31.1, *Power Piping*

ASME B40.1, *Gauges – Pressure Indicating Dial Type – Elastic Element* (NRB)

ASME B40.100, *Pressure Gauges and Gauge Attachments*

ASME B40.7, *Gauges: Pressure Digital Indicating*

ASME Boiler and Pressure Vessel Code Section II-A, *Ferrous Material Specifications (SA-451 to End)* (NRB)

ASME Boiler and Pressure Vessel Code Section II-B, *Nonferrous Material Specifications* (NRB)

ASME Boiler and Pressure Vessel Code Section II-D, *Properties (Customary)* (NRB)

ASME Boiler and Pressure Vessel Code Section IX, *Welding, Brazing, and Fusing Qualifications*

ASME Boiler and Pressure Vessel Code Section V, *Nondestructive Examination* (NRB)

ASME Boiler and Pressure Vessel Code Section VIII, Division 1, *Rules for Construction of Pressure Vessels*, and Division 2, *Alternative Rules*

ASME Boiler and Pressure Vessel Code Section VIII, Division 2, *Nonferrous Material Specification* (NRB)

ASME Boiler and Pressure Vessel Code Section VIII, Division 3, *Alternative Rules for Construction of High-Pressure Vessels* (NRB)

ASME PTB-6-2013, *Guidelines for Strain Gaging of Pressure Vessels Subjected to External Pressure Loading in the PVHO-1 Standard* (NRB)

ASME PVHO-1, *Safety Standard for Pressure Vessels for Human Occupancy*

ASME PVHO-2, *Safety Standard for Pressure Vessels for Human Occupancy: In-Service Guidelines* (NRB)

ASME Y14.100, *Engineering Drawing Practices* (NRB)

ASME Y14.24, *Types and Applications of Engineering Drawings* (NRB)

ASME Y14.34, *Associated* Lists (NRB)

ASME Y14.35, *Revisions of Engineering Drawings and Associated Documents*

ASME/ANSI B16.34, *Valves – Flanged, Threaded, and Welding End*

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

http://www.astm.org/

ASTM A182, *Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service*

ASTM A193, *Standard Specification for Alloy-Steel and Stainless Steel Bolting for Higher Temperature or High-Pressure Service and Other Special Purpose Applications*

ASTM A213, *Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchange Tube*

ASTM A240, *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and General Applications*

ASTM A269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service* (NRB)

ASTM A312, *Standard Specifications for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*

ASTM A336, *Standard Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts*

ASTM A350, *Standard Specification for Carbon and Low-Allow Steel Forgings, Requiring Notch Toughness Testing for Piping Components*

ASTM A351, *Standard Specification for Castings, Austenitic, for Pressure-Containing Parts*

ASTM A494, *Standard Specification for Castings, Nickel and Nickel Alloy*

ASTM A516, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Low-Temperature Service*

ASTM A537, *Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel*

ASTM A745/A745M, *Standard Practice for Ultrasonic Examination of Austenitic Steel Forgings*

ASTM A967, *Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts*

ASTM B127, *Standard Specification for Nickel-Copper Alloy Plate, Sheet, and Strip* (NRB)

ASTM B148 *Standard Specification for Aluminum-Bronze Sand Castings*

ASTM B369, *Standard Specification for Copper-Nickel Alloy Castings*

ASTM B61, *Standard Specification for Steam or Valve Bronze Castings*

ASTM D1418, *Standard Practice for Rubber and Rubber Latices – Nomenclature*

ASTM D4174, *Standard Practice for Cleaning, Flushing, and Purification of Petroleum Fluid Hydraulic Systems*

ASTM E548, *General Criteria Used for Evaluating Laboratory Competence* (NRB)

ASTM F1166, *Marine Systems, Equipment and Facilities, Human Engineering Design for* (NRB)

ASTM G175, *Standard Test Method for Evaluating the Ignition Sensitivity and Fault Tolerance of Oxygen Pressure Regulators Used for Medical and Emergency Applications*

ASTM G63, *Standard Guide for Evaluating Non-metallic Materials for Oxygen Service*

ASTM G88, *Designing Systems for Oxygen Service, Standard Guide for*

ASTM G93, *Standard Guide for Cleanliness Levels and Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments*

ASTM G94, *Standard Guide for Evaluating Metals for Oxygen Service*

ASTM D7193-17, *Standard Specification for Unsintered Pigmented Polytetrafluoroethylene Extruded Film or Tape* (NRB)

ASTM A435/A435M – 17, *Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates* (NRB)

ASTM B171 Alloy 715, *Standard Specification for Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers*

ASTM B466 Alloy 717, *Standard Specification for Seamless Copper-Nickel Pipe and Tube*

ASTM B271 Alloy 958, *Standard Specifications for Copper-Base Alloy Centrifugal Castings*

ASTM B150 Alloy E 63200, *Standard Specification for Aluminum Bronze Rod, Bar, and Shapes*

ASTM Manual 36, *Safe Use of Oxygen and Oxygen Systems*: *Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation*

Journal of ASTM International, Vol. 6, No. 8 (Paper ID JAI102300), *Promoted Ignition Testing of Metallic Filters in High-Pressure Oxygen*

AMERICAN WELDING SOCIETY (AWS)

http://www.aws.org/

AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*

AWS A5.12, *Specification for Tungsten and Tungsten Alloy Electrodes for Arc Welding and Cutting* (NRB)

AWS D1.1, *Structural Welding Code – Steel*

AWS D1.2, *Structural Welding Code – Aluminum*

AWS D1.6, *Structural Welding Code – Stainless Steel*

COMPRESSED GAS ASSOCIATION (CGA)

https://www.cganet.com/

CGA G-4.1, *Cleaning of Equipment for Oxygen Service*

CGA Pamphlet G-4.4*, Industrial Practices for Gaseous Oxygen Transmission and Distribution Systems*

CGA-1, *Standard for Compressed Gas Cylinder Outlet and Inlet Connections* (NRB)

DEPARTMENT OF DEFENSE (DOD) INSTRUCTIONS

http://www.dtic.mil/whs/directives/corres/ins1.html/

COMOPTEVFORINST 3980.2F, *Operational Test Director's Manual* (NRB)

DoD Directive 5000.1, *Defense Acquisition* (NRB)

DoD Directive 5000.2, *Mandatory Procedures for MDAPs and MAIS Acquisition Programs* (NRB)

DODINST 5000.02, *Defense Acquisition Management Policies and Procedures* (NRB)

OPNAVINST 3150.27, *U.S. Navy Diving Program*

OPNAVINST 4790.4, *Ship's Maintenance and Material Management (3-M) Manual*

OPNAVINST 5100.19, *Navy Safety and Occupational Health Program Manual for Forces Afloat*

OPNAVINST 5100.23H, *Navy Safety and Occupational Health Manual*

OPNAVINST 5100.23H (Message), *Navy Safety and Occupational Health Manual, Volume 1: Navy Safety Management System* (NRB)

PNSY INST 0558-839, *Puget Sound Naval Shipyard Industrial Process Instruction, Life Support Gas Systems; Cleaning* (NRB) (Cancelled)

PSNS UIPI 5050-913, *Grip-Type Mechanically Attached Fittings (Swagelok) Shipboard Installation Procedure – Surface Ships*

SECNAVINST 4130.2, *Department of the Navy Configuration Management Policy*

DEPARTMENT OF DEFENSE (DOD) STANDARDS

http://www.dscc.dla.mil/Programs/MilSpec/

DOD-HDBK-289, *Lighting on Naval Ships*

DOD-PRF-24574, *Lubricating Fluid for Low and High-Pressure Oxidizing Gas Mixtures*

DOD-STD-1399-301, *Interface Standard for Shipboard Systems*, Section 301A Ship Motion and Attitude (Metric)

JS-SSA-IG Revision A, *Software System Safety: Implementation Process and Tasks Supporting MIL-STD-882E* (NRB)

MIL-A-18455, *Argon, Technical* (NRB)

MIL-B-24480, *Bronze, Nickel-Aluminum (UNS No. C95800) Castings for Seawater Service*

MIL-C-15726, *Copper-Nickel Alloy, Sheet, Plate Strip, Bar, Rod and Wire*

MIL-C-52211A(ME), *Components and Assemblies for Industrial Gas Production, Storage, and Transport Equipment, Packing of* (NRB)

MIL-DTL-1222, *General Specification for Studs, Bolts, Screws and Nuts for Applications Where a High Degree of Reliability is Required*

MIL-DTL-22606, *Flask Compressed Gas and End Plugs for Air, Oxygen, and Nitrogen*

MIL-DTL-24578, *Vales, Globe Pressure Instrument, Stem Test Connection, Union End*

MIL-DTL-24643, *Cables, Electric, Low Smoke Halogen-Free, For Shipboard Use*

MIL-DTL-901, *Shock Test H.I. (High Impact) Shipboard Machinery, Equipment and Systems, Requirement for* (NRB)

MIL-DTL-917, *Electric Power Equipment, Basic Requirements*

MIL-E-19933E, *Electrodes and Rods – Welding, Bare, Chromium and Chromium-Nickel Steels* (NRB)

MIL-G-10924, *Grease Automotive and Artillery*

MIL-F-22606, *Flask Compressed Gas and End Plugs for Air, Oxygen and Nitrogen* (NRB)

MIL-G-18997, *Gauge, Pressure, Dial Indicating* (NRB)

MIL-G-27617, *Grease, Aircraft and Instrument, Fuel and Oxidizer Resistant* (NRB) (Cancelled)

MIL-HDBK-061A, *Configuration Management Guidance*

MIL-HDBK-454B, *General Guidelines for Electronic Equipment*

MIL-HDBK-2036, *Preparation of Electronic Equipment Specifications*

MIL-HDBK-470, *Designing and Developing Maintainable Products and Systems*

MIL-HDBK-61A, *Configuration Management Guidance*

MIL-I-23413C, *Inserts, Welding, Filler Material, Coiled and Solid Rings* (NRB)

MIL-L-20213, *Lithium Hydroxide (LiOH), Technical*

MIL-P-15024, *General Specification for Plates, Tags, and Bands for Identification of Equipment*

MIL-P-24534, *Planned Maintenance System: Development of Maintenance Requirement Cards, Maintenance Index Pages, and Associated Documentation* (Cancelled) (NRB)

MIL-P-24691, *Pipe and Tube, Carbon, Alloy and Stainless Steel, Seamless and Welded*

MIL-PRF-17331 (2190TEP), *Lubricating Oil, Steam Turbine and Gear, Moderate Service*

MIL-PRF-17672 (2135TH), *Hydraulic Fluid, Petroleum, Inhibited*

MIL-PRF-27210, *Oxygen, Aviator's Breathing, Liquid and Gas*

MIL-PRF-27401, *Propellant Pressurizing Agent, Nitrogen*

MIL-PRF-27407, *Propellant Pressurizing Agent, Helium*

MIL-PRF-27617, *Grease, Aircraft and Instrument, Fuel and Oxidizer Resistant*

MIL-R-83248A, *Rubber Fluorocarbon Elastomer, High Temperature, Fluid, and Compression Set* Resistance (Cancelled)

MIL-STD-202, *Electronic and Electrical Component Parts*

MIL-STD-1246, *Product Cleanliness Levels and Contamination Control Program* (NRB) (Cancelled)

MIL-STD-1310, *Shipboard Bonding, Grounding, and other Techniques for Electromagnetic Compatibility, Electromagnetic Pulse Mitigation, and Safety*

MIL-STD-1330, *Department of Defense Standard Practice, Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen, Nitrogen, and Hydrogen Systems*

MIL-STD-1472, *Human Factors Engineering Report*

MIL-STD-1474, *Noise Limits*

MIL-STD-1622, *Department of Defense Standard Practice for Cleaning of Shipboard Compressed Air Systems*

MIL-STD-1627, *Bending of Pipe or Tube for Ship Piping Systems*

MIL-STD-167-1, *Mechanical Vibrations of Shipboard Equipment* (NRB)

MIL-STD-1689, *Fabrication, Welding and Inspection of Ship's Structure*

MIL-STD-1791, *Design for Internal Aerial Delivery in Fixed Wing Aircraft*

MIL-STD-2003, *Electrical Plant Installation, Standard Methods for Surface Ships and Submarines*

MIL-STD-2035, *Nondestructive Testing Acceptance Criteria* (NRB)

MIL-STD-2193, *Hydraulic System Components, Ship*

MIL-STD-22, *Welded Joint Design*

MIL-STD-3034, *Reliability-Centered Maintenance Process*

MIL-STD-31000, *Technical Data Packages*

MIL-STD-419, *Cleaning, Protecting, and Testing Piping, Tubing, and Fittings for Hydraulic Power Transmission Equipment*

MIL-STD-438*, Schedule of Piping, Valves, Fittings and Associated Piping Components for Submarine Service*

MIL-STD-499, *Engineering Management* (NRB) (Cancelled)

MIL-STD-777, *Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships*

MIL-STD-810, *Test Method Standard for Environmental Engineering Considerations And Laboratory Tests*

MIL-STD-882, *System Safety Program Requirements*

MIL-STD-889, *Dissimilar Metals*

MIL-STD-974, *Contractor Integrated Technical Information Service (CITIS)* (Cancelled)

MIL-T-16420, *Tube, Copper-Nickel Alloy, Seamless and Welded (Copper Alloy Numbers 715 and 706)*

MIL-V-24439, *Valves, Oxygen, Helium and Helium-Oxygen Mixture, High-Pressure for Gas Services*

DEPARTMENT OF DEFENSE (DOD) STYLE GUIDES

Writing and Style Guide and Preferred Usage for DoD Issuances 2019 (NRB)

DET NORSKE VERITAS (DNV) – Germanischer Lloyd (GL)

http://www.dnvgl.com

DNV-OS-E402, *Offshore Standard for Diving Systems DNV Certification Notes No. 2.7-2 Offshore Service Containers* (NRB)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

http://www.ieee.org

IEEE-15288.1, *Application of Systems Engineering on Defense Programs* (NRB)

IEEE-1580, *Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Platforms* (NRB)

IEEE-242*, Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems*

IEEE-315, *Electrical Symbols* (NRB)

IEEE-45, *Recommended Practice for Electrical Installations on Shipboard* (NRB)

IEEE-STD-1012, *Standard for System, Software, and Hardware Verification and Validation*

IEEE-STD-1228, *Standard for Software Safety Plans*

IEEE-STD-829, *Standard for Software and System Test Documentation*

INSTITUE OF ENVIRONMENTAL SCIENCES AND TECHNOLOGY (IEST)

https://www.iest.org/

IEST-STD-CC1246E, *Product Cleanliness Levels – Applications, Requirements, and Determination* (NRB)

INTERNATIONAL MARINE CONTRACTORS ASSOCIATION (IMCA)

http://www.imca-int.com

IMCA D 002, *Guidance Note for Battery Packs in Pressure Housings* (NRB)

IMCA D 003, *Guidelines for Oxy-Arc Cutting* (NRB)

IMCA D 010, *Diving Operations from Vessels Operating in Dynamically Positioned Mode* (NRB)

IMCA D 018, *The Initial and Periodic Examination, Testing and Certification of Diving Plant and Equipment* (NRB)

IMCA D 023, *DESIGN for Surface Orientated (Air) Diving Systems* (NRB)

IMCA D 045, *Code for Practice for the Safe Use of Electricity Underwater*

IMCA/AODC-035, *Code of Practice for the Safe Use of Electricity Underwater* (NRB)

SOLAS International Convention for the Safety of Life at Sea, 1974, as amended

INTERNATIONAL MARITIME ORGANIZATION (IMO)

http://www.imo.org

IMO EA808E, *Code of Safety for Diving Systems* (NRB)

IMO Resolution A.536(13), *Code of Safety for Diving Systems* (as Amended by Res. A.831 (19)) (NRB)

IMO Resolution A.583(14), *Amendments to the Code of Safety for Diving Systems (Resolution A536(13))* (NRB)

INTERNATIONAL ORGANIZATION FOR STANDARDS (ISO)

http://www.iso.org/standard/

ISO 2041, *Mechanical Vibration, Shock, and Condition Monitoring - Vocabulary*

ISO 2631-1*, Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-body Vibration - Part I: General Requirements*

ISO 5805, *Mechanical Vibration and Shock - Human Exposure - Vocabulary*

ISO 9000, *International Standards for Quality Management (NRB)*

ISO 9001, *Quality Management Systems - Requirements*

ISO 10007, *Quality Management Systems – Guidelines for Configuration Management*

ISO-11119-2, *Gas Cylinders – Gas Cylinders of Composite Construction – Specification and Test Methods – Part 2: Fully Wrapped Fiber Reinforced Composite Gas Cylinders with Load-Sharing* (NRB)

ISO/IEC 17025:1999, *General Requirements for the Competence of Testing and Calibration Laboratories*

MISCELLANEOUS

AIAG, *Potential Failure Mode and Effects Analysis (FMEA) Manual*

AISC 325-11, *Steel Construction Manual*

A-A-58092, Commercial Item Description*, Tape, Anti-Seize, Polytetrafluorethylene*

Amron International Tech Bul. T-201A, *Installation, Operation and Maintenance Instructions* (NRB)

Corrosion Vol. 1, *Metal/Environment Reactions;* 1979, Edited by Shreir; Butterworth Publishing (NRB)

Crane Tech Paper, *Flow of Fluids* (www.flowoffluids.com) (NRB)

Easy Ergonomics: A Guide to Selecting Non-Powered Hand Tools (NRB)

Electrical Testing of Current Carrying Cables (Under 7 Volts Alternating Current or 30 Volts Direct Current, End Use) (NRB)

EN 13445, *European Standard for Unfired Pressure Vessels* (NRB)

EN 15333, *Open Circuit Umbilical Supplied Compressed Gas Diving Apparatus*

Finite Element Analysis Modeling Requirements

Finite Element Analysis Review Checklist

Handbook of Corrosion Engineering, Third Edition McGraw Hill (NRB)

IPC-J-STD-001, *Requirements for Soldered Electrical and Electronic Assemblies*

Manual of Biocorrosion; H.A. Videla; 1996 by CRC Press (Lewis Publishers) (NRB)

NAVAIR 00-25-403, Management Manual: *Guidelines for the Naval Aviation RCM Process*

NSW S13-CMP-01, *Fleet Diving Systems CMP*

OSHA 3341-03N, *Guidelines for Shipyards* (NRB)

Parker ORD-5700, *O-Ring Handbook (2007)* (NRB)

Parker ORD-5700A, *O-Ring Handbook (2001*) (NRB)

PD5500, *British Standard for Unfired Fusion Welded Pressure Vessels and Inspection Procedures/Testing Criteria* (NRB)

System Safety Society's System Safety Analysis Handbook

Tescom, *Basics of Pressure Regulation – Technical Information* (NRB)

Tescom, *Droop and Accumulation* (NRB)

UL-94, *Underwriters Laboratory Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances Flammability Ratings*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NASA JSC 20584, *Spacecraft Maximum Allowable Concentration for Airborne Limits* (NRB)

NASA NSS 1740.15, *Safety Standards for Oxygen and Oxygen Systems* (NRB)

NASA SP-118, *Space Cabin Atmospheres Part IV Engineering Tradeoffs*

NASA STD-6001B, *Flammability, Off Gassing, and Compatibility Requirements and Test Procedures* (NRB)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

http://www.nfpa.org/codes-and-standards/

NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres*

NFPA 70, *National Electrical Code*

NFPA 99, *Healthcare Facilities Code* (NRB)

NFPA 101, *Life Safety Code* (NRB)

NAVAL FACILITIES (NAVFAC) UNIFIED FACILITIES CRITERIA (UFC)

http://www.wbdg.org/

NAVFAC 4-159-01N, *Hyperbaric Facilities: Design and Maintenance* (NRB)

NAVFAC 4-390-01, *Operation and Maintenance: Unmanned Pressure Test Facilities Safety Certification Manual* (NRB)

NAVFAC DM-39, *Hyperbaric Facilities* (NRB)

NAVFAC P-307, *Management of Weight Handling Equipment*

NAVFACINST 5100.11J, *NAVFACENGCOM Safety and Health Program* (NRB)

UFC 3-320-07N, *Weight Handling Equipment* (NRB)

UFC 4-159-01N (DM-39), *Design: Hyperbaric Facilities*

UFC 4-510-01, *Design: Military Medical Facilities*

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

SEA 00C: SECURE (navy.mil)

NAVSEA 00C41 White Paper, *Corrosion – Past Hyperbaric and Navy Examples;* 2020 (NRB) (Yet to be Published)

NAVSEA 0900-LP-001-7000, *Fabrication and Inspection of Brazed Piping Systems*

NAVSEA 0994-LP-003-7010, *U.S. Navy Diving-Gas Manual*

NAVSEA 391RA/0233, *Example of Completed FEA Check List* (NRB)

NAVSEA 5100.12-M, *System Safety Engineering Manual* (NRB)

NAVSEA DOC-120C/2011-02, *Saturation Fly Away Diving System (SAT-FADS) System Hazard Analysis* (NRB)

NAVSEA Drawing 8227235, *Functional Block Diagram – Command & Control* (NRB)

NAVSEA Drawing 8227254, *Piping Schematic Pressurization and Depressurization* (NRB)

NAVSEA Letter, *System Safety Certification of Aluminum Divers Recompression Chamber* (NRB)

NAVSEA Letter Series 05S, *Hazard Assessment Report Implementation* (NRB)

NAVSEA S6360-AW-MMO-010, *Technical Manual for Corrosion Prevention and Control Procedures for U.S. Navy Expeditionary Ground Equipment* (NRB)

NAVSEA S6430-AE-TED-010 *Piping Devices, Flexible Hose Assemblies, Volume 1*

NAVSEA S650-AB-MMD-010, *Phosphate Coating of High-Pressure Flask Interiors*

NAVSEA S650-AH-INS-010, *Powdered Fluoropolymer Coating*

NAVSEA S6560-AB-MMD-010, *Cleaning and Phosphate Coating Instructions, High-Pressure Air Flasks Used in Diving* Systems (NRB)

NAVSEA S6560-AH-INS-010, *Use of Powdered Fluoropolymer Coatings on High-Pressure Air Flasks Used in US Navy Diving Systems* (NRB)

NAVSEA S6560-AL-TMM-010, *Underwater Breathing Apparatus (UBA) KM 97 Helmet* (NRB)

NAVSEA S9074-AQ-GIB-010/248, *Requirements for Welding and Brazing Procedure and Performance Qualification.*

NAVSEA S9074-AR-GIB-010/278, *Requirements for Fabrication Welding and Inspection, and Casting Inspection, and Repair for Machinery, Piping, and Pressure Vessels*

NAVSEA S9081-AB-GIB-010, *Reliability-Centered Maintenance Handbook* (NRB)

NAVSEA S9086-CT-STM-010/075, *Fasteners* (NRB)

NAVSEA S9086-H7-STM-010/262, *Lubricating Oils, Greases, Specialty Lubricants, and Lubrication Systems* (NRB)

NAVSEA S9086-RK-STM-010/505, *Piping Systems* (NRB)

NAVSEA S9086-S4-STM-010/556, *Hydraulic Equipment (Power Transmission and Control)* (NRB)

NAVSEA S9086-SY-STM-010/551, *Compressed Air Plants and Systems* (NRB)

NAVSEA S9086-T4-STM-010/589, *Cranes* (NRB)

NAVSEA S9086-UU-STM-010/613, *Wire and Fiber Rope and Rigging* (NRB)

NAVSEA S9310-AQ-SAF-010, *Navy Lithium Battery Safety Program Responsibilities and Procedures* (NRB)

NAVSEA S9320-AM-PRO-020/MLDG (PRO-020), *Underwater Cable Assembly and Encapsulated Components*

NAVSEA S9510-AB-ATM-010, *Nuclear Powered Submarine Atmosphere Control Manual* (NRB)

NAVSEA S9592-AP-MMM-A30*, Dry Deck Shelter System, SSN688 Class Host Ship, Operating and Emergency Procedures* (NRB)

NAVSEA S9800-AB-MAN-010, *Engineering and Technical Authority Manual* (NRB)

NAVSEA S9AA0-AA-SPN-010, *General Specifications for Ships of the U.S. Navy* (GENSPEC) (NRB)

NAVSEA S9AA0-AB-GSO-010, *General Specifications for Overhaul of Surface Ships*

NAVSEA S9ASD-AA-MAN-010, *ASDS Operating Procedures Instruction* (NRB)

NAVSEA SG270-BV-SAF-010, *High Energy Storage System Safety Manual*

NAVSEA SS521-AA-MAN-010, *U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual*

NAVSEA SS521-AG-PRO-010, *U.S. Navy Diving Manual*

NAVSEA SS521-AH-PRO-010, *Diving Umbilical Description, Material and Assembly*

NAVSEA SS521-AK-HBK-010, *Cleaning and Gas Analysis for Diving Applications Handbook*

NAVSEA SS600-AK-MMO-010, *Underwater Breathing Apparatus (UBA) MK 20 MOD 0/1* (NRB)

NAVSEA SS800-AG-MAN-010/P-9290, *System Certification Procedures and Criteria Manual for Deep Submergence Systems*

NAVSEA ST700-F1-PRO-010, *Instrument and Gauge Cleaning for MIL-STD-1330 Applications; Procedures Manual*

NAVSEA T6560-AC-OMP-010, *Underwater Breathing Apparatus (UBA) KM 37 NS Helmet* (NRB)

NAVSEA T9074-AD-GIB-010/1688, *Requirements for Fabrication, Welding, and Inspection of Submarine Structure*

NAVSEA T9074-AS-GIB-010/271, *Requirements for Nondestructive Testing Methods*

NAVSEA T9074-BD-GIB-010/0300, *Base Materials for Critical Applications: Requirements for Low Alloy Steel Plate, Forgings, Castings, Shapes, Bars, and Heads of HY-80/100/130 and HSLA-80/100*

NAVSEAINST 4130.12, *Configuration Management Policy and Guidance*

NAVSEAINST 5000.8, *Naval Systems Command Risk Management Policy*

NAVSEAINST 5100.12, *System Safety Engineering Policy*

NAVSEAINST 5400.97, *Virtual SYSCOM Engineering and Technical Authority Policy* (NRB)

NAVSEAINST 5400.111, *NAVSEA Engineering and Technical Authority Policy* (NRB)

NAVSEAINST 9310.1, *Naval Lithium Battery Safety Program*

NAVSEAINST 10560.2, *Diving Equipment Authorized for Military Use* (ANU)

NEDU TM 15-01, *U.S. Navy Unmanned Test Methods and Performance Limits for Underwater Breathing Apparatus*

NSMRL RPT 83-3 Naval Submarine Medical Research Laboratory Report 83-3, *Anthropometric Indices of U.S. Navy Divers* (NRB)

NSMRLTR 2006-1249, *A Review and Comparison of Anthropometric Indices Applicable to the U.S. Navy Submariner Population*

NSMRL/F1203/MR-2020-1339, *Guidelines for Characterization of Sounds Produced by Underwater Active Acoustic Technologies for Human Exposure*

NSTM Chapter 074, *Welding and Allied Processes* (NRB)

NSTM Chapter 078, *Volume 1: Seals*

NSTM Chapter 262, *Lubricating Oils, Greases, Specialty Lubricants, and Lubrication Systems*

NSTM Chapter 300, *Electric Plant – General*

NSTM Chapter 504, *Pressure, Temperature and Other Mechanical and Electromagnetic Measuring Instruments*

NSTM Chapter 505, *Piping Systems*

NSTM Chapter 550, *Industrial Gases-Generating, Handling and Storage* (NRB)

NSTM Chapter 551, *Compressed Air Plants and Systems*

NSTM Chapter 556, *Hydraulic Equipment (Power Transmission and Control)*

NSTM Chapter 594, *Submarine Escape and Rescue* (NRB)

PSNS IPI-5050-916, *Ball Valve Seat Stack Height Measurement and Globe and Gate Valve Blue Check*

PSNS IPI-6020-901A, *Marking Methods, Controlled Materials and Fabrications (Nonnuclear)* (NRB)

PSNS PI-9500-940-158F CH3, *Electrochemical Marking* (NRB)

SAT-PGDM-001S-01, *System Requirements for the Saturation Fly Away Diving System (SAT-FADS)*

Top Level Requirements Document for Saturation Fly Away Diving System (NRB)

Topside Tech Notes TTN-1, *Relief Valves* (NRB)

Topside Tech Notes TTN-2, *Compressors* (NRB)

Topside Tech Notes TTN-3, *Flex Hoses and Umbilicals for DLSS* (NRB)

Topside Tech Notes TTN-4, *High-Pressure DLSS Flasks* (NRB)

Topside Tech Notes TTN-5, *Filters* (NRB)

Topside Tech Notes TTN-6, *CO_2 Scrubbers and Absorbent* (NRB)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

http://standards.sae.org/

PNSY SAE J429, *Mechanical and Material Requirements for Externally Threaded Fasteners*

SAE AMS-3216, *Fluorocarbon Rubber High-Temperature – Fluid Resistant Low Compression Set* 70 to 80

SAE AMS-3218, *Fluorocarbon Rubber High-Temperature – Fluid Resistant Low Compression Set 85 to 95*

SAE AMS-QQ-S-763, *Steel Bars, Wires, Shapes, and Forgings; Corrosion Resistant*

SAE AMS-STD-595, *Colors Used in Government Procurement*

SAE EIA-649-1, *Configuration Management Requirements for Defense Contracts* (NRB)

SAE J-1739*, Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA)*

SAE J995, *Mechanical and Material Requirements for Steel Nuts*

SAE M-102, *Reliability, Maintainability, and Supportability Guidebook*

SAE AMS8660, *Silicone Compound NATO Code Number S-736*

SOCIETY FOR PROTECTIVE COATINGS (SSPC)

https://www.sspc.org/

SSPC-PA-2, *Paint Application Standard No. 2*

UNITED STATES (U.S.) GOVERNMENT

http://www.dscc.dla.mil/Programs/MilSpec/

23 CFR Part 658, *Truck Size and Weight Regulation*

29 CFR Part 1910, *Occupational Safety and Health Standards*

46 CFR, Chapter 1, Subchapter F, *Marine Engineering*

46 CFR, Chapter 1, Subchapter J, *Electrical Engineering*

49 CFR, *Transportation*

DDS-100-4, *Strength of Structural Members*

DDS-310-1, *Electric Power Load Analysis for Surface Ships*

DoD Systems Management College, *Systems Engineering Fundamentals* (NRB)

FED-SPEC-A-A-59155*, Nitrogen, High Purity, Special Purpose*

FED-SPEC-BB-A-1034, *Air, Compressed for Breathing Purposes* (NRB)

FED-SPEC-RR-W-410C, *Wire Rope Strand* (NRB)

FED-SPEC-RR-W-410D, *Wire Rope and Strand* (NRB)

Naval Coastal Systems Center Technical Manual 4110-1-83*, Design Guidelines for CO_2 Scrubbers.*

Navy Clothing and Textile Research Unit, Technical Report No. 110, *Flame-Retardant Clothing and Textile Items for Use in Oxygen-Enriched Environments of Decompression Chambers*

Navy Medicine OMPA Program 09, *OM Worksite Visits* (NRB)

NRC NUREG-0492, *Fault Tree Handbook*

USCG 16714 CG-ENG Policy Letter No. 01-16 of April 29, 2016

QQ-A-250/11, Federal Specification Sheet; *Aluminum Alloy 6061, Plate and Sheet*

QQ-N-281, *Nickel-Copper Alloy Bar, Rod, Plate, Sheet, Strip, Wire, Forgings, and Structural and Special Shaped Sections*

QQ-N-286, *Nickel-Copper-Aluminum Alloy, Wrought*

APPENDIX B: DEFINITIONS

Acquisition/Program Manager (PM)

The government individual responsible for the procurement and certification of a newly fabricated DLSS to meet the user's operational needs. The PM shall be accountable for cost, schedule, and performance.

Added Mass Effect

The mass of water particles surrounding an object immersed in water that is accelerated with the object as the object is accelerated through the water. When a body is accelerated in a fluid, it behaves as though its mass is greater than it actually is due to the effect of the surrounding fluid. This additional mass must be added to the actual body mass to account for the change in inertia.

Allocated Baseline (ABL)

The currently approved documentation describing a CI's functional, interoperability, and interface requirements and the verification required to demonstrate the achievement of those specified characteristics. The ABL is controlled by the designer and is established after the PDR.

Ancillary Equipment

Any equipment providing services to a hyperbaric chamber or DLSS (e.g., compressors, booster/transfer pumps, hot water heater, water conditioning, atmosphere heating and cooling, electrical power supply, hydraulic power supply, breathing and atmosphere gas supplies).

Appurtenance

An accessory structure directly affecting the integrity of the pressure vessel. Major categories of appurtenances include viewports, doors, hatches, closures, penetrations, and piping.

Batch

A sample of a percentage of a items that have all been manufactured in a similar time period (i.e. having the same lot number).

Certification

The process of certification application, review, survey, and approval of all items and procedures within a diving or hyperbaric system SOC that affect the safety of diving personnel. Certification includes the compilation and review of OQE attesting that an item, procedure or system meets specified requirements.

Coalescing Separator

A coalescing separator is a piece of industrial equipment used in the gas processing to perform coalescence. Coalescence is the process of causing an agglomeration (coming together) of liquid aerosols to form larger droplets which are large enough to be drained away gravitationally.

Collapse Pressure

The lowest pressure at which any one of a series of nominally identical hull structures would collapse.

Configuration Item (CI)
A CI is an aggregation of hardware and/or software that satisfies an end use function and is designated by the government for separate CM.

Critical Design Review (CDR)
This review determines if the system design documentation (PBL including detail, material, and process specifications) is satisfactory to start initial manufacturing (i.e., the design meets all technical and safety requirements). The review will examine how well the detail design satisfies cost, schedule, and performance requirements, the producibility of the production design, the control over the projected production processes, and assess CI(s) risk areas (on a technical, cost, and schedule basis).

Design Load
The maximum force due to the rated load plus some or all of the following: (1) added mass effects, (2) entrained water, (3) any external payloads, (4) drag or wind loads, and (5) dynamic loads which are derived with the aid of the dynamic load factor.

Divers Life Support System
The equipment and components required to maintain adequate breathing gas supply to divers under the conditions defined in the system requirements document.

Design Test Depth Pressure
The pressure equivalent to the maximum depth to which the DLSS was designed to operate.

Designer
An individual, partnership, company, corporation, association, or other service having a contract with the government for the design of the DLSS. The designer is responsible and liable for the safe design of the DLSS that, meets or exceeds contract specifications, can be produced by a competent manufacturer, and is certifiable by the SCA. The designer shall use acceptable engineering principles and prove adequacy of the design through analyses and calculations.

Dynamic Load
The load imposed on a system due to accelerations of gravity and ship (or other transportation) motion. It is dependent upon the magnitude and frequency of ship motions, ship attitude, and the location of the handling system on the ship.

Engineering Change Proposal (ECP)
The documentation by which a proposed engineering change is described, justified, and submitted to (a) the CDCA for approval or disapproval of the

design change in the documentation and (b) to the procuring activity for approval or disapproval of implementing the design change in units to be delivered or retrofit into assets already delivered.

Explodable Volume

Any non-compensated pressure housing containing a compressible fluid at a pressure above the external ambient sea pressure (at any depth) which has the potential to burst. Note that some volumes may be explodable at shallow depths and implodable at deeper depths.

Fail-safe

Components within the handling system that are designed to prevent uncontrolled dropping, shifting, or sudden movement of the DLSS during a hydraulic or electrical system failure or component/equipment malfunction.

Fire Zone

Where the O_2 concentration in the chamber is 6% or greater.

Functional Baseline (FBL)

The initially approved documentation describing a system's functional, interoperability, and interface requirements and the verification required to demonstrate the achievement of those specified characteristics. The FBL is controlled by the PM and is established after the SRR.

Functional Configuration Audit (FCA)

The formal examination of functional characteristics of a DLSS, prior to acceptance, to verify that the item has achieved the requirements specified in its User Design Specifications.

Handling System

The mechanical, electrical, structural equipment and rigging used on board a support platform to launch and recover divers or a manned DLSS.

High-Pressure Gas

Gaseous system which is greater than or equal to 1,000 psig.

Human Systems Integration (HSI)

A process to ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system. HSI includes design and assessment of requirements; concepts and resources for system manpower, personnel, training, safety and occupational health, habitability, personnel survivability; and HFE.

Hydrostatic (Strength and Porosity) Test

A test which subjects pressure containing structural boundaries of pressure vessels, pipe, and piping components to a specified test pressure above the MOP and inspects for leaks and deformation.

Implodable Volume

Any non-compensated pressure housing containing a compressible fluid at a pressure below the external ambient sea pressure (at any depth down to maximum operating depth) which has the potential to collapse. The outer shell volume is used when calculating the volume of an implodable. Subtracting the volume of items internal to the implodable is not allowed.

Isolation Valve
Any valve used as a distinct pressure boundary which in the no-flow position (closed) does not incorporate a self-operating feature (e.g., check valves and regulating valves).

Joint Tightness Test
A test which subjects mechanically joined pressure containing boundaries of pipe, and piping components to an internal pressure equal to 100% of MOP and, if applicable, to an external pressure equal to 100% of DLSS design test depth pressure.

Load Bearing
Those components of the handling system that support the loads resulting from launching and recovering of a manned DLSS.

Load Controlling
Those components of the handling system that position, restrain, or control the movement of a manned DLSS. Towing is excluded from the SOC.

Low-Pressure Gas
Gaseous system which is below 1,000 psig.

Maintainability
The relative ease and economy of time and resources with which an item can be kept in, or restored to, a fully operational and safe condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair. In this context, it is a function of design.

Maximum Allowable Working Pressure (MAWP)
The maximum pressure at which the vessel or equipment is allowed to function at a specific temperature. This term is unique to a pressure vessel designed and stamped IAW ASME BPVC Section VIII Division 1 (see Mandatory Appendix 3 of the Code for full definition of maximum allowable working pressure (MAWP)). The nominal setting of the relief valve (see 2-2.5.9.1.3, which covers relief valve setting and installation) shall not exceed MAWP.

NOTE: For systems with pressure-regulating valves where the downstream piping does not incorporate a relief valve. The MOP of the upstream side of the pressure-regulating valve shall be the MOP of the downstream side of the pressure-regulating valve for test purposes.

Maximum Operating Pressure (MOP)

The highest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is determined by such influences as pump or compressor shutoff pressures, pressure regulating valve lockup (no-flow) pressure, and maximum chosen pressure at the system source.

Minimum Operating Pressure

The lowest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is usually determined by such influences as the minimum allowable oil supply pressure to a bearing or situations where corrective action shall be taken when pressure drops below a safe minimum pressure rather than exceeding a maximum pressure.

Objective Quality Evidence (OQE)

Any statement of fact, either quantitative or qualitative, pertaining to the quality of a product or service based on observations, measurements, or tests which can be verified. Evidence shall be expressed in terms of specific quality requirements or characteristics. These characteristics are identified in drawings, specifications, and other documents which describe the item, process, or procedure. Additional guidance can be found in NAVSEA SS521-AA-MAN-010.

Performance Specification

A statement of requirement in terms of required results with criteria for verifying compliance, without stating methods for achieving the required results. It defines the functional requirements for the item, the environment in which it must operate, and the interface and interoperability requirements.

Preliminary Design Review (PDR)

This review evaluates the progress, technical adequacy, and risk resolution (on a technical, cost, and schedule basis) of the selected design approach; the functions, performance, and interface requirements that will govern design of the items below system level and assures the design will meet overall system performance requirements; and the degree of definition and assess the technical risk associated with the selected manufacturing methods/processes of each CI or aggregate of CIs.

Pressure Drop Test

A test which identifies long term leakage of a system. Compressed gas flasks, pipe, and piping components are initially pressurized to 100% of MOP. Data is then taken to measure the change in pressure and corrected for temperature over an extended period of time.

Product Baseline (PBL)

The initially approved documentation describing all of the necessary functional and physical characteristics of the CI and the selected functional and physical characteristics designated for production acceptance testing and tests necessary for support of the CI. The PBL is controlled by the PM and is established after the CDR.

Rated Load
The maximum weight that shall be lifted by the assembled handling system at its rated speed and under parameters specified in the equipment specifications (e.g., hydraulic pressures, electrical current, electrical voltages).

Recompression Chamber
A type of PVHO that is designed to provide repressurization of individuals for treatments of decompression related injury or surface decompression.

Rigging
Running rigging consists of the rope (wire rope or synthetic line) and end fittings intended to handle the DLSS that passes over sheaves or through rollers. Standing rigging is rope that is stationary and provides mechanical support to the handling system.

Scope of Certification (SOC)
A list defining those systems, subsystems, components, portions of the DLSS, maintenance, and operational procedures which are needed to preserve the physical well-being of the DLSS personnel.

Seat Tightness Test
An internal pressure test that checks a valve's shut-off/isolation capabilities.

Static Test Load
A weight equal to 200% of the rated load of the handling system. It is used to physically verify the structural integrity of the handling system, and the adequacy of its brakes and fail-safe components.

Submersible
This term as it is used within the context of this document is intended to define any submerged object associated with a man-rated DLSS whose hydrostatic and hydrodynamic characteristics may require evaluation for safe operation of the DLSS in all anticipated conditions. Submersibles, as pertaining to DSSs, are not covered under the scope of this document.

Support Platform
Any platform used to transport, launch, and retrieve a DLSS. Ships, boats, vessels, barges, on. An example of a submarine support platform is one modified to carry a dry deck shelter (DDS) for operations with SEAL Delivery Vehicles.

Survivability
Ability of a system, sub-system, component, or equipment to withstand the effects of adverse environmental conditions that could otherwise render the system unusable or unable to carry-out its designed function. Survivability also enables a rapid restoration of the system, sub-system, component, or

equipment and to increase the sustainability of the war-fighting or peacetime operations.

System Certification Authority (SCA)
The organization within the NAVSEA that is delegated, through the USN chain of command – specifically OPNAVINST 3150.27, the responsibility to conduct certification of DLSSs under its cognizance.

System Design Pressure
The pressure used in calculating minimum wall thickness of pressure vessels, piping and piping components. The system design pressure shall not be less than the MOP.

System Design Review (SDR)
This review evaluates the contractor's optimization, traceability, correlation, completeness, and the risk of the allocated requirements including the corresponding test requirements in fulfilling the system/subsystem requirements (the FBL).

System Requirements Review (SRR)
This review evaluates the contractor's understanding of the contract requirements documents (specification, statement of work (SOW), contract schedule, etc.) and the adequacy of the contractor's efforts in defining system technical requirements. To determine initial direction and progress of the contractor's system engineering management effort.

Total Ownership Cost (TOC)
Also referred as life cycle cost. The total cost to the government of acquisition and ownership of the cost of research, development, acquisition, operations, and support (to include manpower and training), and where applicable, disposal.

Traceability
The ability to tie work, equipment or parts/pieces to a system, procedure or repair. Traceability is a key component in creating proper OQE for a system or subsystem.

Validation
The process of determining that a model or simulation implementation and its associated data accurately represent the developer's conceptual description and specifications.

Verification
The process of determining the degree to which a model or simulation and its associated data accurately represent the real world from the perspective of the model's intended uses.

Wave Slap
The dynamic loads placed on a vessel by the ocean (or lake, river, etc.) waves hitting the hull of the vessel. These loads affect not only the vessel but

all equipment mounted to decks and bulkheads in the vessel and need to be accounted for during design.

APPENDIX C: ABBREVIATIONS

°C	Degrees Celsius
µm	Micrometer (micron)
ABL	Allocated Baseline
ABS	American Bureau of Shipping
AC	Alternating Current
ACFM	Actual Cubic Feet per Minute
AIAG	Automotive Industries Action Group
AIT	Auto Ignition Temperature
ANSI	American National Standards Institute
ANU	Authorized for Navy Use
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ata	Atmospheres, Absolute
atm	Atmospheres
AWS	American Welding Society
BIBS	Built-In Breathing System
BOM	Bill of Material
BPVC	Boiler and Pressure Vessel Code
C2	Command and Control
CAOS	Chamber Air & Oxygen System
CCD	Configuration Control Document
CDD	Capability Development Document
CDCA	Current Document Change Authority
CDR	Critical Design Review
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CI	Configuration Item
CITIS	Contractor Integrated Technical Information Services
CM	Configuration Management
CMP	Configuration Management Plan
CNS	Central Nervous System
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COMMS	Communication System
CONOPS	Concept of Operations
COTS	Commercial-Off-The-Shelf
CRES	Corrosion Resistant Steel
CSA	Configuration Status Accounting
CTFE	Chlorotrifluoroethylene
CWP	Controlled Work Procedure
CoC	Certificate of Compliance
DAG	Defense Acquisition Guidebook
dB	Decibel
dBA	A-Weighted Scale
DC	Direct Current
DDC	Deck Decompression Chamber
DDS	Dry Deck Shelter

DI	Deck Interconnect
DISSUB	Disabled Submarine
DLSS	Divers Life Support System
DNA	Descriptive Narrative Analysis
DNV-GL	Det Norske Veritas-Germanischer Lloyd
DoD	Department of Defense
DODSSP	Department of Defense Single Stock Point
DOF	Degree of Freedom
DOT	Department of Transportation
DRL	Disregard Level
DSS	Deep Submergence System
DTL	Deck Transfer Lock
EBS	Emergency Breathing System
ECP	Engineering Change Proposal
ECS	Environmental Control System
EGS	Emergency Gas Supply
EIA	Electronics Industries Alliance
EIPS	Extra Improved Plow Steel
EP	Emergency Procedures
ESP	Elastic Strain Preload
FAT	Factory Acceptance Test
FBL	Functional Baseline
FCA	Functional Configuration Audit
FEA	Finite Element Analysis
FEP	Fluorinated Ethylene Propylene
FID	Flame Ionization Detection
FKM	Fluorocarbon Rubber
FMEA	Failure Mode, and Effects Analysis
F_{O2}	Fraction of Oxygen (percent by volume)
FS	Factor of Safety
FSS	Fire Suppression System
FSW	Feet of Seawater
ft^3/hr	Cubic Feet Per Hour
FTA	Fault Tree Analysis
g	gram
GC	Gas Chromatography
GFCI	Ground Fault Circuit Interrupter
GFD	Ground Fault Detector
GOX	Gaseous Oxygen
H_2	Hydrogen
He	Helium
HELIOX	Helium-Oxygen
HeO_2	Helium-Oxygen
HFE	Human Factors Engineering
HFP	Hexafluoropropylene
HMIS	Hazardous Material Identification System

HP	High-Pressure
HPU	Hydraulic Power Unit
HSI	Human Systems Integration
Hz	Hertz
IAW	In Accordance With
ICD	Initial Capabilities Document
I.D.	Inside Diameter
IEEE	Institute of Electrical and Electronic Engineers
IL	Inner Lock
IMCA	International Marine Contractors Association
IMO	International Maritime Organization
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IPS	Improved Plow Steel
IQI	Image Quality Indicator
IR	Insulation Resistance
ISEA	In-Service Engineering Agent
ISO	International Organization for Standards
IV&V	Independent Verification and Validation
JIC	Joint Industrial Conference
JID	Joint Identification Drawing
JIN	Joint Identification Number
K_{IC}	Fracture Toughness Test
K_{ISCC}	Stress Corrosion Cracking Test
KSA	Knowledge, Skills, and Abilities
L/m	Liters per minute
lb	Pound
LP	Low-Pressure
m	Meter
MΩ	Megaohm
MAF	Mechanically Attached Fittings
MAWP	Maximum Allowable Working Pressure
MCR	Material Certification Review
MIC	Microbiologically Influenced Corrosion
MJT	Mechanical Joint Tightness Test
mmHg	Millimeter of Mercury
MOP	Maximum Operating Pressure
MPC	Multipoint Constraint
MS	Military Standard
MSDS	Material Specification Data Sheet
MSE	Mission Support Equipment
MT	Magnetic Particle Inspection
MTBF	Mean Time Between Failures
MTL	Modified Transfer Lock
MTR	Material Test Report

N_2	Nitrogen
NAB	Nickel Aluminum Bronze
NACE	National Association of Corrosion Engineers
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAVFAC	Naval Facilities Engineering Command
NAVSEA	Naval Sea Systems Command
NCSC	Naval Coastal Systems Center
NDE	Nondestructive Examination
NDT	Non-Destructive Testing
NDTT	Nil Ductility Transition Temperature
NEC JQR	Navy Enlisted Classification Job Qualification Requirement
NEC	Navy Enlisted Classifications
NEDU	Navy Experimental Diving Unit
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Agency
Ni-Cu	Nickel-Copper
Ni-Cu-Al	Nickel-Copper-Aluminum
NIT	Nitrogen
NITROX	Nitrogen-Oxygen
NRB	Not Referenced in Body
NSMRL	Naval Submarine Medical Research Laboratory
NSTM	Naval Ships' Technical Manual
O&M	Operating and Maintenance
O_2	Oxygen
OD	Outside Diameter
OEM	Original Equipment Manufacturer
OGRES	Off-Gas Records System
OL	Outer Lock
OP	Operating Procedures
OPs/EPs	Operating and Emergency Procedures
OPNAVINST	Office of the Chief of Naval Operations Instruction
OSF	Ocean Simulation Facility
OQE	Objective Quality Evidence
PBL	Product Baseline
PCA	Physical Configuration Audit
PCTFE	Polychlorotrifluoroethylene
PDR	Preliminary Design Review
PFM	Pressurized Flexible Manway
PFMS	Pressurized Flexible Manway System
PFPE	Perfluoropolyether
PFT	Prototype First Article Testing
PHA	Preliminary Hazard Analysis
PIT	Pre-Installation Test

PM	Acquisition/Program Manager
PMS	Preventive Maintenance System
POT	Pre-Operational Test
PP_{CO2}	Partial Pressure of Carbon Dioxide
PPE	Personal Protective Equipment
ppm	Parts per Million
PP_{O2}	Partial Pressure of Oxygen
PQR	Procedure Qualification Record
psi	Pounds per Square Inch (same as psig)
psia	Pounds per Square Inch, Absolute
psig	Pounds per Square Inch, Gauge
PSNS	Puget Sound Naval Shipyard
PT	Dye Penetrant Inspection
PTC	Personnel Transfer Capsule
P_{Texp}	Explodable Volume Test Pressure
PTFE	Polytetrafluoroethylene
P_{Timp}	Implodable Volume Test Pressure
PVHO	Pressure Vessel for Human Occupancy
QA	Quality Assurance
RBE	Rigid Body Element
RCM	Reliability-Centered Maintenance
REC	Re-entry Control
RFP	Request for Proposal
RH	Relative Humidity
RM&A	Reliability, Maintainability and Availability
RMP	Risk Management Plan
RMS	Root-Mean Square
RQ	Respiratory Quotient
RT	Radiographic Inspection
SAB	Silicon Aluminum Bronze
SAE	Society of Automotive Engineers
SAT-FADS	Saturation Fly Away Dive System
SCA	System Certification Authority
SCBA	Self-Contained Breathing Apparatus
SCC	Stress Corrosion Cracking
SCUBA	Self-Contained Underwater Breathing Apparatus
SDC	Submarine Decompression Chamber
SDS	Submarine Decompression System
SDR	System Design Review
SE	Systems Engineer
SECNAVINST	Secretary of the Navy Instruction
SEP	Systems Engineering Plan
SEMP	Systems Engineering Management Plan
SEV	Surface Equivalent Value
SFR	System Functional Review

SHIPALT	Ship Alteration
SIT	System Integration Test
SMA	Shape Memory Alloy
SMCL	Submarine Material Control List
SNDL	Standard Navy Double Lock Recompression Chamber System
SOC	Scope of Certification
SOLAS	Safety of Life at Sea
SOT	System Operational Test
SOW	Statement of Work
SPC	Single Point Constraint
SRDRS	Submarine Rescue Diving & Recompression System
SRR	System Requirements Review
SRS	Submarine Rescue System
SSDS	Surface Supplied Diving System
STA	Success Tree Analysis
STPD	Standard Temperature and Pressure, Dry
SUPSALV	Supervisor of Salvage and Diving
TA	Technical Authority
TEMP	Test and Evaluation Master Plan
TM	Technical Manual
TOC	Total Ownership Cost
TWH	Technical Warrant Holder
UBA	Underwater Breathing Apparatus
UIPI	Uniform Industrial Process Instruction
UL	Underwriters Laboratory
UQC	Underwater Telephone
USAF	United States Air Force
USN	United States Navy
UT	Ultrasonic Inspection
VDF	Vinylidene Fluoride
VOC	Volatile Organic Compound
VOO	Vessel of Opportunity
VT	Visual Inspection
WPS	Weld Procedure Specification

APPENDIX D: SAFETY LIST OF HAZARDS

Asphyxiation:

- Contamination
- Chemical Dissociation
- Electrical Power Source Failure
- Explosion
- Fire
- Leakage
- Structural Damage or Failure
- Drowning

Burns:

- Corrosion
- Chemical Dissociation
- Electrical Arc
- Explosion
- Fire
- Oxidation
- Thermal Radiation
- Chemical Replacement

Trauma:

- Acceleration
- Explosion
- High Temperature
- Extreme Temperature Variations
- Rapid Pressure Changes
- Mechanical Shock
- Structural Damage or Failure
- Vibration and Noise

Toxicosis:

- Contamination
- Corrosion
- Chemical Dissociation
- Electromagnetic Radiation
- Leakage
- Oxidation
- Chemical Replacement
- Nuclear Radiation

Hyperthermia:

- Control System Failure
- Operating Environment

Electrocution:

- Inadvertent Electrical Activation
- Exposed Conductors

Hypothermia:

- Electrical Power Source Failure
- Low Temperature
- Leakage
- Structural Damage or Failure

Hazardous Energy Sources:

- Fuels
- Propellants
- Initiators
- Explosive Charges
- Charged Electrical Capacitors
- Storage Batteries
- Static Electrical Charges
- Pressure Containers, Pneumatic/Hydraulic
- Spring-loaded Devices
- Suspension Systems
- Gas Generators
- Electrical Generators
- RF Energy Sources
- Radioactive Energy Sources
- Falling Objects
- Catapulted Objects
- Heating Devices
- Pumps, Blowers, Fans
- Rotating Machinery
- Actuating Devices

- Nuclear

<u>Hazardous Element Sources:</u>

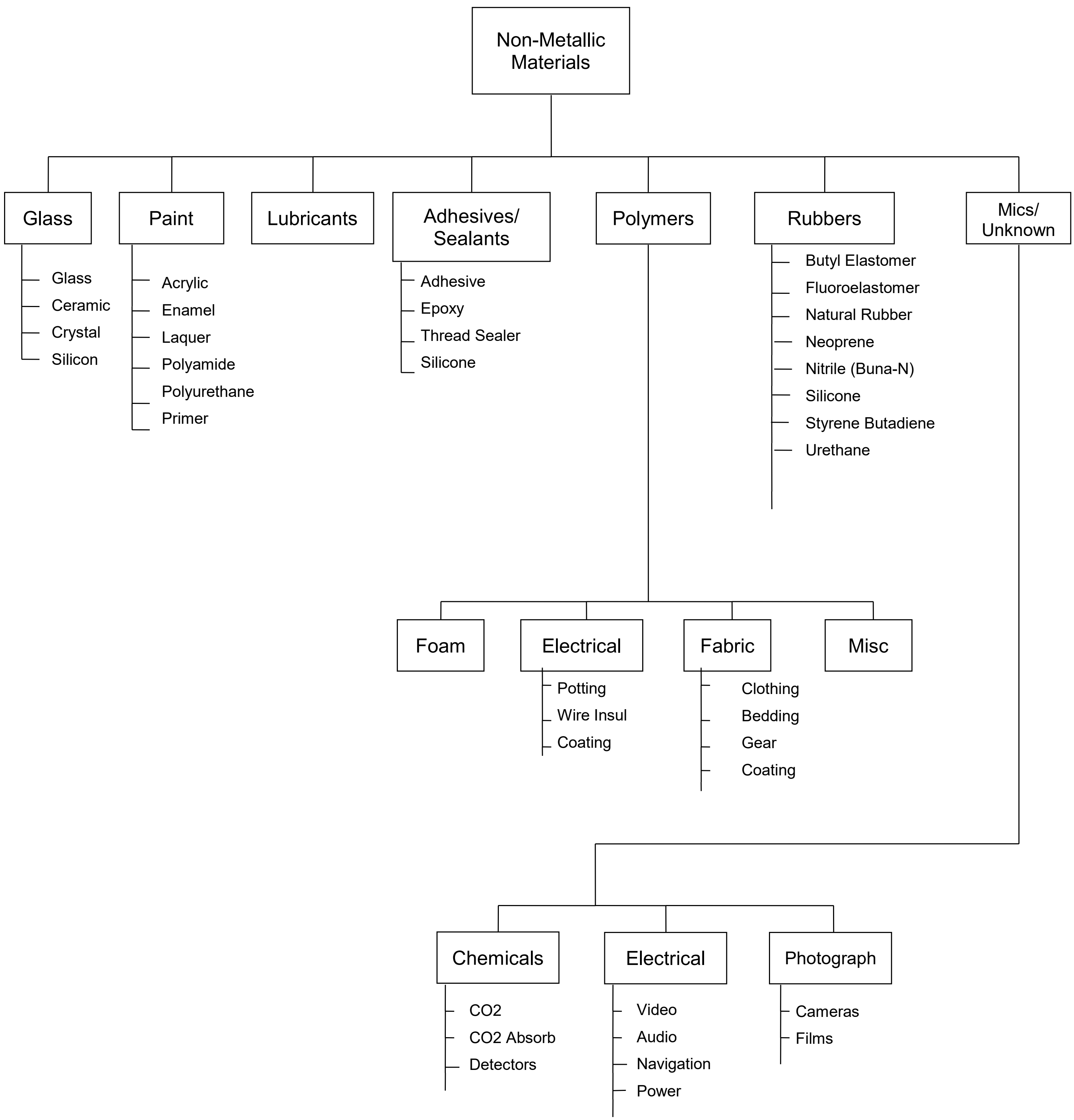
- Corrosion
- Chemical Dissociation
- Electrical
    - Shock
    - Thermal
    - Inadvertent Activation
    - Power Source Failure
    - Electromagnetic
- Heat and Temperature
    - High Temperature
    - Low Temperature
    - Temperature Variations
    - Acceleration
- Contamination
- Explosion
- Fire
- Leakage
- Oxidation
- Moisture
    - High Humidity
    - Low Humidity
- Pressure
    - High-Pressure
    - Low-Pressure
    - Rapid Pressure Changes
    - Pressure Multiplier
- Radiation
    - Thermal
    - Electromagnetic
    - Ionizing
    - Ultraviolet
    - Laser
- Chemical Replacement
- Mechanical Shock
- Stress Concentrations
- Stress Reversals
- Structural Damage or Failure
- Vibration and Noise
- Toxicity
    - Liquids
    - Solids
    - Gases
- Weather and Environment
- Micro-Biological Contaminated Water Diving
- Sharp or Pointed Objects

APPENDIX E: TOXICITY AND FLAMMABILITY

E-1 INTRODUCTION

Any nonmetallic and some metallic materials that can be exposed to the diver's breathable atmosphere, such as in a hyperbaric chamber, shall be considered a potentially toxic material. The toxicity of these materials results from the release of volatile solvents, semi-volatile plasticizers, incompletely polymerized materials, and other vaporized compounds. Any material which will ignite or explode from an electric spark or from heating and which, if so ignited, will independently support combustion in the presence of air or any O_2 enriched atmosphere, that may be encountered under either normal or emergency conditions, shall be considered a potentially flammable material. The following figure provides an illustration of the types of non-metallic materials to consider.

Figure F 1: Non-Metallic Material



E-1.1 SCOPE

Material contained in the breathable space and/or system that supplies breathing gas that have potential impact of toxicity and/or flammability must be identified. A list of these materials used in construction and/or modification of a DLSS, shall be developed by the PM and concurred to by the SCA and cognizant TA.

a. During the life cycle of the system as new and alternate materials are tested and rejected or installed, the list shall be kept continuously updated by the PM to reflect system configuration.

b. The composite list should contain the following data items for each material that undergoes toxicity or flammability testing:

(1) Material identity.

(2) Drawing and piece number or equivalent vendor description.

(3) Toxicity test results.

(4) Toxicity test report number.

(5) Flammability test results.

(6) Flammability test report number.

(7) Components which are tested for flammability and/or toxicity as complete assemblies shall be identified to the maximum extent possible. The drawing or equivalent vendor description shall be provided as well as the toxicity and flammability results, as well as test results. The quantity, location and use shall also be specified.

(8) NAVSEA approval document number if applicable.

(9) Comments (to include other pertinent information and any usage restrictions.

APPENDIX F: JOINT IDENTIFICATION DRAWING (JID) EXAMPLE

F-1 GENERAL

This Appendix includes some of the JIDs from the SNDL. These are to be used as an example only. The actual requirements for a JID are found in sections 2-2.3.2. It should be noted that the method for designating certain components in these drawings is different than what is shown in section 2-2.3.2. This would be acceptable if written authorization was granted by the PM. Table F 1 below contains the standard component nomenclature used in drawings.

Table F 1: Component Nomenclature Convention

Components	Designations
Air Compressor	AC
Air Purifier/Drier	AP
Three Way Ball Valve	3BV
Gauge Calibration Valve	GCV
Back Pressure Control Valve	BPCV
Ball Valve	BV
Check Valve	CV
Diffuser	DIF
Excess Flow Check Valve	EFCV
Filter	FIL
Flow Meter	FM
Glove Valve	GV
Hose	H
High-Pressure Flask	HF
Moisture Separator	MS
Muffler	MUF
Needle Valve	NV
Pressure Gauge	GA
Pressure Regulator	PR
Relief Valve	RV
Volume Tank	VT
Pressure Switch	PS
Solenoid Valve	SV
Stop Check Valve	SCV
Quick Disconnect	QD
Flex Hose	FH
Electric Ball Valve	EBV

Table F 2: System Nomenclature Convention

Systems	Designations
High-Pressure Air System	AHP
Low-Pressure Air System	ALP
Gas Analysis System	ATM
Diver Hot Water System	DHW
Exhaust System	EXH
Fill and Drain	FD
Fire Suppression System	FSS
Gas Mixing Console	GMC
He System	HE
HeO_2 System	HEO_2
Hydraulic System	HYD
Environmental Control System	ECS
N_2 System	N_2
NITROX System	N_2O_2
O_2 System	OX
Potable Water System (Hot)	PWH
Potable Water System (Cold)	PWC
Sanitation System	SAN
Waste Water	WW

THIS PAGE INTENTIONALLY LEFT BLANK

THIRD ANGLE PROJECTION

NOTES: UNLESS OTHERWISE SPECIFIED

1. THIS JOINT IDENTIFICATION DRAWING (JID) PROVIDES INFORMATION FOR THE INSTALLATION/ASSEMBLY OF THE STANDARD NAVY DOUBLE LOCK (SNDL) LIFE SUPPORT SYSTEMS.
2. ITEM TO BE CLEANED TO AIR CLEANING STANDARD, MIL-STD-1622.
3. APPLY CHRISTOLUBE TO ALL O-RING FACE SEALS PRIOR TO INSTALLATION.
4. APPLY TEFLON TAPE (OXYGEN SERVICE APPROVED) TO MALE THREAD PRIOR TO INSTALLATION. APPLY TEFLON TAPE TO WITHIN ONE THREAD IN FROM END BY WRAPPING IN OPPOSITE DIRECTION TO THREAD DIRECTION.
5. F.F.W.R DENOTES FLATS FROM WRENCH RESISTANCE.
6. ITEM TO BE CLEANED TO OXYGEN SERVICE STANDARD, MIL-STD-1330.
7. ALL TUBE, CONNECTIONS AND GAUGE SIZES ARE IN INCHES.
8. COLOUR CODING OF TUBES, QUICK DISCONNECTS, GAUGES SHALL BE IN ACCORDANCE WITH SS521-AG-PRO-010 "U.S NAVY DIVING MANUAL".
9. ALL ITEMS REQUIRE CERTIFICATE OF CONFORMANCE.
10. ALL COMPONENTS TO BE PNEUMO/HYDROSTATICALLY TESTED AND DOCUMENTED WITH IAW COWAN MANUFACTURING PTYL LTD, FACTORY ACCEPTANCE PROCEDURE.
11. ITEM TO BE PURCHASED WITH A 15 MICRON MONEL FILTER.
12. VALVE TO BE WIRED OPEN WITH FRANGIBLE WIRE.
13. ITEM TO BE PURCHASED WITH A CALIBRATION CERTIFICATE VALID FOR 12 MONTHS.
14. ITEM TO BE PURCHASED WITH HYDROSTATIC TEST RESULTS.
15. ALL BRASS COMPONENTS TO BE MANUFACTURED FROM ASTM B16 GRADE OR EQUIVALENT
16. THE TORQUE METHOD OF ASSEMBLY IS THE PREFERRED METHOD OF ASSEMBLY. IT REDUCES THE RISK OF HUMAN ERROR DURING ASSEMBLY THAT IS MORE PREVALENT IN THE FLATS FROM WRENCH RESISTANCE (F.F.W.R) METHOD. TO ENSURE THE MOST ACCURATE ASSEMBLY OF THE SEAL-LOK FITTING IT IS STRONGLY RECOMMENDED THAT THE TORQUE METHOD BE UTILIZED.
17. RELIEF VALVE TO BE SUITABLE FOR BREATHING AIR SERVICE (NO OIL) AND SUPPLIED WITH ASME CERTIFICATE.
18. SUPPLIED OIL FREE FOR BREATHING AIR SERVICE, HAVE FILTER DAMPENING, WITH WITH CALIBRATION CERTIFICATE.
19. SUPPLIED OIL FREE FOR BREATHING AIR SERVICE, HAVE FILTER DAMPENING, WITH CERTIFICATE OF CONFORMANCE.
20. SUPPLIED FOR OXYGEN SERVICE, HAVE FILTER DAMPENING, WITH CERTIFICATE OF CONFORMANCE & CLEANING.
21. ORDER WITH SENSOR SAMPLE CAP C/W 1/4" HOSE BARB.
22. REQUIRES VITON O RING 2-011 V90 (MIL-R-83248 TYPE 1 CLASS 2) 1/4" TUBE.
23. REQUIRES VITON O RING 2-012 V90 (MIL-R-83248 TYPE 1 CLASS 2) 3/8" TUBE.
24. REQUIRES VITON O RING 2-014 V90 (MIL-R-83248 TYPE 1 CLASS 2) 1/2" TUBE.
25. REQUIRES VITON O RING 2-021 V90 (MIL-R-83248 TYPE 1 CLASS 2) 1" TUBE.
26. REQUIRES VITON O RING 2-029 V90 (MIL-R-83248 TYPE 1 CLASS 2) 1 1/2" TUBE.
27. REQUIRES VITON O RING 3-904 V90 (MIL-R-83248 TYPE 1 CLASS 2) SAE 1/4"
28. REQUIRES VITON O RING 3-906 V90 (MIL-R-83248 TYPE 1 CLASS 2) SAE 9/16"
29. REQUIRES VITON O RING 2-215 V75 (MIL-R-83248 TYPE 1 CLASS 1) VCO 1" TUBE.
30. ASTM A269 ANNEALED 316 SST SEAMLESS HYDRAULIC TUBE, SCRATCH FREE AND SUITABLE FOR BENDING, MILL CERTIFICATION AND PROPERTIES REQUIRED. OD AND WALL THICKNESS TO BE MEASURED ON RECEIPT.
31. TUBE SIZE 6.35 OD x 0.89 WALL.

JOINT IDENTIFICATION CODING.

XXX-XXXXXXXX

TYPE OF JOINT :
BR = BARBED.
WJ = WELDED JOINT.
ST = STRAIGHT THREAD.
OU = O-RING FACE SEAL.
PT = PIPE THREAD.
FL = 37° FLARED (JIC).
CG = COMPRESSED GAS ASSN 540.

JOINT No: STARTING AT 001 FOR EACH SUBSYSTEM

TORQUE VALUE :
00 = NONE REQUIRED.
01 = .250 - .500 F.F.W.R - (220 - 242 IN-LB)
02 = .250 - .500 F.F.W.R - (360 - 396 IN-LB)
03 = .250 - .500 F.F.W.R - (480 - 528 IN-LB)
04 = .250 - .500 F.F.W.R - (720 - 792 IN-LB)
05 = .250 - .500 F.F.W.R - (1020 - 1122 IN-LB)
06 = .250 - .500 F.F.W.R - (1140 - 1254 IN-LB)
07 = .250 - .500 F.F.W.R - (1320 - 1452 IN-LB)
08 = .250 - .500 F.F.W.R - (1680 - 1848 IN-LB)
09 = .250 - .500 F.F.W.R - (2160 - 2376 IN-LB)
10 = 4320 - 4752 IN-LB
11 = 2-3 TURNS PASS FINGER TIGHT
12 = 2-3 TURNS PASS FINGER TIGHT
13 = 2-3 TURNS PASS FINGER TIGHT
14 = 2-3 TURNS PASS FINGER TIGHT
15 = 2-3 TURNS PASS FINGER TIGHT
16 = 1.5 - 2.5 TURNS PASS FINGER TIGHT
17 = 1.5 - 2.5 TURNS PASS FINGER TIGHT
18 = 1.5 - 2.5 TURNS PASS FINGER TIGHT
19 = 1.5 - 2.5 TURNS PASS FINGER TIGHT
20 = 156 - 172 IN-LB
21 = TIGHT TILL NO LEAKS

SUBSYSTEM DESIGNATION :
1 = AIR GAS SYSTEM.
2 = OXYGEN GAS SYSTEM.
3 = MIXED GAS SYSTEM.
4 = EXHAUST, BIBS EXHUST, CHAMBER RELIEF VALVE SYSTEMS.
5 = DEPTH PRESSURE GAUGE & GAS SAMPLE SYSTEMS.
6 = EQUALISATION & SPARES.
7 = MEDICAL LOCK.
8 = DIANOGSTICS AND COMMUNICATION.
9 = ENVIRONMENTAL CONTROL.

USAGE :
ALP = AIR LOW PRESSURE.
ATM = ATMOSPHERE (CHAMBER PRESSURE).
EQ = EQUALISATION.
EXH = EXHAUST.
OLP = OXYGEN LOW PRESSURE.
MLP = MIXED LOW PRESSURE.
ECS = ENVIRONMENTAL CONTROL SYSTEM

FITTING IDENTIFICATION CODING.

F-XXXX

FITTING No. : START AT 001 FOR EACH SYSTEM.

SUBSYSTEM DESIGNATION :
1 = AIR GAS SYSTEM.
2 = OXYGEN GAS SYSTEM.
3 = MIXED GAS SYSTEM.
4 = EXHAUST, BIBS EXHUST, CHAMBER RELIEF VALVE SYSTEMS.
5 = DEPTH PRESSURE GAUGE & GAS SAMPLE SYSTEMS.
6 = EQUALISATION & SPARES.
7 = MEDICAL LOCK.
8 = DIANOGSTICS AND COMMUNICATION.
9 = ENVIRONMENTAL CONTROL.

VALVE & GAUGE IDENTIFICATION CODING.

XXX-X-XX

SEQUENTIAL NUMBER

GAUGE / VAVLE DESCRIPTION :
G = GAUGE.
V = VALVE.
S = CO2 SCRUBBER.
R = REGULATOR

USAGE :
ALP = AIR LOW PRESSURE.
ATM = ATMOSPHERE (CHAMBER PRESSURE).
EQ = EQUALISATION.
EXH = EXHAUST.
OLP = OXYGEN LOW PRESSURE.
MLP = MIXED LOW PRESSURE.
ECS = ENVIRONMENTAL CONTROL SYSTEM

TUBE IDENTIFICATION CODING.

XX-X-XXX

SEQUENTIAL NUMBER

TYPE :
T = TUBE.
F = FLEXIBLE HOSE.

SUBSYSTEM DESIGNATION :
M = MIXED GAS SYSTEM.
O2 = OXYGEN GAS SYSTEM.
AS = AIR GAS SYSTEM.
ML = MEDICAL LOCK.
EXH = EXHAUST SYSTEM.
ATM = DEPTH PRESSURE, GAS SAMPLE.
ECS = ENVIRONMENTAL CONTROL UNIT.

NOTES CONTINUED: UNLESS OTHERWISE SPECIFIED

32. TUBE SIZE 9.525 OD x 0.89 WALL.
33. TUBE SIZE 12.7 OD x 1.2 WALL.
34. TUBE SIZE 25.4 OD x 1.6 WALL.
35. TUBE SIZE 38.1 OD x 1.6 WALL.
36. WELD IAW GPC APPROVED PROCEDURE.
37. COMPONENT IDENTIFICATION NUMBERS TO BE ENGRAVED ON EACH ITEM.
38. ITEM NOT AS SHOWN FOR VCM 197. SEE 7317813
39. VALVE TAG MUST BE ATTACHED. REF ITEM 592-7317789-97 FOR DETAILS.
40. NOTCH OUT COMMS BOX SHELL TO ALLOW ELECTRICAL CONNECTION TO ENTER THROUGH BASE.
41. EXH-T-006, 007, 011 & 012 MOUNTED TO CABLE TRAY USING 1/4" P-CLIP (SWAGELOCK PART NUMBER SS-TBP-4). P-CLIPS ATTACHED TO CABLE TRAY WITH 3/16 UNC X 1/2 LONG PAN PHILLIPS MOUNTS, NYLOCK NUT AND FLAT WASHER. THERE ARE 25 PER SYSTEM.
42. NUMBERS ENGRAVED ON PIPING COMPONENTS ARE FITTING NUMBERS AND NOT JID NUMBERS. USE THIS DRAWING (592-7317812) TO CROSS REFERENCE FITTING NUMBERS WITH JID NUMBERS FOR USE IN REENTRY CONTROL PROCEDURES.
43. VALVE MUST BE SET TO 200PSI BEFORE SERVICE.
44. REPLACEMENT FILTER ELEMENT IS NORMAN PART NUMBER 416G-20VN.

REVISION	REV STATUS OF SHEETS
SHEET	

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
-	1	REVISED TO AS BUILT.		
-	2	NOTES 30 - 37 ADDED.		
-	3	ADDED NOTE 38	2/26/02	RMW
-	4	ADDED NOTE 39.	24JUL02	
-	5	ADDED NOTE 40.	04SEP02	
-	6	ADDED NOTE 41.	06SEP02	RMW
-	7	ADDED NOTE 42.	10SEP02	RMW
-	8	NOTE 11 WAS 60 MICRON FILTER. NOTE 43 ADDED.	18SEP02	
F6,D9	9	ECS ADDED TO USAGE SECTION OF JID & VALVE/GAUGE I/D CODING.	10DEC02	
-	10	-	-	

QTY REQD	CAGE CODE	PART OR IDENTIFYING NO.	DESCRIPTION	SPECIFICATION	ZONE	ITEM NO.

PARTS LIST

PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
	QTY REQD PER ASSY		APPLICATION	

INCHES
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
TOLERANCES ARE:
.X ± 0.3 ANGLES: ± 1°
.XX ± 0.13
CAD FILE No. 7812-s01.dwg
DESIGN BY
FE FINK ENGINEERING PTY LTD MELBOURNE, AUSTRALIA

CONTRACT NO. -
CONTRACTOR: GPC - A JOINT VENTURE P.O. BOX JK WILLIAMSBURG, VIRGINIA 23187

PREPARED	MARK ANDERSON	05.07.2001
CHECKED	HOWARD ROME	06.07.2001
ENGINEER	RYAN WEBB	10/15/2001
ACCEPTED BY NAVSEA	MICHAEL P. LEESE (SIGNATURE DOES NOT DENOTE APPROVAL)	12/9/03
APPROVED FOR NAVSEA	MICHAEL P. LEESE (SIGN ONLY IF ENGINEERING HAS BEEN 'PROVED' BY MANUFACTURE AND TEST)	12/9/03

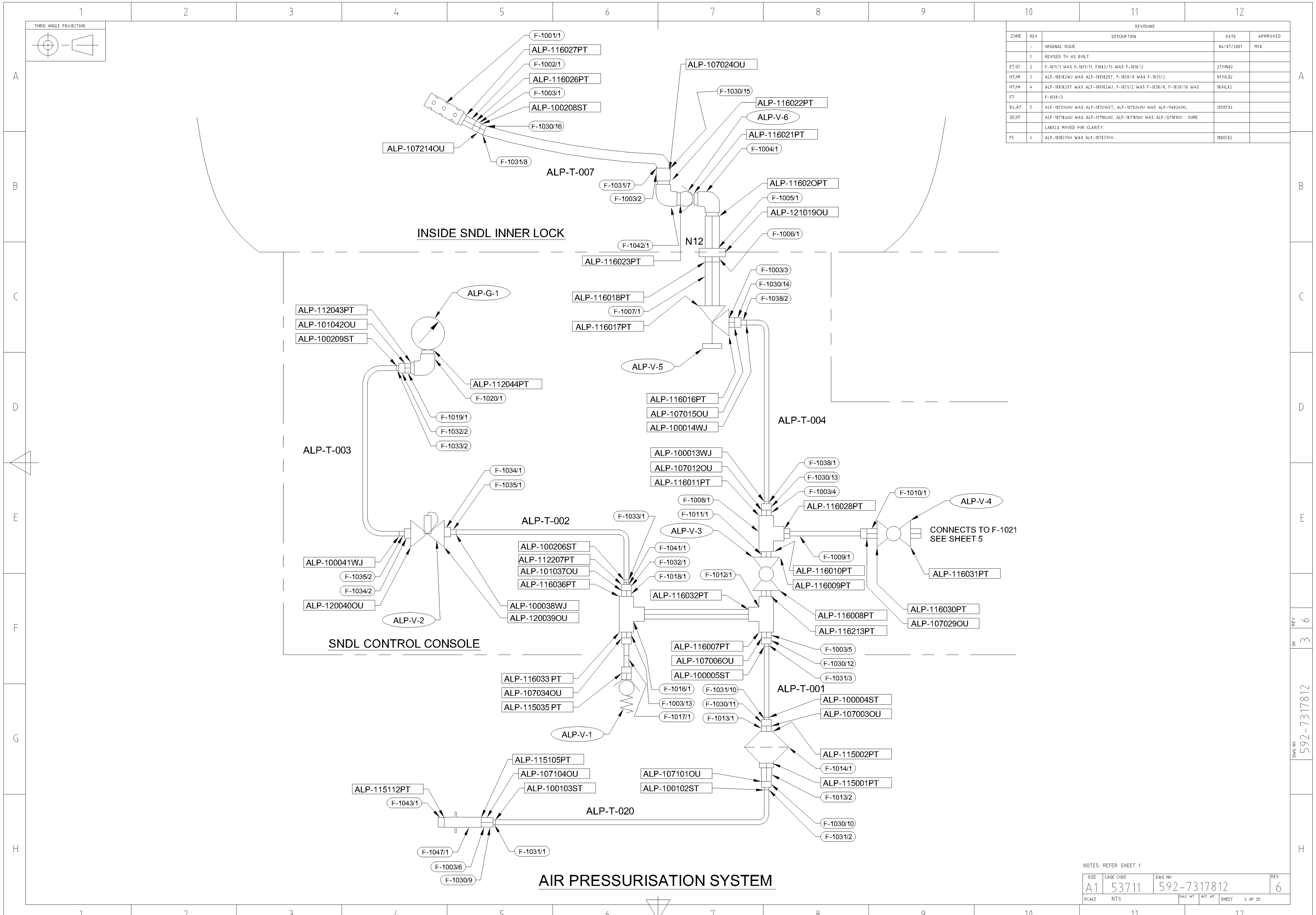
DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
ARLINGTON VIRGINIA 22242

TITLE
JOINT IDENTIFICATION DRAWING

SIZE	CAGE CODE	DWG NO	REV
A1	53711	592-7317812	10

SCALE N.T.S CALC.WT. ACT.WT. SHEET 1 OF 25

DWG NO 592-7317812 SH 1 REV 10



REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	-	ORIGINAL ISSUE	06/07/2001	MJA
	1	REVISED TO AS BUILT.		
E7,G7	2	F-1011/1 WAS F-1011/11, F1003/13 WAS F-1010/2.	27JUN02	
H7,H8	3	ALP-100102WJ WAS ALP-100102ST, F-1038/8 WAS F-1031/2.	09JUL02	
H7,H8	4	ALP-100102ST WAS ALP-100102WJ, F-1031/2 WAS F-1038/8, F-1038/10 WAS	18JUL02	
F7		F-1038/3.		
B4,A7	5	ALP-107214OU WAS ALP-107214ST, ALP-107024OU WAS ALP-116024OU,	12SEP02	
G5,H7		ALP-107104OU WAS ALP-121104OU, ALP-107101OU WAS ALP-121101OU. SOME		
		LABELS MOVED FOR CLARITY.		
F5	6	ALP-101037OU WAS ALP-107037OU.	10DEC02	

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX G: SAMPLE DRAWING NOTES

G-1 GENERAL

Part 3 of the Genspecs Supplemental Documentation, dated 31 Jan 2023, Serial Number 00C3/3012 provides an example of types of some possible notes that can be found on various drawings. Drawing notes need to be specifically generated and/or tailored for the type of system and driven by system size and complexity.

The example notes do not have specific year edition, issue or revision listed. When using drawing notes that specify codes, standards and/or specifications, its most recent edition, issue or revision should be used when applying references unless there is a contractual requirement to used other less current issues or revisions.

APPENDIX J: TESTING PARAMETERS FOR PERMANENTLY OR TEMPORARILY MOUNTED IMPLODABLE AND EXPLODABLE ITEMS

J-1 INTRODUCTION

This Appendix provides guidelines for ensuring that DLSSs are not subjected to underwater explosion or implosion loading, resulting from the failure of an uncompensated DLSS component. This Appendix is applicable to equipment permanently or temporarily mounted on the DLSS, and exposed to ambient submergence pressure during operations. This includes:

a. Equipment mounted anywhere on a DLSS designed to maintain the DLSS personnel in a submerged ambient environment.

b. Equipment mounted external to a hyperbaric diving chamber (e.g., diving bell) or carried by divers but not previously qualified and listed as ANU by divers.

c. Equipment located in the water column, which may not be part of a DLSS but may come in close proximity to divers.

NOTE: For equipment inside a dry environment such as a hyperbaric chamber, implosion does not present the same risk as it does in the water column or in a wet pot. In a dry environment, energy will not transmit to the diver as it does in the wet environment, where the liquid molecules efficiently transfer energy. For items such as lights and cameras that are internal to the dry chamber/habitat, it is sufficient to leverage off of design rating and OEM integrity testing with PM approval.

NOTE: Some DLSSs (e.g., lockout chamber) represent a hybrid case in which the personnel are in a dry environment for part of the mission and are exposed to wet ambient conditions (i.e., fully or partially flooded chamber) for part of the mission. In this case, all explodable or implodable volumes will be evaluated IAW this Appendix at the maximum design depth, wet or dry, whichever is greater. All such volumes classified as critical will be tested IAW sections J-4 and/or J-5 using the maximum design depth of the DLSS as the basis for determining the test pressure. Without exception, all other explodable or implodable volumes will be tested IAW sections J-4 and/or J-5 using the maximum depth at which DLSS personnel (divers) are expected to enter or exit the DLSS as the basis for determining the test pressure.

J-2 DEFINITIONS

Implodable volume – Any pressure housing containing a noncompensated compressible volume at a pressure below the external ambient sea pressure (at any depth down to maximum operating depth) which has the potential to collapse. The outer shell volume is used when calculating the volume of an implodable. Subtracting the volume of items internal to the implodable is not allowed unless approved by the PM.

Explodable volume – Any pressure housing containing a volume of gas, at a pressure above the external ambient sea pressure (at any depth) which has the potential to burst. Note that some volumes may be explodable at shallow depths and implodable at deeper depths.

Critical implodable volume – Any implodable volume, which by imploding, affects the safety of the diver.

Critical explodable volume – Any explodable volume, which by exploding, affects the safety of the diver.

Noncritical implodable volume – Any implodable volume, which by imploding, does not affect the safety of the diver.

Noncritical explodable volume – Any explodable volume, which by exploding, does not affect the safety of the diver.

Minimum required standoff distance – The minimum distance, from any system or item, at which an implodable or explodable volume can be located, such that if an implosion or explosion occurred, the diver would not be affected (i.e., the distance at which a critical explodable or implodable becomes a noncritical explodable or implodable).

P_{Timp} – Implodable volume test pressure, which is equal to 1.5 times the system's maximum allowable external operating pressure.

P_{Texp} – Explodable volume test pressure, which is equal to 1.5 times the item's maximum allowable internal operating pressure.

J-3 IMPLODABLE ITEMS

All volumes that contain gas at a pressure less than the ambient external sea pressure have the potential to implode. When such a volume does implode it releases a pressure pulse similar to that which is produced when the expanded gas bubble from an underwater explosion collapses. In the event of an implosion it is the initial pressure pulse that is of concern.

J-3.1 EXPLODABLE ITEMS

All volumes that contain gas at pressures greater than the ambient external sea pressure have the potential to explode. When such a volume does explode it releases an explosive shock wave. During an explosion a gas bubble expands beyond the point of equilibrium with the surrounding hydrostatic sea pressure. This expanded volume of gas then collapses, causing a pressure pulse. The gas bubble continues to expand and collapse, releasing pressure pulses of decreasing magnitude, until equilibrium with the surrounding hydrostatic pressure is reached. It is the initial explosive shock wave and subsequent pressure pulse that are of concern in the event of an explosion.

J-3.2 EXPLODABLE ITEMS DUE TO DECOMPRESSION

This Appendix does not cover the requirements for explosive decompression testing of volumes used in pressurized gaseous environments (e.g., recompression chambers or saturation diving chambers). Volumes used in such environments are subject to He intrusion (or intrusion of some other gas) while at elevated pressures and thus have the potential to explode during the decompression cycle, as well as implode during the compression cycle. For all such volumes subject to explosive decompression, the requirements of Appendix K, in addition to the requirements of this section, apply.

J-3.3 PRESSURE VESSELS

Pressure hulls/vessels, personnel spheres, buoyancy tanks, air flasks, syntactic foam, and like items are implodable or explodable volumes by definition but are exempt from the requirements of this Appendix. These items shall be designed and tested IAW Part 2 and Part 3 of this specification.

J-4 DETERMINATION OF WHETHER OR NOT AN EXPLODABLE OR IMPLODABLE IS CRITICAL OR NONCRITICAL

In order to determine whether or not an implodable or explodable volume is critical (requires testing) or noncritical (does not require testing), the effects of the initial explosive shock wave and/or the initial implosion pulse on all critical systems or components must be analyzed to ascertain whether or not the explosion or implosion would jeopardize the safety of the DLSS. If the effects jeopardize the safety of the DLSS personnel, then the explodable or implodable is to be classified as critical. Otherwise, the explodable or implodable is classified as noncritical. All explodable or implodable volumes on a DLSS designed to maintain the operators in an ambient sea pressure environment, and which were not tested to a more severe requirement, will be classified as critical and tested IAW sections J-4 and/or J-5 using the maximum depth at which DLSS personnel are expected to operate the DLSS as the basis for determining the test pressure.

There are no testing requirements for implodable or explodable volumes which have been classified as noncritical volumes. The potential effect an explodable or implodable volume has on a diver is directly related to the standoff distance between an implodable or explodable volume and a diver. Thus a standoff distance becomes part of the SOC for that particular volume and the system/component combination. For example: an implodable camera housing has a minimum required standoff distance of 4 feet with respect to the diver. If this camera housing is located 5 feet away, anywhere, from the diver, the camera housing would be classified as a noncritical implodable volume and would require no testing. However, if this same camera housing were located only 3.9 feet from the diver, the camera housing would be classified as a critical implodable volume and would require implosion testing. It is therefore imperative to determine the minimum required standoff for all noncritical implodable or explodable volumes and to retain this information in such a manner that ensures that all noncritical volumes are located no closer than the minimum required standoff to the diver.

J-5 TESTING NECESSARY FOR CRITICAL IMPLODABLE/EXPLODABLE VOLUMES

All volumes designated as critical implodable volumes, at any depth, shall be tested by pressurizing the volume externally to 1.5 times the P_{Timp} for 10 cycles: cycles one through nine shall each be held at P_{Timp} for 10 minutes and cycle 10 shall be held at P_{Timp} for one hour. The test shall be conducted in 35°F (1.67°C) seawater, if practical. Leakage or visible signs of damage shall be cause for test failure.

NOTE: All volumes that are certified in this manner will require recertification by implosion testing if repairs or modifications are made which alter the "as-tested" configuration of the volume. The following are examples (not a complete list) of work or conditions that if performed or noticed on a certified (successfully tested) implodable volume will require a retest: welding, grinding, machining, any work that removes material, excessive corrosion, or replacement of a pressure boundary part (except O-rings, gaskets, in-kind fasteners, etc.)

All volumes designated as critical explodable volumes, at any depth, shall be tested by pressurizing the volume internally to 1.5 times the P_{Texp} for 10 cycles: cycles one through nine shall each be held at P_{Texp} for 10 minutes and cycle 10 shall be held at P_{Texp} for one hour. Leakage or visible signs of damage shall be cause for test failure.

NOTE: All volumes which are certified in this manner will require recertification by explosion testing if repairs or modifications are made which alter the "as tested" configuration of the volume. The following are examples (not a complete list) of work or conditions that if performed or noticed on a certified (successfully tested) explodable volume will require a retest: welding, grinding, machining, any work that removes material, and excessive corrosion or replacement of a pressure boundary part (except O-rings, gaskets, etc.).

NOTE: The need to test and serialize each uncompensated volume for implodability is dependent on several factors. These factors include component design and materials, environmental use conditions, operational parameters (mission CONOPS), component repeatability and traceability, builder manufacturing processes, other component structural testing and builder QA processes and implementation. In some cases 100% testing and serialization of each article is not required. With prior PM approval and documented justification, the following sampling table can be used to accept the use of a batch of uncompensated components without subjecting each component to implodability testing.

SAMPLING TABLE	
Lots or Batch Size	Sample Size
2 to 8	2
9 to 15	3
16 to 25	5
26 to 50	8
51 to 90	13
91 to 150	20

J-6 TEST RECORD OBJECTIVE QUALITY EVIDENCE (OQE) REQUIRED FOR CRITICAL IMPLODABLE AND EXPLODABLE VOLUMES

A submergence Pressure Test Record shall be kept for all components tested IAW sections J-4 and J-5. Records, as a minimum, shall include the following information:

a. Name(s) and serial number(s) of component(s) tested.

b. Date of test.

c. Serial number(s) of gauge(s) used for the test.

d. Last calibration date of the pressure gauge(s) used in the test.

e. Next calibration due date of the pressure gauge(s) used in the test.

f. Test medium temperature required and actual test medium temperature used.

g. Pressure range and accuracy of gauge(s) used.

h. Test pressure for each pressure cycle.

i. Required and actual duration of each pressure cycle.

j. Results of inspection for leakage or visible signs of damage.

k. Printed name(s) and signature(s), or identification number(s) and signature(s) of test conductor(s) and/or inspector(s) and the date of each signature.

J-9 EXEMPTIONS TO TESTING CRITICAL IMPLODABLE/EXPLODABLE VOLUMES

The designer may request an exemption from testing those implodable/explodable volume components that have a maximum design depth rating of four or more times the maximum operating depth of the DLSS and have a first article test of the item performed, as required above, to the item's maximum operating depth.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX K: TESTING PARAMETERS FOR EXPLODABLE ITEMS DUE TO DECOMPRESSION

K-1 INTRODUCTION

Many devices, such as interior lights and instrument bulbs inside the DLSS, are subject to inadvertent explosion during decompression because they have been infiltrated by He or other gases during a compression cycle. These devices may become hazards within the DLSS. At the present time, there is no known analytical method for determining the material adequacy of items within a DLSS that may explode and cause a casualty. To achieve a maximum reasonable level of assurance for these items, the following paragraphs contain the requirements for determining the material adequacy of all such items.

K-2 DESCRIPTION AND ORIENTATION

A list shall be generated which describes the size, quantity, and locations of all potentially explodable items. All such items shall be explosively tested as described below. If 100% batch testing is impractical or otherwise considered unnecessary, the builder may request a waiver of the 100% testing requirement and shall provide detailed justification for the waiver and a procedure for selecting the batch sample size. The approved sample will be tested IAW the requirements of this Appendix.

K-3 TEST PROCEDURE

Each item selected shall be tested as follows:

a. Subject the item to a pressurized soak test, using a test medium (e.g., air, He) representative of the actual environment in which the explodable item will operate. For convenience, it may be permissible to substitute a test medium (e.g., air for water or He for air) that is more likely to infiltrate the test article. The time of the soak shall be 2 times the maximum expected exposure period or 24 hours, whichever is less. The pressure shall be the MOP of the DLSS.

b. Following the soak test, depressurize the test chamber at a rate not less than 1.5 times the maximum depressurization rate of the manned space. For items that may be locked in or out of manned spaces, the maximum travel rate of the service lock must be considered.

c. Items that do not show evidence of physical deterioration or damage shall be acceptable for service.

d. Items that do show evidence of physical deterioration or damage shall be rejected.

e. Depending on the type of failure, rejected items may be allowed to be repaired and then undergo a retest. If these items successfully pass the retest they will be acceptable for service.

NOTE: The need to test and serialize each component for explodability is dependent on several factors. These factors include component design and materials, environmental use conditions, operational parameters (mission CONOPS), component repeatability and traceability, builder manufacturing processes, other component structural testing and builder QA processes and implementation. In some cases 100% testing and serialization of each article is not required. With prior PM approval and documented justification, the below sampling table can be used to accept the use of a batch of components without subjecting each component to explodability testing.

SAMPLING TABLE	
Lots or Batch Size	Sample Size
2 to 8	2
9 to 15	3
16 to 25	5
26 to 50	8
51 to 90	13
91 to 150	20

K-4 POROUS OR VENTED COMPONENTS

Porous or vented components of an explodable item, which by their fabrication or design are known or intended to continuously equalize their internal pressure with ambient external pressure, shall be shown to have the ability to intake and exhaust a test medium, representative of the actual operating environment, within the maximum pressurization/depressurization rates of the system in order to provide assurance that the porous or vented components will not explode during pressurization or depressurization. Testing done IAW section K-3 above, including authorized substitutions of test medium, will provide this assurance.

APPENDIX L: FINITE ELEMENT ANALYSIS (FEA)

L-1 FINITE ELEMENT ANALYSIS (FEA) MODELING REQUIREMENTS

Standard accepted modeling practices/software, which has been validated, shall be utilized with the following additional requirements.

L-1.1 GENERAL REQUIREMENTS

a. Ne/Nastran stress gradients (energy or stress norms) shall be no more than 10% overall and no more than 5-7% in areas of interest (above 5% shall only be utilized if the model has been refined three times). ANSYS model mesh density may be validated by refining the mesh within the region(s) of interest and re-running the model to confirm that stress values do not increase beyond a reasonable value. Von Mises stresses should not change by more than 7% within the region of interest after mesh refinement.

b. Transition elements shall be away from areas of interest and shall not influence the load path or stresses (in the area(s) of interest(s)).

c. Element aspect ratio shall not exceed 4:1 in regions of interest.

d. FEA shall be validated by hand calculations; i.e., web crippling, trunk punch through, etc.

e. FEA shall not be used for spherical or cylindrical shell stress predictions unless authorized by the PM.

f. Where the area of interest is next to a boundary condition, stresses shall be either recovered away from the influence or “walk” the stress in.

L-1.2 SHELL ELEMENTS

a. Submodels, utilizing solid elements, shall be used in areas where stresses exceed 75% of the material’s yield strength, except when the peak stress is localized to one node.

b. Load path/stresses shall not be influenced by the transition or use of coarse mesh.

c. Lower order triangular elements shall not be used.

L-1.3 SOLID ELEMENTS

a. In areas of interest, there shall be a minimum of four elements through the thickness.

b. Load path/stresses shall not be influenced by the transition or use of a coarse mesh.

c. Lower order Tet elements shall not be used.

L-2 FINITE ELEMENT ANALYSIS REVIEW CHECKLIST

MODELING

Geometry

- Geometry/dimensions of the model are consistent with those of the drawings. (This is especially important if you've transformed units).
- The model uses worst-case dimensional tolerances, including corrosion.
- Assumptions used for the model simplification of the real world make very small contribution to the result.

Material Properties

- Applicable, authorized and current material specifications are used. Verify that the properties of each sub-components are applied correctly. At a minimum check the elastic modulus, Poisson' n ration and density.
- Units are consistent with those used elsewhere.

Finite Element Model

- Proper element use – Are you using the right element for the job? Are you using it correctly? For example, rigid body element (RBE) 3's aren't really "rigid" and shouldn't be used as structural elements. They are primarily for calculating average motion or distributing loads. CELAS elements should be between coincident grids or may generate artificial forces during rigid body rotation.
- Multipoint constraint's (MPC) and RBE's – MPC's formulated correctly? Appropriate RBE? For example, is that component modeled with that RBE2 really stiffer than the structure you are attaching it to? Will you artificially lock up your structure with a big RBE? Avoid over-constraining the structure with RBE's.
- Coordinate systems – If multiple input and output coordinate systems are used, make sure which ones your elements and constraints are referencing. For example, RBE elements will use the grid output coordinate system when assigning degrees of freedom (DOF).
- Constraints and load application are a good approximation of the real world.
- Minimum of four solid elements through the thickness where bending is expected.

Modeling Checks

- Free edge – Check to make sure elements are connected properly, particularly where 1D, 2D, and 3D elements are connected to zero-length elements (springs).
- Coincident nodes – Check for erroneous coincident nodes; but be careful not to merge intentional coincident nodes.

- Coincident elements – Check for coincident elements; this can happen if you are not careful when creating multiple meshes.
- Bar/beam orientation – Use orientation visualization to determine if bar and beam elements are oriented properly.
- Plate element normals – Check that plate normals are in the same direction where necessary.
- Contact elements – Check surface/elements that are within the contact region. Are contact pairs normals facing each other?
- Mass – Check to be certain the model's mass is reasonable and accurate.

Specific to ANSYS:

- Check the weight of each element type using the SOLVE or PSOLVE command and insure the weight makes sense.
- Check for solid element connectivity using MCHBCK command and use /EDGE,1,1 command to check visually.
- Make sure element aspect ratio warning is changed from the default 20:1 to 4:1.
- Review the element shape using SHPP, SUMMARY to ensure proper element shape within the region of interest.
- For temperature dependent analyses, check the reference temperature using the TREF command.

Analysis

- Was the appropriate analysis selected, such as elastic static, non-linear material, non-linear for large displacements, buckling, contact, etc.?

Analysis Checks

- FS on load/stress is correctly used where required by governing specifications.
- Summation of single point constraint (SPC) reactions is equal in magnitude and opposite in direction to applied load.
- Summation of forces on each free-body diagrams equals zero.

Results

- Review all automated error alerts resulting from the analysis, and resolve.
- Singularities – If you have singularity errors, are they because of rotational degrees of freedom from plates and solids? Are those removed by AUTOSPC? If you are unsure, then you should try to remove the singularities and re-run the model. If some still exist, they may indicate grounding problems.

- If stress levels are relatively high, are they acceptable based on fatigue cycle considerations?
- Displacements – Do displacements and contours make sense for loads and constraints applied? Contact elements behaving as expected?
- Determine if stress levels are meaningful, by review of:
  - Classical, hand calculation of stresses/deflections for simplified, similar structure/loading.
  - Continuity and smoothness of stressors and deflections.
  - Stress gradients (energy or stress norms) no more than 10% overall and less than 7% in region of interest.
- Where stressors appear to be excessively high on plate element models, use refined, solid element modeling to validate stresses.

APPENDIX M: MATERIALS AND COMPONENTS

Table N 1 through Table N 4 list typical DLSS materials and/or components with their application. The specifications listed are representative of requirements for the material identified and are provided for guidance.

Table N 1: Pressure Hull/Vessel Materials

Material	Stock	Specification	Remarks
HY-80/100	Plate Forging Bars Castings Heads	NAVSEA T9074-BD-GIB-010/0300(1)	When fabricated and welded to requirements of NAVSEA T9074-AD-GIB-010/1688, or ASME PVHO-1
Carbon Steel for pressure vessels for moderate and lower temperature service.	Plate Forging	ASTM A537(2) ASTM A516 ASTM A350(2)	ABS Rules for *Building and Classing Steel Vessel, Part 4* or ASME PVHO-1
Stainless Steel (Grade 316L or 304L)	Plate Forging/Flanges/ Fittings Castings	ASTM A240 SAE AMS-QQ-S-763 ASTM A336 ASTM A182 ASTM A351	
Stainless Steel (Grade 318)	Plate	ASTM A240	
Cast Polymethyl Methacrylate Plastic	Viewports	ASME PVHO-1	

(1) This specification include impact property requirements for HY-80/100 material in military applications. Consideration will be given to lower impact values for HY-80/100 where the material meets the toughness requirements of ASME PVHO-1, Safety Standard for PVHO.

(2) When specified to a maximum NDTT of 60°F (15.56°C) below the minimum design temperature, or a dynamic tear value of at least 200 ft/lbs from a 5/8 -inch specimen tested at the minimum design temperature. These materials would require justification if subjected to a seawater environment.

Table N 2: Piping and Diver Life Support (DLSS) Materials and Components

Material	Stock	Specification
Stainless Steel	Pipe and Tubing Forgings, Flanges & Fittings Castings	MIL-P-24691 ASTM A312 ASTM A213 SAE-AMS-QQ-S-763, ASTM A336, ASTM A182, ASTM A350 ASTM A351
Ni-Cu (Monel)	Cast Wrought Tubing	ASTM A494 MIL-C-15726 ASTM B171 MIL-T-16420
70/30 Cu-Ni	Cast Wrought Tubing	ASTM B369 MIL-C-15726 ASTM B171 Alloy C71500 MIL-T-16420 ASTM B466 Alloy 715
Valve Bronze		ASTM B61
O_2 Valves		MIL-V-24439
Aluminum Bronze	Wrought	MIL-B-24480 ASTM B271 Alloy C95800 ASTM B150 Alloy E 63200 ASTM B148 (temper annealed per MIL-B-24480)
Compressed Gas Flasks	Seamless Steel Tube and Composite[1]	MIL-DTL-22606 ASME BPVC Section VIII DOT-3AA DOT-SP-10945
CO_2 Absorbent	Calcium Hydroxide w/NaOH w/BaOH Lithium Hydroxide[2]	Dive SorbPro: Draeger Sofnolime-Grade 408L with no indicator: Molecular Products Baralyme: Commercial MIL-L-20213

(1) Composite flasks would require justification if subjected to a seawater environment.

(2) Because of the possibility of severe caustic burns, lithium hydroxide shall not be used in UBAs, or any environment where the operator may come in contact with it.

Table N 3: Mechanical Bolting Material

Material	Stock	Specification
Nickel-Copper-Aluminum (Ni-Cu-Al) Alloy (K-Monel)	Round Stock	QQ-N-286
Ni-Cu	Round Stock	QQ-N-281
Corrosion Resistant Steel (CRES)	Round Stock	ASTM A193

Table N 4: Electrical Components

Material	Specification
Detail Specification, Electric Power Equipment, Basic Requirements For	MIL-DTL-917
Detail Specification, Enclosures for Electric and Electronic Equipment, Naval Shipboard	MIL-HDBK-2036
Electrical Cables	NAVSEA S9320-AM-PRO-020/MLDG (PRO-020) (When procured from a NAVSEA approved vendor certified IAW this specification