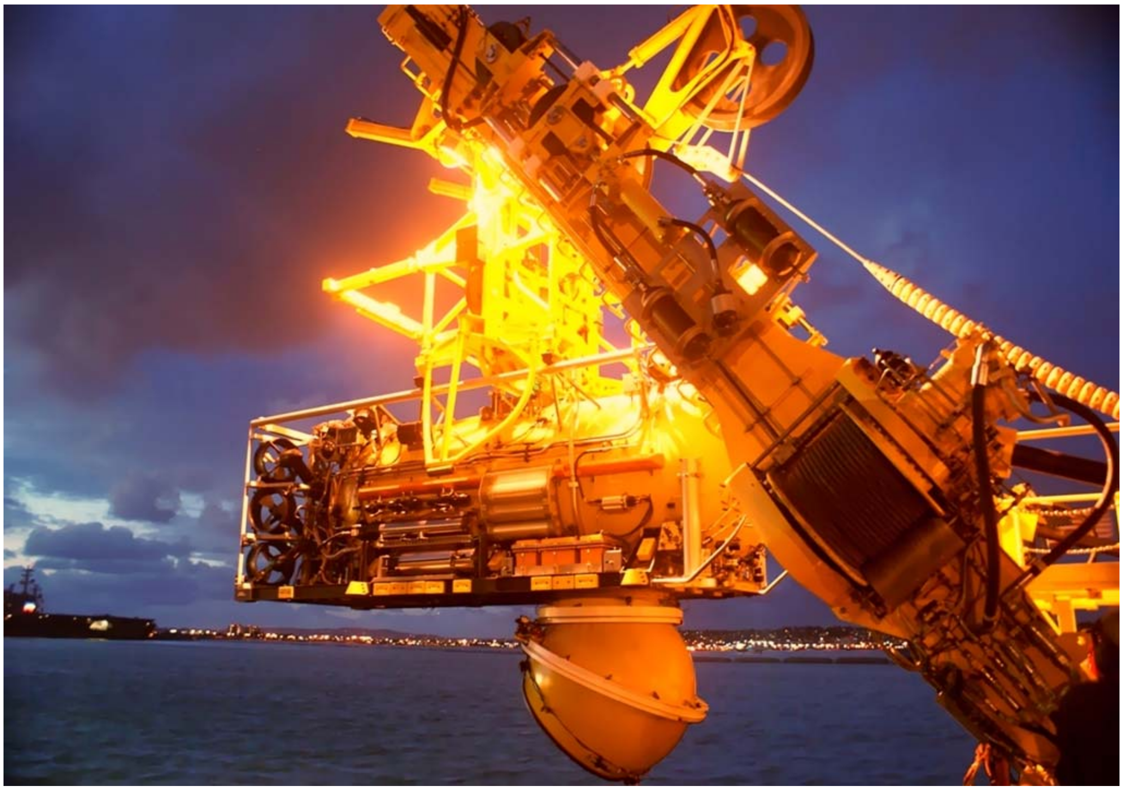
SH420-AA-PRO-010 0910-LP-118-6308

U.S. NAVY
SUBMARINE RESCUE SYSTEM (SRS)
DECOMPRESSION PLAN



DEPARTMENT OF THE NAVY

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0910-LP-118-6308

Revision 1, 31 March 2020

TECHNICAL MANUAL CERTIFICATION SHEET

CERTIFICATION APPLIES TO: NEW MANUALS ☐ REVISION ☒ CHANGE ☐

APPLICABLE TMINS/PUB. NO.	PUBLICATION DATE (day, month, year)	READING GRADE LEVEL (RGL)
SH420-AA-PRO-010	3/31/2020	

TITLE

U.S. NAVY SUBMARINE RESCUE SYSTEM (SRS) DECOMPRESSION PLAN

TMCR/TMSR/SPECIFICATION NUMBER

N39040-18-KK01

CHANGES AND REVISIONS:
PURPOSE

Corrections of tables not being mentioned in the text and the TMDER correction.

EQUIPMENT ALTERATION NUMBERS INCORPORATED

N/A

TMDER/ACN NUMBERS INCORPORATED

N39040-18-KK01

Continued on additional pages as needed.

CERTIFICATION STATEMENT

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LIST OF ACRONYMS AND ABBREVIATIONS

ºC	Degrees Celsius
ºF	Degrees Fahrenheit
AGE	Arterial Gas Embolism
AirIWO2D	Air In-Water Oxygen Decompression
AR	Ambulatory Rescuee
ATA	Atmospheres Absolute
ATM	Atmospheres
Aux Van	Auxiliary Van
BIBS	Built-In Breathing System
BVM(3)	Duke University, 3 Compartment Bubble Volume Probabilistic Model
CNS	Central Nervous System
CO2	Carbon Dioxide
CONOPS	Concept of Operations
CPTD	Cumulative Pulmonary Oxygen Toxicity Dose
CT	Custodial Tender
DCS	Decompression Sickness
DET	DISSUB Entry Team
DISSUB	Disabled Submarine
DMO	Diving Medical Officer
DSUBTD	DISSUB Transfer Depth
DTL	Deck Transfer Lock
EAD	Equivalent Air Depth
EASD	Equivalent Air Saturation Depth
EABS	Emergency Air Breathing System on DISSUB
EBS	Emergency Breathing System on PRM
ELSS	Emergency Life Support Stores
fsw	Feet of Seawater
fswg	Feet of Seawater, Gauge Pressure
ft3	Cubic Foot
FCO2	Fractional Concentration of Carbon Dioxide
FN2	Fractional Concentration of Nitrogen
FO2	Fractional Concentration of Oxygen
Gen Van	Generator Van
GR	Gas Rack
h	hour
HP	High Pressure
HPU	Hydraulic Power Unit
LARS	Launch and Recovery System
LIO	Lock in/Lock out
LiOH	Lithium Hydroxide
LP	Low Pressure
mbar	millibar
min	minute
MBS 2000	Morgan Breathing System 2000
MT	Medical Tender

MTL	Modified Transfer Lock
N2	Nitrogen
NAVSEA	Naval Sea Systems Command
NDP	Navy Dive Planner
NEDU	Navy Experimental Diving Unit
NMRI 98	Naval Medical Research Institute, 1998 Probabilistic Model
No-D	No-Decompression
O2	Oxygen
ORD	Operational Requirements Document
PBT	Pre-Breathe Tender
PCO2	Inspired Partial Pressure of Carbon Dioxide
PIN2	Inspired Partial Pressure of Nitrogen
PN2	Partial Pressure of Nitrogen
PN2 360	Partial Pressure of Nitrogen in the 360 min half-time compartment
PO2	Inspired Partial Pressure of Oxygen
PFM	Pressurized Flexible Manway
PRM	Pressurized Rescue Module
PRMA	Pressurized Rescue Module Attendant
PRMS	Pressurized Rescue Module System
RECo	Rescue Element Commander
RN2	Rate of Change of Inspired Partial Pressure of Nitrogen
SDC	Submarine Decompression Chamber
SDCTD	SDC Transfer Depth
SDS	Submarine Decompression System
SEV	Surface Equivalent Value
SITS	Ship Interface Template System
SRDRS	Submarine Rescue Diving and Recompression System
SRS	Submarine Rescue System
SRS-TUP	Submarine Rescue System - Transfer Under Pressure Configuration
ST	Non-Ambulatory Rescuee (Stretcher Case)
SurDO2	Surface Decompression Using Oxygen
TAT	Total Ascent Time
TBD	To be Determined
TT	Terminal Tender
TWA	Time-Weighted Average
TUP	Transfer Under Pressure
UMO	Undersea Medical Officer
URC	Undersea Rescue Command
UPTD	Unit Pulmonary Oxygen Toxicity Dose
VO2	Oxygen Consumption Rate
VOO	Vessel of Opportunity
XT	Transfer Tender

Chapter 1 - Introduction

This document describes the methods and procedures available to decompress personnel rescued from a pressurized Distressed Submarine (DISSUB) using the Submarine Rescue System in the full Transfer Under Pressure configuration (SRS-TUP). SRS-TUP system/component descriptions, operational configuration and submarine rescue mission states are presented completely in the Concept of Operations (CONOPS) [1] and will not be repeated here. The discussion focuses on the "Decompress Personnel" Mission State (Mission State 20) identified in the CONOPS.

This document has three purposes:

1. To present the tables available for decompressing rescuees, PRM attendants and SDC tenders including instructions for their use.
2. To establish a Base Case for the rescue of 155 ambulatory rescuees that can be used to support the design review, testing, and certification of the SRS-TUP system. The ability to rescue 155 pressurized submariners with repetitive use of the system is a design requirement imposed by the SRDRS Operational Requirements Document (ORD)[2].
3. To suggest alternate management scenarios when the rescue is complicated by the use of a DISSUB Entry Team (DET), the requirement to remove stretcher cases, or a total number of rescuees that exceeds 155. These complex situations cannot be predicted in advance and a situational assessment of available resources to conduct the rescue will be required. These unusual situations are not considered in the design of the system.

Chapter 2 - System Description and Plan of Employment of Chambers

The principal components of the system are the Pressurized Rescue Module (PRM), the Deck Transfer Lock (DTL) and two Submarine Decompression Chambers (SDC's). These components are joined together by flexible manways which allow rescuees to transfer under pressure from the PRM to the DTL and subsequently to the SDC, where they undergo saturation decompression to the surface. A Modified Transfer Lock (MTL) allows PRM attendants and SDC tenders to enter and exit the SDC.

Figure 2-1 shows the SRS-TUP system mounted on a Vessel of Opportunity (VOO).

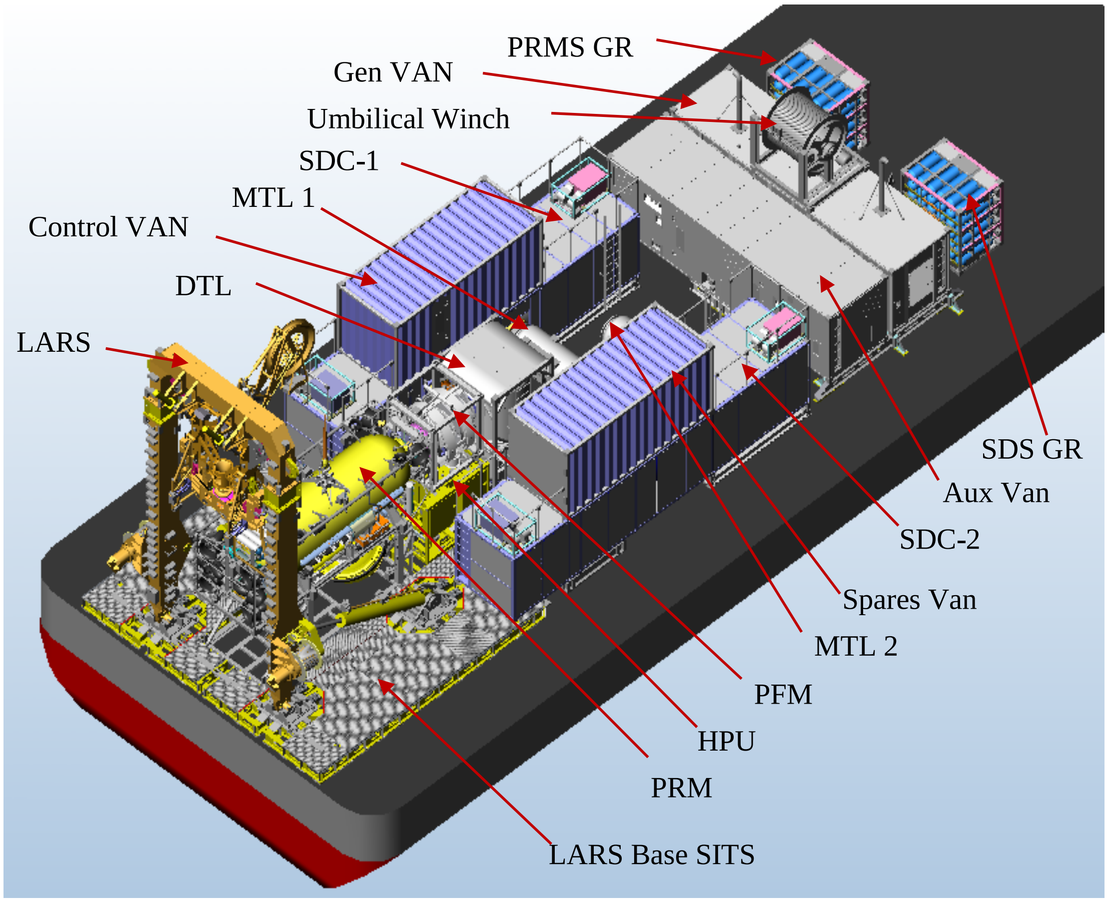

Figure 2-1. On Deck Spread for the SRS-TUP Configuration

2-1 PRM Sortie Timeline

The rescue begins with launch of the PRM and descent to the DISSUB. Once a mate with the DISSUB is achieved, the pressure between the PRM and the DISSUB is equalized and the submarine hatch opened. The rescuees are then transferred from the DISSUB to the PRM. The process is then reversed to demate from the DISSUB. The PRM ascends to the surface, is brought on deck, and mates with the DTL. Once that mate is achieved, the rescuees transfer under pressure from the PRM to the DTL, and then from the DTL to SDC.

Table 2-1 shows the current best estimate of the minimum and maximum times involved in a typical PRM sortie (personal communication from LCDR J. Gamble, URC, to Dr. E. Flynn, NAVSEA 00C, 27 Nov

2012). These estimates come primarily from the INDIAEX (October 2012) exercise which involved unpressurized transfer of subjects on multiple occasions from a bottomed submarine to the deck of the rescue vessel. The sortie times increase with the depth of the DISSUB because the PRM descent and ascent rates are limited to 100 fsw/min.

Table 2-1. Sortie Time as a Function of DISSUB Depth

Phase	Step	300 fsw		1000 fsw		2000 fsw	
		Min	Max	Min	Max	Min	Max
I	Launch PRM	4	4	4	4	4	4
	Descent and Soft Seal Mate	25	30	32	37	42	47
	Soft to Hard Seal Mate	6	7	6	7	6	7
	Open PRM Hatch/Reposition HP Pump Hoses	8	10	8	10	8	10
	Pump down Transfer Skirt	15	15	15	15	15	15
	Rig Transfer Skirt for Transfer	26	33	26	33	26	33
	Total Phase I	84	99	91	106	101	116
II	Pressurize PRM/Equalize with DISSUB	1	5	1	5	1	5
	Drain DISSUB Hatch Cavity	5	10	5	10	5	10
	Open DISSUB Hatch	2	5	2	5	2	5
	Transfer ELSS Stores	10	12	10	12	10	12
	Transfer Rescuees to PRM	25	60	25	60	25	60
	DISSUB Hatch Closed/Flood TS/PRM Liftoff	20	20	20	20	20	20
	Ascend and Recover in Deck Cradle	12	14	19	21	29	31
	Mate to DTL (PRM Decompressed as Needed)*	15	15	15	15	15	15
	Total Phase II	90	141	97	148	107	158
III	Transfer Rescuees to SDC	25	60	25	60	25	60
IV	Clean and Reprovision PRM	60	90	60	90	60	90
	Grand Total (min)	259	390	273	404	293	424
	Grand Total (h)	4.3	6.5	4.6	6.7	4.9	7.1

*Note: At Equivalent Air Depths of 70-132 PRM will be decompressed to the first decompression stop while mating with the DTL

For the purposes of this document, a six hour average sortie time is assumed unless otherwise stated. This stylized sortie is divided into four phases. Phase I includes launch, descent to, and hard mating with the DISSUB and requires 90 min. In Phase I, the PRM remains unpressurized or is pre-pressurized on deck prior to launch depending on the DISSUB internal pressure (see later discussion for specifics). Phase II includes equalization with the DISSUB, transfer of rescuees to the PRM, demating from the DISSUB, ascent to the surface, and mating with the DTL. Phase II requires 150 min (2.5 h) and is always conducted under pressure. Phase III involves the transfer of rescuees from the PRM to the SDC and requires 30 min. This phase is always under pressure. Phase IV is the refurbishment of the PRM for the next sortie and requires 90 min. The PRM is depressurized to allow the deck crew to refurbish the PRM without incurring a decompression obligation. This phase is always unpressurized. The stylized six hour sortie is shown in Table 2-2.

Table 2-2. Stylized Six Hour Sortie Timeline Used in the Analysis

Phase	Event	Time (min)	Total Time (min)	Pressurized (Yes/No)
I	Launch	15	90	Yes or No
	Descend to DISSUB	35		
	Mate and Dewater Skirt	40		
II	Pressurize PRM	3	150	Yes
	Transfer ELSS Stores	12		
	Transfer Rescuees to PRM	60		
	Demate	20		
	Ascend and Recover	40		
	Mate to DTL	15		
III	Transfer Rescuees to SDC	30	30	Yes
IV	Clean and Reprovision PRM	90	90	No
		Total	360 min	
			6.0 hours	

2-2 PRM Capacity

The PRM can transport a maximum of 16 seated rescuees per sortie. In terms of the whole rescue evolution, the most efficient way to transport stretcher cases is one per sortie. This stretcher case is placed on the deck in the aft end of the PRM between the two rows of rescues. The number of seated rescues in the aft end has to be reduced from 8 to 7 because of the limited number of EBS masks.

Stretcher cases can also be placed on the seats. One stretcher case will occupy four seats and will reduce the seated occupancy to 12 (personal communication from LCDR G. Virgilio, URC, to Dr. E. Flynn, NAVSEA 00C, 19 Nov 2012). Two stretcher cases will reduce the seated occupancy to 8. A maximum of three stretcher cases can be accommodated. The third stretcher case is placed on the deck between the other two stretchers. The seated occupancy with 3 stretcher cases aboard is 8.

2-3 SDC Capacity

Each SDC can seat a maximum of 33 occupants. The maximum occupancy is 35; this number is dictated by the number of Emergency Breathing System masks available in the event of an atmosphere casualty. Each set of 4 seats can be converted to two bunks to accommodate stretcher cases or to allow other personnel to lie down. When rescuees and tenders are breathing oxygen, they must be sitting or lying down.

2-4 SDC Operational Modes

The SDC's can be operated in one of three distinct modes: (1) the Single Chamber Mode, (2) the Dual Chamber (No Hold) Mode, or the Dual Chamber (Hold) Mode. The selection of which mode to use will depend on the Equivalent Air Depth (EAD) of the rescuees and the round trip PRM sortie time. The methods for determining rescuee EAD and sortie timelines are discussed in subsequent sections. Each operational mode is described below:

2-4.1 Single Chamber Mode.

This mode is employed when the decompression time required by the rescuees plus the chamber refurbishment time is shorter than the PRM sortie time. This situation typically occurs when the EAD is shallow or when PRM sortie times are long. By the time the next sortie arrives, the chamber is clean, re-pressurized, and ready for use.

There are three distinct advantages of operating in the single chamber mode:

1. Only one chamber is required to keep up with the decompression requirements of the DISSUB rescuees. Thus, the second chamber and MTL can be used to treat personnel who develop decompression sickness after surfacing.
2. A maximum of only 20 personnel are decompressing in the SDC together. Since the maximum-seated capacity of the chamber is 33, there will be more room for the personnel to spread out and permit some of the personnel to lie down. Stretcher cases and DET personnel are more easily accommodated.
3. With 16 ambulatory rescuees being extracted with each PRM sortie, only ten sorties are required to recover the 155 personnel mandated by the ORD. (The 10th sortie only transports 11 rescuees).

2-4.2 Dual Chamber (No Hold) Mode.

This mode is employed when the decompression time required by the rescuees plus the chamber refurbishment time is longer than one sortie time but shorter than two sortie times. Sortie 1 loads rescuees into SDC 1. Sortie 2 loads rescuees into SDC 2. Sortie 3 loads rescuees back into SDC 1, which is now ready to receive them. The rescue operation continues by alternating between chambers as each PRM sortie completes until all DISSUB personnel are recovered.

There are two advantages of operating in the dual chamber (no hold) operational mode:

1. A maximum of only 20 personnel are decompressing in the SDC together. Since the maximum-seated capacity of the chamber is 33, there will be more room for the personnel to spread out and permit some of the personnel to lie down.
2. With 16 ambulatory rescuees being extracted with each PRM sortie, only ten sorties are required to recover the 155 personnel mandated by the ORD.

The one disadvantage is that both chambers are in use simultaneously. Thus, there is no chamber that can specifically be used to treat decompression sickness. However, there may be windows of opportunity when one chamber is on the surface long enough to be available for treatment. (See Section 6 for additional details on the treatment of decompression sickness in rescuees and tenders).

2-4.3 Dual Chamber (Hold) Mode.

This mode must be employed when the decompression time required by the rescuees plus the chamber refurbishment time is longer than TWICE the PRM sortie time. This typically occurs when the EAD is deep or when PRM sortie times are short. Rescuees from the first sortie are held at depth in the chamber while the PRM is launched to recover the second load. When the full complement of 30+ rescuees is in the chamber, decompression commences.

There are two disadvantages of operating in the dual chamber (hold) operational mode:

1. The chamber is filled to its maximum operating capacity and the personnel will be required to sit upright for the entire decompression cycle.
2. Both chambers will be in use simultaneously. There is no opportunity to use one of the chambers for treatment of decompression sickness.

With a 6 hour sortie time, rescues at an EAD of 25 and 30 fsw can be conducted in the Single Chamber mode. Rescues at 35, 40 and 45 fsw can be conducted in the Dual Chamber (No Hold) mode. Rescues deeper than 45 fsw will require the Dual Chamber (Hold) mode.

2-5 Rescue Delay

At equivalent air depths of 60 fsw and deeper, there will be a delay in the rescue between the 4th and 5th sorties and again between the 8th and 9th sorties. These delays will be of the same length. The launches of Sortie 5 and Sortie 9 have to be delayed so that by the time they are ready to mate with the DTL, Chamber 1 will have been emptied, cleaned, and repressurized to the rescue depth. Table 2-3 shows the magnitude of the delay as a function of the sortie time, the equivalent air depth, and the variables that govern the total time Chamber 1 will be unavailable. The rescue delay increases with increasing EAD and decreases with increasing sortie time. At a depth of 132 fsw, the rescue delay time can approach 24 hours.

Table 2-3. Rescue Delay Time as a Function of Sortie Time

DISSUB Depth (fsw)	Input Variables					Rescue Delay Time (h)			
	Transfer Time (min)	MBS 2000 Prep Time (min)	Decompression Time (min)	Chamber Prep Time (min)	Chamber Press Time (min)	4.5 h Sortie	5.0 h Sortie	5.5 h Sortie	6.0 h Sortie
60	30	35	755	60	12	1.37	0.00	0.00	0.00
70	30	30	850	60	10	2.83	1.33	0.00	0.00
80	30	30	955	60	12	4.62	3.12	1.62	0.12
90	0	0	1200	60	13	7.72	6.22	4.72	3.22
100	0	0	1605	60	15	14.50	13.00	11.50	10.00
110	0	0	1800	60	16	17.77	16.27	14.77	13.27
120	0	0	1970	60	17	20.62	19.12	17.62	16.12
132	0	0	2170	60	17	23.95	22.45	20.95	19.45

The CONOPS is specific about prohibiting storage of rescuees in the PRM and DTL on deck while awaiting the availability of an SDC. This is because neither the PRM nor the DTL have an active environmental conditioning package that can control the temperature and humidity of the space. High heat loads may be experienced in these chambers if exposed to direct sunlight in warm climates. Short periods of storage, however, may be required if the launch times of Sorties 5 or 9 are misjudged or the sorties proceed at a pace faster than expected.

2-6 Rescuee Decompression

The procedures for decompressing saturated rescuees are detailed in Section 4. At EADs of 20 fsw or less, no decompression is required [3]. Rescuees can surface directly. At EADs of 25-60 fsw, rescuees breathe oxygen for approximately 2 hours at the transfer depth prior to completing decompression stops to the surface, also on oxygen. The 2-h period breathing oxygen at the transfer depth is referred to as “oxygen pre-breathing”. Its purpose is to remove some nitrogen from the body before lowering the ambient pressure, thus minimizing the potential for bubble formation. At EADs of 70-132 fsw, oxygen pre-breathing is not possible at the transfer depth because of the risk of central nervous system (CNS) toxicity. Rescuees are decompressed to the first decompression stop and then go on oxygen or continue on an air decompression schedule to some subsequent stop where they go on oxygen. In all cases, there is the option of decompressing rescuees solely on air which requires a much longer time. This option can be used when oxygen is unavailable, the rescuees cannot tolerate oxygen, or all rescuees have been recovered and accelerated decompression is not required.

2-7 PRM Attendants and SDC Tenders

For the purposes of this document, PRM attendants and SDC tenders are identified by the role they perform during various phases of the operation. A single individual may perform more than one role.

2-7.1 PRM Attendants (PRMA)

Two PRM attendants are required for each sortie. They require special training in the operation of the PRM. In general, they remain in the PRM during transfer of rescuees, but on occasion may have to enter the DISSUB which may have a different oxygen and carbon dioxide concentration than the PRM. Their decompression requirement is driven by the equivalent air depth of their exposure.

For rescues at an EAD of 25-60 fsw, PRM attendants satisfy their decompression requirement by breathing oxygen at the transfer depth. They then lock out of the chamber. A second set of fresh PRM attendants make the second sortie. They also breathe oxygen at the transfer depth and lock out of the chamber. This management scheme allows PRM attendants to avoid a lengthy, and potentially unhealthy, period of oxygen breathing during the terminal portion of the rescuee decompression. To make this scheme work, all sorties must be launched unpressurized to minimize the PRM attendant’s total time under pressure

For rescues at an EAD of 90-132 fsw, PRM attendants perform back-to-back sorties. At the end of the first sortie, they decompress in the PRM to the first stop in the rescuee schedule then transfer to the SDC along with the rescuees. The PRM/DTL complex is brought to the surface for replenishment of the PRM. When this is complete, the PRM/DTL is repressurized to the depth of the first stop. The PRM attendants re-enter the PRM and launch for the second sortie. After mating with the DISSUB, the PRM is pressurized the remaining distance between the first stop depth and the DISSUB depth. Upon return to the SDC for the second time, the PRM attendants decompress with the rescuees. They will have to join the rescuees in breathing oxygen at some point during the rescuee’s decompression schedule. The total amount of oxygen breathing required will be substantially greater than if the PRM attendants had locked out at the end of each sortie.

For rescues at an EAD of 70-80 fsw, the situation is intermediate. If SRS high pressure gas supplies will permit sorties to go down unpressurized, PRM attendants can lock out after each sortie, particularly at 70 fsw and at 80 fsw if the total exposure can be limited to 2.5 h. Otherwise, back-to-back sorties will be required. (See Appendices K and L for details). Additional support equipment such as a high pressure air compressor could be utilized to increase the amount of stored gas.

2-7.2 Transfer Tenders (XT)

Transfer Tenders are used in certain circumstances to help move rescuees from the PRM to the SDC. Use of Transfer Tenders frees up the PRM attendants to begin oxygen breathing immediately after mating rather than accruing additional time under pressure. Time under pressure for transfer tenders is typically 30 min. This function does not require any special training, so skilled personnel can perform other functions.

2-7.3 Custodial Tenders (CT)

Custodial tenders are required in the Dual Chamber (Hold) mode to attend to the first load of rescuees in the SDC while the PRM is on its way to pick up the second load. Typically, only one custodial tender is required at a time because the maximum number of rescuees is 16.

2-7.4 Pre-breathe Tenders (PBT)

Pre-breathe tenders are required to teach rescuees the use of the MBS 2000 rebreather and help rescuees stay on oxygen during the initial two hours of oxygen pre-breathing. Experience at NEDU has shown that at least one pre-breathe tender is required per 10 rescuees. Plan for one pre-breathe tender if the number of rescuees and DET members in the chamber ranges from 1-11, two pre-breathe tenders if the number ranges from 12-20, and three pre-breathe tenders if the number ranges from 21-30.

For rescues at EADs of 90-132 fsw, pre-breathe tender responsibilities can be performed by the custodial tender and the two PRM attendants before they are required to go on oxygen.

2-7.5 Terminal Tenders (TT)

Terminal tenders lock into the chamber when the pre-breathe tenders begin breathing oxygen to satisfy their decompression obligation. This lockin occurs at a relatively shallow depth and these tenders can ride the remainder of the saturation decompression to the surface on air without incurring a decompression obligation.

2-7.6 Medical Tenders (MT)

Medical tenders may be required to lock into the SDC on an ad hoc basis to attend to specific medical problems with the rescuees. Their pressure exposure and cycling cannot be defined in advance. In the appendices, these tenders are shown by a dotted bar and are labeled “Doctor/Nurse” although an independent duty corpsman or other medical technician may be involved.

2-8 Decompression of PRM attendants and SDC Tenders

There are three options for the decompression for PRM attendants and SDC tenders who will not ride with the rescuees to the end of the decompression.

2-8.1 Standard Air or Air/Oxygen Decompression

The Standard Air or Air/Oxygen decompression schedules contained in Chapter 9 of the U.S. Navy Diving Manual [4] may be used to decompress personnel in the MTL. The disadvantage of this approach is that the MTL may be tied up when other lockin/lockouts are required. This approach is most desirable for personnel who are in a no-decompression status or have a minimal decompression requirement.

2-8.2 Surface Decompression

The Surface Decompression procedure contained in Chapter 9 of the U.S. Navy Diving Manual is an ideal method of removing personnel from the SDCs via the MTL if the VOO is equipped with a recompression chamber that can receive them in the required time. Ascent rate in the MTL should not exceed 60 fsw/min.

2-8.3 Oxygen Breathing at Depth

This will be the principal method of decompressing PRM attendants and SDC tenders. Tenders breathe oxygen at their current depth until enough nitrogen has been removed from their body to allow direct surfacing. Table 4-5 in Section 4 provides details for PRM attendants and SDC tenders at actual or equivalent air depths of 35-60 fsw. Table 4-6 provides the details for equivalent air depths of 70 and 80 fsw. In all cases, the tender is allowed 3 minutes on air to make his way to the MTL and begin decompression to the surface at 30 fsw/min.

Chapter 3 - Special Considerations

3-1 Equivalent Air Depth/Equivalent Air Saturation Depth of Rescuees

The decompression time needed by rescuees, PRM attendants, and SDC tenders is determined by the partial pressure of nitrogen in the gas they breathe and the duration of their exposure. Divers often refer to the latter as "bottom time" and this term is used in the tables in Section 4. When the inspired partial pressure of nitrogen is above normal atmospheric levels, body tissues will absorb excess nitrogen until they come into equilibrium with the new higher partial pressure. Some tissues come into equilibrium quickly, while others equilibrate more slowly. Full equilibration of all body tissues to a new inspired nitrogen partial pressure takes approximately 2-3 days. This is the situation faced by rescuees who can spend up to seven days in the DISSUB awaiting rescue. The rescuees are said to be "saturated" and their decompression is referred to as "saturation decompression". The partial pressure of nitrogen in all of their body tissues is equal to the inspired partial pressure. In contrast, PRM attendants are not fully saturated; some of their body tissues will not be in full equilibrium with the inspired partial pressure of nitrogen at the end of their exposure time. Accordingly, they will require less decompression time than rescuees.

It is customary in decompression work to make decompression tables based on the depth of the exposure rather than on the inspired partial pressure of nitrogen at that depth. This is convenient for divers who are breathing known gas mixtures because it avoids the need to make tedious calculations of partial pressure. However, such calculations cannot be avoided in the DISSUB scenario because the atmosphere in both the DISSUB and the PRM are likely to vary over time.

Because divers are familiar with the term, we use the Equivalent Air Depth (EAD) rather than the inspired partial pressure of nitrogen in the construction of decompression tables in this document. The EAD is simply another way of stating the inspired partial pressure of nitrogen. For the purpose of calculating EAD, air is considered to contain 79% nitrogen, 21% oxygen and 0% carbon dioxide. Gas mixtures in which the sum of the oxygen and carbon dioxide content is less than 21% will have an EAD that is greater than the actual depth of the exposure. Gas mixtures in which the sum of the oxygen and carbon dioxide content is greater than 21% will have an EAD which is less than the actual depth of the exposure.

The inspired partial pressure of nitrogen during an air dive can be computed as:

$$PN2\ air = (Dair + 33) * 0.79 \tag{1}$$

The inspired partial pressure of nitrogen in the DISSUB can be computed as:

$$PN2\ sub = (Dsub + 33) * (1 - FO2 - FCO2) \tag{2}$$

If we equate *PN2 air* and *PN2 sub* and solve for *Dair*:

$$Dair = \frac{(Dsub + 33) * (1 - FO2 - FCO2)}{0.79} - 33 \tag{3}$$

where:

Dair = depth on air in fsw (the Equivalent Air Depth)

Dsub = internal pressure in the DISSUB in fsw

FO2 = fractional concentration of oxygen in the DISSUB (%O2/100)

FCO2 = fractional concentration of carbon dioxide in the DISSUB (%CO2/100)

0.79 = fractional concentration of nitrogen in air

33 = the number of feet of seawater in one atmosphere

The Analox Sub MK II P analyzer carried by the DISSUB displays the oxygen and carbon dioxide levels in the DISSUB percent surface equivalent (%SEV). This is not the actual percentage of oxygen and carbon dioxide in the boat, but rather an alternative way of expressing of the partial pressure of the two gases. %SEV/100 gives the partial pressure of the gas in atmospheres while (%SEV/100)*33 gives the partial pressure in fsw. When % SEV is used to measure oxygen and carbon dioxide levels, the equation above for EAD can be rearranged as follows:

$$EAD = \frac{(Dsub + 33) - \left(\frac{\%O2sev + \%CO2sev}{100}\right) * 33}{0.79} - 33 \tag{4}$$

If the pressure and gas composition in the DISSUB has not remained relatively constant during the two days prior to rescue, the slower body tissues of the rescuees may not be in equilibrium with the inspired nitrogen partial pressure. If the internal pressure of the DISSUB is rising or falling during this period, the partial pressure of nitrogen in the slow body tissues which control the saturation decompression requirement may lag behind the inspired partial pressure. When the DISSUB pressure is increasing, the partial pressure of nitrogen in the slow tissues may be lower than the inspired partial pressure. When the pressure is decreasing, the partial pressure of nitrogen in the slow tissues may be higher than the inspired partial pressure. Thus, the calculated EAD may not be representative of the true saturation status of the body in these transient situations. When the DISSUB internal pressure and/or atmosphere are not stable in the two days prior to rescue, the Equivalent Air Saturation Depth (EASD) should be determined. Appendix B explains what the EASD is and how to compute it from the DISSUB atmospheric logs. If the computed EASD is different than the computed EAD, the rescuee decompression tables should be entered using the EASD rather than the EAD.

3-2 Equivalent Air Depth of PRM Attendants

The atmospheric monitoring unit in the PRM reads the oxygen level in actual percent and the carbon dioxide level in millibars (mbar). The EAD formula for PRM attendants has to be modified accordingly:

$$EAD = \frac{\big((Dprm + 33) * (1 - FO2)\big) - \frac{mbar * 33}{1013}}{0.79} - 33 \tag{5}$$

The oxygen level in the PRM is normally controlled between 18 and 21%. The CO2 level is controlled below 10 millibars. However, there may be instances where the DISSUB oxygen percentage is well below 18% and the carbon dioxide partial pressure is well above 10 millibar. This DISSUB atmosphere will mix with the PRM atmosphere as resuees are transferred to the PRM. In addition it may be necessary for PRM attendants to spend some time in the DISSUB during which they will be exposed to the full DISSUB conditions. To calculate the PRM attendant's EAD, calculate the EAD for each significant pressure and/or atmospheric composition change during the sortie, then select to highest EAD for use in entering the tables.

Note: Oxygen percentages in the PRM below 20% can have a significant impact on the calculated EAD. The magnitude of this effect depends both on the oxygen percentage and on the depth of the PRM. For example, at a PRM depth of 165 fsw and an oxygen percentage of 18%, the EAD in the PRM will be 7 fsw higher than the actual depth. At a depth of 60 fsw and an oxygen percentage of 18%, on the other hand, the EAD will be only 3 fsw higher than the actual depth.

Example:

The PRM mates to the DISSUB at an internal pressure (depth) of 48 fsw. The atmospheric composition in the PRM is 18% oxygen and 5 mbar carbon dioxide. The atmosphere in the DISSUB is 21% SEV oxygen and 1.4% SEV carbon dioxide. The PRM attendants enter the DISSUB for a short period of time after mating, then return to the PRM to receive the rescuees. During subsequent ascent to the surface, the PRM warms up due to the heat generated by the occupants and CO2 scubbers and the higher water temperature near the surface. The pressure in the PRM increases accordingly from 48 to 51 fsw, but the atmospheric composition remains the same at 18% oxygen, 5 mbar carbon dioxide.

The EAD in the PRM after mating can be computed from the equation immediately above. With 18% oxygen and 5 mbar carbon dioxide, the computed EAD is 50.9 fsw. During the DISSUB entry phase, the EAD of the PRM attendants is the same as that of the DISSUB and can be computed using the DISSUB EAD equation (Equation 4). For 21% SEV oxygen and 1.4% SEV carbon dioxide, the EAD is 60.2 fsw, 9.3 fsw higher than in the PRM. Upon arrival at the surface, the EAD in the PRM is 54.0 fsw. This is 3.1 fsw higher than the EAD in the PRM on the bottom and is due to the increased pressure in the PRM at the end of ascent. For this sortie, 60.2 fsw is the deepest EAD obtained during the sortie and should be used to select the PRM attendant's decompression table.

3-3 Pulmonary Oxygen Toxicity

Pulmonary oxygen toxicity will be an increasing problem for rescues at DISSUB internal pressures greater than 50 fsw. Numerous studies have indicated the threshold for the onset of pulmonary oxygen toxicity occurs at an oxygen partial pressure of 0.5 atmospheres. Above this threshold the incidence and severity of toxicity will vary with the PO2 and the exposure time.

Two methods are available to assess the risk of pulmonary oxygen toxicity: the Lambertsen method and the Harabin method [5,6]. The Harabin method is used in this analysis.

The Harabin risk equation is given by:

$$\Delta VC(\%) = -0.011 * (PO2 - 0.5) * t \tag{6}$$

where:

ΔVC(%) = Percent decrease in vital capacity of the lungs, a measure of lung damage

PO2 = Oxygen partial pressure in the DISSUB in atmospheres

t = Exposure time in min

The oxygen partial pressure in the DISSUB in atmospheres is given by:

$$PO2 = \left(\frac{Dsub + 33}{33}\right) * FO2 \qquad (7)$$

Where:

Dsub = DISSUB internal pressure in fsw

FO2 = fractional concentration of oxygen in the DISSUB (%O2/100)

A well know reference point is an exposure to air (FO2 = 0.21) at 5 ata (132 fsw) for 12 hours (720 min). Nearly all individuals will begin to experience symptoms or signs of pulmonary oxygen toxicity during this exposure [7]. The predicted decrement in vital capacity may be computed as follows:

$$\Delta VC(\%) = -0.011 * (1.05 - 0.5) * 720 = 4.36\% \qquad (8)$$

The Harabin equation may be used to compute the time at a given PO2 (t) that will produce the same amount of lung damage as an exposure to reference PO2 (t ref). Write the equations for ΔVC(%) in both conditions and set them equal:

$$0.011 * (PO2 - 0.5) * t = -0.011 * (PO2\,ref - 0.5) * t\,ref \qquad (9)$$

Rearranging and solving for t:

$$t = \frac{(PO2\,ref - 0.5) * t\,ref}{PO2 - 0.5} \qquad (10)$$

For example, if a PO2 of 1.05 atm for 720 min is the reference condition that should not be exceeded, what is the allowable exposure time at a PO2 of 0.8 atm?

$$t = \frac{(1.05 - 0.5) * 720}{0.8 - 0.5} = 1320 \text{ min} \qquad (11)$$

The Harabin equation can be used to calculate the Unit Pulmonary Oxygen Toxicity Dose (UPTD), a common measure of the pulmonary risk associated with an oxygen decompression schedule. The UPTD is defined as an exposure to 1.0 atm oxygen for one minute. Substitute 1.0 atm for PO2 ref and UPTD for t ref in the above equations and rearrange:

$$UPTD = \frac{PO2 - 0.5}{1.0 - 0.5} * t \qquad (12)$$

For example, the UPTD of a 720 min exposure to a PO2 of 1.05 atm is:

$$UPTD = \frac{1.05 - 0.5}{1.0 - 0.5} * 720 = 792\,units \qquad (13)$$

To evaluate a decompression schedule, compute the UPTD for each PO2/time segment, then add these doses over the total decompression. The resultant total is usually referred to as the Cumulative Pulmonary Toxicity Dose (CPTD).

Almost all of the rescuee decompression schedules in Section 4 have CPTD's well above 750 units, indicating that there is significant risk to the rescuees. This is unavoidable if decompression is to be accelerated to optimize the chances that all survivors will be rescued from the DISSUB. Experience has shown that if air breaks are inserted into the oxygen schedule, CPTD's up to 1500 units are generally tolerable, albeit with symptoms. The highest dose in all the rescue schedules is 1887 units (132 fsw schedule).

The decompression schedules for PRM attendants and SDC tenders are designed to avoid pulmonary oxygen toxicity to the greatest extent possible. This allows these tenders to be used on a repetitive basis. Tenders are removed from the SDC by a relatively short period of oxygen breathing at depth. Once an internal pressure of 90 fsw is reached, however, this scheme is no longer possible. Both PRM attendants (who perform back-to-back sorties) and custodial tenders have to breathe oxygen for prolonged periods during decompression. They cannot be used in a repetitive status.

Because of the risk of pulmonary toxicity in the DISSUB, it is imperative that rescuees attempt to breathe down the PO2 in the boat. This breathe down procedure is addressed directly in the Guard Books [8]. Survivors should aim for an oxygen level in the DISSUB of no more than 18% SEV.

Breathe down of oxygen in the DISSUB will be a slow process because of the large compartment volumes relative to the number of survivors. The breathe-down rate can be computed as follows:

$$Rate\ \left(\frac{atm}{h}\right) = \frac{VO2 * No.Survivors}{Vsub} \tag{14}$$

where:

VO2 = Oxygen consumption rate per survivor in cubic feet/hour (ambient temperature)

Vsub = volume of the compartment in which the survivors reside in cubic feet

For example, for 155 rescuees in a compartment of 50,000 cubic feet, consuming oxygen at a rate of 1 cubic foot (70F) per hour:

$$Rate = \frac{1 * 155}{50000} = 0.0031\ atm/h \tag{15}$$

For a 7 day (168h breathe down period), the total reduction in PO2 would be:

$$Reduction\ in\ PO2 = 0.0031 * 168 = 0.52\ atm \tag{16}$$

Thus, a significant reduction in PO2 is possible during the period awaiting rescue, provided oxygen is not added during this period.

If the oxygen in the DISSUB is breathed down and the carbon dioxide produced by the crew in the process is absorbed by the LiOH curtains or other methods, the internal pressure in the DISSUB will decrease. The DISSUB internal pressure after the breathe down can be computed using the following equation:

$$Final\ DISSUB\ Depth = Original\ Depth - (PO2\ start - PO2\ end) * 33 \tag{17}$$

Table 3-1 shows the relationship between the original and final depth for a range of original depths and final PO2's. The final depth may be significantly less than the original depth. This particularly affects the pre-breathe tenders who may perform their function at depth significantly lower than the EAD of the resucees. Their decompression obligation is accordingly reduced. Pre-breathe tender decompression schedules are given in each appendix as a function of the pre-breathe depth to take advantage of this situation.

Table 3-1. Decrease in DISSUB Pressure and Oxygen Fraction during Breathe Down of DISSUB Oxygen Levels

Initial Condition			Final Depth and Oxygen Percentage							
Depth	Oxygen	PO2	PO2 = 0.5 atm		PO2 = 0.4 atm		PO2 = 0.3 atm		PO2 = 0.2 atm	
(fsw)	(%)	(atm)	Depth	% O2	Depth	% O2	Depth	% O2	Depth	% O2
132	20.5	1.03	114.7	11.2	111.4	9.1	108.1	7.0	104.8	4.8
120	20.5	0.95	105.1	11.9	101.8	9.8	98.5	7.5	95.2	5.1
110	20.5	0.89	97.2	12.7	93.9	10.4	90.6	8.0	87.3	5.5
100	20.5	0.83	89.2	13.5	85.9	11.1	82.6	8.6	79.3	5.9
90	20.5	0.76	81.3	14.4	78.0	11.9	74.7	9.2	71.4	6.3
80	20.5	0.70	73.3	15.5	70.0	12.8	66.7	9.9	63.4	6.8
70	20.5	0.64	65.4	16.8	62.1	13.9	58.8	10.8	55.5	7.5
60	20.5	0.58	57.4	18.2	54.1	15.1	50.8	11.8	47.5	8.2

Note 1: Assumes DISSUB CO2 content is constant at 0.5% during the breathe down period

It is important to note that during breathe down of DISSUB oxygen levels if the DISSUB temperature remains constant, the partial pressure of nitrogen in the DISSUB will not change. No nitrogen is added to or subtracted from the DISSUB atmosphere and this nitrogen is distributed in the same DISSUB volume. Thus, the equivalent air depth of the rescuees remains constant during the breathe down. The internal DISSUB pressure will fall to the extent that the oxygen consumed from the atmosphere is not replaced by an equivalent amount of carbon dioxide. The same statement can be made about adding oxygen to the DISSUB from high pressure stores or from candles. Addition of oxygen will increase the internal pressure of the DISSUB but will not change the partial pressure of nitrogen or the equivalent air depth of the rescuees.

3-4 DISSUB Entry Team (DET)

The DISSUB Entry Team describes the individual or group of individuals who may be required to transfer from the rescue vehicle to the DISSUB for the purpose of providing direct assistance to the DISSUB rescuees. As each DISSUB scenario is unique, so, too, will be the composition and even the necessity for having a DET. The composition and disposition of the DET will be determined by the Rescue Element Commander (RECo). Some potential functions of the DET could include medical assistance, atmospheric monitoring and replenishment assistance, and communication assistance. Care must be taken to balance the risk of placing rescue force personnel in a potentially harmful environment on the DISSUB against the potential benefits of rendering assistance to the rescuees. Additionally, considerations for decompression obligations, gas utilization, and sortie management must be factored when deploying individuals to the DISSUB. For all of these reasons, the decision to implement a DET has potential serious consequences and should not be made indiscriminately.

At the present time, it is assumed that two DET members will be present in the DISSUB throughout the rescue to the greatest extent possible. One DET member will have medical qualifications; the other will be an engineer who can assist with mating the PRM and transferring rescuees.

If a DET is deployed to the DISSUB, particular attention must be paid to the risk of pulmonary oxygen toxicity. For a DISSUB pressurized with air, DET stay time should not exceed approximately 72 hours at 60 fsw, 23 hours at 90 fsw, or 12 hours at 132 fsw. Shallower than 60 fsw, DET stay time is unlimited.

Table 3-2 shows the maximum stay time as a function of the DISSUB depth when the atmosphere in the DISSUB is air. These times are based on a 720 min exposure to air at 132 fsw being acceptable. They are calculated using the equations given in Section 3-3 above. In reality, the DET stay time in the DISSUB will be a function of the PO2 in the DISSUB at the time of the exposure rather than the depth. The PO2 may be considerably lower than the corresponding air values if breathe down efforts have been successful. The stay time for PO2's other than air can be computed using the equations in Section 3-3 above. Table 3-3 shows the maximum stay time as a function of constant PO2. In all situations, employment of the DET will be favored by breathe down of the oxygen in the DISSUB atmosphere.

Table 3-2. Maximum Stay Time in DISSUB To Limit Pulmonary Oxygen Toxicity in DISSUB Entry Team as a Function of Depth Assuming an Air Atmosphere

Depth (fsw)	PO_2 (atm)	Maximum Stay Time	
		Minutes	Hours
132	1.05	720	12.0
120	0.97	836	13.9
110	0.91	966	16.1
100	0.85	1143	19.1
90	0.78	1401	23.3
80	0.72	1807	30.1
70	0.66	2547	42.5
60	0.59	4313	71.9

Table 3-3. Maximum Stay Time in DISSUB for DISSUB Entry Team as a Function of PO2

PO2 (atm)	Maximum Stay Time	
	Minutes	Hours
0.50	Unlimited	Unlimited
0.55	7920	132.0
0.60	3960	66.0
0.65	2640	44.0
0.70	1980	33.0
0.75	1584	26.4
0.80	1320	22.0
0.85	1131	18.9
0.90	990	16.5
0.95	880	14.7
1.00	792	13.2

Maximum stay times will determine how DET members are rotated in and out of the DISSUB. A second factor is the rescue delay. Deeper than 110 fsw it will not be possible to provide coverage inside the DISSUB during the delay unless the crew has been successful in breathing down the PO2. At 132 fsw, it will also not be possible to provide coverage inside the DISSUB between the 2nd and 3rd sorties, the 6th and 7th sorties, the 10th and 11th sorties.

3-5 Central Nervous System (CNS) Oxygen Toxicity in PRM Attendants and SDC Tenders

In general, pulmonary oxygen toxicity will not be a problem for PRM attendants performing single sorties or SDC tenders locking in and out of the SDC's. However, CNS oxygen toxicity may pose a risk for these individuals if they satisfy their decompression requirement by breathing oxygen at depths of 45 fsw and deeper prior to lock out.

The Harabin CNS oxygen toxicity risk model [9] may be used to judge the safe stay time on oxygen as a function of the inspired PO2. This model was derived from an analysis of wet working divers breathing oxygen, but it can be used to make predictions about dry, resting divers such as PRM attendants and SDC tenders provided the model is referenced to a condition where the safe exposure time for a dry, resting diver is reasonably well known.

The probability of a CNS oxygen toxicity "hit" is a function of the both the inspired PO2 and the exposure time:

$$P_{CNS} = 1 - e^{-0.00133*(PO2-thr)^{3.4}*t} \tag{18}$$

Where: P_{CNS} = Probability of a CNS event

PO2 = Inspired partial pressure of oxygen (atm)

thr = Threshold for onset of CNS toxicity (assumed by the model to be 1 atm)

t = Exposure time (min)

e = the base of the natural logarithm, a number approximately equal to 2.718

We can compute the exposure time at a given PO2 that will produce the same probability of a hit as an exposure to the reference condition (reference PO2 and exposure time) by first setting the P_{CNS} under the condition of interest equal to the P_{CNS} under the reference condition and then solving for t. Most of the complexity of original equation disappears. The result is:

$$t = \frac{(PO2\, ref - 1)^{3.4} * t\, ref}{(PO2 - 1)^{3.4}} \tag{19}$$

Where: PO2 ref = Inspired PO2 at the reference condition (atm)

t ref = Safe exposure time at the reference condition (min)

PO2 = Inspired PO2 of interest (atm)

t = Safe time at the PO2 of interest (min)

It is not unusual to extend treatment time at 60 fsw on a Treatment Table 6 by two 20 min oxygen periods, resulting in a total oxygen exposure time of 100 minutes. This procedure has proven reasonably safe. In a study of naïve divers breathing oxygen at 60 fsw for 30 minutes during an oxygen tolerance test, Walters et al. [10] observed 6 episodes of CNS oxygen toxicity in 6,250 exposures giving an incidence of 0.096%. Since the Harabin risk equation is linear in time, the expectation is that a 100 min exposure to oxygen at 60 fsw would result in an incidence approximately 3.3 times this value (100/30) or 0.32% (3.2 cases per 1000 exposures).

In the DISSUB scenario, PRM attendants and SDC tenders will breathe oxygen in 30 min periods separated by 5 min air breaks. The MBS 2000 system is set to provide a minimum of 90% oxygen dry gas fraction. This is about the same oxygen concentration seen with a typical open-circuit mask such as those used for treatments. A reasonable reference condition, therefore, would be three 30 min oxygen periods separated by 5 min air breaks for a total of 90 min on oxygen at 60 fsw. The estimated risk for this condition is approximately 0.29% (2.9 cases per 1000 exposures).

If a 90 min exposure to 90% oxygen at 60 fsw is deemed safe, we can use the equation immediately above to compute safe exposure times to 90% oxygen at 45, 50, and 55 fsw as shown in Table 3-4.

Table 3-4. Safe Exposure Times to 90% Oxygen as a Function of Depth

Depth (fsw)	Safe CNS Time (min)	
	Calculated	Rounded
60	90.0	90
55	123.4	120
50	174.9	180
45	257.9	240

The limits in Table 3-4 were used as a guide in the construction of Tables 4-5 and 4-6 for PRM Attendants and SDC Tenders. They can also be used when building custom tables using the Dive Planner. These values should be considered guidelines only; the on-scene diving medical officer can modify these times as he sees fit.

An intermittency scheme of 30 min on oxygen and 5 min on air has been adopted for PRM attendants and SDC tenders independent of the depth. However, the scheme can be modified if lengthening the 30 min time would avoid the need for an additional oxygen period. Either the first or the last oxygen breathing period can be modified as follows:

60 fsw Lengthen time by 5 min, from 30 to 35 min
55 fsw Lengthen time by 10 min, from 30 to 40 min
50 fsw Lengthen time by 15 min, from 30 to 45 min
45 fsw Lengthen time by 30 min, from 30 to 60 min

Not all oxygen breathing by PRM attendants and SDC tenders will take place at a constant depth. In some cases oxygen breathing will start at one depth then continue at shallower depths as the attendants/tenders decompress along with the rescuees. In this case, the safety of the proposed procedure can be determined by computing the "oxygen clock". The exposure time at each depth is divided by the safe exposure time at that depth to obtain the fraction of the total exposure allowed. These fractions are then added up across the depths at which oxygen breathing takes place. If summed fraction is 1.0 or less, the exposure is considered safe. It is not necessary to compute fractions for depths shallow to 45 fsw. These depths are considered free of any CNS risk.

Example: An attendant breathes 90% oxygen for 10 min at 60 fsw, 45 min at 55 fsw, 50 min at 50 fsw and 55 min at 45 fsw. The safe times at 60, 55, 50 and 45 fsw are 90, 120, 180, and 240 min respectively. The computed fractions of the oxygen clock are:

$$
\begin{aligned}
10/90 &= 0.111 \\
45/120 &= 0.375 \\
50/180 &= 0.278 \\
55/240 &= \underline{0.229} \\
\text{Total:}\ & 0.993
\end{aligned}
$$

The oxygen clock is less than 1.0. This exposure is considered safe. Note: The oxygen clock provides guidance only. The on-scene diving medical officer may elect to proceed with a given oxygen exposure even though the computed oxygen clock exceeds 1.0.

3-6 PRM Pre-Pressurization for First Sortie

The first sortie may take longer to mate successfully with the DISSUB due to unfamiliarity with the external condition of the DISSUB and its surroundings. To avoid needless decompression obligation for the PRM Attendants during a prolonged initial mating, pre-pressurization of the first sortie should be avoided when possible. Any pressurization of the PRM required during mating is provided by PRM onboard HP air. However that air supply is limited and at DISSUB internal pressures deeper than 90 fsw, the PRM must be partially pre-pressurized on the surface. Table 3-5 provides the minimum PRM pre-pressurization required for a given DISSUB internal pressure.

Table 3-5. PRM Pre-Pressurization Pressure Required as a Function of DISSUB Internal Pressure

DISSUB Internal Pressure (fsw)	PRM Pre-Pressurization Pressure (fsw)
0-90	No pre-pressurization.
100	5
110	25
120	45
132	65

Chapter 4 - Decompression Tables and Instructions

4-1 Rescuee Decompression Schedules

4-1.1 Primary SRS Air/Oxygen Saturation Decompression Schedules - 20-60 fsw

Table 4-1 contains the primary air/oxygen saturation decompression schedules for rescue at internal DISSUB pressures ranging from 20-60 fsw.[11] These tables feature a period of oxygen pre-breathing at depth to remove some of the dissolved nitrogen from the body prior to actually reducing the ambient pressure. This greatly reduces the potential for bubble formation upon the pull to the first decompression stop. The table shows the required oxygen time in minutes at DISSUB depth and at each decompression stop. These oxygen stop times do not include air breaks (discussed below) which may increase the total time required by as much as 25%. All schedules assume that the rescuee breathes at 90% (dry gas fraction) oxygen at the oxygen stops.

Table 4-1 Primary SRS Air/Oxygen Saturation Decompression Schedules - 20-60 fsw

Oxygen Breathing Times at Depth (min)

EAD (fsw)	O_2 Time at Depth (O_2 Pre-breathe) (min)	Decompression Stop Depth (fsw)						Total O_2 Time (min)
		45	40	35	30	25	20	
20	0							0
25	70							70
30	140							140
35	120					40	40	200
40	120				10	85	40	255
45	120			20	105	115	50	410
50	120			85	105	115	50	475
55	120		55	95	105	115	50	540
60	120	30	85	95	105	115	50	600

Note 1: Oxygen breathing times are given in minutes.
Note 2: If air breaks are used, the time for each decompression stop may increase (see below)
Note 3: The time required to purge the closed-circuit breathing loop of nitrogen is included in the pre-breathing and decompression stop times and does not need to be accounted for separately.

To use Table 4-1, follow these steps:

1. First calculate the rescuee's Equivalent Air Depth (EAD). This calculation is necessary because the pressurized atmosphere of the DISSUB will likely have different partial pressures of oxygen, nitrogen, and carbon dioxide than standard air. Decompression requirements are determined by the partial pressure of nitrogen in the tissues, and the use of the EAD is a convenient method of expressing the partial pressure of nitrogen in the pressurized atmosphere. The EAD may be calculated from the following formula:

$$EAD = \frac{(Dsub + 33) - \left(\frac{\%O2sev + \%CO2sev}{100}\right) * 33}{0.79} - 33 \tag{20}$$

where: EAD = Equivalent Air Depth in fsw

D_{sub} = DISSUB internal pressure or depth in fsw

%O2 sev = Partial pressure of oxygen expressed in % surface equivalent

%CO2 sev = Partial of carbon dioxide expressed in % surface equivalent

Note 1: The Analox Sub MK II P analyzer carried by the DISSUB displays the concentration of oxygen and carbon dioxide in the DISSUB atmosphere in units of percent surface equivalent (%SEV). This is not the actual percentage of oxygen and carbon dioxide present in the boat, but rather a measurement of the partial pressure of the two gases. %SEV/100 gives the partial pressure in atmospheres; (%SEV/100)*33 gives the partial pressure in fsw.

Note 2: If the pressure and gas composition in the DISSUB has not remained relatively constant during the two days prior to rescue, see Appendix B for more details on how to compute the EAD.

Note 3: If the DISSUB survivors consume oxygen without replacement, the actual pressure in the DISSUB will be significantly less than the calculated equivalent air depth.

2. Enter Table 4-1 at the depth which is exactly equal or next greater than the calculated EAD. Begin the procedure by placing the rescuees on the closed-circuit oxygen breathing system. Breathe oxygen for the time indicated in the second column, "O_2 Time at Depth." Time is given in minutes. This oxygen period is termed "pre-breathing" because it takes place before decompression begins.
3. When the pre-breathing period is complete, resume air breathing and decompress at 1-5 fsw/min (1 fsw/min preferred) to the first decompression stop indicated in the table.
4. Breathe oxygen at each decompression stop for the time indicated in the table. Oxygen breathing times are given in minutes.
5. Ascend between decompression stops at 1-5 fsw/min (1 fsw/min preferred). Ascent time on oxygen between stops is included in the subsequent stop time.
6. Upon completion of the last oxygen breathing period, remove the oxygen mask and decompress to atmospheric pressure at 1-5 fsw/min (1 fsw/min preferred).
7. Periodic interruption of 100% oxygen breathing during pre-breathing and decompression is highly desirable to reduce the injurious effects of oxygen on the central nervous system and lung. Interruption of oxygen breathing may also be necessary to change CO2 canisters in the closed-circuit breathing loop. Unexpected interruption of oxygen breathing may also occur because of rescuee illness or injury.

   When at a pressure greater than 45 fsw (actual pressure, not EAD), interrupt oxygen breathing every 30 minutes with at least five minutes on air to minimize the risk of central nervous system oxygen toxicity. (In this section, the term "air" refers to any approximately normoxic breathing mixture, or ambient chamber atmosphere).

   When 45 fsw and shallower, interrupt oxygen breathing every 60 minutes with 15 minutes on air. This pattern of 60 minutes on oxygen, 15 minutes on air is optimal for minimizing lung injury.

   Once oxygen breathing is begun, consider any time spent on air to be "dead time," that is, not to count toward meeting the oxygen decompression requirement. Lengthen the time at each stop, and the total decompression time, correspondingly so that all the required time on oxygen during pre-breathing and at each stop is completed.

8. There is no contraindication to ascending between decompression stops while on air. Ascent time, however, should not be included in the subsequent stop time since the rescuee is not on oxygen.

Detailed decompression schedules including all recommended air breaks are contained in Appendices C-J.

4-1.2 Secondary SRS Air/Oxygen Saturation Decompression Schedules 45 - 60 fsw.

Table 4-2 contains the secondary air/oxygen saturation decompression schedules for rescue at internal DISSUB pressures ranging from 45-60 fsw. These secondary schedules may be used when oxygen pre-breathing at depth on the primary schedules provokes symptoms of central nervous system toxicity or when the Diving Medical Officer decides in advance that a reduced total dosage of oxygen is desirable. All schedules assume that the rescuee breathes at least 90% oxygen. The risk of decompression sickness may be somewhat higher on these schedules than on the primary schedules because of the reduced or absent oxygen pre-breathing period at depth. No secondary schedules are given for depths of 25-40 fsw as the likelihood of CNS oxygen toxicity during oxygen pre-breathing at those depths is minimal.

Table 4-2. Secondary SRS Air/Oxygen Saturation Decompression Schedules 45 - 60 fsw.

		Decompression Stop Time (min)																	
Equivalent Air Depth		**85**	**80**	**75**	**70**	**65**	**60**	**55**	**50**	**45**	**40**	**35**	**30**	**25**	**20**	**15**	**10**	**5**	**Total Stop Time (hrs)**
45 fsw	**Air**												125	240	260	290	325	90	22.2
	Oxygen												**35**	**75**	**80**	**90**	**130**		6.8
50 fsw	**Air**											75	215	240	260	295	325	100	25.2
	Oxygen											**25**	**65**	**75**	**80**	**95**	**135**		7.9
55 fsw	**Air**										35	195	215	240	260	290	320	120	27.9
	Oxygen										**10**	**60**	**70**	**75**	**80**	**95**	**140**		8.8
60 fsw	**Air**									5	170	200	215	240	260	290	325	120	30.4
	Oxygen									**5**	**55**	**65**	**70**	**75**	**85**	**95**	**145**		9.9

To use Table 4-2, follow these steps:

1. First calculate the rescuee's Equivalent Air Depth (EAD) as outlined above for Table 4-1.

   Note: If the DISSUB survivors consume oxygen without replacement, the actual pressure in the DISSUB may be significantly less than the calculated equivalent air depth.

2. Enter Table 4-2 at the depth that is exactly equal to or next greater than the calculated EAD.
3. If aborting to the secondary table due the oxygen toxicity symptoms during pre-breathing on the primary table, decompress on air to the first stop at 1 fsw/min after all symptoms at depth have resolved. Wait a total of 15 min (including ascent time to the first stop) before resuming oxygen breathing at the first stop. Take credit for any time spent on oxygen during pre-breathing by subtracting this time from the oxygen time at the end of the last oxygen stop.
4. If substituting the secondary table for the primary in advance to avoid oxygen pre-breathing at depth, decompress on air to the first stop at 5 fsw/min. This first stop may be only a few feet shallower than the actual DISSUB depth. Ascent time to the first stop is not included in the first stop time. Upon arrival at the first stop, insert a 35 min period on air into the stop to allow pre-breathe tenders to lock into the chamber and instruct the rescuees in the use of the MBS-2000 rebreather. Then begin oxygen breathing according to the schedule.
5. Complete the decompression time listed for the first stop and subsequent stops. The rate of ascent between stops may vary from 1-5 fsw/min (1 fsw/min preferred). Ascent time between stops on oxygen is included in the subsequent stop time.

6. Upon completion of the last stop, ascend to the surface on air at 1-5 fsw/min (1 fsw/min preferred).
7. Two schedules are given at each depth. The upper schedule labeled “Air” is the air saturation schedule. The lower schedule labeled “Oxygen” is the oxygen-accelerated schedule. Oxygen-breathing times are shown in bold print. The rescuee may be switched to oxygen upon arrival at the first stop, or the switch to oxygen may be delayed until a shallower stop is reached. This allows the dose of oxygen to be reduced in those cases where the rescuee is suffering from significant pulmonary oxygen toxicity.

   Example: For the 60 fsw schedule, the rescuee normally begins breathing oxygen at the 45 fsw first stop. However, the Diving Medical Officer may elect to delay the shift to oxygen to a shallower stop, say 20 fsw, to allow time for recovery from pulmonary oxygen toxicity. In this case, the rescuee would continue on the air schedule through 25 fsw then shift to oxygen upon arrival at the 20 fsw stop.

8. Upon completion of a stop, the rescuee may shift from oxygen back to air and complete decompression on air if conditions warrant. This situation might arise if oxygen supplies are exhausted.
9. The rescuee may also shift back and forth between air and oxygen during the course of a single stop. The air to oxygen trading ratio is determined by dividing the air time by the oxygen time at the stop. This trading ratio is generally close to three, i.e., three minutes on air is equivalent to one minute on oxygen. The trading ratio is used to partition the stop time between air and oxygen. (Note: For partitioning at the 10 fsw oxygen stop, the air stop time at 10 and 5 fsw should be added prior to calculating the trading ratio.)

   Example: The air stop time at 40 fsw on the 60 fsw schedule is 170 min. The oxygen stop time is 55 min. The trading ratio is 170/55 = 3.1. Conditions dictate that the rescuees take an hour air break to eat, drink, and urinate. The 60 min spent on air is equivalent to 19 min spent on oxygen. The oxygen time at this stop can be reduced to from 60 to 41 min (60-19). The adjusted 40-fsw stop time is 101 min—60 min on air and 41 min on oxygen.

10. Periodic interruption of 100% oxygen breathing is highly desirable to reduce the injurious effects of oxygen on the central nervous system and lung. Interruption of oxygen breathing may also be necessary to change CO2 canisters in the closed-circuit breathing loop. Unexpected interruption of oxygen breathing may also occur because of rescuee illness or injury.

    When the rescuee is deeper than 45 fsw, interrupt oxygen breathing every 30 min with 5 min of air to minimize the risk of central nervous system oxygen toxicity. When the rescuee is at 45 fsw or shallower, interrupt oxygen breathing every 60 min with 15 min of air to minimize pulmonary oxygen toxicity. The intermittency schedule need not be rigid. It may be adjusted to account for the needs of the rescuees and to fit the decompression.

    Generally speaking, short air breaks (5-15 min) should be considered “dead time”, that is, not count toward meeting the oxygen decompression requirement at the stop. Lengthen the stop time so that all the listed oxygen time is completed. However, if desired, time spent on air can be used to shorten required oxygen time as outlined in Paragraph 9 above. For longer air breaks (30-60 min), shortening of the oxygen time is desirable.

11. There is no contraindication to ascending between oxygen stops while on an air break. Ascent time, however, should not be included in the subsequent oxygen stop time because the rescuee is not on oxygen.

Details of these secondary schedules including all recommended air breaks are shown in Appendices G-J.

4-1.3 Primary Air/Oxygen Saturation Decompression Schedules 70 - 132 fsw.

Table 4-3 contains the primary air/oxygen saturation decompression schedules for rescue at internal DISSUB pressures ranging from 70-132 fsw. Oxygen cannot be breathed safely at these depths; therefore, there is no oxygen pre-breathing period and the risk of decompression sickness may be increased on these schedules by not removing nitrogen from the body prior to ascent to the first stop. Rescuees decompress in the PRM to the first stop prior to transfer into the DTL and subsequently into the SDC. All schedules assume that the rescuee breathes at least 90% oxygen at the oxygen stops.

Table 4-3. Primary Air/Oxygen Saturation Decompression Schedules 70 - 132 fsw.

		Decompression Stop Time (min)																	
Equivalent Air Depth		**85**	**80**	**75**	**70**	**65**	**60**	**55**	**50**	**45**	**40**	**35**	**30**	**25**	**20**	**15**	**10**	**5**	**Total Stop Time (hrs)**
70 fsw	**Air**								85	170	185	200	215	240	260	290	325	140	35.2
	Oxygen								**25**	**55**	**60**	**65**	**70**	**80**	**85**	**95**	**150**		11.4
80 fsw	**Air**						20	145	160	170	185	200	220	235	260	285	325	155	39.3
	Oxygen						**10**	**45**	**50**	**55**	**60**	**65**	**75**	**75**	**85**	**90**	**155**		12.8
90 fsw	**Air**					95	140	150	160	170	185	200	215	235	260	290	325	165	43.2
	Oxygen					95	140	**50**	**55**	**55**	**60**	**65**	**70**	**75**	**85**	**95**	**160**		16.8
100 fsw	**Air**			35	130	130	145	150	165	170	180	200	215	235	265	290	325	165	46.7
	Oxygen			35	130	130	145	150	165	**55**	**60**	**65**	**75**	**80**	**85**	**95**	**160**		23.8
110 fsw	**Air**		100	120	125	135	140	150	160	170	185	200	220	235	260	290	325	175	49.8
	Oxygen		100	120	125	135	140	150	160	**60**	**60**	**65**	**75**	**80**	**85**	**95**	**160**		26.8
120 fsw	**Air**	150	115	120	130	130	145	150	160	175	180	200	220	235	260	295	330	175	52.8
	Oxygen	150	115	120	130	130	145	150	160	**60**	**60**	**70**	**75**	**80**	**85**	**95**	**165**		29.8
132 fsw	**Air**	305	115	125	130	135	145	150	165	175	190	205	225	245	275	305	345	215	57.5
	Oxygen	305	115	125	130	135	145	150	165	**60**	**65**	**70**	**75**	**80**	**90**	**100**	**180**		33.2

To use Table 4-3, follow these steps:

1. First calculate the rescuee's Equivalent Air Depth (EAD) as outlined above for Table 4-1.

   Note: If the DISSUB survivors consume oxygen without replacement, the actual pressure in the DISSUB will be significantly less than the calculated equivalent air depth.

2. Enter Table 4-3 at the depth that is exactly equal to or next greater than the calculated EAD.
3. Begin decompression by ascending to the first decompression stop indicated in the Table. This first stop may be only a few feet shallower than the actual DISSUB depth. The rate of ascent to the first stop may vary from 1-5 fsw/min (5 fsw/min preferred). Ascent time to the first stop is not included in the first stop time.
4. Complete the decompression time listed for the first stop and subsequent stops. The rate of ascent between stops may vary from 1-5 fsw/min (1 fsw preferred). Ascent time between stops is

included in the subsequent stop time, unless the subsequent stop is the first oxygen stop. Ascent time to the first oxygen stop is not included in the first oxygen stop time.

5. Upon completion of the last stop, ascend to the surface on air at 1-5 fsw/min (1 fsw/min preferred).
6. Two schedules are given at each depth. The upper schedule labeled "Air" is the air saturation schedule. The lower schedule labeled "Oxygen" is the oxygen-accelerated schedule. Oxygen-breathing times are shown in bold print. The rescuee may be switched to oxygen upon arrival at the first oxygen stop, or the switch to oxygen may be delayed until a shallower stop is reached. This allows the dose of oxygen to be reduced in those cases where the rescuee is suffering from significant pulmonary oxygen toxicity.

Example: For ascent from 132 fsw, the rescuee completes decompression on air through the 50-fsw stop. Upon arrival at the first oxygen stop at 45 fsw, he switches to oxygen and completes the remaining stops on oxygen. However, the Diving Medical Officer may elect to delay the shift to oxygen to a shallower stop, say 20 fsw, to allow time for recovery from pulmonary oxygen toxicity. In this case, the rescuee would continue on the air schedule through 25 fsw then shift to oxygen upon arrival at the 20 fsw stop.

7. Upon completion of a stop, the rescuee may shift from oxygen back to air and complete decompression on air if conditions warrant. This situation might arise if oxygen supplies are exhausted.
8. The rescuee may also shift back and forth between air and oxygen during the course of a single stop. The air to oxygen trading ratio is determined by dividing the air time by the oxygen time at the stop. This trading ratio is generally close to three, i.e., three minutes on air is equivalent to one minute on oxygen. The trading ratio is used to partition the stop time between air and oxygen.

Example: The air stop time at 40 fsw on the 120 fsw schedule is 180 min. The oxygen stop time is 60 min. The trading ratio is 180/60 = 3. Conditions dictate that the rescuees take an hour air break to eat, drink, and urinate. The 60 min spent on air is equivalent to 20 min spent on oxygen. The oxygen time at this stop can be reduced to from 60 to 40 min (60-20). The adjusted 40-fsw stop time is 100 min—60 min on air and 40 min on oxygen.

9. Periodic interruption of 100% oxygen breathing is highly desirable to reduce the injurious effects of oxygen on the central nervous system and lung. Interruption of oxygen breathing may also be necessary to change CO2 canisters in the closed-circuit breathing loop. Unexpected interruption of oxygen breathing may also occur because of rescuee illness or injury.

When deeper than 45 fsw, interrupt oxygen breathing approximately every 30 min with at least 5 min of air to minimize the risk of central nervous system oxygen toxicity. When 45 fsw and shallower, interrupt oxygen breathing approximately every 60 min with at least 15 min of air to minimize pulmonary oxygen toxicity. The intermittency schedule need not be rigid. It may be adjusted to account for the needs of the rescuees and to fit the decompression.

Generally speaking, short air breaks (5-15 min) should be considered "dead time", that is, not count toward meeting the oxygen decompression requirement at the stop. Lengthen the stop time so that all the listed oxygen time is completed. However, if desired, time spent on air can be used to shorten required oxygen time as outlined in Paragraph 8 above. For longer air breaks (30-60 min), shortening of the oxygen time is desirable.

10. There is no contraindication to ascending between oxygen stops while on an air break. Ascent time, however, should not be included in the subsequent oxygen stop time because the rescuee is not on oxygen.

4-1.4 SRS Air Saturation Decompression Schedules 25 – 132 fsw.

Table 4-4 contains air saturation decompression schedules that can be used to bring rescuees to the surface in the event that oxygen is unavailable, cannot be tolerated by the rescuees, or oxygen accelerated decompression is unnecessary because all rescuees have been recovered from the DISSUB.

Table 4-4. SRS Air Saturation Decompression Schedules 25 – 132 fsw.

	Decompression Stop Time (min)																	
Equivalent Air Depth	**85**	**80**	**75**	**70**	**65**	**60**	**55**	**50**	**45**	**40**	**35**	**30**	**25**	**20**	**15**	**10**	**5**	**Total Stop Time (hrs)**
25 fsw															110	310	35	7.6
30 fsw														50	285	315	55	11.8
35 fsw													5	245	290	320	65	15.4
40 fsw													185	260	290	320	80	18.9
45 fsw												125	240	260	290	325	90	22.2
50 fsw											75	215	240	260	295	325	100	25.2
55 fsw										35	195	215	240	260	290	320	120	27.9
60 fsw									5	170	200	215	240	260	290	325	120	30.4
70 fsw								85	170	185	200	215	240	260	290	325	140	35.2
80 fsw						20	145	160	170	185	200	220	235	260	285	325	155	39.3
90 fsw					95	140	150	160	170	185	200	215	235	260	290	325	165	43.2
100 fsw			35	130	130	145	150	165	170	180	200	215	235	265	290	325	165	46.7
110 fsw		100	120	125	135	140	150	160	170	185	200	220	235	260	290	325	175	49.8
120 fsw	150	115	120	130	130	145	150	160	175	180	200	220	235	260	295	330	175	52.8
132 fsw	305	115	125	130	135	145	150	165	175	190	205	225	245	275	305	345	215	57.5

To use Table 4-4, follow these steps:

1. First calculate the rescuee's Equivalent Air Depth (EAD) as outlined above for Table 4-1.
2. Enter Table 4-4 at the depth that is exactly equal to or next greater than the calculated EAD.
3. Begin decompression by ascending to the first decompression stop indicated in the Table. Ascent rate may vary from 1-5 fsw/min (5 fsw/min preferred). Ascent time to the first stop is not included in the first stop time.
4. Complete the decompression time listed for the first stop and subsequent stops. Ascent rate may vary from 1-5 fsw/min during ascent between stops (1 fsw/min preferred). Ascent time between stops is included in the subsequent stop time.

5. Upon completion of the 5 fsw stop, ascend to the surface at 1-5 fsw/min (1 fsw/min preferred).
6. Rescuees and attendants breathe air throughout the entire decompression.

4-2 PRM Attendant and SDC Tender Decompression Schedules

4-2.1 Attendant and Tender Oxygen Breathing Schedules at Depth (35 - 60 fsw)

Table 4-5 contains the primary decompression tables for PRM attendants and SDC tenders for exposure pressures ranging from 35-60 fsw. These tables satisfy the tenders' decompression requirement by having tenders breathe oxygen at depth rather than during decompression stops. This frees up the MTL for transfer of medical personnel and bulk equipment and supplies into and out of the SDC's.

Attendants and tenders can alternatively decompress in the MTL on the U.S. Navy Standard Air Table, In-Water Air/O2 mode, if MTL availability is not critical. In rare instances where a standard recompression chamber is available on the VOO, tenders may also decompress on the U.S. Navy Standard Air Table in the SurDO2 mode.

For PRM attendants Table 4-5 is entered using the attendant's equivalent air depth (see Section 3-2 for the calculation of EAD). For the most part, the equivalent air depth will be very close to the actual DISSUB internal pressure. For SDC tenders, who will always be breathing air, the table is entered at the actual SDC depth.

All schedules assume that the attendant or tenders breathe at least 90% oxygen (dry gas fraction). Oxygen can be provided by the MBS-2000 or by open-circuit mask. Bottom time is calculated from the time pressurization on air begins in the PRM or SDC to the time the attendant/tender goes on oxygen for the first time. For PRM attendants, bottom time includes the time needed to transfer from the PRM to the SDC. For calculation purposes, the tables assume compression to depth at 60 fsw/min. However, the tables can be used for any slower compression rate.

Oxygen breathing is nominally interrupted every 30 min by a 5 min air break to minimize the risk of CNS oxygen toxicity. However, the first 30 min period can be extended as follows if the first air break can be avoided by doing so:

60 fsw: Extend by 5 min, from 30 to 35 min

55 fsw: Extend by 10 min, from 30 to 40 min

50 fsw: Extend by 15 min, from 30 to 45 min

45 fsw: Extend by 30 min, from 30 to 60 min

The same extensions can be applied to subsequent oxygen breathing periods if by doing so the subsequent air break can be avoided. The pattern above is already built into the tables and does not have to be considered explicitly. These rules, however, will come into play if custom tables are calculated for attendants or tenders using the Navy Dive Planner (NDP) (see Appendix A).

Upon completion of oxygen breathing, the attendant/tender is allowed 3 min to make his way from the SDC to the MTL and begin ascent on air to the surface at 30 fsw/min. This 3-min time has already been included in the oxygen requirement and does not require any modification to the tables.

Table 4-5. Attendant and Tender Oxygen Breathing Schedules at Depth (35 - 60 fsw)

Bottom Time (min)	Sequential Oxygen/Air Breathing Periods at Depth (min)							Total O2 Time (min)	Repetitive Group	Clean Time (min)
	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen			
35 FSW										
240	2							2	Z	1302
40 FSW										
170	3							3	O	1171
180	5							5	Z	1206
190	7							7	Z	1239
200	9							9	Z	1271
210	11							11	Z	1301
220	13							13	Z	1330
230	15							15	Z	1357
240	18							18	Z	1378
45 FSW										
130	2							2	O	1086
140	6							6	O	1124
150	9							9	O	1164
160	12							12	Z	1202
170	15							15	Z	1238
180	17							17	Z	1277
190	19							19	Z	1314
200	23							23	Z	1339
210	26							26	Z	1368
220	30							30	Z	1389
230	33							33	Z	1414
240	36							36	Z	1437
50 FSW										
100	3							3	N	985
110	4							4	N	1049
120	8							8	O	1097
130	13							13	O	1137
140	16							16	Z	1184
150	20							20	Z	1224
160	23							23	Z	1267
170	26							26	Z	1307
180	30							30	Z	1340
190	35							35	Z	1365
200	39							39	Z	1393
210	43							43		1419
220	30	5	19					49		1459
230	30	5	22					52		1486
240	30	5	25					55		1512

Bottom Time (min)	Sequential Oxygen/Air Breathing Periods at Depth (min)							Total O2 Time (min)	Repetitive Group	Clean Time (min)
	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen			
55 FSW										
80	3							3	M	910
90	6							6	N	978
100	8							8	N	1046
110	13							13	O	1098
120	18							18	O	1146
130	23							23	Z	1192
140	27							27	Z	1239
150	31							31	Z	1283
160	35							35	Z	1324
170	30	5	14					44	Z	1370
180	30	5	19					49	Z	1400
190	30	5	24					54		1427
200	30	5	28					58		1457
210	30	5	32					62		1486
220	30	5	35					65		1517
230	30	5	39					69		1542
240	30	5	30	5	16			76		1577
60 FSW										
70	5							5	L	882
80	8							8	M	959
90	11							11	N	1033
100	17							17	O	1089
110	23							13	O	1142
120	28							28	Z	1195
130	33							33	Z	1245
140	30	5	11					41	Z	1315
150	30	5	18					48	Z	1347
160	30	5	24					54	Z	1380
170	30	5	29					59		1416
180	30	5	34					64		1448
190	30	5	30	5	13			73		1493
200	30	5	30	5	18			78		1520
210	30	5	30	5	21			81		1555
220	30	5	30	5	26			86		1577
230	30	5	30	5	31			91		1597
240	30	5	30	5	30	5	11	101		1621
or: 240	30	5	30	5	30	3	6 @ 20 fsw	96		1613

To use Table 4-5, follow these steps:

1. For PRM attendants, first calculate the attendant's Equivalent Air Depth (EAD) as outlined in Section 3-2. Enter Table 4-5 at the depth that is exactly equal to or next greater than the calculated EAD.
2. For SDC tenders, enter Table 4-5 at the depth that is exactly equal to or next greater than the SDC depth.

3. Choose the bottom time that is exactly equal to or next greater than the attendant's or tender's bottom time. Bottom time is the time from beginning of pressurization on air in the PRM or SDC to the time the individual begins to breathe oxygen.
4. Breathe oxygen and air according to the sequential times listed in the table. MBS-2000 purge times are included in the oxygen times and do not have to be taken into account separately. Begin timing the oxygen time when the individual goes on the mask. Begin timing the air breaks when the individual goes off the mask.
5. Upon completion of the required oxygen time, have the tender come off the mask and make his way to the MTL breathing air. Three minutes is allowed for this transit. Decompress directly to the surface on air in the MTL at 30 fsw/min. If the 3-min transit allowance on air at depth has been exceeded, take a decompression stop on oxygen at 20 fsw equal to the excess time spent on air at depth, then continue decompression to the surface on air.
6. Note that the 60 fsw 240 min schedule provides two choices. In the first choice, all the oxygen breathing is completed at depth. The total oxygen time is 101 min which exceeds the nominal limit of 90 min at 60 fsw. In the second choice, 90 min of oxygen breathing is completed at depth. This is followed by a 3 min period on air while the tender makes his way to the MTL. Once in the MTL, the tender is decompressed to 20 fsw and goes on oxygen for 6 min to complete denitrogenation. He then ascends on air to the surface. Ascent rate from 60 to 20 fsw and from 20 fsw to surface is at 30 fsw/min. The choice of which schedule to follow depends on the risk of CNS toxicity with 11 min of extra oxygen at 60 fsw vs. the availability of the MTL for a brief 6 min period of oxygen breathing.
7. Repetitive dives may be conducted. Follow the instructions in Section 4-3 and Appendix A.

4-2.2 PRM Attendant Oxygen Breathing Schedules at Depth (70, 80 & 90 fsw EAD)

Table 4-6 contains the primary decompression tables for PRM attendants at attendant equivalent air depths of 70-90 fsw. After transfer to the SDC, the attendants satisfy their decompression requirement by breathing oxygen at depth, then surface in the MTL. This frees up the MTL for transfer of medical personnel and bulk equipment and supplies into and out of the SDC's.

PRM attendants can alternatively decompress in the MTL on the U.S. Navy Standard Air Table, In-Water Air/O2 mode, if MTL availability is not critical. In rare instances where a standard recompression chamber is available on the VOO, attendants may also decompress on the U.S. Navy Standard Air Table in the SurDO2 mode.

There are two sets of tables for the 70 fsw equivalent air depth, two sets for the 80 fsw equivalent air depth, and one set for the 90 fsw equivalent air depth.

PRM attendants whose equivalent air depth is 70 fsw and who will be accompanied by rescuees eligible for the 70 fsw rescuee schedule, will initially decompress to the 50 fsw first stop on that schedule. The attendants from the first sortie of a given chamber load will satisfy their decompression obligation by breathing oxygen at 50 fsw. The attendants from the second sortie will satisfy their decompression obligation by breathing oxygen initially at 50 fsw and then at shallower depths as they ascend with the rescuees. This is the first set of schedules at 70 fsw.

In some cases, rescuees may require the 80 fsw rescuee schedule, but the PRM attendants will have an EAD that puts them on the 70 fsw attendant schedule due to a breathe down of the PO2 in the DISSUB. In this case, both rescuees and PRM attendants will decompress to the 60 fsw first stop depth on the rescuee schedule. Attendants from the first sortie of a given chamber load will satisfy their decompression obligation by breathing oxygen at 60 fsw. The attendants from the second sortie will satisfy their decompression obligation by breathing oxygen initially at 60 fsw and then at shallower depths as they ascend with the rescuees. This is the second set of schedules at 70 fsw. Because of the risk of CNS oxygen toxicity, the total oxygen time at 60 fsw is restricted to approximately 90 min. If the bottom time requires more than 90 minutes on oxygen, an alternative schedule is provided that lets the PRM attendant reduce his CNS risk by traveling to 20 fsw in the MTL and completing his oxygen decompression there. This option depends on MTL availability. In general, the total oxygen time will be slightly shorter if the attendant decompresses to 20 fsw. This is due to the fact that he is breathing 90% not 100% oxygen. Therefore, there is a higher partial pressure of nitrogen in the mix at 60 fsw compared to 20 fsw. This increase slows the tissue washout.

In the case of on-going flooding or a compressed air leak, the attendant's EAD may be up to 10 fsw deeper than the EASD of the rescuees due to the lag in nitrogen uptake in the slow tissues of the rescuees. Thus attendants could have an EAD of 80 fsw while the rescuees have an EASD of only 70 fsw. In this case, both rescuees and PRM attendants will decompress to the 50 fsw first stop depth on the rescuee schedule. Attendants from the first sortie of a given chamber load will satisfy their decompression obligation by breathing oxygen at 50 fsw. The attendants from the second sortie will satisfy their decompression obligation by breathing oxygen initially at 50 fsw and then at shallower depths as they ascend with the rescuees. This is the first set of schedules at 80 fsw.

PRM attendants whose equivalent air depth is 80 fsw and who will be accompanied by rescuees eligible for the 80 fsw rescuee schedule, will initially decompress to the 60 fsw first stop on that schedule. The attendants from the first sortie of a given chamber load will satisfy their decompression obligation by breathing oxygen at 60 fsw. The attendants from the second sortie will satisfy their decompression obligation by breathing oxygen initially at 60 fsw and then at shallower depths as they ascend with the rescuees. This is the second set of schedules at 80 fsw. Since oxygen time is limited to 90 min at 60 fsw, the option of decompressing to 20 fsw to complete the decompression is provided.

In the case of on-going flooding or a compressed air leak, the attendant's EAD may be 90 fsw while the EASD of the rescuees is only 80 fsw. In this case, both rescuees and PRM attendants will decompress to the 60 fsw first stop depth on the 80 fsw rescuee schedule. Attendants from the first sortie of a given chamber load will satisfy their decompression obligation by breathing oxygen at 60 fsw. The attendants from the second sortie will satisfy their decompression obligation by breathing oxygen initially at 60 fsw and then at shallower depths as they ascend with the rescuees. This is the first set of schedules at 90 fsw. Bottom time is limited to 200 min because of the lengthy oxygen breathing time.

All schedules in Table 4-6 assume that the attendant breathes at least 90% oxygen (dry gas fraction). Oxygen can be provided by the MBS-2000 or by open-circuit mask.

Bottom time is calculated from the time pressurization of the PRM begins to the time that the PRM is mated and ready to be depressurized to 50 or 60 fsw. The calculation allows for depressurization of the PRM to 50 or 60 fsw at 5 fsw/min) and 5 min for transfer the attendants from the PRM to the SDC. The tables assume initial compression of the PRM to DISSUB depth at 60 fsw/min. However, the tables can be used for any slower compression rate.

Oxygen breathing is nominally interrupted every 30 min by a 5 min air break to minimize the risk of CNS and pulmonary oxygen toxicity. However, the first 30 min period can be extended as follows if the first air break can be avoided by doing so:

60 fsw: Extend by 5 min, from 30 to 35 min

55 fsw: Extend by 10 min, from 30 to 40 min

50 fsw: Extend by 15 min, from 30 to 45 min

45 fsw: Extend by 30 min, from 30 to 60 min

The same extensions can be applied to subsequent oxygen breathing periods if by doing so the subsequent air break can be avoided. The pattern above is already built into the tables and does not have to be considered explicitly. These rules, however, will come into play if custom tables are calculated for PRM attendants using the Navy Dive Planner (see Appendix A).

Upon completion of oxygen breathing, the PRM attendant is allowed 3 min to make his way from the SDC to the MTL and begin ascent on air to the surface at 30 fsw/min. This 3-min time has already been included in the oxygen requirement and does not require any modification to the tables. The 3 min allowance at depth is also in effect when part of the decompression takes place at 20 fsw. The attendant travels to 20 fsw at 30 fsw/min, completes the required oxygen breathing time and air breaks, then ascends to the surface at 30 fsw/min.

Table 4-6. PRM Attendant Oxygen Breathing Schedules at Depth (70, 80 & 90 fsw EAD)

Bottom	Sequential Oxygen/Air Breathing Periods at Depth (min)											Total O2	Repetitive	Clean
Time (min)	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen	Time (min)	Group	Time (min)
70 FSW (Oxygen breathing starting at 50 fsw and continuing shallower as needed)														
60	9											9	M	935
70	13											13	N	1021
80	20											20	O	1088
90	27											27	O	1150
100	34											34	Z	1208
110	40											40	Z	1265
120	30	5	19									49	Z	1331
130	30	5	26									56	Z	1374
140	30	5	33									63		1412
150	30	5	40									70		1447
160	30	5	45									75		1489
170	30	5	30	5	23							83		1536
180	30	5	30	5	29							89		1565
190	30	5	30	5	35							95		1591
200	30	5	30	5	42							102		1609
210	30	5	30	5	30	5	21					111		1635
220	30	5	30	5	30	5	26					116		1658
230	30	5	30	5	30	5	31					121		1679
240	30	5	30	5	30	5	36					126		1698
70 FSW (Oxygen breathing starting at 60 fsw and continuing shallower as needed)														
60	11											11	M	929
70	15											15	N	1017
80	22											22	O	1085
90	29											29	O	1149
100	36											36	O	1207
110	30	5	15									45	Z	1290
120	30	5	23									53	Z	1333
130	30	5	31									61	Z	1371
140	30	5	30	5	12							72	-	1426
150	30	5	30	5	19							79	-	1460
160	30	5	30	5	24							84	-	1501
170	30	5	30	5	29							89	-	1539
180	30	5	30	5	35							95	-	1569
or: 180	30	5	30	5	30	3	plus 5 min O2 at 20 fsw					95	-	1567
190	30	5	30	5	30	5	17					107	-	1596
or: 190	30	5	30	5	30	3	plus 12 min O2 at 20 fsw					102	-	1589
200	30	5	30	5	30	5	23					113	-	1619
or: 200	30	5	30	5	30	3	plus 18 min O2 at 20 fsw					108	-	1614
210	30	5	30	5	30	5	29					119	-	1639
or: 210	30	5	30	5	30	3	plus 24 min O2 at 20 fsw					114	-	1636
220	30	5	30	5	30	5	34					124	-	1662
or: 220	30	5	30	5	30	3	plus 30 min O2 at 20 fsw					120	-	1655
230	30	5	30	5	30	5	30	5	14			134	-	1687
or: 230	30	5	30	5	30	3	plus 35 min O2 at 20 fsw					125	-	1678
240	30	5	30	5	30	5	30	5	20			140	-	1699
or: 240	30	5	30	5	30	3	plus 30/5/11 min O2/Air at 20 fsw					131	-	1693

Table 4-6 (Continued).

Bottom Time (min)	Sequential Oxygen/Air Breathing Periods at Depth (min)											Total O2 Time (min)	Repetitive Group	Clean Time (min)
	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen			
80 FSW (Oxygen breathing starting at 50 fsw and continuing shallower as needed)														
50	11											11	M	923
60	16											16	N	1022
70	25											25	O	1096
80	34											34	O	1163
90	41											41	Z	1234
100	30	5	21									51	Z	1312
110	30	5	30									60	Z	1360
120	30	5	39									69	-	1402
130	30	5	30	5	19							79	-	1461
140	30	5	30	5	26							86	-	1503
150	30	5	30	5	33							93	-	1541
160	30	5	30	5	40							100	-	1576
170	30	5	30	5	30	5	21					111	-	1608
180	30	5	30	5	30	5	28					118	-	1634
190	30	5	30	5	30	5	35					125	-	1656
200	30	5	30	5	30	5	41					131	-	1682
210	30	5	30	5	30	5	30	5	22			144	-	1698
220	30	5	30	5	30	5	30	5	29			149	-	1711
230	30	5	30	5	30	5	30	5	36			156	-	1721
240	30	5	30	5	30	5	30	5	43			163	-	1729
80 FSW (Oxygen breathing starting at 60 fsw and continuing shallower as needed)														
50	13											13	M	918
60	18											18	N	1018
70	27											27	O	1094
80	30	5	10									40	Z	1185
90	30	5	17									47	Z	1255
100	30	5	25									55	Z	1314
110	30	5	35									65	Z	1358
120	30	5	30	5	18							78	-	1417
130	30	5	30	5	25							85	-	1464
140	30	5	30	5	32							92	-	1507
150	30	5	30	5	30	5	14					104	-	1554
or: 150	30	5	30	5	30	3	plus 9 min O2 at 20 fsw					99	-	1545
160	30	5	30	5	30	5	21					111	-	1587
or: 160	30	5	30	5	30	3	plus 17 min O2 at 20 fsw					107	-	1575
170	30	5	30	5	30	5	29					119	-	1611
or: 170	30	5	30	5	30	3	plus 25 min O2 at 20 fsw					115	-	1602
180	30	5	30	5	30	5	36					126	-	1638
or: 180	30	5	30	5	30	3	plus 33 min O2 at 20 fsw					123	-	1625
190	30	5	30	5	30	5	30	5	18			138	-	1665
or: 190	30	5	30	5	30	3	plus 30/5/10 min O2/Air at 20 fsw					130	-	1650
200	30	5	30	5	30	5	30	5	24			144	-	1690
or: 200	30	5	30	5	30	3	plus 30/5/16 min O2/Air at 20 fsw					136	-	1679
210	30	5	30	5	30	5	30	5	32			152	-	1700
or: 210	30	5	30	5	30	3	plus 30/5/24 min O2/Air at 20 fsw					144	-	1692
220	30	5	30	5	30	5	30	5	30	5	15	165	-	1711
or: 220	30	5	30	5	30	3	plus 30/5/32 min O2/Air at 20 fsw					152	-	1703
230	30	5	30	5	30	5	30	5	30	5	21	171	-	1727
or: 230	30	5	30	5	30	3	plus 30/5/30/5/9 min O2/Air at 20 fsw					159	-	1717
240	30	5	30	5	30	5	30	5	30	5	29	179	-	1728
or: 240	30	5	30	5	30	3	plus 30/5/30/5/17 min O2/Air at 20 fsw					167	-	1723

Table 4-6 (Continued).

Bottom	Sequential Oxygen/Air Breathing Periods at Depth (min)											Total O2	Repetitive	Clean
Time (min)	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen	Air	Oxygen	Time (min)	Group	Time (min)
90 FSW (Oxygen breathing starting at 60 fsw and continuing shallower as needed)														
40	13											13	L	884
50	20											20	N	994
60	29											29	O	1087
70	30	5	13									43	Z	1189
80	30	5	22									52	Z	1264
90	30	5	32									62	Z	1327
100	30	5	30	5	18							78	Z	1389
110	30	5	30	5	27							87	-	1441
120	30	5	30	5	30	5	11					101	-	1498
or: 120	30	5	30	5	30	3	plus 6 min O2 at 20 fsw					96	-	1486
130	30	5	30	5	30	5	18					108	-	1548
or: 130	30	5	30	5	30	3	plus 14 min O2 at 20 fsw					104	-	1535
140	30	5	30	5	30	5	27					117	-	1583
or: 140	30	5	30	5	30	3	plus 23 min O2 at 20 fsw					113	-	1572
150	30	5	30	5	30	5	30	5	12			132	-	1614
or: 150	30	5	30	5	30	3	plus 33 min O2 at 20 fsw					123	-	1600
160	30	5	30	5	30	5	30	5	20			140	-	1644
or: 160	30	5	30	5	30	3	plus 30/5/12 min O2/Air at 20 fsw					132	-	1629
170	30	5	30	5	30	5	30	5	28			148	-	1670
or: 170	30	5	30	5	30	3	plus 30/5/20 min O2/Air at 20 fsw					140	-	1659
180	30	5	30	5	30	5	30	5	30	5	11	161	-	1697
or: 180	30	5	30	5	30	3	plus 30/5/28 min O2/Air at 20 fsw					148	-	1686
190	30	5	30	5	30	5	30	5	30	5	20	170	-	1708
or: 190	30	5	30	5	30	3	plus 30/5/30/5/8 min O2/Air at 20 fsw					158	-	1697
200	30	5	30	5	30	5	30	5	30	5	28	178	-	1723
or: 200	30	5	30	5	30	3	plus 30/5/30/5/17 min O2/Air at 20 fsw					167	-	1711

To use Table 4-6, follow these steps:

1. Enter Table 4-6 at the depth that is exactly equal to or next greater than the PRM attendant's equivalent air depth.
2. Select the set of schedules at that EAD that corresponds to the first stop depth of the rescuee schedule.
3. Select the bottom time that is exactly equal to or just greater than the actual bottom time. Bottom time is the time from beginning of pressurization on air in the PRM to the time the PRM is back in the deck cradle and ready to be depressurized to 50 or 60 fsw.
4. Breathe oxygen and air according to the sequential times listed in the table. MBS-2000 purge times are included in the oxygen times and do not have to be taken into account separately. Begin timing the oxygen time when the individual goes on the mask. Begin timing the air breaks when the individual goes off the mask.
5. Upon completion of the required oxygen time, have the attendant come off the mask and make his way to the MTL breathing air. Three minutes is allowed for this transit. Decompress to the surface on air in the MTL at 30 fsw/min.
6. Following the first sortie for a given chamber load, the PRM attendants will perform all of their oxygen breathing at either 50 or 60 fsw while the PRM returns to the DISSUB for the second load. Following the second sortie, PRM attendants will have a variable period of time available at 50 or 60 fsw before decompression of rescuees to the next shallower stop begins. This time includes the time required to transfer the rescuees from the PRM to the SDC, the time required to

instruct them in the use of the MBS-2000, and the oxygen/air time required by the rescuees at either 50 or 60 fsw before decompression to the next shallower stop. If the PRM attendants have not completed their oxygen breathing requirement by this time, they continue to breathe oxygen while decompressing along with the rescuees until all their oxygen time is completed. They then lock out via the MTL.

7. Since the PRM attendants may spend some time breathing oxygen at a depth shallower than 60 fsw following the second sortie, the equations in Section 3-4 can be used to access the CNS oxygen toxicity risk of continuing on the primary oxygen-at-depth schedule and avoiding ascent to 20 fsw to complete decompression. The Navy Dive Planner can be used to calculate a custom schedule for the second sortie that incorporates the shallower depths explicitly (see Appendix A) or the oxygen times in the primary schedule can be simply continued at the shallower depths.
8. Repetitive dives may be conducted. Follow the instructions in Section 4-3 and Appendix A.

4-3 Repetitive Diving of PRM Attendants and SDC Tenders

At rescue depths up to and including 80 fsw, the goal is to minimize the risk of decompression sickness and oxygen toxicity in PRM attendants and SDC tenders by keeping their exposure times relatively short. To minimize total manpower requirements, these attendants and tenders are then reused later in the rescue operation when their surface interval has been long enough for them to eliminate excess nitrogen and return to normal baseline conditions.

At rescue depths of 90 fsw and deeper, this scheme is no longer feasible for PRM attendants or custodial tenders. Their exposure times will vary from 8-12 hours and they must breathe oxygen for extended periods of time along with the rescuees during arduous decompressions.

The following individuals are eligible for repetitive diving:

- PRM attendants with bottom times of 4 hours or less.
- DISSUB Entry Team members with bottom times of 4 hours or less
- Transfer Tenders
- Custodial Tenders with bottom times of 4 hours or less
- Pre-Breathe Tenders with bottom times of 4 hours or less
- Terminal Tenders who ride the tail portion of the saturation decompression to the surface along with the rescuees. Terminal tenders breathe air throughout.

The following individuals are not eligible for repetitive diving:

- Rescuees
- DISSUB Entry Team members with bottom times in excess of 4 hours
- PRM Attendants with bottom times in excess of 4 hours
- Custodial Tenders with bottom times in excess of 4 hours

These individuals are not eligible for repetitive diving because of their prolonged exposure to high oxygen partial pressures during decompression. The limitation on repetitive diving is a pulmonary oxygen toxicity limitation, not necessarily a decompression limitation.

Decompression schedules for PRM attendants and SDC tenders eligible for repetitive diving are given in Chapter 9 the U.S. Navy Diving Manual and in Tables 4-5 and 4-6. Schedules that cover certain depth-dependent situations are given in Appendices C-L.

Repetitive diving is a complicated business given the infinite number of possible dive combinations that must be considered. The rules in the U.S. Navy Diving Manual are considered entirely adequate for the relatively short dives that transfer tenders and medical personnel locking into and out of the SDC will perform. These dives require no further consideration. However, for longer dives performed by PRM attendants, Custodial Tenders, Pre-Breathe Tenders, and Terminal Tenders special attention is required. To simplify matters, these attendants/tenders should wait until they are “clean” before performing a repetitive dive. To be “clean” means that the proposed repetitive dive will not impose any greater decompression obligation or decompression sickness risk on the individual than the same dive performed by an individual with no prior hyperbaric exposure. Risk can be assessed using the NMRI 98[12] or BVM(3)[13] probabilistic models embodied in the Navy Dive Planner.

The time required to become clean following a dive is not a single number. It depends on the length of the repetitive dive that will be performed. A short second dive will require a shorter surface interval to become clean than a long second dive. Complicating matters is the fact that the duration of the second dive may not be known until it is actually underway. For example consider a PRM attendant who performs a 150 min dive then anticipates performing a second 150 min dive after a suitable surface interval. The required surface interval for the second 150 min dive can be calculated, but there is no guarantee that this dive will in fact be 150 min. It might extend out to 240 min due to unforeseen circumstances. The required surface interval to become clean has to be calculated based on the longest possible repetitive dive.

Tables 4-5 and 4-6 and the tables in the appendices include both a Repetitive Group Designator and an entry called “Clean Time”. The Clean Time is the time required after a dive for all body tissues to desaturate to within 1 fsw of the surface equilibrium nitrogen partial pressure. This time is generally longer than the clean time given in Diving Manual Table 9-8 for a given repetitive group and is due to uptake of nitrogen in very slowly exchanging body compartments. The uptake in these compartments does not control the decompression from the current dive but can affect the repetitive dive if it has a long bottom time. For decompression schedules that include a repetitive group designator, first estimate the clean time using Table 9-8 from the Diving Manual, then determine whether a longer clean time is needed for the planned dive using the Navy Dive Planner (See Appendix A for instructions). For schedules that do not include a repetitive group designator, estimate the clean time using the Clean Time value indicated in the tables and then determine whether this time can be shortened using the Dive Planner. No action is required if the surface interval between dives exceeds the Clean Time listed in the tables.

If the Dive Planner is unavailable to estimate the clean time between dives without a repetitive group designator, assume that the safe surface interval is 24 hours. This is longer than the 18 hour interval prescribed by the Diving Manual. This longer time recognizes the fact that many attendant and tender dives will be measured in hours rather than in minutes.

Chapter 5 - Coordination of Decompression Tables

Section 4- provides individual decompression tables for rescuees and PRM attendants. This section shows how to coordinate these various sets of schedules. The coordination problem arises from the fact that the equivalent air depth of the rescuees, the equivalent air depth of the PRM attendants, and the actual depth at which the transfer from the DISSUB to the PRM occurs may all be different.

For example, if the crew of a DISSUB breathes the oxygen down from 0.58 to 0.20 atm while awaiting rescue and all the CO_2 produced metabolically is absorbed by LiOH, the pressure in the DISSUB can be expected to decline from 60 to 47.5 fsw and the oxygen fraction to fall from 20.5 to 8.2%. When the PRM mates to the DISSUB, the equivalent air depth of the rescuees will still be 60 fsw, but the transfer will occur at an actual depth of 47.5 fsw. The equivalent air depth of the PRM attendants in this case will be 47.5 fsw if they remain in an air-filled PRM, but will be higher if they descend into the DISSUB which is only at 8.2% oxygen.

The basic principle of coordination is that the decompression schedule for the rescuees, as determined by their equivalent air saturation depth, governs the operation. The PRM attendant schedules wrap around this primary schedule as needed.

Note: Unlike PRM attendant schedules, the SDC tender schedules are not complicated by a potential disparity between equivalent air depth and actual depth. SDC tenders will always be breathing air and their equivalent air depth will always be equal to their actual depth. This section does not involve SDC tender schedules.

5-1 Definitions

Before proceeding, several definitions are in order:

Equivalent Air Depth (EAD). This is a measure of the partial pressure of nitrogen that a rescuee or PRM attendant is inhaling at any given moment. It is given by Equation 4 for rescuees and Equation 5 for PRM attendants in Section 3-1. In both cases, EAD may change over the course of a given exposure and thus change the amount of nitrogen absorbed by the body during that exposure. For the relatively short exposures experienced by the PRM attendants, the change in EAD is accommodated by computing the EAD at various points during the sortie then using the deepest EAD experienced to select the table. For rescuees, the change in EAD is accommodated by computing the Equivalent Air Saturation Depth of the rescuees from the time the submarine sinks to the time rescue occurs.

Equivalent Air Saturation Depth (EASD). This is a measure of the degree to which the slow, 360 min half-time body compartment is saturated with nitrogen. Appendix B explains how the EASD is calculated from records maintained in the DISSUB prior to rescue. EASD is the depth to be used in selecting the decompression schedule for the rescuees. In most cases where the atmospheric composition and pressure in the DISSUB has been stable for the two days prior to rescue, the EASD will be essentially equal to the EAD computed using Equation 4 in Section 3-1.

DISSUB Transfer Depth (DSUBTD). This is the actual depth (internal DISSUB pressure) at which transfer from the DISSUB to the PRM occurs. When two sorties will fill an SDC prior to decompression, these depths are labeled DSUBTD 1 and DSUBTD 2. When conditions are rapidly changing in the DISSUB these two depths may be different.

SDC Transfer Depth (SDCTD). This is the actual depth at which transfer from the PRM to the DTL and SDC occurs. For rescues occurring at rescuee EASD's of 70-132 fsw, the PRM is decompressed in the deck cradle to 50-85 fsw prior to transfer of the resucees to the SDC.

5-2 Potential Range of Conditions

An actual rescue may produce unusual scenarios that cannot be predicted entirely in advance. For planning purposes it is necessary to make assumptions about the likely scenarios and leave outliers to on the spot management. Table 5-1 gives an estimate of the potential range of transfer depths and PRM EAD's that might be encountered in a majority of DISSUB scenarios.

Table 5-1. Potential Range of Transfer Depths and PRM EADS's as a Function of EASD

EASD (fsw)	Transfer Depth (fsw)		PRM EAD on18% O2 (fsw)	
	Min	Max	Min	Max
40	31.6	49.0	33.6	51.7
45	35.6	54.0	37.8	56.9
50	39.6	59.0	41.9	62.1
55	43.6	64.0	46.1	67.3
60	47.5	69.0	50.1	72.5
70	55.5	79.0	58.4	82.8
80	63.4	89.0	66.6	93.2
90	71.4	99.0	75.0	103.6
100	79.3	109.0	83.2	114.0
110	87.3	119.0	91.5	124.4
120	95.2	129.0	99.7	134.7
132	104.8	141.0	109.6	147.2

The first column of Table 5-1 shows the computed EASD of the rescuees. This is the table that will be used for rescuee decompression. The next two columns show the minimum and maximum DISSUB transfer depths that might be expected with that EASD.

The minimum transfer depth is derived by assuming that the DISSUB is initially pressurized with 20.5% oxygen and 0.5% carbon dioxide to the EAD/EASD indicated. The crew then breathes the oxygen down to 0.2 atm while any carbon dioxide produced metabolically is removed by LiOH. During this process, the pressure in the DISSUB falls while the EAD/EASD remains constant.

The maximum transfer depth is derived by assuming that the DISSUB is initially pressurized to some depth with 20.5% oxygen and 0.5% carbon dioxide (79% nitrogen) and the rescuees remain at that depth until the 360 min half-time tissue becomes fully saturated. The DISSUB is then further pressurized with a 79% nitrogen mixture at a constant linear rate of 25 fsw/day (~1 fsw/h). During pressurization at a constant rate, the EASD will lag behind the actual DISSUB depth by an amount that gradually approaches a constant value with increasing time. At a pressurization rate of 25 fsw/day, the lag will gradually approach a maximum value of 9 fsw. The DISSUB depth, therefore, will be a maximum of 9 fsw deeper than the EASD.

Note 1: The lag between EASD and DISSUB depth with linear pressurization on 79% nitrogen can be easily computed for other pressurization rates and pressurization times. The lag is given by:

$$\text{Lag} = R/k*(e^{-kt}-1) \qquad (21)$$

Where: Lag = Lag between EASD and DISSUB depth (fsw)

R = Rate of pressurization on air (fsw/h)

k = Rate constant of body tissue in question (0.1155 h^{-1} for 360 min half-time tissue)

t = Elapsed time since pressurization began (h)

As the pressurization time becomes longer and longer, the term e-^{kt} approaches zero and the right hand term in parenthesis approaches -1. The maximum lag that can be seen with prolonged pressurization, therefore, is:

$$\text{Maximum Lag} = -R/k \qquad (22)$$

The maximum lag is a linear function of the pressurization rate and the tissue rate constant. For a 360 min half-time tissue, the maximum lag will be 0 fsw when the DISSUB pressure is constant (i.e., R = 0) and will increase by 0.36 fsw for each 1 fsw/day increase in the pressurization rate above zero. For a pressurization rate of 25 fsw/day, the maximum lag is 0.36*25 = 9 fsw.

The term e^{-kt} – 1gives the fraction of the maximum computed lag that will be seen at any time t. For a 6 h pressurization, this fraction is 0.5. At the end of 6 hours, the lag in EASD behind the DISSUB depth will be 50% of the maximum possible lag, i.e., 4.5 fsw for a 9 fsw maximum lag. The corresponding fractions are 0.37 and 0.75 for pressurizations of 4 and 12 hours respectively. For a 24 h pressurization, the fraction is 0.94%. The lag is only slightly less than the maximum after 24 hours of pressurization.

Note 2: If pressurization starts after the 360 min tissue has equilibrated with the ambient PN2 in the DISSUB, but the pressure in the DISSUB has decreased from its initial value due to a breathe down of PO2 by the crew, the calculation above has to be modified to account for the fact that the DISSUB pressure is now lower than the EAD and the nitrogen percentage in the DISSUB is above 79%. First compute the lag for R, k, and t using the equations above. This will be the lag in EASD behind the EAD rather than the lag in EASD behind the DISSUB depth. Then correct by adding the difference between the EAD and DISSUB depth to the computed lag. The result will be the difference between the EASD and the DISSUB depth. This value may be positive rather than negative in some cases.

Note 3: Appendix B gives two examples where the calculated lag is greater than 9 fsw. One example involves massive flooding while the other involves survivors breathing from the EABS. In both cases the DISSUB pressurization rate is non-linear. These two examples are considered extreme cases. For most rescues, it is considered unlikely that that the lag between EASD and DISSUB depth will exceed 9 fsw.

If the PRM contains an air atmosphere, the PRM EAD will be the same as the actual PRM depth which in turn is the same as the DISSUB transfer depth. However, if the PRM oxygen content is allowed to fall to 18% and the carbon dioxide partial pressure allowed to rise to 10 mbar, the PRM EAD will be higher than the actual PRM depth and this difference between PRM EAD and PRM depth will be magnified as the actual PRM depth increases. Projected minimum and maximum PRM EAD's with 18% oxygen and 10 mbar CO2 are shown for each EASD in the two right hand columns.

5-3 Venting off of the PRM

During ascent the pressure in a fully loaded PRM could increase due to an increase in cabin temperature. Metabolic heat production by the rescuees and heat generation by the CO2 scrubbers will increase the thermal load, while the rising external water temperature will reduce the ability of the PRM to dissipate heat. The temperature increase could be especially steep when the PRM leaves the water, docks in the cradle, and is exposed to direct sunlight. Thus far, this has not proved to be a practical problem. During recent exercises cabin temperatures barely increased over bottom levels during ascent and docking (personal communication from LCDR J. Gibbs, URC, to Dr. E. Flynn, NAVSEA 00C, 5 Dec 2013). However, this possibility needs to be kept in mind.

An increase in PRM pressure during ascent may also occur if there is any source of compressed air leakage into the PRM. Typical sources include volume makeup for mask leakage if the PRM occupants are on the EBS and open circuit operation of the EBS during CO2 canister changes.

Even a large increase in PRM pressure during ascent will have little impact on the computed EASD of the rescuees because of the short time needed for ascent and docking relative to the nitrogen uptake time of the 360 min tissue. For rescuees any increase in PRM pressure during ascent can be safely ignored. For PRM attendants, however, the increase in PRM pressure cannot be ignored. It must be taken into account when computing the EAD of the PRM attendants and selecting their decompression schedule.

To prevent both an unneeded and unwanted increase in oxygen pre-breathing depth for the rescuees, any PRM pressure in excess of the DISSUB transfer depth should be vented off prior to transfer of the rescuees to the DTL. This action will also prevent continued exposure of the PRM attendants to the higher pressure. Venting may produce in a small decompression step for the PRM attendants, but in almost every case the transfer to the DTL and SDC will occur at a much higher pressure than the computed first stop depth on the attendant's schedule. Thus, there will be very little risk of decompression sickness in the PRM attendants associated with this action.

5-4 Single Chamber or Dual Chamber (No-Hold) Mode

Figure 5-1 is a flowchart for the management of rescues in the single chamber or dual chamber (no hold) mode. Since only one sortie per chamber load is involved, this is the simplest situation. There is no concern that a second sortie will arrive on deck at a pressure higher or lower than the pressure of the SDC that will receive it. Use of the single chamber or dual chamber (no-hold) modes can be expected at EASD's of 25-40 fsw and in some cases 45 fsw. Figure 5-1 is self-explanatory.

5-5 Dual Chamber (Hold) Mode and EASD 1 and EASD 2 are both 41-60 fsw

The dual chamber (hold) mode is more complicated because both the first and second sortie transfer rescuees to the same SDC. The DISSUB transfer depth for the second sortie may be higher or lower than for the first sortie. Figure 5-2 is a flowchart for the management of rescuees in the Dual Chamber (Hold) Mode when the EASD for the rescuees on both Sorties 1 and 2 falls in the range of 41-60 fsw.

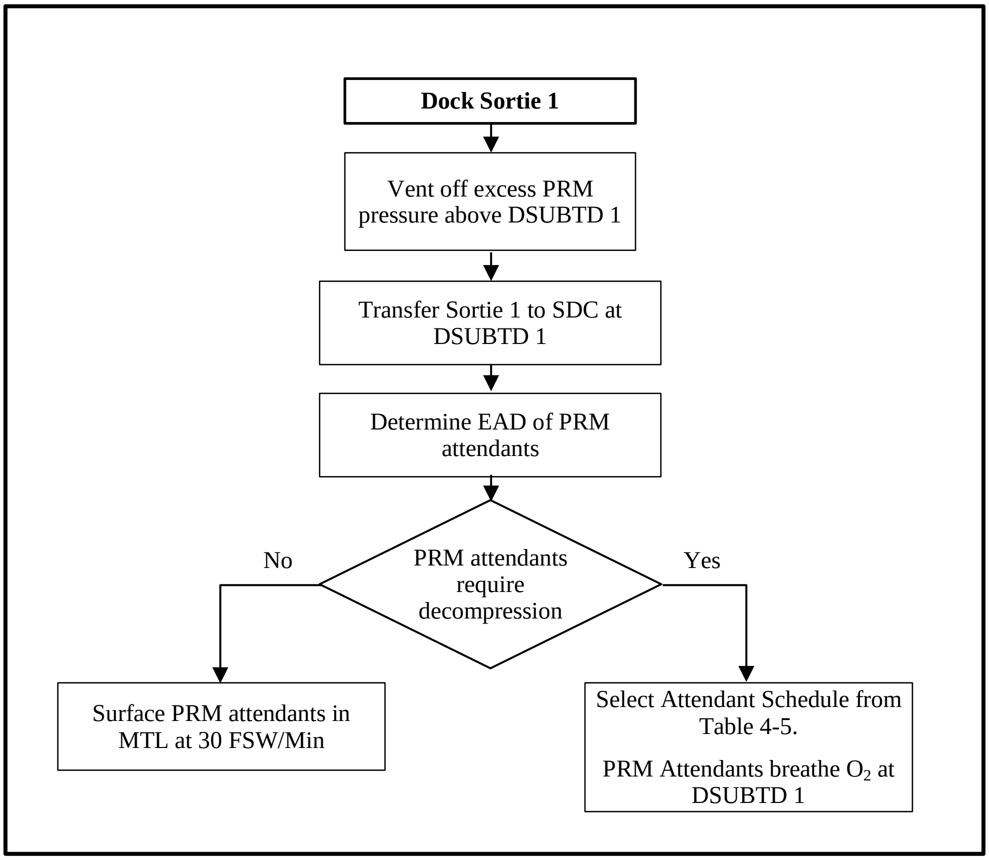

Figure 5-1. Single Chamber or Dual Chamber (No Hold) Mode – EASD 1 25 – 45 FSW (No-Hold) Mode

Sortie 1 (top half of Figure 5-2):

The DISSUB transfer depth for Sortie 1 may be greater than 60 fsw in situations where pressure in the boat has been rising and, due to the lag in uptake of nitrogen in the 360 min body tissue, the EASD remains 60 fsw or less. In this case (right arm of chart), any pressure in the PRM above 60 fsw is vented off to 60 fsw prior to transfer of the PRM attendants and rescuees to the DTL/SDC. The first set of rescuees are held at 60 fsw. Once the EAD of the PRM attendants has been determined, the attendants satisfy their decompression obligation by breathing oxygen at 60 fsw.

If DISSUB transfer depth is 60 fsw or less (left arm of chart), PRM attendants and rescuees are transferred to the DTL/SDC at DSUBTD 1. The first set of rescuees are held at DSUBTD 1. Once the EAD of the PRM attendants has been determined, the attendants satisfy their decompression obligation by breathing oxygen at DSUBTD 1.

Sortie 2 (bottom half of Figure 5-2):

If the DISSUB transfer depth for Sortie 2 is greater than 60 fsw, vent off any PRM pressure in excess of 60 fsw. If the SDC is shallower than 60 fsw as a result of the first sortie, compress the SDC to 60 fsw. Transfer the second set of PRM attendants and rescuees to the SDC at 60 fsw. Compare the EASD for the first and second set of rescuees. Use the deeper of the two EASD's to select the decompression schedule for the rescuees. Rescuees will pre-breathe oxygen at a depth of 60 fsw. PRM attendants will also satisfy their decompression obligation by breathing oxygen at 60 fsw.

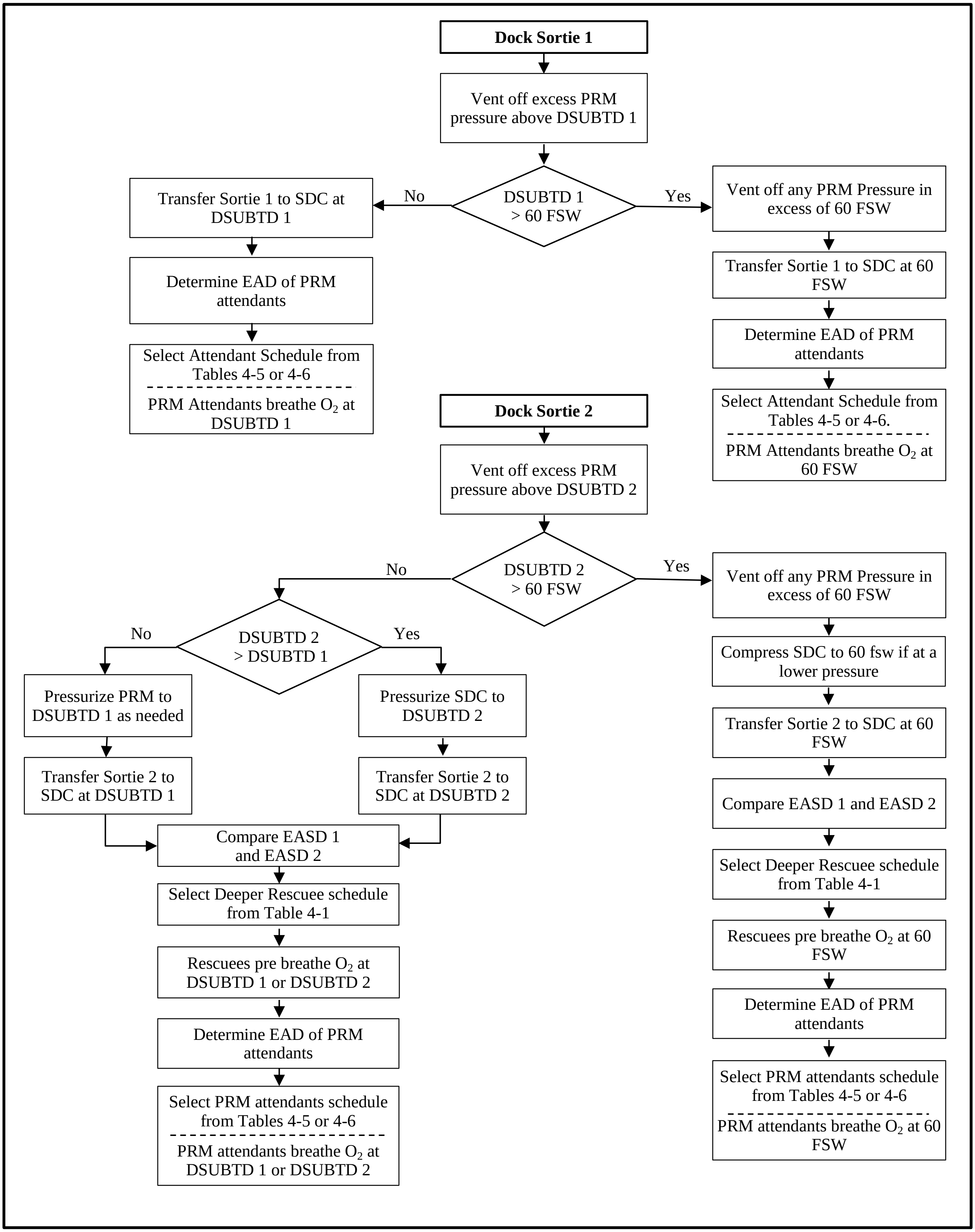

Figure 5-2 – Dual Chamber (Hold) Mode – EASD 1 and EASD 2 41-60 fsw

If the DISSUB transfer depth for Sortie 2 is 60 fsw or less, compare the DISSUB transfer depths for Sorties 1 and 2. If the transfer depth for Sortie 2 is greater than the transfer depth for Sortie 1, compress the SDC to the DISSUB transfer depth for Sortie 2, then effect transfer. If the transfer depth for Sortie 2 is equal to or shallower than the transfer depth for Sortie 1, compress the PRM as needed to bring the PRM up to the transfer depth for Sortie 1, then effect transfer. Compare the EASD for the first and second set of rescuees. Use the deeper of the two EASD's to select the rescuees decompression schedule. Rescuees will breathe pre-breathe oxygen at the current SDC depth. PRM attendants will also satisfy their decompression obligation by breathing oxygen at the current SDC depth.

Example 1:

The computed EASD for Sortie 1 is 50 fsw, but the actual depth in the DISSUB is only 42 fsw because the crew has been successful in breathing down the oxygen level. The rescuees are transferred from the DISSUB to the PRM at 42 fsw (DSUBTD1). They are also transferred from the PRM to the SDC at this depth (SDCTD1). The PRM during the sortie was maintained at 18% O2 and 10 mbar CO2. The equivalent air depth for the PRM attendants, therefore, is 42 fsw. If they had a 160 min bottom time, they will be required to breathe oxygen in the SDC for 12 min at 40 fsw prior to locking out via the MTL (Table 4-5, 45 fsw/160 min). If one or both of the PRM attendants had entered the DISSUB, their EAD would be increased to 50 fsw. In this case the oxygen breathing requirement at 40 fsw would be increased to 23 min (Table 4-5, 50 fsw/160 min).

Shortly after the first sortie departs the DISSUB, a compressed air leak develops in the DISSUB. By the time the second sortie is ready to depart the DISSUB, the internal DISSUB pressure has increased from 40 to 45 fsw and the EASD for the rescuees has increased from 50 to 51.4 fsw. The rescuees are transferred from the DISSUB to the PRM at 45 fsw (DSUBTD2). The SDC, along with the occupants from the first sortie, is compressed from 40 to 45 fsw to match the higher pressure. Transfer to the SDC takes place at 45 fsw (SDCTD2). The PRM is once again maintained at 18% O2 and 10 mbar CO2 yielding a PRM EAD of 47.5 fsw. Exposure time is 160 min. The PRM attendants breathe oxygen in the SDC for 23 min at 45 fsw prior to locking out by the MTL (Table 4-5, 50 fsw/160 min).

EASD1 and EASD2 are now compared and the deeper of the two is used to select the rescuees' decompression schedule. In this case, 51.4 fsw is the deeper of the two, so the decompression takes place on the 55 fsw schedule (Table 4-1). Pre-breathing of oxygen by the rescuees takes place at 45 fsw, then the rescuees are decompressed to the first stop on the 55 fsw schedule, 40 fsw, to continue the decompression.

(Note that the EASD for the first sortie will decrease during the 4-6 hour hold in the SDC at 40 fsw while the second sortie is being recovered. Because of the breathe down of oxygen in the DISSUB the concentration of nitrogen in the DISSUB at the time of transfer to the PRM will be substantially higher than 79%. When these rescuees enter the PRM and subsequently the SDC, the nitrogen fraction will abruptly decrease to 79% while the ambient pressure remains constant. The inspired PN2, therefore, will fall and nitrogen will washout from the slow body compartments reducing the EASD.)

Example 2:

The computed EASD for Sortie 1 is 57 fsw. The actual depth in the DISSUB is also 57 fsw because the crew has not been successful in breathing down the oxygen level. The rescuees are transferred from the DISSUB to the PRM at 57 fsw (DSUBTD1). They are also transferred from the PRM to the SDC at this depth (SDCTD1). The PRM during the sortie was maintained at 18% O2 and 10 mbar CO2. The equivalent air depth for the PRM attendants, therefore, is 60 fsw. If they had a 160 min bottom time, they will be required to breathe oxygen in the SDC for 54 min at 60 fsw prior to locking out via the MTL (Table 4-5, 60 fsw/160 min).

Shortly after the first sortie departs the DISSUB, a compressed air leak develops in the DISSUB. By the time the second sortie is ready to depart the DISSUB, the internal DISSUB pressure has increased from 57 to 62 fsw and the EASD for the rescuees has increased from 57 to 58.4 fsw. The rescuees are transferred from the DISSUB to the PRM at 62 fsw (DSUBTD2). Once the PRM is docked in the cradle, the PRM is decompressed from 62 to 60 fsw. The SDC, along with the occupants from the first sortie, is compressed from 57 to 60 fsw to match the higher pressure. Transfer to the SDC takes place at 60 fsw (SDCTD2). The PRM is once again maintained at 18% O2 and 10 mbar CO2 yielding a PRM EAD of 65.2 fsw. Exposure time is 160 min. The PRM attendants breathe oxygen in the SDC for 75 min at 60 fsw prior to locking out by the MTL (Table 4-6, 70 fsw/160 min).

EASD1 and EASD2 are now compared and the deeper of the two is used to select the rescuees' decompression schedule. In this case, 58.4 fsw is the deeper of the two, so the decompression takes place on the 60 fsw schedule (Table 4-1). Pre-breathing of oxygen by the rescuees takes place at 60 fsw, then the rescuees are decompressed to the first stop on the 60 fsw schedule, 45 fsw, to continue the decompression.

If the EASD for the second sortie exceeds 60 fsw, Figure 5-2 cannot be used. If the second sortie is eligible to decompress on the 70 fsw EASD schedule, vent the PRM off to a depth of 50 fsw as needed. Compress or decompress the SDC to a matching depth of 50 fsw, then effect transfer. (Note: If the EASD is just above 60 fsw, the DISSUB transfer depth may be slightly under 50 fsw. In this case, transfer the rescuees to the SDC at the DISSUB transfer depth.) Decompress rescuees on the 70 fsw EASD schedule (the first stop may be executed at less than 50 fsw if the transfer depth is less than 50 fsw). Compute the EAD for the PRM attendants on the second sortie and select the decompression schedule from Table 4-6 for initial oxygen breathing at 50 fsw. PRM attendants will satisfy their decompression obligation by breathing oxygen initially at 50 fsw (or slightly shallower) and then shallower as they decompress with the rescuees.

5-6 Dual Chamber (Hold) Mode and EASD 1 and EASD 2 are both 61-80 fsw

This depth range is the most complicated. The Dual Chamber (Hold) Mode is required and the transfer depths for Sorties 1 and 2 may vary as described above. The 70 and 80 fsw rescuee schedules do not feature oxygen pre-breathing at depth prior to actual decompression. Decompression is begun by immediate ascent to the first stop (50 fsw for the 70 fsw schedule and 60 fsw for the 80 fsw schedule). Finally, the PRM attendants may start the operation in the single sortie mode with oxygen breathing at depth to satisfy their decompression obligation, but later switch to the back-to-back mode and ride to the surface with the rescuees.

Figure 5-3 is a flowchart for the management of rescuees in the Dual Chamber (Hold) Mode when the EASD for the rescuees on both Sorties 1 and 2 falls in the range of 61-80 fsw.

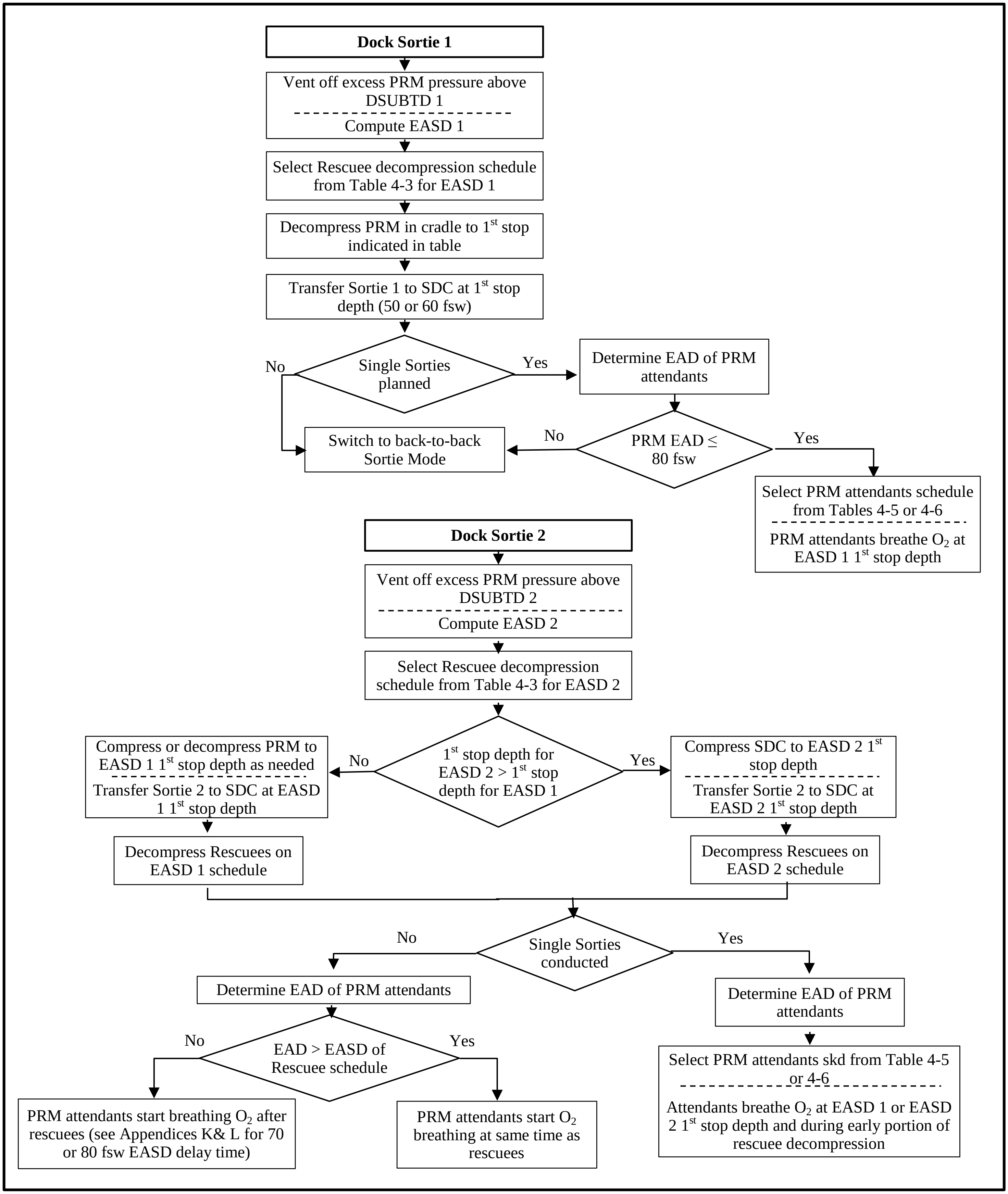

Figure 5-3. Dual Chamber (Hold) Mode, Single or Back-To-Back Sorties, EASD 1 and EASD 2 61-80 fsw

Sortie 1 (top half of Figure 5-3):

After venting off any excess PRM pressure above the DISSUB transfer depth, determine the EASD for Sortie 1. If the rescuees are eligible for decompression on the 70 fsw schedule and the PRM is deeper than 50 fsw, vent off the PRM to the first stop depth of 50 fsw and transfer rescuees and attendants to the SDC at 50 fsw. If the PRM is shallower than 50 fsw (for example, if the EASD is 63 fsw but because of a breathe down on PO2 in the DISSUB, the DISSUB pressure is less than 50 fsw), transfer rescuees and attendants to the SDC at the shallower depth.

If the rescuees require decompression on the 80 fsw schedule and the PRM is deeper than 60 fsw, vent off the PRM to the first stop depth of 60 fsw and transfer rescuees and attendants to the SDC at 60 fsw. If the PRM is shallower than 60 fsw, transfer rescuees and attendants to the SDC at the shallower depth.

If single sorties by the PRM attendants have been planned and the PRM EAD is 80 fsw or less, the PRM attendant's decompression schedule is obtained from Table 4-5 or 4-6. Attendants satisfy their decompression obligation by breathing oxygen at the SDC transfer depth.

If the PRM EAD is greater than 80 fsw, or if the bottom time at PRM EAD's of 71-80 fsw exceeds 140 min, the PRM attendants switch to the back-to-back mode and remain in the SDC with the rescuees to conduct the second sortie.

Sortie 2 (bottom half of Figure 5-3):

After venting off any excess PRM pressure above the DISSUB transfer depth, determine the EASD for Sortie 2. If the first stop depth for EASD 2 (or the PRM depth after venting) is greater than the SDC transfer depth for Sortie 1, compress the SDC to the first stop depth or the PRM depth whichever is shallower, then effect transfer to the SDC at that depth. Decompress rescuees on the EASD 2 schedule.

If the first stop depth for EASD 2 (or the PRM depth after venting), is equal to or less than the SDC transfer depth for Sortie 1, decompress the PRM to the SDC transfer depth for Sortie 1 as needed, then effect transfer. Decompress rescuees on the EASD 1 schedule.

If a fresh set of PRM attendants made the second sortie, determine the EAD of the attendants. Select the attendant decompression schedule from Table 4-5 or 4-6. Attendants breathe oxygen initially at the SDC transfer depth for Sortie 2 and then during the early portion of the rescuee decompression.

If the PRM attendants made back-to-back sorties, determine the EAD of the attendants. If the PRM attendant's EAD is greater than the EASD of the rescuee schedule, the PRM attendants start oxygen breathing at the same time as the rescuees during decompression. If the PRM attendant's EAD is equal to or less than the EASD of the rescuee schedule, the PRM attendants delay going on oxygen until later in the decompression. See Appendices K & L for the times PRM attendants go on oxygen.

If the EASD for the second sortie exceeds 80 fsw, Figure 5-3 cannot be used. If the rescuees are eligible for decompression on the 90 fsw EASD schedule and the PRM is deeper than 65 fsw, vent the PRM off to a depth of 65 fsw. Compress the SDC to the matching depth of 65 fsw, then effect transfer. If the PRM is shallower than 65 fsw, hold the PRM at that depth while compressing the SDC to the matching depth, then effect transfer. Decompress rescuees on the 90 fsw EASD schedule. Compute the EAD of the PRM attendants, whether from the second sortie only or from back-to-back sorties. If the PRM attendant's EAD is greater than 90 fsw, the PRM attendants start oxygen breathing at the same time as the rescuees during decompression. If the EAD of the PRM attendants is 90 fsw or less, the PRM attendants delay going on oxygen until later in the decompression. See Appendix M for the time PRM attendants go on oxygen.

Example 3: (PRM Attendant Single Sortie Mode)

The computed EASD for Sortie 1 is 70 fsw. The actual depth in the DISSUB is also 70 fsw because the crew has not been successful in breathing down the oxygen level. The rescuees are eligible for the 70 fsw schedule (Table 4-3). They are transferred from the DISSUB to the PRM at 70 fsw (DSUBTD1). Once docked in the creadle, the PRM is vented off to the first stop depth on the 70 fsw schedule, 50 fsw. The rescuees are transfer from the PRM to the SDC at this depth (SDCTD1). The PRM during the sortie was maintained at 21% O2 and 3 mbar CO2. The equivalent air depth for the PRM attendants, therefore, is 69.9 fsw. If they had a 160 min bottom time, they will be required to breathe oxygen in the SDC for 75 min at 50 fsw prior to locking out via the MTL (Table 4-6, 70 fsw/160 min/50 fsw stop).

Shortly after the first sortie departs the DISSUB, a compressed air leak develops in the DISSUB. By the time the second sortie is ready to depart the DISSUB, the internal DISSUB pressure has increased from 70 to 75 fsw and the EASD for the rescuees has increased from 70 to 71.4 fsw. The rescuees are transferred from the DISSUB to the PRM at 75 fsw (DSUBTD2). The second sortie requires decompression on the 80 fsw schedule which has a first stop of 60 fsw. Once the PRM is docked in the cradle, the PRM is decompressed from 75 to 60 fsw. The SDC, along with the occupants from the first sortie, is compressed from 50 to 60 fsw to match the higher pressure. Transfer to the SDC takes place at 60 fsw (SDCTD2). The PRM for the second sortie was maintained at 18% O2 and 10 mbar CO2 yielding a PRM EAD of 78.7 fsw. Exposure time is 140 min. The PRM attendants breathe oxygen in the SDC for 93 min at 60 fsw prior to locking out by the MTL (Table 4-6, 80 fsw/140 min/60 fsw stop). The 80 fsw rescuee schedule has only 10 min of oxygen breathing at 60 fsw. Approximately 35 min will be required at 60 fsw prior to this to train the rescuees in the use of the MBS 2000. Thus the total time at 60 fsw will be approximately 45 min which is shorter than the 93 min of oxygen required by the PRM attendants. The PRM attendants will continue to breathe oxygen during decompression to 55 fsw and shallower until all their required oxygen time has been completed.

Example 4: (PRM Attendant Single Sortie Mode)

The EASD for the first sortie is 61 fsw which requires a rescuee schedule of 70 fsw with a first stop at 50 fsw. However, in this instance the crew has been successful in breathing down the O2 and the DISSUB pressure is actually 48 fsw, two fsw shallower than 50 fsw. The rescuees and PRM attendants transfer from the DISSUB to the SDC at 48 fsw. PRM attendants complete their decompression requirement by breathing oxygen at 48 fsw prior to lockout via the MTL.

Example 5: (PRM Attendant Back-to-Back Sorties)

The EASD for the first sortie is 75 fsw, but due to an on-going compressed air leak, the DISSUB internal pressure is actually 84 fsw. The rescuees are eligible for decompression on the 80 fsw schedule (Table 4-3), which has a first stop at 60 fsw. The resuees and PRM attendants are transferred from the DISSUB to the PRM at 84 fsw. Once in the cradle, the PRM is decompressed to 60 fsw. Transfer to the SDC is effected at 60 fsw (SDCTD1). The PRM was maintained at 18% O2 and 10 mbar CO2 yielding an EAD of 88 fsw. Since the PRM EAD of 88 fsw is greater than the EAD/EASD of the rescuee schedule, the PRM attendants are switched to the back-to-back mode and remain in the SDC with the rescues to make the second sortie.

Shortly after the first sortie departs the DISSUB, the compressed air leak is secured. The actual depth of the DISSUB remains constant at 84 fsw, but the EASD increases from 75 fsw to 79.5 fsw as the 360 min catches up to the DISSUB EAD. The second sortie also requires decompression on the 80 fsw schedule. Transfer of the rescuees and PRM attendants from the DISSUB to the PRM takes place at 84 fsw. Once in the cradle, the PRM is decompressed to 60 fsw. Transfer to the SDC is effected at 60 fsw (SDCTD2). The PRM during the second sortie was also maintained at 18% O2 and 10 mbar CO2, yielding a PRM EAD of 88 fsw. Since the maximum PRM EAD is 88 fsw which is greater than the 80 fsw EAD of the rescuee schedule, the PRM attendants begin breathing oxygen at the same time as the rescuees during decompression.

5-7 Dual Chamber (Hold) Mode and EASD 1 and EASD 2 are both 81-132 fsw

At these depths, PRM attendants will always perform back-to-back sorties and will decompress with the rescues in the SDC.

Figure 5-4 is a flowchart for the management of rescuees in the Dual Chamber (Hold) Mode when the EASD for the rescuees on both Sorties 1 and 2 falls in the range of 81-132 fsw.

Sortie 1 (top half of Figure 5-4):

After venting off any excess PRM pressure above the DISSUB transfer depth, determine the EASD for Sortie 1. Select the rescuee decompression schedule from Table 4-3. Vent off any additional pressure in the PRM above the first stop depth indicated in the table. Transfer the rescuees and PRM attendants from the first sortie to the SDC at the first stop depth.

Sortie 2 (bottom half of Figure 5-4):

After venting off any excess PRM pressure above the DISSUB transfer depth, determine the EASD for Sortie 2. If the first stop depth for EASD 2 (or the PRM depth after venting) is greater than the SDC transfer depth for Sortie 1, compress the SDC to the first stop depth or the PRM depth whichever is shallower, then effect transfer to the SDC at that depth. Decompress rescuees on the EASD 2 schedule.

If the first stop depth for EASD 2 (or the PRM depth after venting), is equal to or less than the SDC transfer depth for Sortie 1, decompress the PRM to the SDC transfer depth for Sortie 1 as needed, then effect transfer. Decompress rescuees on the EASD 1 schedule.

PRM attendants will have performed back-to-back sorties. If the EAD of the attendants is greater than the EASD of the rescuee's schedule, attendants will start breathing oxygen at the same time as the rescuees. If EAD of the attendants is equal to or less than the EASD of the rescuee's schedule, the PRM attendants delay going on oxygen until later in the decompression. See Appendices M-Q for the times PRM attendants go on oxygen.

Example 6: (Back-to-Back Sorties)

The EASD for the first sortie is 101 fsw, but the actual DISSUB depth is only 80 fsw due to successful breathe down of the oxygen level. Transfer of rescuees and PRM attendants from the DISSUB to the PRM takes place at 80 fsw (DSUBTD1). The rescuees are eligible for the 110 fsw schedule (Table 4-3) which has a first stop at 80 fsw. Since the PRM is already at 80 fsw, no further decompression in the PRM is needed. Rescuees and PRM attendants are transferred to the SDC at 80 fsw (SDCTD1).

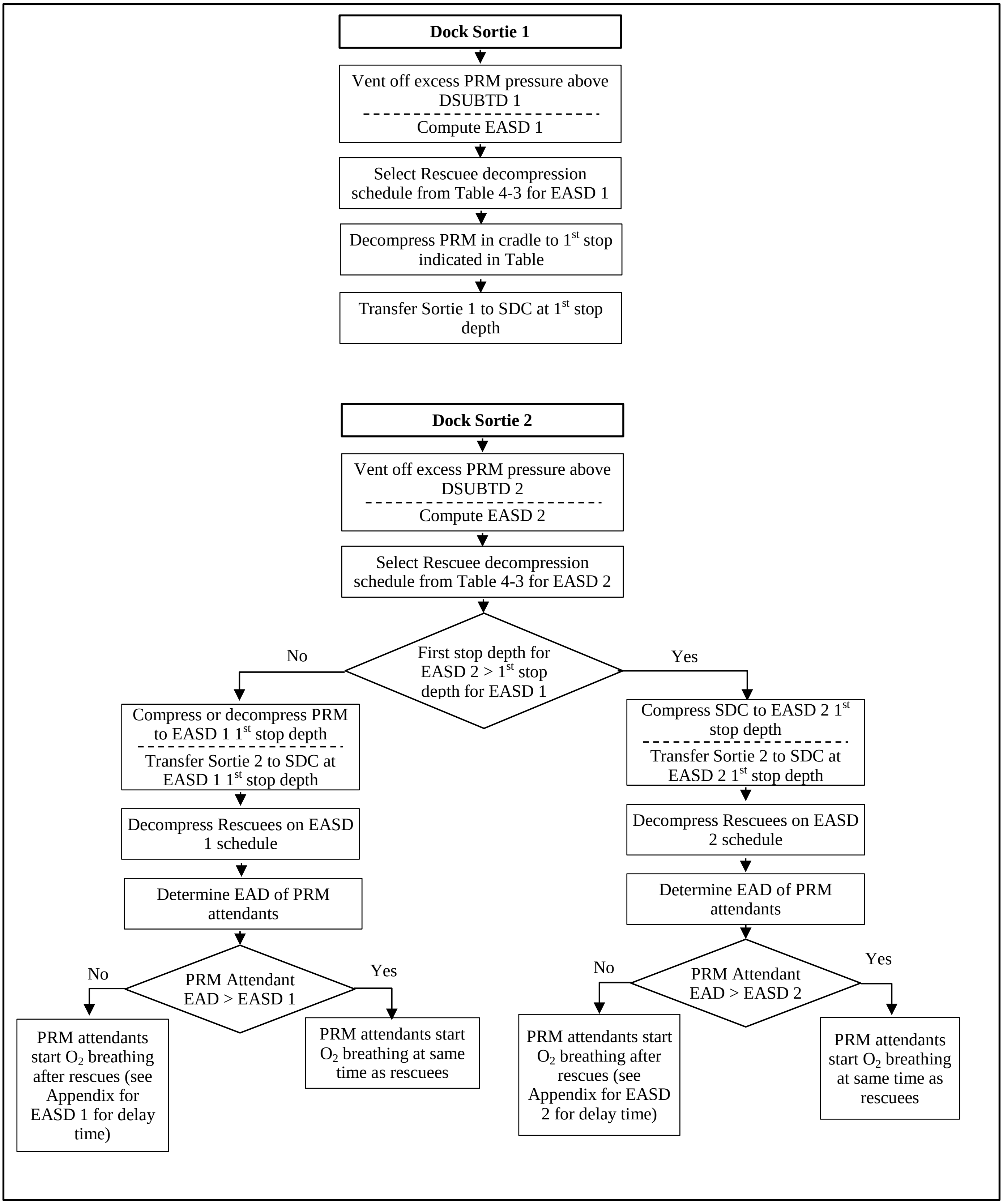

Figure 5-4. Dual Chamber (Hold) Mode, Back-To-Back Sorties, EASD 1 and EASD 2 81- 132 fsw

In the interim between the first and second sorties, the DISSUB rapidly cools from 70 °F to 60 °F. The DISSUB internal pressure accordingly falls from 80 fsw to 77.9 fsw (DSUBTD2). The PN2 in the DISSUB also falls causing the 360 min body tissue to give up nitrogen. The EASD declines from 101 fsw to 99.75 fsw. The second set of rescuees are eligible for decompression on the 100 fsw schedule which has a first stop at 75 fsw. However, the first set of rescuees require decompression on the 110 fsw schedule.

Upon docking in the cradle, the PRM is compressed from 77.9 fsw to 80 fsw. Rescuees and PRM attendants are transferred to the SDC at 80 fsw (SDCTD2). Decompression of the rescuees takes place on the 110 fsw schedule.

The PRM for both sorties maintained an air environment. The maximum PRM EAD therefore was 80 fsw. The PRM EAD is less than the EAD of the rescuee schedule (110 fsw). The PRM attendants begin breathing oxygen after the rescuees as shown in Appendix N.

(Note: This example shows that temperature changes in the DISSUB between sorties produce relatively minor effects.)

Chapter 6 - Emergency Surface Interval Decompression

There may be instances where the flexible manways and/or the Deck Transfer Lock become inoperative during a rescue or the SDC's cannot be delivered to the rescue scene in a timely manner. In this instance, DISSUB rescuees can be managed using Surface Interval Decompression Procedures. After docking in the cradle, rescuees and PRM attendants breathe oxygen in the PRM for a specified period, decompress to the surface, and transfer as quickly as possible in small groups to the pressurized SDC using the MTL as an elevator. A tender can be locked into the SDC via the MTL in advance to receive the rescuees. Rescuees may also be transferred to small recompression chambers resident on the VOO or adjacent platforms.

The Surface Interval Decompression Procedures are considered emergency procedures to be used only when it is impossible to conduct the rescue using approved transfer under pressure (TUP) techniques. These procedures have not been tested experimentally and the risk of using them is unknown. In addition, it has not been possible to develop a credible procedure for equivalent air depths deeper than 90 fsw.

6-1 Structure and Basis for Surface Interval Decompression Tables

The requirement for oxygen pre-breathing in the PRM starts with the 35 fsw EAD (EASD) table. No pre-breathing is required for depths shallower than 35 fsw. This depth cutoff is based on an analysis of bends onset times in the human saturation dives with direct, no-stop decompression to the surface.

At EAD's (EASD's) greater than 30 fsw, the oxygen pre-breathe time increases by 15 min for every 5 fsw increase in the EAD. The total pre-breathe time for the 60 fsw EAD table, therefore, is 90 min. The total pre-breathe time for the 90 fsw EAD table is 180 min. These times are based on bends rates observed during large animal saturation experiments with direct, no-stop decompression to the surface with and without oxygen pre-breathing.

For EADs from 35 to 60 fsw, oxygen pre-breathing takes place at the saturation depth. For EADs deeper than 60 fsw, the rescuees ascend to 60 fsw and begin pre-breathing there. The pre-breathing time for EAD's deeper than 60 fsw is also spread out over PRM depths of 60, 50 and 40 fsw to reduce pulmonary and CNS O2 toxicity risk.

Upon completion of the pre-breathe time, the PRM is surfaced as quickly as possible and the rescuees walk/run over to the awaiting chamber for recompression. There are two sets of tables, one for a surface interval of 30 min (Table 6-1) and one for a surface interval of 60 min (Table 6-2). The surface interval is the time from leaving depth in the PRM to arriving at 60 fsw in the deck recompression chamber. The PRM oxygen pre-breathing time is designed to minimize risk in a 60 min surface interval. This same pre-breathe time is used for the 30 min surface interval tables under the assumption that it will not be possible to know in advance how long the surface interval will be. The rescuees might easily miss a 30 min window due to unforeseen events or sea conditions if the recompression chamber is located off the VOO. If they are able to make the 30 min window, however, they will be rewarded with 30 min less oxygen time at 60 fsw. The Undersea Rescue Command (URC) estimates that up to 45 min will be required to transfer rescuees from the VOO to an adjacent platform (personal communication from LCDR Gertner, URC, to Dr. E. Flynn, NAVSEA 00C, 11 Oct 2010).

No provision is made for a surface interval exceeding 60 min. If the surface interval exceeds 60 min, the 60 min tables should be used regardless of the actual duration of the surface interval. If the surface interval does exceed 60 min, some decompression sickness may be observed before the recompression chamber is reached.

Regardless of the EAD and the duration of the surface interval, all rescuees are recompressed to 60 fsw. This is to immediately compress any bubbles formed during the decompression and surface interval to a smaller size.

For the 30 min surface interval, the required time on oxygen at 60 fsw is 30 min. This interval allows further time to reverse bubbling and put nitrogen back into solution. The 30 min at 60 fsw is considered dead time from the gas exchange standpoint, i.e., this time does not count toward satisfying the total oxygen decompression time specified by the model.

For the 60 min surface interval, the required time on oxygen at 60 fsw is 60 min. This interval allows a greater time for reversal of bubbling and tissue damage induced by the longer surface interval. The first 30 min period at 60 fsw is considered dead time. However, the second 30 min period counts towards satisfying the total oxygen decompression time specified by the model. In both cases, no adjustment of the printed tables is necessary.

If one or more rescuees develop decompression sickness during the first 30 min of the surface interval, the oxygen time at 60 fsw should be increased from 30 to 60 min even if the 30 min surface interval was met.

The chamber oxygen stop times are self-explanatory with the exception of the 30 fsw stop time which is fixed at 120 min whenever the calculated value is shorter than 120 min (25 fsw schedule is the exception). With 30-60 min of oxygen concentrated at 60 fsw and 120 min of oxygen concentrated at 30 fsw, the surface interval table has the look of a treatment table than a regular saturation decompression table despite the fact that the total oxygen times are nearly the same. This rearrangement of total oxygen time recognizes the fact that the surface interval may induce pathology that needs to be treated along with continued denitrogenation of the tissues.

The 25-60 fsw schedules are based on the total oxygen time required on the primary rescuee schedules in Table 4-1. These schedules feature a 120 min pre-breathe at the saturation depth prior to decompression. The surface interval decompression tables don’t require that much pre-breathing time so the stop time distributions on the two schedules look different. However, the total oxygen times are essentially identical once the 30 min dead time at 60 fsw is excluded. The final stop on these 25-60 fsw surface interval schedules is 20 fsw in all cases.

The 70-90 fsw schedules are based on the total oxygen time required for the 70-90 fsw primary rescuee schedules in Table 4-3. For the 90 fsw schedule, air time at 65 and 60 fsw was first converted to an equivalent oxygen time using a 3/1 conversion ratio then added to the actual oxygen time to arrive at the total oxygen time. The 70-90 fsw primary schedules have no mandated pre-breathing time prior to decompression. Hence the stop time distribution on the 70-90 fsw surface interval schedules look different than the stop time distribution on the primary schedules. However, the total oxygen times are identical once the 30 min dead time at 60 fsw is excluded. The last stop in the 70-90 fsw surface interval schedules is taken at 10 fsw to minimize pulmonary oxygen toxicity.

Table 6-3 compares Cumulative Pulmonary Toxicity Does (CPTD) described in Section 3-3, between the emergency Surface Interval Decompression schedules (Table 6-1 and 6-2) and the corresponding primary rescue schedules (Table 4-1 and 4-3).

Table 6-1. Surface Interval Decompression Table--30 min Surface Interval

Equivalent Air Depth (fsw)	Oxygen Pre-Breathe time in PRM (min)	Surface Interval (min)	Chamber Oxygen Time (min) 60 fsw	45 fsw	40 fsw	35 fsw	30 fsw	25 fsw	20 fsw
25	0	0-30	30				70	0	0
30	0	0-30	30				140	0	0
35	15	0-30	30				120	25	40
40	30	0-30	30			25	120	40	40
45	45	0-30	30		5	90	120	100	50
50	60	0-30	30		55	90	120	100	45
55	75	0-30	30	15	85	95	120	95	50
60	90	0-30	30	60	85	90	120	100	45

Equivalent Air Depth (fsw)	Oxygen Pre-Breathe time in PRM (min) 60 fsw	50 fsw	40 fsw	Surface Interval (min)	Chamber Oxygen Time (min) 60 fsw	50 fsw	45 fsw	40 fsw	35 fsw	30 fsw	25 fsw	20 fsw	15 fsw	10 fsw
70	90	30	0	0-30	30		0	20	65	120	80	85	95	100
80	60	60	30	0-30	30		10	60	65	120	75	85	90	110
90	60	60	60	0-30	30	3	55	60	65	120	75	85	95	110

Table 6-2. Surface Interval Decompression Table--60 min Surface Interval

Equivalent Air Depth (fsw)	Oxygen Pre-Breathe time in PRM (min)	Surface Interval (min)	Chamber Oxygen Time (min) 60 fsw	45 fsw	40 fsw	35 fsw	30 fsw	25 fsw	20 fsw
25	0	31-60	60				40	0	0
30	0	31-60	60				110	0	0
35	15	31-60	60				120	0	35
40	30	31-60	60				120	40	35
45	45	31-60	60		0	70	120	95	50
50	60	31-60	60		25	95	120	95	50
55	75	31-60	60		70	95	120	95	50
60	90	31-60	60	30	85	90	120	100	45

Equivalent Air Depth (fsw)	Oxygen Pre-Breathe time in PRM (min) 60 fsw	50 fsw	40 fsw	Surface Interval (min)	Chamber Oxygen Time (min) 60 fsw	45 fsw	40 fsw	35 fsw	30 fsw	25 fsw	20 fsw	15 fsw	10 fsw
70	90	30	0	31-60	60	0	0	55	120	80	85	95	100
80	60	60	30	31-60	60	0	40	65	120	75	85	90	110
90	60	60	60	31-60	60	28	60	65	120	75	85	95	110

Table 6-3. CPTD of Surface Interval Tables Compared to Primary Tables

EAD/EASD (fsw)	Primary Table	30 Min Surface Interval Table	60 Min Surface Interval Table
25	151	294	344
30	341	465	515
35	487	586	646
40	642	735	781
45	1044	1132	1175
50	1254	1337	1383
55	1479	1562	1591
60	1700	1779	1805
70	1482	1749	1785
80	1782	1968	1999
90	1830	2222	2247

6-2 Instructions for Use of Tables 6-1 and 6-2

1. Vent off any excess PRM pressure above the DISSUB transfer depth.
2. Calculate the rescuee's EAD. If the DISSUB atmosphere and pressure have not been reasonably stable for the preceding 48 hours, compute the EASD in accordance with Appendix B.
3. Enter Table 6-1 at the depth that is exactly equal to or next greater than the calculated EAD/EASD.
4. Determine the oxygen pre-breathing time that will be required in the PRM prior to decanting to the surface. This time is the same for Tables 6-1 and 6-2.
5. Oxygen pre-breathing will be conducted at the DISSUB transfer depth unless the transfer depth exceeds 60 fsw. If the DISSUB transfer depth exceeds 60 fsw, vent the PRM off to a depth of 60 fsw prior to starting the pre-breathing period. At EAD's of 80 and 90 fsw, some of the pre-breathing takes place at 50 and 40 fsw to minimize the risk of CNS oxygen toxicity.
6. Both PRM attendants and rescuees breathe oxygen for the same period of time prior to decanting.
7. At depths of 60 and 50 fsw, interrupt oxygen breathing every 30 min with a 5 min break on cabin air to minimize the risk of CNS oxygen toxicity. At 40 fsw, oxygen can be breathed for a full 60 min period without an air break. Air breaks are considered dead time and do not count toward the total oxygen time.
8. When oxygen time is specified at 50 and 40 fsw (70, 80 and 90 fsw EAD schedules), ascend from 60 to 50 fsw and from 50 to 40 fsw over a 5 min period while breathing cabin air (ascent rate = 2 fsw/min). The air break requirement will be satisfied during the ascent period, so the rescuee can resume oxygen breathing upon arrival at 50 or 40 fsw.
9. When all the PRM oxygen pre-breathing time has been completed, go off oxygen and surface the PRM at the fastest rate possible.
10. Once the surface is reached, transfer the rescuees to the awaiting recompression chamber as fast as possible. The surface interval is the time from leaving the final depth in the PRM to arriving at 60 fsw in the recompression chamber. If this interval is 30 min or less, use Table 6-2. If this interval is greater than 30 min or if one or more rescuees develop decompression sickness in the 30 min interval use Table 6-2.

11. In almost all cases, PRM attendants will have satisfied their decompression obligation by pre-breathing oxygen in the PRM along with the rescuees. These attendants do not need further recompression and can be diverted to other tasks. Other tenders will be required in the recompression chamber.
12. Recompress the rescuees as quickly as possible to 60 fsw. They will remain at 60 fsw for 30 or 60 min depending on the table. If the oxygen time at 60 fsw is 60 min, a 5-min air break should be inserted after 30 min on oxygen.
13. Upon completion of the 60 fsw oxygen time, switch to air and decompress to the first decompression stop over a 15 min period. This first stop depth will range from 30 to 45 fsw. Upon arrival at the first stop, resume oxygen breathing according to the schedule. Interrupt oxygen breathing every 60 min with a 15 min air break for the remainder of the decompression. Ascent rate between stops is 1-5 fsw/min (1 fsw/min preferred). Any oxygen breathed during ascent between stops can be included in the oxygen time for the subsequent stop.
14. All oxygen time prescribed by the table should be completed prior to surfacing. Air breaks are considered dead time and do not count toward the oxygen time.
15. Upon completion of the last stop (10 or 20 fsw), switch to air and surface at 1-5 fsw/min (1 fsw/min preferred).

6-3 Decompression of PRM attendants and Recompression Chamber Tenders.

In almost all instances, the oxygen pre-breathing time in the PRM will satisfy whatever decompression requirement the PRM attendants have. This requirement can be determined by computing the EAD of the PRM attendants and entering Tables 4-5 and 4-6 at the appropriate bottom time. To minimize the attendant's oxygen requirement, the PRM oxygen level should be controlled at 21% whenever possible, and PRM attendants should not enter a DISSUB with an EAD greater than the actual depth of the mate. Also, all sorties should go down unpressurized if at all possible.

If the PRM attendant's oxygen requirements exceed those given in Tables 6-1 and 6-2, the PRM oxygen time should be extended to match that additional requirement. Recompressing PRM attendants along with rescuees is undesirable because of the limited space available in the small recompression chambers.

Note: At DISSUB EAD's of 70-90 fsw, Table 4-6 may not show the full four hour range of bottom times for PRM attendants. This is due to limitations on oxygen breathing time at 60 fsw. For the surface interval schedules, however, oxygen breathing in the PRM is spread out between 60, 50, and 40 fsw to reduce the risk of CNS oxygen toxicity. This situation is not covered by Table 4-6. Table 6-4 shows the maximum bottom time that will still allow PRM attendants to surface without a remaining decompression obligation if they pre-breathe oxygen as prescribed by the rescuee's schedule.

Table 6-4. Allowable Bottom Times for PRM Attendants Breathing Oxygen on the 70-90 fsw DISSUB Surface Interval Tables.

Surface Interval Table EAD	PRM EAD (fsw)	Maximum Bottom Time (min)
70 fsw	70	230
	80	180
80 fsw	80	220
	90	190
90 fsw	90	220
	100	190

Recompression chamber tenders should be handled using the rules for an extended Treatment Table 6 in Chapter 20 of the Diving Manual [4]. Oxygen breathing times should be marked off from the end of the Tables 6-1 and 6-2, i.e., required oxygen breathing should be completed just prior to surfacing. If the tenders have performed repetitive exposures their oxygen breathing times should be extended according to the Diving Manual rules. New tenders are not required in the chamber when the old tenders go on oxygen.

Chapter 7 - Treatment of DCS In Rescuees and Tenders

7-1 DISSUB Internal Pressure 60 fsw or Less:

7-1.1 Decompression Sickness (DCS) in Saturated Rescuees:

Rescuees undergoing saturation decompression from depths of 60 fsw or less are unlikely to develop decompression sickness while still under pressure. Symptoms of DCS will generally occur 2-8 hours after surfacing. By this time, rescuees will have been transferred off the rescue platform and should be further evacuated to distant treatment facilities as required. These individuals will not be treated in the SRS.

7-1.2 Decompression Sickness or Arterial Gas Embolism (AGE) in PRM Attendants and SDC Tenders:

At depths of 60 fsw or less, PRM Attendants and SDC Tenders are managed in a way that avoids the need for saturation decompression. These attendants and tenders will lock out of the SDC via the MTL after a variable period of oxygen breathing at depth.

PRM Attendants and SDC Tenders are an integral part of the rescue team and have many duties in addition to serving as tenders. They should be recompressed in the MTL/DTL as availability permits and returned to duty. If the MTL/DTL is unavailable, these individuals will have to be evacuated off the platform for treatment. Return to duty after distant treatment will be judged on an individual case basis.

The risk of decompression sickness during non-saturation SDC lock in/lock out evolutions ranges from 0.8 to 6.4% according to the BVM(3) probabilistic model [13]. These estimates are undoubtedly on the high side because the model assumes divers at work rather than tenders at rest. Rescue at 60 fsw constitutes the worst case. Based on the planned rotation of PRM attendants and SDC tenders at 60 fsw, a maximum of 2.8 cases of DCS can be expected in Attendants and Tenders during the rescue of 155 survivors.

During certain phases of the rescue operation at 60 fsw or less, the MTL will be occupied by individuals transferring in and out of the SDC. At other times, especially the tail end of saturation decompression, the MTL will be empty for relatively long periods of time (9 hours in the case of the 60 fsw decompression). The DTL will also be empty for approximately 4 hours during each sortie.

The Senior Diving Medical Officer (DMO) present may modify Treatment Tables 5 and 6 to match MTL/DTL availability. Treatments may be shortened or split into parts. Clinical trials during the development of Tables 5 and 6 showed the minimum requirement for successful treatment to be: (1) a full treatment depth of 60 fsw, (2) at least 30 min on oxygen at 60 fsw, and (3) at least 90 min total oxygen breathing time. [14]

The probability of an arterial gas embolism during lock outs from the SDC is very low. AGE during the course of a rescue will be a rare event. However, the severity of symptoms will mandate immediate recompression in the MTL/DTL, if at all possible. Ninety percent of AGE cases will respond to standard recompression treatment on USN Treatment Table 6. About 10% will require additional recompression to 165 fsw on USN Treatment Table 6A. Treatment for AGE may be modified to match MTL/DTL availability as outlined above. If immediate AGE treatment is not available in the MTL/DTL, the AGE case will be evacuated off the platform for treatment.

7-1.3 Decompression Sickness in DISSUB Entry Team (DET) Members:

DISSUB Entry Team members will be saturated and will undergo the same saturation decompression as the rescuees. The total number of DET crew members at 60 fsw or less will range from 1-6. The risk of DCS following saturation decompression can be estimated at 5%. Thus, six DET crew members would be expected to produce 0.3 cases of DCS. If a case does occur, it will occur 2-8 hours after surfacing.

DET crew members are a vital part of the rescue team. A DET crew member with DCS should be recompressed in the MTL/DTL as availability permits and returned to duty. If the MTL/DTL is unavailable, this individual will have to be evacuated off the platform for treatment. Return to duty after distant treatment will be judged on an individual case basis. Based on experience, Treatment Table 6 should suffice to resolve symptoms of saturation DCS. Table 6 may be modified to match MTL/DTL availability as outlined above.

7-1.4 Total Requirement:

Considering the risks of DCS and AGE in PRM Attendants, SDC Tenders and DET crew members, the maximum number of cases requiring recompression treatment in the MTL/DTL should not exceed 3. In terms of treatment tables, the capability to perform one Treatment Table 5, one Treatment Table 6, and one Treatment Table 6A should suffice. Assuming a respiratory minute ventilation of 0.35 actual cubic feet per minute at 68 °F, 452 standard cubic feet of oxygen (68 °F) will be required to support these three treatments.

7-2 DISSUB Internal Pressure 61-132 fsw

7-2.1 Decompression Sickness (DCS) in Saturated Rescuees**:**

Rescuees undergoing saturation decompression from depths deeper than 60 fsw may develop decompression sickness while still under pressure. The likelihood of DCS under pressure increases as the saturation depth increases. Symptoms are most likely to appear at 10-15 fsw. These patients can be treated using a modified version of the minimal recompression procedures for saturation DCS outlined in Chapter 15 of the Diving Manual.

- If two or fewer individuals are involved, these individuals can be recompressed 5-15 fsw in the MTL and treated on oxygen for two hours while the remaining crew continues the planned decompression in the SDC. Upon completion of the two hour treatment, these individuals can be decompressed at 1 fsw/min to the current SDC depth and rejoin the remaining crew in the SDC for completion of saturation decompression.
- If more than two individuals are involved, all the SDC occupants can be recompressed together to treatment depth in the SDC. Upon completion of a two hour oxygen treatment, the SDC can be decompressed at 1 fsw/min to the depth/time point in the original schedule that would have been reached if no treatment had taken place. The planned saturation decompression can continue from that point.
- Oxygen breathing during recompression treatment may make completion of the saturation decompression schedule on oxygen undesirable from the pulmonary oxygen toxicity standpoint. Saturation decompression after treatment may have to be completed on air.

The probability that decompression sickness will occur in the rescuees during or following saturation decompression can be estimated at 5%. For 155 rescuees, therefore, a total of 8 cases of DCS can be expected. At depths greater than 60 fsw, some proportion of the 8 cases will occur under pressure and will require treatment in the MTL or SDC before surfacing. This proportion will increase as the saturation depth increases. Risk modeling indicates that at 90 fsw, 4 of the 8 cases will occur under pressure. At 132 fsw, 5 of the 8 cases can be expected to occur under pressure. The remaining 4 and 3 cases respectively will present after the rescuees surface, most likely after they have been transferred off the rescue platform. These individuals should be evacuated to distant treatment facilities as required. Rescuees presenting with DCS after surfacing will not be treated in the SRS.

7-2.2 Decompression Sickness in PRM Attendants, Custodial Tenders, DISSUB Entry Team Members, and Terminal Tenders:

At depths greater than 60 fsw, each chamber load will contain 2 PRM attendants and 1 Custodial Tender if back-to-back sorties are performed. This is always the case at 90 fsw and deeper. These individuals will not be fully saturated like the rescuees, but they also undergo a shorter oxygen decompression than the rescuees. Their risk for DCS can be estimated at 5%. With 6 chamber loads there will be 18 attendants/custodial tenders at risk. The total number of expected cases of DCS therefore is 18 x 0.05 = 0.9 cases.

DISSUB Entry Team Members at most depths will be fully saturated like the rescuees and will undergo the same oxygen decompression. Their risk of DCS can be estimated at 5%. However beginning at approximately 110 fsw, the DISSUB entry stay times will be reduced due to oxygen toxicity concerns and DET members will not be fully saturated when they start decompression with the rescuees. Their risk of DCS will be lower than for the rescuees. Four percent is a reasonable estimate. Two representative depths can be considered:

1. At 90 fsw, nominally 8 DET members will be required to perform the mission (See Appendix M). The number of expected DCS cases, therefore, is 8 x 0.05 = 0.40 cases.
2. At 132 fsw, nominally 12 DET members will be required to perform the mission (See Appendix Q). The number of expected DCS cases, therefore, is 12 x 0.04 = 0.48 cases.

Terminal Tenders also incur a risk of decompression sickness that varies with the depth of the decompression schedule. For the 90 fsw schedule, the average risk of DCS by the BVM(3) probabilistic model is 2.8% taking into consideration that terminal tenders are used on a repetitive basis. At 132 fsw, the average risk is 2.6%. With 6 chamber loads, a total of 12 terminal tenders will be required. The number of expected cases at 90 fsw, therefore, is 12 x 0.028 = 0.34 cases. The number of expected cases at 132 fsw is 12 x 0.026 = 0.31 cases.

Adding these numbers up, the total number of expected cases in attendants, custodial tenders, DET members and terminal tenders is 1.64 cases at 90 fsw and 1.69 cases at 132 fsw. Both estimates can be rounded up to 2 cases. The two cases are most likely to occur after surfacing and would be treated on the VOO with a full or modified Treatment Table 6, depending on MTL/DTL availability. If the MTL/DTL is unavailable, the two cases would be evacuated off the platform for treatment.

7-2.3 Total Requirement:

At depths deeper than 60 fsw, the number of cases of DCS presenting under pressure and requiring modified saturation DCS treatment in the MTL/SDC could range from 0-5 depending on the depth of the saturation. The number of cases requiring treatment with Treatment Table 6 after surfacing is estimated at 2. One saturation DCS treatment in the MTL at a depth of 30 fsw with 2 hours of open-circuit oxygen breathing will require 74.1 standard cubic feet of oxygen (1 ATA, 68 °F). This figure takes into account a savings of 6 standard cubic feet of oxygen related to the fact that the individual is no longer breathing from the MBS 2000 while the treatment is underway. One Treatment Table 6 without extensions will require 179.5 standard cubic feet of oxygen (1 ATA, 68 °F). The total requirement for treatment oxygen at representative depths of 90 and 132 fsw, therefore, can be summarized as follows:

90 fsw: (4 cases)*(74.1) + (2 cases)*(179.5) = 665.4 standard cubic feet

132 fsw: (5 cases)*(74.1) + (2 cases)*(179.5) = 729.5 standard cubic feet

Table 7-1 summarizes the total number of cases expected on the VOO during saturation decompression and on and off the VOO after surfacing.

Table 7-1. Number of Personnel Requiring Recompression Treatment

Equivalent Air Depth		After Surfacing	
	During Decompression	On VOO	Off VOO
60 fsw	0	3	8
90 fsw	4	2	4
132 fsw	5	2	3

Chapter 8 - References

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Appendix A. Instructions for Computing PRM Attendant and SDC Tender Decompression Schedules Using the U.S. Navy Thalmann Algorithm Dive Planner, Version 4.03.

A-1. Introduction.

The Thalmann Algorithm Dive Planner computes decompression schedules for divers in a wide variety of circumstances. Although it was not designed specifically for submarine rescue, the Planner can be used to compute decompression schedules for PRM attendants and SDC tenders, albeit with extra effort due to the iterative nature of the calculation. These attendant tender schedules differ from diver schedules in that most if not all of the decompression obligation is satisfied by breathing oxygen at the current depth of the SDC rather than by decompression in the Modified Treatment Lock (MTL). Breathing oxygen at depth keeps the MTL's open to allow other tenders, in particular transfer and medical tenders, to lock in and out of the chamber. The Dive Planner also allows repetitive dives to be planned with an explicit consideration of the risk of decompression sickness involved.

A-2. Setting Up the Dive Planner for Submarine Rescue Operations

1. Install the Thalmann Algorithm Dive Planner for Windows, Version 4.03 following the instructions in Chapter 1 of the User's Manual.[15] Install the programs contained in the NAVSEA folder on the CD. The SPECWAR version of the Dive Planner does not have the full capability needed for the SRDRS application.
2. It will be necessary to make two changes to the existing Dive Planner files in C:/Program Files/Dive Plan before getting started:

    a) Edit the VVal18M.MPF file to produce a new model parameter file labeled DISSUB.mpf
    b) Edit the Dive Plan.ini file to disable the LIO option.

3. Edit VVal18M.MPF. Using Windows Explorer, identify and click on the VVal-18M model parameter file, VVal18M.MPF in C:/Program Files/Dive plan. Create a copy of this file and rename it DISSUB. Open the new file with Notepad. On the 4th line, change O2 Ceil from 30.0 to 60.0. Click Save on the Menu Bar under File. This change allows oxygen to be breathed as deep as 60 fsw on in-water oxygen decompression and also to invoke a decrease in the saturation desaturation ratio from 1.0 to 0.7 whenever oxygen is breathed at a depth of 60 fsw or shallower.
4. Edit Dive Plan.ini. Using Windows Explorer, identify and click on Dive Plan.ini in C:/Program Files/Dive Plan. This file is labeled as a configuration file. Create a copy of this file in the Dive Plan directory for future use in restoring the Dive Planner to its original purpose. Open Dive Plan.ini using Notepad. Under the heading Options in the file, change LIO_Enabled=1 to LIO_Enabled=0. On the menu bar, click File then Save to save this change. Elimination of the LIO option frees up space in the Gas Mix box and eliminates the need for scrolling in this box at run time. This change is made to reduce the number of gas mix options, but is not essential.
5. Run the Dive Planner following the instructions given in Chapters 2-6 of the User's Manual. The following are specific instructions for creating SRDRS tender schedules at Run Time:

    a) The Dive Planner can handle multiple divers under a single dive profile. However it is probably best to create an individual dive profile for each PRM attendant and SDC tender as they are likely to have a complicated dive history during the course of the rescue. This profile can be identified by the attendants first and last name rather than a depth/bottom time combination or some other event marker during the rescue. This individual file can be edited and updated as the rescue proceeds.

b) The attendants and tenders will breathe oxygen using the MBS 2000. The minimum time-weighted average oxygen (TWA O2) is 90%. On the tool bar, click on the 3 bottle “Add Mix” button (6th from left). The Add Gas Mix dialog box will appear:

(1). Type 90% Oxygen in the Gas Mix Label box.
(2). Select Constant O2 fraction (open-circuit). The program will ask for the fraction of oxygen.
(3). Type 90 in the Enter Constant O2 Fraction box.
(4). Click on Line Color.
(5). Click on the box in the third column and third row on the color matrix to select medium green for 90% oxygen. Click OK.
(6). The program will indicate that selected color is already in use for Air IWO2D, use anyway. Click yes.
(7). Click Accept
(8). 90% Oxygen will appear in the Gas Mix box in the Data Entry Section at the bottom of the screen.

c) The DISSUB Model Parameter File matrix will be used to decompress attendants and tenders. On the menu bar, select Options, then Global. Move the cursor to the right and click on Change Model Parameter File. Click on DISSUB, then click Open. The model parameter file at the mid-right above the DCS risk estimate line will indicate that DISSUB has been selected.

d) On the menu bar, select Options then Global again. Move the cursor to the right and click on Include Travel Times in Stop Times. This will mimic the behavior of the tables in Chapter 9 of the Diving Manual.

6. The following examples show how to compute the decompression requirement in several typical scenarios.

A-3. Example 1: Single-Level PRM Attendant Schedule

1. Consider a PRM attendant who makes a dive to an equivalent air depth of 45 fsw in the PRM. The actual depth in the PRM is also 45 fsw. The total bottom time including transfer from the PRM to the SDC before going on oxygen at 45 fsw is 240 min.
2. Construct the dive profile prior to the onset of oxygen breathing by entering the data for the initial dive segment in the Data Entry Section:

a) Enter the Depth of the segment (fsw), in this case 45 fsw.
b) Enter the Time spent at depth during the segment (min), in this case 240 min.
c) Enter the Gas Mix breathed by the attendant during the segment, in this case Air because we are using the Equivalent Air Depth to characterize the depth of the PRM attendant’s exposure.
d) Enter the Ascent Rate to be used for travel to the segment if the segment is shallower than the preceding segment. The default ascent rate is 30 fsw/min. In this case, this entry is inoperative because no ascent will take place prior to going on oxygen.

e) Enter the Descent Rate to be used for travel to the segment if the segment is deeper than the preceding segment or the tender is descending from the surface. The default descent rate is 60 fsw/min. In this case the 60 fsw/min will apply since the PRM attendant starts at the surface.

f) Click on Enter Data in the Actions Section. The initial exposure profile will appear in the graphical portion of the display.

(Note: The Dive Planner usually does not include descent or ascent time in segment time. The full time entered for a segment is spent at the depth of the segment. The singular exception is for dive segments that originate at the surface. For those segments, descent time is subtracted from the entered segment time making the actual time spent at depth less. See Page 27 of the Instructions for more detail on this feature.)

3. The decompression stop display indicates that a 65 min stop of on air at 10 fsw would be required if the attendant elected to ascend to the surface on air at 30 fsw/min.
4. Click on 90% oxygen in the Gas Mix box. The decompression stop display now changes to 31 min on oxygen at 10 fsw, indicating that ascent on 90% oxygen at 30 fsw/min would require a 31 min stop on oxygen at 10 fsw. The total ascent time (TAT) on oxygen is shown in the box to the far left of the decompression stop display. This is 33 min.
5. Use 33 min as an initial estimate of the total time on oxygen at 45 fsw that will be required to satisfy the attendant's decompression obligation. Enter a second segment in the Data Entry Section as follows: Depth = 45 fsw, Bottom Time = 33 min, Gas Mix = 90% Oxygen, Ascent Rate = 30 fsw/min, Descent Rate = 60 fsw/min. Click on Enter Data.
6. The decompression stops display indicates that no stops will be required if ascent to the surface occurs on 90% oxygen at 30 fsw/min following 33 min on oxygen at 45 fsw.
7. Click on Air in the Gas Mix Box. The decompression stop display indicates that a 2 min stop on air at 10 fsw would be required if the attendant switched from 90% oxygen to air at 45 fsw and then immediately ascended to the surface on air at 30 fsw/min.
8. For all decompressions in which oxygen is breathed initially at depth, a 3 min break on air at depth must added following the oxygen time at depth to allow the attendant to secure the MBS 2000 and make his way from the SDC to the MTL to begin decompression. This extra 3 min time on air at depth will alter the attendant's required oxygen time at depth.
9. It is clear that 33 min of oxygen at 45 fsw will not allow an ascent to the surface on air at 30 fsw/min without decompression stops either with or without the mandatory 3 min period on air at 45 fsw. The oxygen time at 45 fsw therefore must be titrated until the remaining no-decompression time on air at 45 fsw is 3 min or greater.
10. Erase the last data entry with 33 min of 90% oxygen then add a new entry with 34 min of oxygen. Click on Air. The decompression stops display shows no stops are required on air. The No-Decompression Time Box indicates that the remaining No-D time on air at 45 fsw is 0 min. This time must be increased to 3 min or greater.
11. Erase the last data entry with 34 min of 90% oxygen and add a new entry of 35 min of oxygen. Click on Air. The decompression stops display indicates no stops are required on air. The No-Decompression Time Box indicates that the remaining No-D time on air at 45 fsw is 2 min. 3 min is the minimum requirement.
12. Erase the last data entry with 35 min of 90% oxygen and add a new entry of 36 min of oxygen. Click on air. The decompression stops display again indicates that no stops are required on air.

The No-Decompression Time Box indicates that the remaining No-D time on air at 45 fsw is 4 min, more than enough to accommodate a 3 min transit on air from the SDC to the MTL.

13. Add a 3rd dive segment as follows: Depth = 45 fsw, Bottom Time = 3 min, Gas Mix =Air, Ascent Rate = 30 fsw/min, Descent Rate = 60 fsw/min. The No-Decompression Time Box indicates that 1 min of no-decompression time on air remains at 45 fsw, as expected.
14. Click on the “S” button to surface the PRM attendant. (This can also be done by entering a 4th dive segment with Depth = 0 fsw, Bottom Time = 0 min, Gas Mix = Air, Ascent Rate = 30 fsw/min, Descent Rate = 60 fsw/min). The graphical display shows a no-stop ascent to the surface on air.
15. Click on the Display Dive History button in the Actions Section. Then click on Show Stops. Verify that no decompression stops are required. (Any stops will be shown in parenthesis.) This step is required because the graphical display may not clearly show required stops when the dive profile is very long. The absence of stops may also be verified by clicking on All Nodes w/elapsed Time, where the exact details of the dive profile are shown.
16. Close the Display Dive History dialog box. Note that the Repetitive Group Designator for this dive, shown at the top right of the display is Z. The Time to Clean on Air is 1437 min.

Warning: When a PRM attendant or SDC tender satisfies his entire decompression obligation by breathing oxygen at depth and is in a No-Decompression status when the ascent command is given, the Dive Planner will display a repetitive group designator that is technically correct but may not be adequate to support repetitive diving using the tables in Chapter 9 of the Diving Manual. If the Time to Clean on Air indicated by the Planner is greater than 1400 min, consider the repetitive group designator shown to be “Out-of Range”.

17. The risk of decompression sickness following this dive is shown in the middle of the display on the right above the decompression stop display. The risk of DCS according to the NMRI 98 probabilistic model[12] is 4.717%. On the tool bar, click on the Dice button, 8th button from left. A dialog box will open. Click on BVM(3), then Open. The estimate of DCS risk by the BVM(3) probabilistic model[13] will then replace the estimate by the NMRI 98 probabilistic model. For this dive the BVM(3) risk is 3.344%. Note that when oxygen is breathed at depth, the risk of DCS by the NMRI 98 model will generally be higher than by the BVM(3) model. This is because the NMRI 98 model considers that some of the oxygen breathed at depth behaves as nitrogen and therefore contributes to the DCS risk.
18. In summary following an exposure to an equivalent air depth of 45 fsw for 240 min, the PRM attendant will have to breathe 90% oxygen from the MBS 2000 at 45 fsw for 36 min. The attendant can then take 3 minutes to secure the MBS 2000 and enter the MTL to decompress to the surface on air at 30 fsw/min.

A-4. Example 2: Multi-Level PRM Attendant Schedule.

1. Consider a PRM attendant who mates with the DISSUB at an actual depth of 47.5 fsw. Initially his equivalent air depth is 47.5 fsw. After a 15 min exposure, the PRM attendant enters the DISSUB which is at 47.5 fsw but still has an equivalent air depth of 60 fsw because the crew has breathed down the PO2 to 0.2 atm. The PRM attendant takes 1 minute to enter the DISSUB then spends the next 30 min at the higher equivalent air depth. At the end of this time, the PRM attendant takes another minute to climb back into the PRM. While he was in the DISSUB, the equivalent air depth of the PRM increased from 47.5 fsw to 50 fsw as some of the DISSUB atmosphere mixed with the PRM atmosphere. He spends the next 103 min at an equivalent air

depth of 50 fsw while the rescuees are loaded into the PRM and the PRM ascends and mates with the DTL. After mating with the DTL at a transfer depth of 47.5 fsw, the attendant takes 1 minute to exit the PRM and 4 minutes to enter the SDC and start breathing oxygen from the MBS 2000.

2. Enter the following segments for this dive into the Dive Planner:

	Depth	Bottom Time	Gas Mix	Descent Rate	Ascent Rate
Segment 1	47.5	15	Air	60	30
Segment 2	60.0	0	Air	12.5	30
Segment 3	60.0	30	Air	60	30
Segment 4	50.0	0	Air	60	10
Segment 5	50.0	103	Air	60	10
Segment 6	47.5	0	Air	60	2.5
Segment 7	47.5	4	Air	60	30

Note that the proper Depth entry is the Equivalent Air Depth not the actual depth of the PRM or DISSUB (unless these two depths happen to be equal because the fractional concentration of nitrogen in the PRM or DISSUB is 79%). Once the attendant has entered the DTL/SDC the equivalent air depth and the actual depth will always be equal as these two compartments are pressurized and ventilated with air.

Between Segments 1 & 2, 3 & 4, and 5 & 6, there is a change in the equivalent air depth, but no change in the actual depth. These changes in EAD are handled as “descents” and “ascents” even though no physical change in the actual depth occurs. Increases in EAD are considered descents; decreases in EAD are considered ascents. The rate of change in EAD is computed off line then entered as a descent or ascent as appropriate. For example in Segment 2, the PRM attendant descends from 47.5 to 60.0 fsw (12.5 fsw) in 1 minute. The descent to Segment 2 takes place at 12.5 fsw/min. When the rate for a segment has computed and entered, the bottom time for that segment can be entered as zero or as the actual time it takes to make the transition. Either approach gives an identical result. When a new segment is added that does not have a uniquely calculated descent or ascent rate, it is best to restore the default rates of 60 fsw/min descent and 30 fsw/min ascent for that segment. This is especially true for the ascent rate. Failure to restore the ascent rate to 30 fsw/min can lead to a false estimation of the decompression required when the operator toggles between oxygen and air.

3. After entering Segment 7, the Decompression Stop Display will show a 41 min stop on air at 10 fsw. Click on 90% Oxygen. The display will now show a total ascent time of 22 min on oxygen. Use this as an initial estimate of the time required on oxygen at 47.5 fsw. Enter:

	Depth	Bottom Time	Gas Mix	Descent Rate	Ascent Rate
Segment 8	47.5	22	90 % Oxygen	60	30

4. Click on Air. The remaining no-decompression time is 1 min which is shorter than the 3 minutes necessary to secure the MBS 2000 and move into the MTL. Erase the 22 min segment and enter a new 23 min segment on 90% oxygen. Click on Air. The remaining no-decompression time is now 3 minutes, exactly the amount of time required.

5. Enter a 3 min segment on air at 47.5 fsw. The no-decompression time now correctly shows zero no-decompression time remaining. Click on the "S" button to surface the PRM attendant. (This can also be done by entering a 10th dive segment with Depth = 0 fsw, Bottom Time = 0 min, Gas Mix = Air, Ascent Rate = 30 fsw/min, Descent Rate = 60 fsw/min). The graphical display shows a no-stop ascent to the surface on air.
6. Click on the Display Dive History button in the Actions Section. Then click on Show Stops. Verify that no decompression stops are required. (Any stops will be shown in parenthesis.) This step is required because the graphical display may not clearly show required stops when the dive profile is very long. The absence of stops may also be verified by clicking on All Nodes w/elapsed Time, where the exact details of the dive profile are shown.
7. Close the Display Dive History dialog box. Note that the Repetitive Group Designator for this dive is Z. The Time to Clean on Air is 1268 min.
8. The risk of DCS on this multi-level dive is 3.960% by the NMRI 98 probabilistic model and 2.234% by the BVM(3) probabilistic model.
9. In summary, following this multi-level exposure to equivalent air depths of 47.5, 60.0 and 50.0 fsw in the PRM and DISSUB, the PRM attendant will have to breathe 90% oxygen from the MBS 2000 for 23 min in the SDC at a depth of 47.5 fsw. The attendant can then take 3 minutes to secure the MBS 2000 and enter the MTL to decompress to the surface on air at 30 fsw/min.

A-5. Example 3: PRM Attendant Schedule with Air Breaks and Two Level Decompression.

1. Consider a PRM attendant who makes a dive to an equivalent air depth of 70 fsw for 240 min. Transfer to the DTL/SDC takes place at 60 fsw.
2. Enter the first dive segment with a depth of 70 fsw, a bottom time of 240 min, a gas mix of Air, descent rate of 60 fsw/min and ascent rate of 30 fsw/min. The decompression stops display shows that 25 min stop on air is required at 30 fsw, followed by an 80 min stop at 20 fsw, and a153 min stop at 10 fsw.
3. Click on 90% Oxygen. The decompression stop display now shows the required stops if decompression on 90% oxygen is undertaken. These stops are 11 min at 30 fsw, 35 min at 20 fsw, and 61 min at 10 fsw, for a total ascent time on 90% oxygen of 109 minutes.
4. The goal is to satisfy as much of the decompression requirement as possible by breathing oxygen at depth rather than during decompression stops. For depths of 40 fsw and shallower, there is no limit to the amount of time that can be spent breathing oxygen. For deeper depths, the following oxygen time limits should generally be observed to minimize the risk of CNS oxygen toxicity:

Table A-1. Oxygen Time Limits

Depth (fsw)	Oxygen Time Limit (min)
45	240
50	180
55	120
60	90

If these oxygen times are insufficient to satisfy the full decompression obligation, then additional oxygen decompression time must be spent at 20 fsw. For the 60 fsw transfer depth, the oxygen time is limited to 90 min.

5. We first need to ascend from 70 to 60 fsw in the PRM at 5 fsw then allow an additional 5 min for transfer to the SDC to start oxygen breathing. Enter:

	Depth	Bottom Time	Gas Mix	Descent Rate	Ascent Rate
Segment 2	60.0	0	Air	60	5
Segment 3	60.0	5	Air	60	30

6. The estimated oxygen requirement at 60 fsw is 109 min which is longer than the 90 min recommended exposure time. Oxygen at 60 fsw will be breathed in 30 min periods separated by 5 min air breaks. Enter the following segments to equal 90 min of oxygen breathing at 60 fsw:

	Depth	Bottom Time	Gas Mix	Descent Rate	Ascent Rate
Segment 4	60.0	30	90 % Oxygen	60	30
Segment 5	60.0	5	Air	60	30
Segment 6	60.0	30	90 % Oxygen	60	30
Segment 7	60.0	5	Air	60	30
Segment 8	60.0	30	90 % Oxygen	60	30
Segment 9	60.0	3	Air	60	30

Segment 9 is the 3 min period on air required to secure the MBS 2000 and transfer to the MTL for decompression. At the end of this segment, the decompression stops display shows that a 79 min stop on air is required at 10 fsw.

7. To complete the oxygen decompression at 20 fsw, enter:

	Depth	Bottom Time	Gas Mix	Descent Rate	Ascent Rate
Segment 10	0	0	AirIWO2D	60	30

8. The graph shows that two oxygen periods are required at 20 fsw to satisfy the decompression obligation. These two periods are separated by a 5 min air break.
9. Click on the Display Dive History button in the Actions Section. Then click on All Nodes w/ Elapsed Time. The length of each oxygen period at 20 fsw will be shown. The first oxygen period is 30 min; the second is 11 min. The air break between them is 5 min.
10. Close the Display Dive History dialog box. Note that the Repetitive Group Designator for this dive is “Out of Range”. The Time to Clean on AirIWO2D is 1693 min.
11. The risk of DCS on this dive with part of the decompression at 60 fsw and the remainder at 20 fsw is 4.747% by the NMRI 98 probabilistic model and 4.090% by the BVM(3) probabilistic model.
12. In summary, this 240 min dive at an equivalent air depth of 70 fsw required 90 min of oxygen breathing at 60 fsw followed by 41 min of oxygen at 20 fsw. All oxygen periods were separated by 5 min air breaks. Three minutes was allowed to secure the MBS 2000 and enter the MTL for

the second portion of the decompression. This 3 minutes plus the time to ascend from 60 fsw to 20 fsw on air at 30 fsw/min in the MTL (1.3 min) constituted the air break between the last O2 period at 60 fsw and the first O2 period at 20 fsw. Upon completion of the last O2 period at 20 fsw, the PRM attendant ascended to the surface at 30 fsw/min breathing air

A-6. Example 4: Repetitive Dive of Pre-Breathe Tender at 60 fsw.

1. Consider a Pre-Breathe Tender at who has a 170 min exposure to air at 60 fsw, then decompresses to 45 fsw on air at 1 fsw/min and starts oxygen breathing according to the 60 fsw 170 min pre-breathe tender schedule (Table J-2, Appendix J). What is the risk to the pre-breathe tender if he performs the identical dive on the second, third, or fourth chamber run?
2. Enter the dive profile for the first dive:

	Depth	**Bottom Time**	**Gas Mix**	**Descent Rate**	**Ascent Rate**
Segment 1	60.0	170	Air	60	30
Segment 2	45.0	0	Air	60	1
Segment 3	45.0	30	90% Oxygen	60	30
Segment 4	40.0	0	90% Oxygen	60	1
Segment 5	40.0	21	90% Oxygen	60	30
Segment 6	40.0	3	Air	60	30
Segment 7	0	0	Air	60	30

The graphical display shows direct ascent to the surface without stops.

3. 3. Click on the Display Dive History button in the Actions Section. Then click on Show Stops. This will verify that no additional decompression stops on air are required on the way to the surface.
4. Close the Display Dive History dialog box. Note that the Repetitive Group Designator for this dive is Z. The Time to Clean on Air is 1438 min.
5. The risk of DCS on this multi-level dive is 4.164% by the NMRI 98 probabilistic model and 3.081% by the BVM(3) probabilistic model.
6. If the pre-breathe tender performed this dive on the first chamber run and the sortie time was 6 hours, the surface interval between the first and second dives would be 475 min if the tender made the same dive on the second chamber run, 1195 min if he made the same dive on the third chamber run, and 1915 min if he made the same dive on the fourth chamber run. These surface interval times would be different if the sortie times were different.
7. The 1195 min surface interval is the most likely to be the best choice given a Repetitive Group of Z and a Time to Clean on Air of 1438 min.

8. Create a dive profile with a 1195 min surface interval by adding the following segments to the dive profile:

	Depth	Bottom Time	Gas Mix	Descent Rate	Ascent Rate
Segment 8	0	1000	Air	60	30
Segment 9	0	195	Air	60	30
Segment 10	60.0	170	Air	60	30
Segment 11	45.0	0	Air	60	1
Segment 12	45.0	30	90% Oxygen	60	30
Segment 13	40.0	0	90% Oxygen	60	1
Segment 14	40.0	21	90% Oxygen	60	30
Segment 15	40.0	3	Air	60	30
Segment 16	0	0	Air	60	30

Note the Dive Planner will not accept a bottom time entry greater than 1000 min. Therefore, the surface interval has to be entered as two segments, one with a bottom time of 1000 min and the other with a bottom time of 195 min.

9. After Segment 16 has been entered, the Dive Planner will indicate that no additional decompression stops are required on the second dive. The DCS risk estimate for the second dive is 4.684% by the NMRI probabilistic model, an increase in risk compared to the 4.164% risk of the first dive. The DCS risk estimate for the second dive is 3.417% by the BVM(3) probabilistic model, an increase in risk compared to the 3.081% risk of the first dive.
10. This two-dive profile with a surface interval of 1195 min should now be saved as a *.div file. An appropriate file name would be PBT 60,170,1195,60,170 based on the dive profile. This file can now be edited to make risk estimates for the 475 min and 1915 surface intervals without having to re-enter the segments for the first and second dives.
11. Click on the View/Edit Existing Profile button on the tool bar, the Eye Chart button fifth from the left. Select PBT 60,170,1195,60,170 then click Open. Locate the line in the file coding the 195 min surface interval. The surface interval is the second number from the left in that line. Change the surface interval time for this segment from 195 to 915 min. The total surface interval will now be 1915 min (1000 + 915 min). Change the file name to PBT 60,170,1915,60,170 to reflect the new 1915 surface interval. Click Save then Exit.
12. Repeat Step 11. Change the time entry for the 1000 min surface interval segment from 1000 to 475 min. Change the time entry on the next line from 195 to 0 minutes. The total surface interval will now be 475 min. Change the file name to PBT 60,170,475,60,170 to reflect the new 475 min surface interval. Click Save then Exit.
13. Click on the Open File button on the tool bar, first button on the left. Select PBT 60,170,475,60,170 then Click Open. The complete two dive profile with the 475 min surface interval will now appear in the graphical display. The details of this profile can be checked by clicking on Display Dive History, then All Nodes w/Elapsed Time. Note that a 54 min stop on air at 10 fsw is required on the second dive. Close the Display Dive History box. The repetitive group designator for the second dive is listed as “Out of Range.” The time to clean on air for the second dive is 1709 min. The risk of DCS on the second dive is 5.393% by the NMRI 98 probabilistic model even with the additional 54 min stop imposed. This is substantially higher than the 4.164% risk on the first pre-breathe tender dive. The risk of DCS on the second dive is

4.214% by the BVM(3) probabilistic model with the additional 54 min stop imposed. This risk is also substantially higher than the 3.081% risk on the first pre-breathe tender dive. Performing a second pre-breathe tender dive on the second chamber load will not only impose an increase in the decompression requirement for the second dive, but also will increase the risk of DCS substantially.

14. Click on the Open File button on the tool bar again. Select PBT 60,170,1915,60,170 then Click Open. The complete two dive profile with the 1915 min surface interval will now appear in the graphical display. The details of this profile can be checked by clicking on Display Dive History, then All Nodes w/Elapsed Time. No additional decompression stops are required on the second dive. Close the Display Dive History box. The repetitive group designator for the second dive is Z. The time to clean on air for the second dive is 1449 min. The risk of DCS on the second dive is 4.285% by the NMRI 98 probabilistic model, barely above the 4.164% risk on the first dive. The risk of DCS on the second dive is 3.149% by the BVM(3) probabilistic model, barely above the 3.081% risk on the first dive.
15. Of the three surface interval choices, 1195 min appears to be the best in terms of overall efficiency. There is no increase in the decompression obligation on the second dive and the risk of DCS is increased only modestly. A surface interval of 475 min is too short. Additional decompression time is imposed on the second dive and the risks are increased substantially. The 1915 min surface interval is the safest with risks nearly equal to those on the first dive. However, to execute this strategy, the total number of pre-breathe tenders needed to support the rescue effort will have to be increased.

Appendix B. Calculation of Equivalent Air Saturation Depth

B-1. Equivalent Air Saturation Depth

The concept of Equivalent Air Depth was explained in Section 3-1. To apply the equivalent air depth equation given in that section to rescuees, the pressure, temperature, and atmospheric composition in the DISSUB must be reasonably stable for the two days prior to rescue. This is to insure that the slowest exchanging body compartments are in equilibrium with the inspired partial pressure of nitrogen.

Adding or removing oxygen and/or carbon dioxide to the DISSUB atmosphere per se will not change the partial pressure of nitrogen in the DISSUB. The equivalent air depth accordingly will remain constant while the internal pressure of the DISSUB varies. However, if the partial pressure of nitrogen rises or falls because of temperature changes in the boat, addition or subtraction of air from the boat, or compression of the atmosphere in the boat due to flooding, the EAD will change. If this change occurs in the two day period prior to rescue, the slow body compartments may not have enough time to come back into equilibrium with the change.

In this appendix, we introduce the concept of the *Equivalent Air Saturation Depth (EASD)*. This is the nitrogen partial pressure in the 360 min half-time compartment, expressed in terms of its air equivalent depth. The 360 min compartment is considered representative of the slowly exchanging body compartments that control saturation decompression. If there is a significant disparity between the EAD and the EASD, the EASD is used to select the decompression table for the rescuees.

Few increases or decreases in inspired nitrogen partial pressure in the DISSUB will be linear over time.

For Example:

1. For a constant number of moles of gas in the DISSUB and a constant DISSUB volume, the relationship between pressure and temperature in the boat will be linear. However, the temperature itself may not change linearly over time, therefore the pressure change over time will not be linear. In general, changes in boat pressure due to temperature change will be modest. For example, if the DISSUB temperature increases from 70 to 90 °F, the pressure in a DISSUB at 60 fswg will increase to 63.5 fswg.
2. In the case of flooding at a constant rate (cubic feet per hour), the rate of rise of pressure in the boat will become progressively faster as the flood volume becomes a bigger fraction of the remaining volume in the DISSUB.
3. If the survivors breathe off the Emergency Air Breathing System (EABS), the pressure in the DISSUB will rise exponentially according to the following equation:

$$P_t = P_o * e^{RMV*t/V_{boat}} \qquad \text{(B-1)}$$

Where: Pt = Pressure in the DISSUB at time t (ata)

Po = Pressure in the DISSUB at time zero (ata)

RMV = Total respiratory minute ventilation of crew on EABS (ft^3/h)

T = Elapsed time on EABS (h)

Vboat = Volume of DISSUB (ft^3)

(Note: This equation can also be used to compute the rise in pressure in the PRM if the occupants breathe off the Emergency Breathing System (EBS) in the open-circuit mode in the PRM.)

Despite the fact that most changes in inspired nitrogen partial pressure will not be linear over time, the curvilinear relationship can be approximated satisfactorily in almost all cases by a series of short linear ramps. For a body compartment that exchanges nitrogen exponentially, the partial pressure of nitrogen in the compartment at the end of an exposure in which the inspired partial pressure of nitrogen increases or decreases linearly with time, can be computed as follows:

$$P(t) = PIN2(0) * \left(1 - e^{-kt}\right) + P(0) * e^{-kt} + RN2 * t + \frac{RN2}{k} * \left(e^{-kt} - 1\right) \qquad \text{(B-2)}$$

Where: P(t) = Partial pressure of N2 (fsw) in the compartment at time t (end of exposure)

P(0) = Partial pressure of N2 (fsw) in the compartment at time 0 (beginning of exposure)

PIN2(0) = Inspired partial pressure of N2 (fsw) at time 0 (beginning of exposure)

k = rate constant of the compartment = 0.693/half time in hours = 0.1155

t = exposure time in hours

RN2 = rate of change of inspired partial pressure of nitrogen (fsw/h)

$$RN2 = (PIN2(t) - PIN2(0))/t \qquad \text{(B-3)}$$

Where: PIN2(t) = Inspired partial pressure of N2 (fsw) at time t (end of exposure)

RN2 is positive when the inspired nitrogen partial pressure is increasing over time. RN2 is negative when the inspired nitrogen partial pressure is decreasing over time.

When the inspired nitrogen partial pressure is constant, RN2 = 0. The last two terms of the equation drop out leaving the standard equation for exponential gas exchange in response to a step increase or decrease in PIN2.

Once the partial nitrogen partial pressure in the 360 min compartment has been computed, it may be converted to the Equivalent Air Saturation Depth (EASD) as follows:

$$EASD = \frac{P(t)}{0.79} - 33 \qquad \text{(B-4)}$$

When the conditions in the DISSUB are unstable during the two day period prior to rescue, the EASD should be compared to the EAD calculated according to Section 3-1. If there is a major disparity, Tables 4-1 through 4-4 should be entered using the EASD rather than the EAD.

The pressure, temperature, oxygen partial pressure and carbon dioxide partial pressure are recorded in the DISSUB every half to one hour which is a short enough period to allow the change in PIN2 over time to be approximated by a series of linear ramps. The PIN2 in the DISSUB for each set of measurements can be computed as follows:

$$PIN2 = (Dsub + 33) - \left(\frac{\%O2sev + \%CO2\ sev}{100}\right) * 33 \qquad \text{(B-5)}$$

These PIN2's and the elapsed time of each segment can then be used to compute the nitrogen tension in the 360 min compartment and the EASD using the above equations.

B-2. Example 1: Flooding

Assume a DISSUB with 155 crew members and a volume of 50,000 ft^3 has been on the bottom for 72 h. The internal pressure is 35.5 fswg. At the 72 h mark, flooding begins at a steady rate of 500 ft^3/h and continues unabated for the next 48 h. A total of 24,000 ft^3 of water is taken on board and the DISSUB volume is reduced from 50,000 to 26,000 ft^3.

Table B-1. Example of Equivalent Air Saturation Depth Lag During Flooding

Input Data					Calculations									
Elapsed Time (h	Segment Time (h)	Pressure (fsw)	Oxygen (% SEV)	CO2 (% SEV)	PIN2 (fsw)	RN2 (fsw/hr)	Terms in Equation B-2 1st	2nd	3rd	4th	PN2 360 (fsw)	EASD (fsw)	EAD (fsw)	Lag (fsw)
72	Start	35.5	42.2	1.3	54.1	*	*	*	*	*	54.1	35.5	35.5	0.0
84	12	43.4	43.6	1.5	61.5	0.61	40.6	13.5	7.4	-4.0	57.5	39.8	44.8	-5.0
96	12	53.0	45.0	1.7	70.5	0.76	46.1	14.4	9.1	-4.9	64.6	48.8	56.3	-7.5
108	12	66.2	47.0	2.0	83.0	1.04	52.9	16.2	12.5	-6.8	74.8	61.7	72.1	-10.4
120	12	85.6	50.2	2.5	101.2	1.51	62.3	18.7	18.2	-9.8	89.3	80.0	95.1	-15.0

The leftmost columns of Table B-1 show the pressure, oxygen, and CO2 levels that might be recorded in the boat during this evolution. Entries are shown here every 12 h for simplicity; in reality measurements would be obtained every 30-60 min. The pressure in the boat rises from 35.5 fswg to 85.6 fswg by the end of the 48 hour period. The oxygen level rises from 42.2 to 50.2 % SEV even though the crew continues to consume oxygen and no new oxygen is added to the boat. This increase is due to the reduced volume of the DISSUB which concentrates the residual oxygen. The same is true for CO2 which rises from 1.3 to 2.5% SEV even though all the CO2 produced metabolically is absorbed by LiOH.

The 6th column shows the calculated PIN2 according to Equation B-5. At the 72h start time, the PIN2 is 54.1 fsw. The 360 min compartment is fully saturated at this same value; therefore the EAD and the EASD are both equal to 35.5 fsw. (Note that the actual depth and the EAD at the start just happen to be equal in this example. This is fortuitous. The fractional concentration of nitrogen at the 72 h start time is 0.79, the same as the fractional concentration of nitrogen in air.).

Over the ensuing 48 h period of flooding, the PIN2 increases from 54.1 to 101.2 fsw. The rate of increase for each linear segment (RN2), computed according to Equation B-3, increases progressively from 0.61 to 1.51 fsw/h.

Columns 8-11 show the computed value of each of the four terms in Equation B-2 at the end of the respective 12 hour segment. The starting value for PIN2(0) in the first term is obtained from Column 6 of the preceding row. The starting value for P(0) in the second term is obtained from Column 12 of the preceding row.

The PN2 in the 360 min compartment, P(t), is the sum of the four terms in Columns 8-11. This value is shown in Column 12. The EASD is computed in Column 13 using Equation B-4. The EAD in Column 14 is also computed using Equation B-4, but substituting PIN2 in Column 6 for P(t) in Column 12.

The last column shows the lag between the EASD and the EAD. The lag increases progressively from -5 fsw to -15 fsw. At the end of the 48 hours of flooding, the EAD is 95.1 fsw, but the EASD is only 80.0 fsw. In this scenario, the tables for the rescuees should be entered at the 80 fsw depth.

B-3. Example 2: Use of EABS

At the 72 h mark a DISSUB has prematurely expended its LiOH supply and the CO2 level has risen to 6.3% SEV. The 155 DISSUB survivors are forced onto the EABS.

The starting pressure in the boat is 37.1 fswg and the oxygen level is 42.2% SEV. Coupled with the 6.3% CO2 level, the calculated PIN2 in the boat is 54.1 fsw. The 360 min compartment is in equilibrium with this value. The EASD and the EAD are both equal to 35.5 fswg.

While on the EABS, each crew member exhales 20 ft^3 of air (at 70F and ambient pressure) into the DISSUB per hour. The total RMV for the 155 man crew is 3100 ft^3/h. The volume of the DISSUB is 50,000 ft^3.

Table B-2 shows successive 1 hour segments on the EABS. The pressure in the boat at the end of each segment, computed from Equation B-1 above, is shown in the 3rd column. The pressure rises from the starting value of 37.1 fswg to 114.6 fswg over the 12 hour period.

The oxygen and CO2 concentrations in the boat are not shown in the second and subsequent rows because the crew members are breathing from the ship service air bank not the DISSUB atmosphere. In this example, the ship service air bank is assumed to contain 79% nitrogen, therefore PIN2 for each row after the first can be computed as 0.79*(D+33), where D = the DISSUB pressure in fswg. These values are shown in the 6th column.

The remaining columns in the Table are computed in the same manner as the previous example. The EASD progressively lags behind the EAD. After one hour, the lag is -5.8 fsw. After 12 hours, the lag is-45.9 fsw, a very large disparity compared with the previous example. This is because the PIN2 is rising approximately five times faster in this example than in the flooding example.

Table B-2. Example of Equivalent Air Saturation Depth Lag During Use of EBS

Input Data					Calculations									
Elapsed Time (h)	Segment Time (h)	Pressure (fsw)	Oxygen (% SEV)	CO2 (% SEV)	PIN2 (fsw)	RN2 (fsw/h)	Terms in Equation B-2 1st	2nd	3rd	4th	PN2 360 (fsw)	EASD (fsw)	EAD (fsw)	Lag (fsw)
72	Start	37.1	42.2	6.3	54.1	*	*	*	*	*	54.1	35.5	35.5	0
73	1	41.6	*	*	58.9	4.83	5.9	48.2	4.8	-4.6	54.4	35.8	41.6	-5.8
74	1	46.4	*	*	62.7	3.79	6.4	48.4	3.8	-3.6	55.1	36.7	46.4	-9.7
75	1	51.4	*	*	66.7	3.95	6.8	49.1	4.0	-3.7	56.1	38.1	51.4	-13.3
76	1	56.8	*	*	70.9	4.27	7.3	50.0	4.3	-4.0	57.5	39.8	56.8	-17.0
77	1	62.6	*	*	75.5	4.58	7.7	51.2	4.6	-4.3	59.2	42.0	62.6	-20.6
78	1	68.7	*	*	80.3	4.82	8.2	52.8	4.8	-4.6	61.3	44.6	68.7	-24.1
79	1	75.2	*	*	85.5	5.14	8.8	54.6	5.1	-4.8	63.6	47.6	75.2	-27.6
80	1	82.1	*	*	90.9	5.45	9.3	56.7	5.5	-5.1	66.3	51.0	82.1	-31.1
81	1	89.5	*	*	96.8	5.85	9.9	59.1	5.8	-5.5	69.3	54.8	89.5	-34.7
82	1	97.3	*	*	102.9	6.16	10.6	61.8	6.2	-5.8	72.7	59.0	97.3	-38.3
83	1	105.7	*	*	109.6	6.64	11.2	64.7	6.6	-6.3	76.3	63.6	105.7	-42.1
84	1	114.6	*	*	116.6	7.03	12.0	68.0	7.0	-6.6	80.4	68.7	114.6	-45.9

Use of a Spreadsheet to Calculate the EASD and EAD

These two examples appear very complicated, but in practice the EASD and the EAD can be derived quickly using a spreadsheet.

The clock time, pressure, and O2 and CO2 levels can be copied from the Atmosphere Log into the leftmost columns of the spreadsheet. The first row would contain those variables immediately prior to the casualty. The second row would contain those variables immediately after the casualty. A column would have to be added to compute the segment time (h) from the elapsed clock time.

The remaining columns in the spreadsheet would contain the formulas described above. The formulas for PIN2, EASD and EAD would be entered into the first row. PN2 360 in the first row would be set at the value of PIN2 in the first row. The formulas for RN2, the four terms of the exponential, and the PN2 in the 360 min compartment would be entered into the second row. All subsequent row computations can now be made by using the Auto Fill feature. Simply grabbing the lower right corner of a filled-in cell and dragging it down over the empty cell below it will fill in that cell with the computed value.

Appendix C. Equivalent Air Saturation Depth 25 fsw

C-1. Concept of Operation

1. SDC's are operated in the Single Chamber mode. Decompression is begun when the first load of 16 rescuees has been transferred to the SDC.
2. All sorties go down unpressurized. This minimizes the bottom time of the PRM attendants. Each sortie launches with a fresh set of PRM attendants.
3. The No-Decompression Time at 25 fsw is 595 min. PRM attendants help with the transfer of rescuees to the SDC to minimize the need for transfer tenders. They then lock out and are replaced by pre-breathe tenders who complete the remainder of the decompression with the rescuees. Both the PRM attendants and pre-breathe tenders are in a no-decompression status and do not have to breathe oxygen prior to surfacing. Use of pre-breathe tenders minimizes the bottom time of the PRM attendants and allows both groups to perform repetitive dives more frequently.
4. Rescuees pre-breathe oxygen for 70 min in the SDC at the transfer depth, then switch to air and decompress to the surface without stops. There is virtually no risk of CNS oxygen toxicity during the pre- breathing period at this depth.
5. DET members are not limited by pulmonary oxygen toxicity. They may lock into the DISSUB on the first sotie and be removed on the last.
6. PRM Attendants and SDC Tenders may perform repeat dives later in the rescue following guidance in Chapter 9 of the U.S. Navy Diving Manual.

C-2. Rescuee Decompression Schedules

The schedules available for decompressing rescuees at 25 fsw are shown in Table C-1. These basic tables are expanded to show all recommended air breaks in Table C-3 and Figure C-2. Figure C-2.

Table C-1. Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)					O2 Stop Time (min)	CPTD (units)
	25	20	15	10	5		
Oxygen	**70**					**70**	151
Air			110	310	35	**0**	0

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

C-3. Tender Management Plan.

Figure C-1 shows the tender management plan for one chamber run.

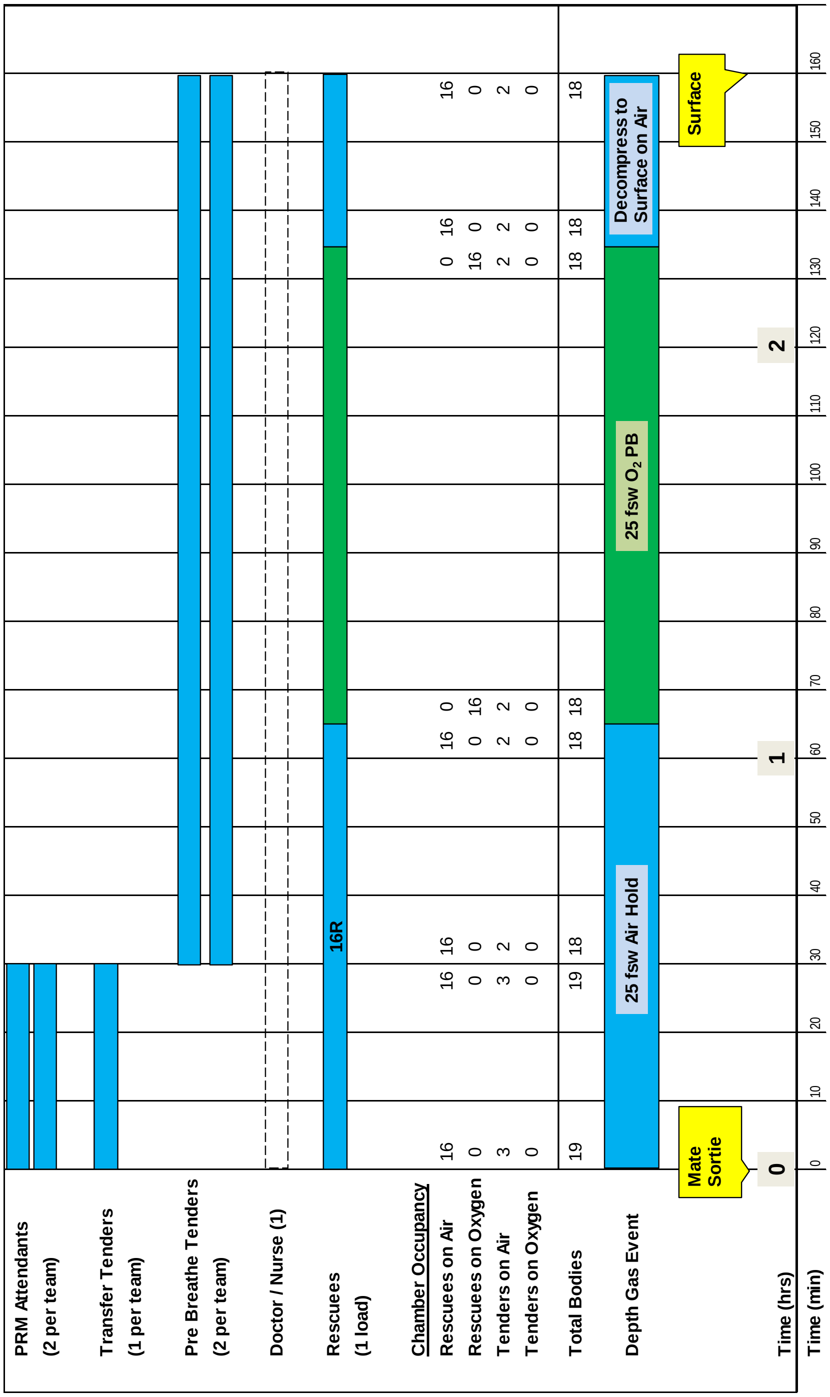


Figure C-1. Tender Management 25 FSW Rescue

Immediately prior to the mate of the first sortie, one transfer tender locks into the SDC via the MTL. The transfer tender positions himself in the SDC and assists the two PRM attendants in transferring the reescuees from the PRM to the SDC. This transfer nominally takes 30 min. The bottom time of the transfer tender is 30 min and the bottom time of the PRM attendants is the sum of the sortie bottom time plus 30 min, or 3 h for a nominal 2.5h time under pressure in the PRM. Both the transfer tender and the two PRM attendants are in a no-decompression status and can exit the SDC via the MTL without taking decompression stops.

Just before the transfer tender and the PRM attendants lock out, two pre-breathe tenders lock in. Their role is to teach the rescuees how to use the MBS 2000, and then assist them during the pre-breathing period. They spend a total of 105 min at 25 fsw: 5 min for lockin, 30 min for instructing the rescuees, and 70 min for the pre-breathe itself. The pre-breathe period consists of a single 70 min period on oxygen without an air break. The pre-breathe tenders then ascend at 1 fsw/min to the surface. Their total bottom time is 105 min and no decompression stops are required.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure C-2. The maximum number of personnel in the chamber is 19. During the pre-breathing period there are 18 people in the chamber.

C-4. Sortie/Chamber Loading Analysis

Table C-2 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression.

Table C-2. 25 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	16	16	0	16	0	0
2	Ch. 1	16	16	0	15	1	0
3	Ch. 1	16	16	0	15	1	0
4	Ch. 1	16	16	0	15	1	0
5	Ch. 1	16	16	0	15	1	0
6	Ch. 1	16	16	0	15	1	0
7	Ch. 1	16	16	0	15	1	0
8	Ch. 1	16	16	0	16	0	0
9	Ch. 1	16	16	0	16	0	0
10	Ch. 1	11	11	2	11	0	2
Total:		155	155	2	149	6	2

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 10 sorties and 10 chamber runs. The last sortie and chamber run carries only 11 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Only 1 DET team is required at this depth and this team can be inserted on the first sortie and removed on the tenth. Ten sorties and 10 chamber runs are required with the 10^{th} sortie and the 10^{th} chamber load only carrying 13 personnel.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and a two-man DET team. Ten sorties and 10 chamber runs are required to execute this scenario with the last sortie and chamber run only carrying 13 personnel. The 6 stretcher cases are carried one per sortie on Sorties 2-7.

(Note: Both URC and Submarine Development Squadron 5 estimate that number of stretcher cases in a DISSUB scenario is unlikely to exceed 5 (personal communications from LCDR Virgilio, URC, and CAPT Bradshaw, CDS-5, to Dr. E. Flynn, NAVSEA 00C, 25 Oct 2012). A maximum of 6 was chosen for illustration purposes in this and the following appendices (C-Q) because this higher number does not add to the length or complexity of the rescue operation.)

C-5. Repetitive Exposure of PRM Attendants and SDC Tenders

C-5.1. PRM Attendants

At 25 fsw, PRM attendants also serve as transfer tenders. Their bottom time therefore will be 30 min longer than the actual bottom time spent in the PRM. Surface interval calculations for PRM attendants are based on the worst case scenario, two sorties with 4 hours under pressure on each.

Attendants with a total bottom time of 270 min on the first dive (240 min in PRM and 30 min in SDC) will surface in Repetitive Group L according to Table 9-7 of the Diving Manual. Table 9-8 indicates that Group L has a clean time of 12h 21min (741 min). The Dive Planner shows a total clean time of 1041 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 4 is 809 min, approximately an hour longer than the Dive Manual clean time and approximately 4 hours shorter than the Dive Planner clean time. If a second 270 min dive is made after a 809 min surface interval, the second dive will also be a no-decompression dive. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 1.600% to 2.151% by the NMRI 98 probabilistic model and from 1.358% to 1.806% by the BVM(3) probabilistic model. A dive with a predicted risk of 3% or less is considered low risk.

Therefore, for 6 hour sorties:

PRM attendants from the 1st sortie can dive again on the 4th, 7th, and 10th sorties.
PRM attendants from the 2nd sortie can dive again on the 5th, 8th, and 11th sorties.
PRM attendants from the 3rd sortie can dive again on the 6th, 9th, and 12th sorties.

Two PRM attendants are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 6 attendants.

C-5.2. Transfer Tender

One transfer tender is required to supplement the two PRM attendants. Each transfer tender is exposed to 25 fsw for 30 min. With a 6 hour sortie time, the surface interval between transfer tender dives is 330 min. This surface interval is more than adequate to allow the same transfer tender to be used repetitively on every sortie. It may be necessary to add a second transfer tender to allow time for transfer tenders to eat and sleep during off duty time.

C-5.3. Pre-breathe Tenders

Pre-breathe tenders will have a bottom time of 105 min and then ascend to the surface at 1 fsw/min. If the 25 min ascent time to the surface is included in the bottom time (making a total of 130 min), the tenders will surface in Repetitive Group H according to Table 9-7 of the Diving Manual. Table 9-8 indicates that

Group L has a clean time of 8h 52min (532 min). The Dive Planner shows a total clean time of 605 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 3 is 590 min, 58 min longer than the Dive Manual clean time and 15 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 590 min, the second dive will remain a no-decompression dive. The risk of decompression sickness on the second dive will not increase from its baseline (totally clean) value of 0.375% by the NMRI 98 probabilistic model or from its baseline value of 0.002% by the BVM(3) probabilistic model. These dives are extremely low risk.

Therefore, for 6 hour sorties:

PBT from the 1st sortie/chamber run can repeat their dive on the 3th, 5th, 7th, and 9th sorties.
PBT from the 2nd sortie/chamber run can repeat their dive on the 4th, 6th, 8th, and 10th sorties.

Two pre-breathe tenders are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 4 pre-breathe tenders.

C-5.4. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above is:

PRM Attendants	6
Transfer Tenders	2
Pre-Breathe Tenders	4
Total	12

Table C-3. 25 FSW Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)
25’	70	O2	1:10
Travel 1 FPM to surface	25	Air	1:35

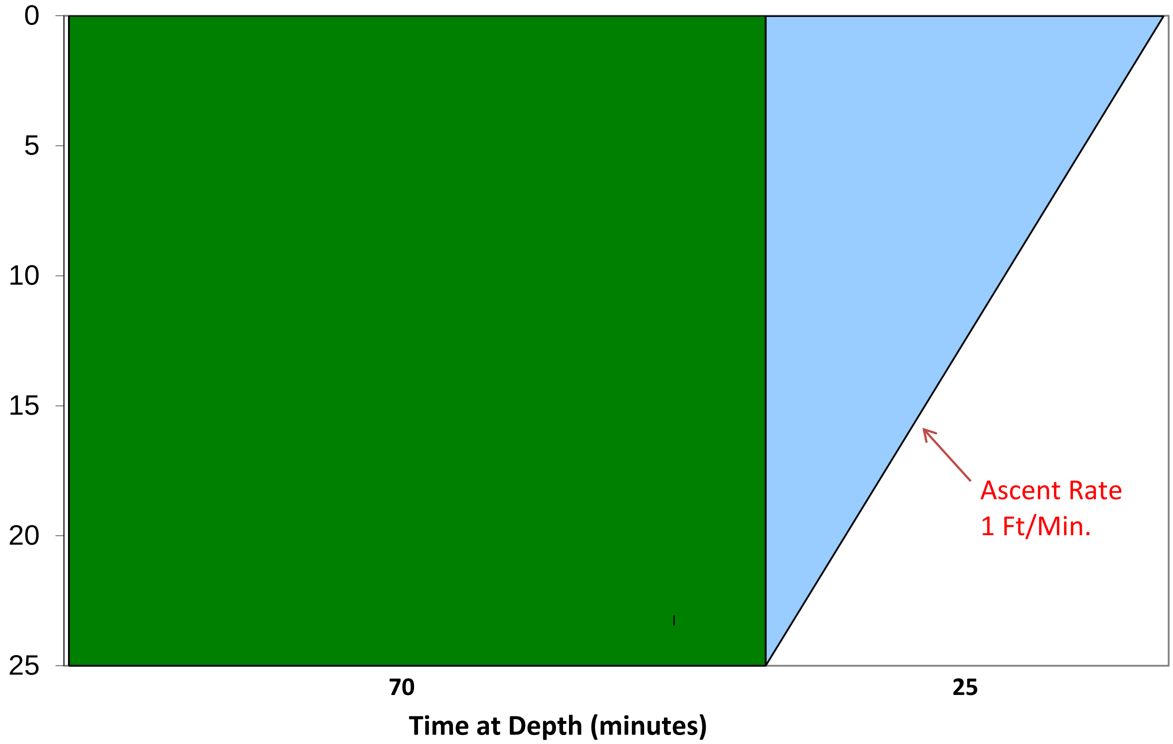


Figure C-2. 25 FSW Air/Oxygen Decompression Table with Air Breaks Included

Appendix D. Equivalent Air Saturation Depth 30 fsw

D-1. Concept of Operation

1. SDC's are operated in the Single Chamber mode. Decompression is begun when the first load of 16 rescuees has been transferred to the SDC.
2. All sorties go down unpressurized. This minimizes the bottom time of the PRM attendants. Each sortie launches with a fresh set of PRM attendants.
3. The No-Decompression Time at 30 fsw is 371 min. PRM attendants help with the transfer of rescuees to the SDC to minimize the need for transfer tenders. They then lock out and are replaced by pre-breathe tenders who complete the remainder of the decompression with the rescuees. Both the PRM attendants and pre-breathe tenders are in a no-decompression status and do not have to breathe oxygen prior to surfacing. Use of pre-breathe tenders minimizes the bottom time of the PRM attendants and allows both groups to perform repetitive dives more frequently.
4. Rescuees pre-breathe oxygen for 140 min in the SDC at the transfer depth, and then switch to air and decompress to the surface without stops. There is virtually no risk of CNS oxygen toxicity during the pre- breathing period at this depth.
5. DET members are not limited by pulmonary oxygen toxicity. They may lock into the DISSUB on the first sortie and be removed on the last.
6. PRM Attendants and SDC Tenders may perform repeat dives later in the rescue following guidance in Chapter 9 of the U.S. Navy Diving Manual.

D-2. Rescuee Decompression Schedules

The schedules available for decompressing rescuees at 30 fsw are shown in Table D-1. These basic tables are expanded to show all recommended air breaks in Table D-3 and Figure D-2.

Table D-1. Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)						O2 Stop Time (min)	CPTD (units)
	30	25	20	15	10	5		
Oxygen	**140**						**140**	341
Air			50	285	315	55	**0**	0

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

D-3. Tender Management Plan

Figure D-1 shows the tender management plan for one chamber run.

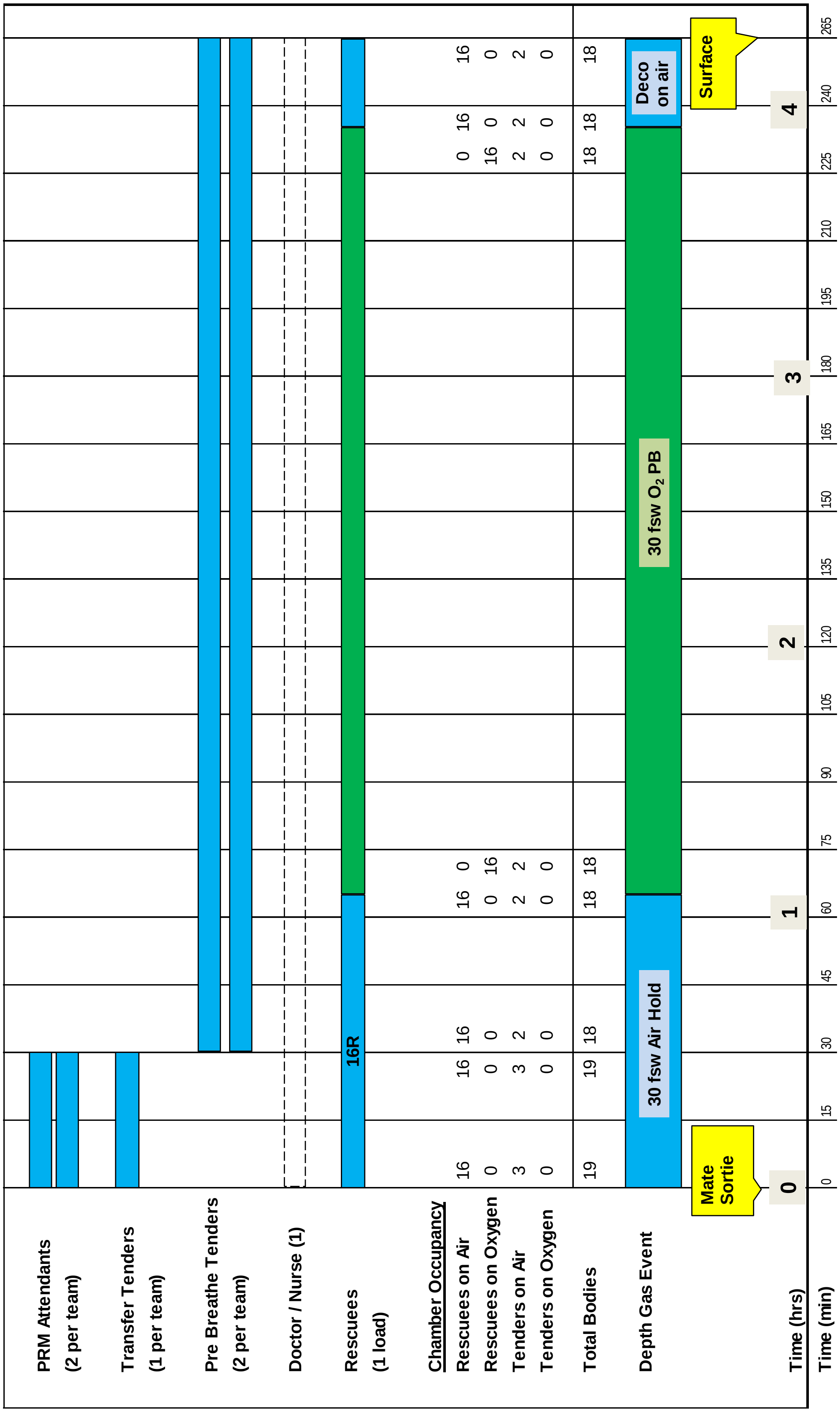


Figure D-1. Tender Management 30 FSW Rescue

Immediately prior to the mate of the first sortie, one transfer tender locks into the SDC via the MTL. The transfer tender positions himself in the SDC and assists the two PRM attendants in transferring the reescuees from the PRM to the SDC. This transfer nominally takes 30 min. The bottom time of the transfer tender is 30 min and the bottom time of the PRM attendants is the sum of the sortie bottom time plus 30 min, or 3 h for a nominal 2.5h time under pressure in the PRM. Both the transfer tender and the two PRM attendants are in a no-decompression status and can exit the SDC via the MTL without taking decompression stops.

Just before the transfer tender and the PRM attendants lock out, two pre-breathe tenders lock in. Their role is to teach the rescuees how to use the MBS 2000, and then assist them during the pre-breathing period. They spend a total of 205 min at 30 fsw: 5 min for lockin, 30 min for instructing the rescuees, and 170 min for the pre-breathe itself. The pre-breathe period consists of 60 min on oxygen, 15 min on air, 60 min on oxygen, 15 min on air and finally 50 min on oxygen. The pre-breathe tenders then ascend at 1 fsw/min to the surface. Their total bottom time is 205 min and no decompression stops are required.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure D-2. The maximum number of personnel in the chamber is 19. During the pre-breathing period there are 18 people in the chamber.

D-4. Sortie/Chamber Loading Analysis

Table D-2 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression.

Table D-2. 30 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	16	16	0	16	0	0
2	Ch. 1	16	16	0	15	1	0
3	Ch. 1	16	16	0	15	1	0
4	Ch. 1	16	16	0	15	1	0
5	Ch. 1	16	16	0	15	1	0
6	Ch. 1	16	16	0	15	1	0
7	Ch. 1	16	16	0	15	1	0
8	Ch. 1	16	16	0	16	0	0
9	Ch. 1	16	16	0	16	0	0
10	Ch. 1	11	11	2	11	0	2
Total:		155	155	2	149	6	2

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 10 sorties and 10 chamber runs. The last sortie and chamber run carries only 11 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Only 1 DET team is required at this depth and this team can be inserted on the first sortie and removed on the tenth. Ten sorties and 10 chamber runs are required with the 10th sortie and the 10th chamber load only carrying 13 personnel.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and a two-man DET team. Ten sorties and 10 chamber runs are required to execute this scenario with the last sortie and chamber run carrying only 13 personnel. The 6 stretcher cases are carried one per sortie on Sorties 2-7.

D-5. Repetitive Exposure of PRM Attendants and SDC Tenders

D-5.1. PRM Attendants

At 30 fsw, PRM attendants also serve as transfer tenders. Their bottom time therefore will be 30 min longer than the actual bottom time spent in the PRM. Surface interval calculations for PRM attendants are based on the worst case scenario, two sorties with 4 hours under pressure on each.

Attendants with a total bottom time of 270 min on the first dive (240 min in PRM and 30 min in SDC) will surface in Repetitive Group O according to Table 9-7 of the Diving Manual. Table 9-8 indicates that Group O has a clean time of 14h 58 min (898 min). The Dive Planner shows a total clean time of 1220 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 4 is 809 min, 89 min shorter than the Dive Manual clean time. The surface interval available between Sortie 1 and Sortie 5 is 1169 min, 271 min longer than the Dive Manual clean time and 51 min shorter than the Dive Planner clean time. If a second 270 min dive is made after a 1169 min surface interval, the second dive will also be a no-decompression dive. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 2.968% to 3.372% by the NMRI 98 probabilistic model and from 2.498% to 2.775% by the BVM(3) probabilistic model. A dive with a predicted risk of 3% or less is considered low risk. A dive with a risk between 3 and 5% is considered a moderate risk dive.

Therefore, for 6 hour sorties:

PRM attendants from the 1st sortie can dive again on the 5th, and 9th sorties.
PRM attendants from the 2nd sortie can dive again on the 6th, and 10th sorties.
PRM attendants from the 3rd sortie can dive again on the 7th, and 11th sorties.
PRM attendants from the 4th sortie can dive again on the 8th and 12th sorties

Two PRM attendants are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 8 attendants.

D-5.2. Transfer Tender

One transfer tender is required to supplement the two PRM attendants. Each transfer tender is exposed to 30 fsw for 30 min. With a 6 hour sortie time, the surface interval between transfer tender dives is 330 min. This surface interval is more than adequate to allow the same transfer tender to be used repetitively on every sortie. It may be necessary to add a second transfer tender to allow time for transfer tenders to eat and sleep during off duty time.

D-5.3. Pre-breathe Tenders

Pre-breathe tenders will have a bottom time of 205 min and then ascend to the surface at 1 fsw/min. If the 30 min ascent time to the surface is included in the bottom time (making a total of 235 min), the tenders will surface in Repetitive Group N according to Table 9-7 of the Diving Manual. Table 9-8 indicates that Group N has a clean time of 14h 5min (845 min). The Dive Planner shows a total clean time of 1040 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 4 is 845 min, exactly equal to the Dive Manual clean time. If an identical dive is made after a surface interval of 845 min, the second dive will remain a no-decompression dive. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 1.541% to 2.091% by the NMRI 98 probabilistic model or from its baseline value of 1.264% to 1.712% by the BVM(3) probabilistic model. A dive with a predicted risk of 3% or less is considered low risk.

Therefore, for 6 hour sorties:

PBT from the 1st sortie/chamber run can repeat their dive on the 4th, 7th, and 10th sorties.
PBT from the 2nd sortie/chamber run can repeat their dive on the 5th, 8th, and 11th sorties.
PBT from the 3rd sortie/chamber run can repeat their dive on the 6th, 9th, and 12th sorties.

Two pre-breathe tenders are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 6 pre-breathe tenders.

D-5.4. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above is:

PRM Attendants	8
Transfer Tenders	2
Pre-Breathe Tenders	6
Total	16

Table D-3. 30 FSW Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)
30	60	O2	1:00
30	15	Air	1:15
30	60	O2	2:15
30	15	Air	2:30
30	20	O2	2:50
Travel 1 FPM to surface	30	Air	3:20

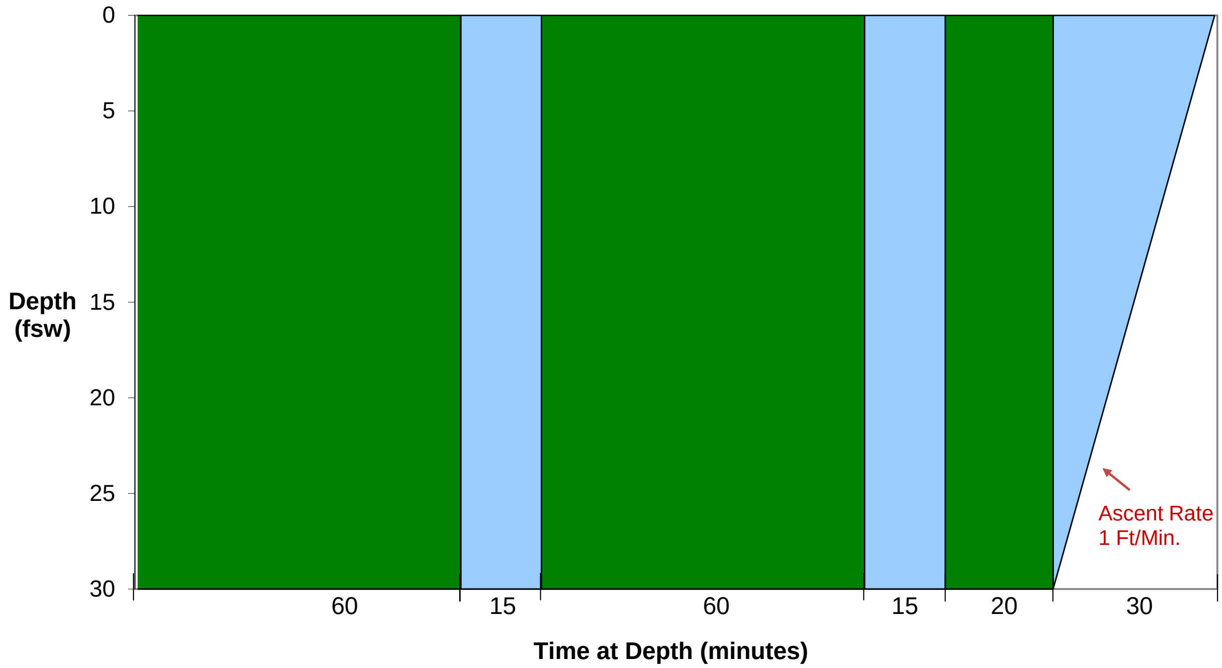


Figure D-2. 30 FSW Air/Oxygen Decompression Table with Air Breaks Included

Appendix E. Equivalent Air Saturation Depth 35 fsw

E-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (No Hold) mode. Decompression is begun when the first load of 16 rescuees has been transferred to the SDC.
2. All sorties go down unpressurized. This minimizes the bottom time of the PRM attendants. Each sortie launches with a fresh set of PRM attendants.
3. The No-Decompression time at 35 fsw is 232 min. PRM attendants help with the transfer of rescuees to the SDC to minimize the need for transfer tenders. They then lock out and are replaced by pre-breathe tenders who complete the remainder of the decompression with the rescuees. Both the PRM attendants and the pre-breathe tenders are in a no-decompression status and do not have to breathe oxygen prior to surfacing. Use of pre-breathe tenders minimizes the bottom time of the PRM attendants and allows both groups to perform repetitive dives more frequently.
4. Rescuees pre-breathe oxygen for two hours in the SDC at the transfer depth to reduce the risk of bubble formation during the subsequent oxygen decompression on oxygen (Table 4-1). There is virtually no risk of CNS oxygen toxicity during the pre-breathing period at this depth.
5. DET members are not limited by pulmonary oxygen toxicity even if there has been no breathe down of the DISSUB oxygen level. They may lock into the DISSUB with the first sortie and be removed on the last.
6. PRM Attendants and SDC Tenders may perform repeat dives later in the rescue. Each attendant/tender is assigned a fixed role and repeats that exact role on subsequent dives when the surface interval has been long enough not to increase the decompression obligation for the subsequent dive.

E-2. Rescuee Decompression Schedules

The schedules available for decompressing rescuees at 35 fsw are shown in Table E-1. These basic tables are expanded to show all recommended air breaks in Table E-3 and in Figure E-2.

Table E-1. Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)						O2 Stop Time (min)	CPTD (units)
	35	25	20	15	10	5		
Oxygen	**120**	**40**	**40**				**200**	487
Air		5	245	290	320	65	**0**	0

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by the Harabin method assuming 90% oxygen in the MBS 2000

E-3. Tender Management Plan

Figure E-1 shows the tender management plan for one chamber run.

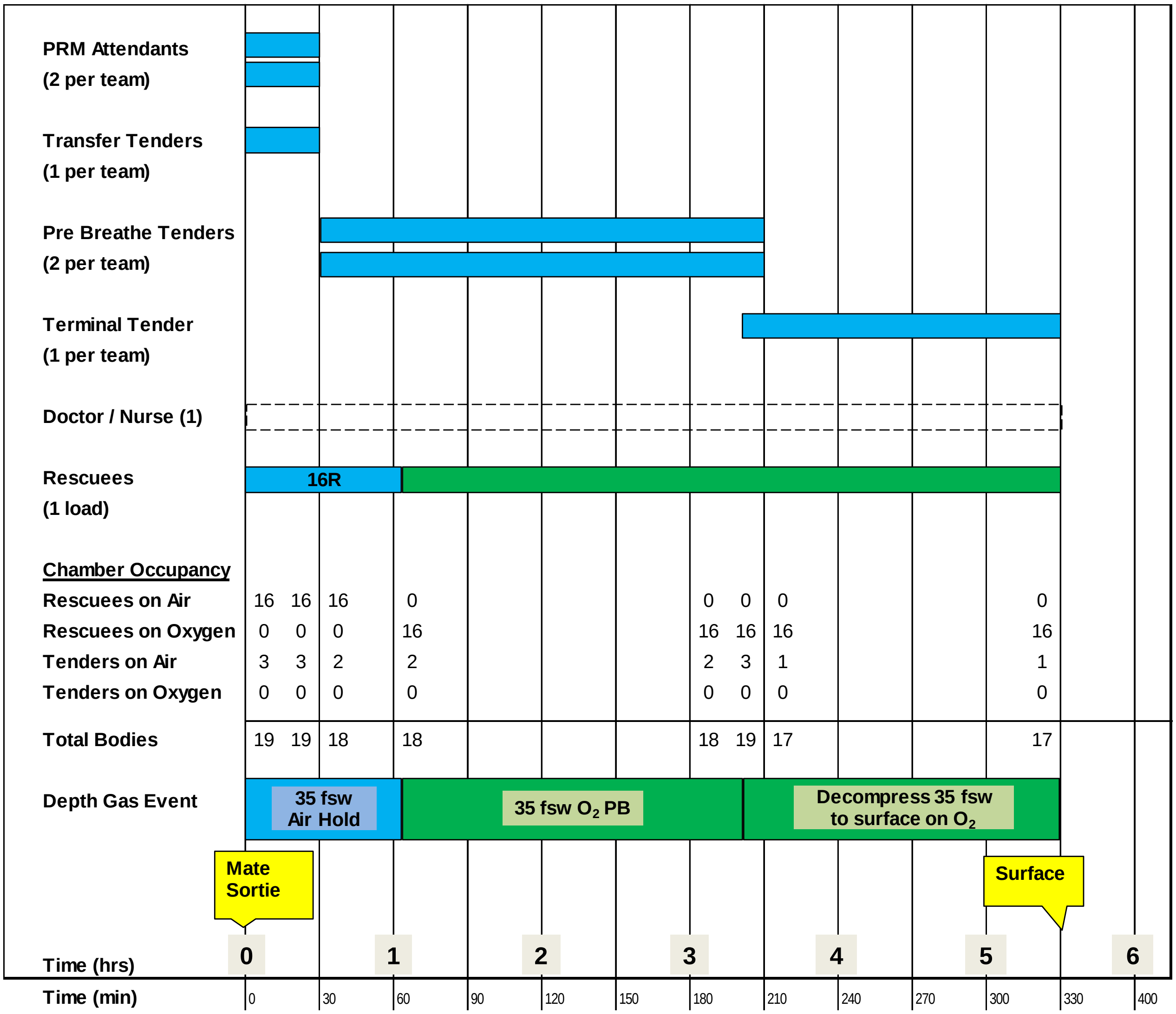


Figure E-1. Tender Management 35 FSW Rescue

Immediately prior to the mate of the first sortie, one transfer tender locks into the SDC via the MTL. The transfer tender positions himself in the SDC and assists the two PRM attendants in transferring the reescuees from the PRM to the SDC. This transfer takes 30 min. The bottom time of the transfer tender is 30 min and the bottom time of the PRM attendants is the sum of the sortie bottom time plus 30 min, or 3 h for a 2.5h time under pressure in the PRM. Both the transfer tender and the two PRM attendants are in a no-decompression status and can exit the SDC via the MTL without taking decompression stops.

Just before the transfer tender and the PRM attendants lock out, two pre-breathe tenders lock in. Their role is to teach the rescuees how to use the MBS 2000, and then assist them during the pre-breathing period. They spend a total of 170 min at 35 fsw: 5 min for lockin, 30 min for instructing the rescuees, and 135 min for the pre-breathe itself. The pre-breathe consists of two 60 min periods on oxygen separated by a 15 min air break. The pre-breathe tenders then ascend at 1 fsw/min to the first decompression stop at 25 fsw and lock out via the MTL. Their total bottom time is 180 min and no decompression stops are required.

As the chamber is leaving 35 fsw, one terminal tender locks into the chamber to tend to the rescuees. He can ride the remaining portion of the decompression schedule to the surface with the rescuees while breathing air.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure E-2. The maximum number of personnel in the chamber is 19. During the terminal portion of the saturation decompression there are 17 people in the chamber.

E-4. Sortie/Chamber Loading Analysis

Table E-2 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression.

Table E-2. 35 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	16	16	0	16	0	0
2	Ch. 2	16	16	0	15	1	0
3	Ch. 1	16	16	0	15	1	0
4	Ch. 2	16	16	0	15	1	0
5	Ch. 1	16	16	0	15	1	0
6	Ch. 2	16	16	0	15	1	0
7	Ch. 1	16	16	0	15	1	0
8	Ch. 2	16	16	0	16	0	0
9	Ch. 1	16	16	0	16	0	0
10	Ch. 2	11	11	2	11	0	2
Total:		155	155	2	149	6	2

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 10 sorties and 10 chamber runs. The last sortie and chamber run carries only 11 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Only 1 DET team is required at this depth and this team can be inserted on the first sortie and removed on the tenth. Ten sorties and 10 chamber runs are required with the 10th sortie and the 10th chamber load only carrying 13 personnel.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and a two-man DET team. Ten sorties and 10 chamber loads are required to execute this scenario with the last sortie and chamber run carrying 13 personnel. The 6 stretcher cases are carried one per sortie for Sorties 2-7.

E-5. Repetitive Exposure of PRM Attendants and SDC Tenders

E-5.1. PRM Attendants

At 35 fsw, PRM attendants also serve as transfer tenders. Their bottom time therefore will be 30 min longer than the actual bottom time spent in the PRM. Surface interval calculations for PRM attendants are based on the worst case scenario, two sorties with 4 hours under pressure on each.

Attendants with a total bottom time of 270 min on the first dive (240 min in PRM and 30 min in SDC) will surface in Repetitive Group Z according to the Dive Planner. Table 9-8 indicates that Group Z has a clean time of 15h 50 min (950 min). The Dive Planner shows a total clean time of 1369 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 4 is 779 min, 171 min shorter than the Dive Manual clean time. The surface interval available between Sortie 1 and Sortie 5 is 1159 min, 209 min longer than the Dive Manual clean time and 210 min shorter than the Dive Planner clean time. If a second 270 min dive is made after a 1159 min surface interval, the second dive will require a 1 min stop on air at 10 fsw in addition to the oxygen breathing time at depth. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 4.192% to 4.715% by the NMRI 98 probabilistic model and from 3.198% to 3.538% by the BVM(3) probabilistic model. A dive with a predicted risk of 3% or less is considered low risk. A dive with a predicted risk between 3 and 5% is considered moderate risk.

Therefore, for 6 hour sorties:

PRM attendants from the 1st sortie can dive again on the 5th, and 9th sorties.
PRM attendants from the 2nd sortie can dive again on the 6th, and 10th sorties.
PRM attendants from the 3rd sortie can dive again on the 7th, and 11th sorties.
PRM attendants from the 4th sortie can dive again on the 8th and 12th sorties

Two PRM attendants are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 8 attendants.

E-5.2. Transfer Tender

One transfer tender is required to supplement the two PRM attendants. Each transfer tender is exposed to 35 fsw for 30 min. With a 6 hour sortie time, the surface interval between transfer tender dives is 330 min. This surface interval is more than adequate to allow the same transfer tender to be used repetitively on every sortie. It may be necessary to add a second transfer tender to allow time for transfer tenders to eat and sleep during off duty time.

E-5.3. Pre-breathe Tenders

Pre-breathe tenders will have a bottom time of 170 min at 35 fsw, ascend to 25 fsw at 1 fsw/min and then ascend to the surface in the MTL at 30 fsw/min. If the 10 min ascent time to 25 fsw is included in the bottom time (making a total of 180 min), the tenders will surface in Repetitive Group N according to Table 9-7 of the Diving Manual. Table 9-8 indicates that Group N has a clean time of 14h 5min (845 min). The Dive Planner shows a total clean time of 1074 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 4 is 899 min, 54 min longer than the Dive Manual clean time and 175 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 899 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 2.161% to 2.714% by the NMRI 98 probabilistic model or from its baseline value of 1.688% to 2.141% by the BVM(3) probabilistic model.   A dive with a predicted risk of 3% or less is considered low risk.

Therefore, for 6 hour sorties:

PBT from the 1st sortie/chamber run can repeat their dive on the 4th, 7th, and 10th sorties.
PBT from the 2nd sortie/chamber run can repeat their dive on the 5th, 8th, and 11th sorties.
PBT from the 3rd sortie/chamber run can repeat their dive on the 6th, 9th, and 12th sorties.

Two pre-breathe tenders are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 6 pre-breathe tenders.

E-5.4.   Terminal Tender

The terminal tender locks into the SDC at 35 fsw and then rides to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is G by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group G has a clean time of 8h 0min (480 min). The Dive Planner shows a clean time of 1074 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 3 is 590 min, 110 min longer than the Dive Manual clean time and 484 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 899 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will not increase from its baseline (totally clean) value of 0.284% by the NMRI 98 probabilistic model or from its baseline value of 0.000% by the BVM(3) probabilistic model. The second dive is very low risk.

Therefore, for 6 hour sorties:

TT from the 1st sortie/chamber run can repeat their dive on the 3rd, 5th, 7th, and 9th sorties.
TT from the 2nd sortie/chamber run can repeat their dive on the 4th, 6th, 8th and 10th sorties.

There is one terminal tender on each sortie/chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 2 terminal tenders.

E-5.5.   Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above is:

PRM Attendants	8
Transfer Tender	2
Pre-Breathe Tenders	6
Terminal Tenders	2
Total	18

Table E-3. 35 FSW Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)
35	60	O2	1:00
35	15	Air	1:15
35	60	O2	2:15
Travel 1 FPM to 25	10	Air	2:25
25	5	Air	2:30
25	40	O2	3:10
Travel 1 FPM to 20"	5	O2	3:15
20	15	O2	3:30
20	15	Air	3:45
20	20	O2	4:05
Travel 1 FPM to Surface	20	Air	4:25

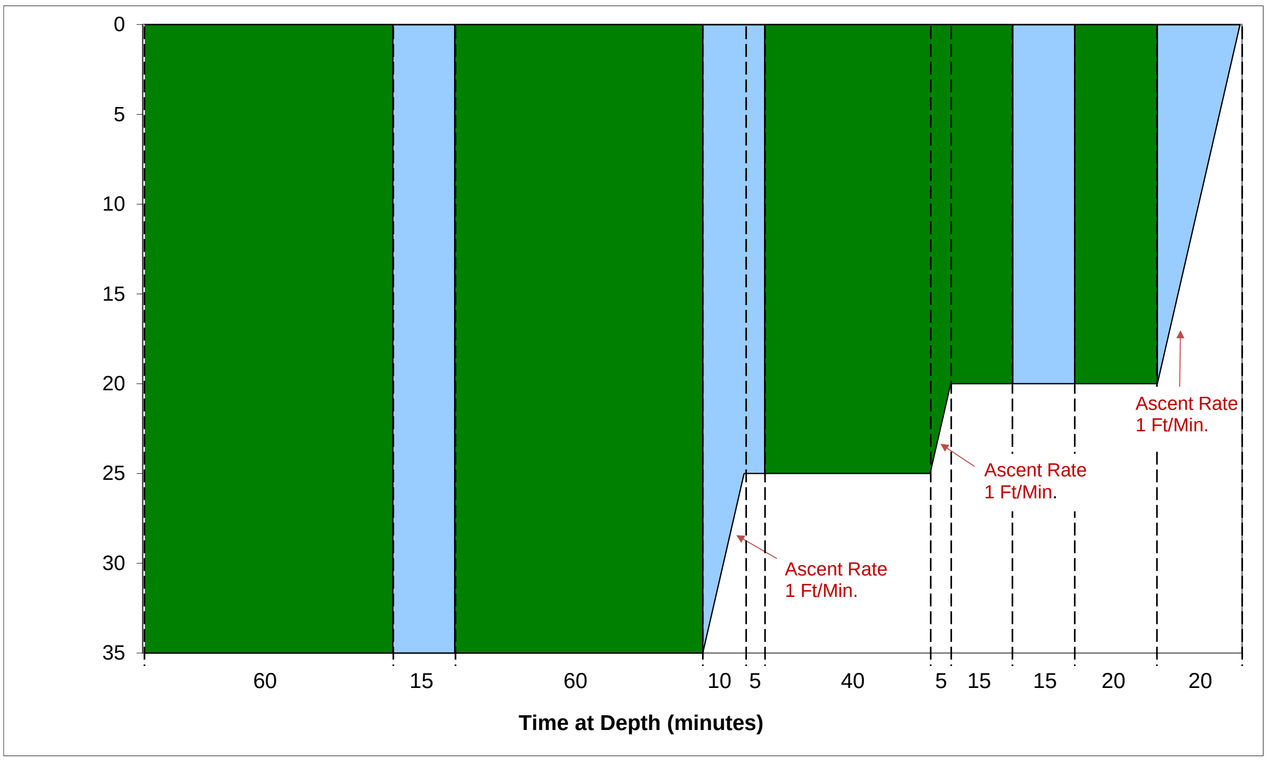


Figure E-2. 35 FSW Air/Oxygen Decompression Table with Air Breaks Included

Appendix F. Equivalent Air Saturation Depth 40 fsw

F-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (No Hold) mode. Decompression is begun when the first load of 16 rescuees has been transferred to the SDC.
2. All sorties go down unpressurized. This minimizes the bottom time of the PRM attendants. Each sortie launches with a fresh set of PRM attendants.
3. The No-Decompression time at 40 fsw is 163 min. The PRM attendants will be close to the limit when they complete their nominal 150 min bottom time in the PRM. After mating, they immediately enter the SDC and decompress to the surface via the MTL. Transfer of the rescuees from the PRM to the SDC is accomplished by three transfer tenders who lock in for this purpose. These transfer tenders are subsequently replaced by pre-breathe tenders and then by terminal tenders. Pre-breathe tenders will require a short period of oxygen breathing at depth prior to surfacing. The terminal tenders can ride to the surface on air with the rescuees without incurring a decompression obligation.
4. Rescuees pre-breathe oxygen for two hours in the SDC at the transfer depth to reduce the risk of bubble formation during the subsequent decompression to the surface on oxygen (Table 4.1). There is very little risk of CNS oxygen toxicity during the pre-breathing period at this depth.
5. DET members are not limited by pulmonary oxygen toxicity even if there has been no breathe down of the DISSUB oxygen level. They may lock into the DISSUB with the first sortie and be removed on the last.
6. PRM Attendants and SDC Tenders may perform repeat dives later in the rescue. Each attendant/tender is assigned a fixed role and repeats that exact role on subsequent chamber runs once the surface interval has been long enough not to increase the decompression obligation for the subsequent dive.

F-2. Rescuee Decompression Schedules

The schedules for decompressing rescuees at 40 fsw are shown in Table F-1. These basic tables are expanded to show all recommended air breaks in Table F-3 and Figure F-2.

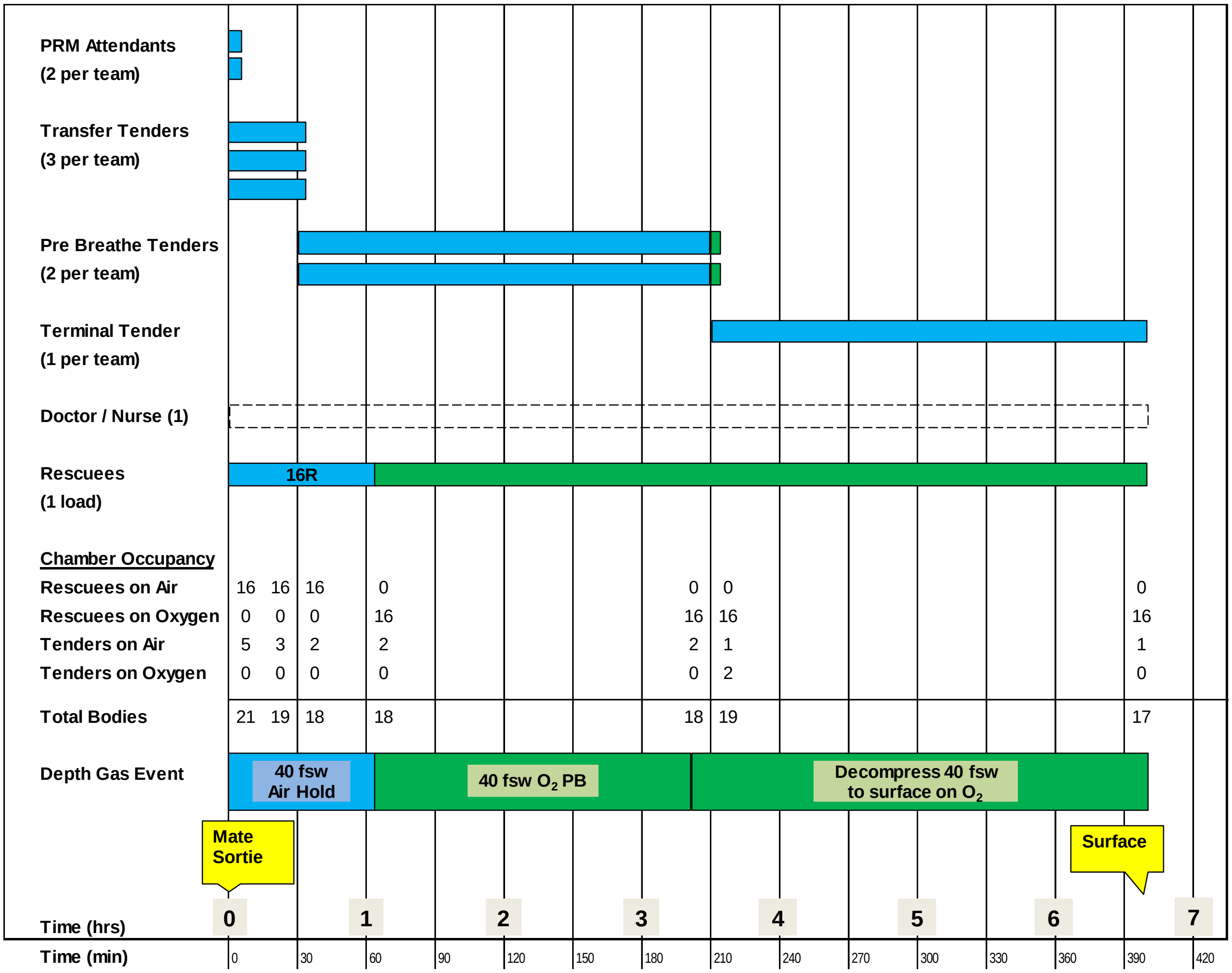
Table F-1. Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)							O2 Stop Time (min)	CPTD (units)
	40	30	25	20	15	10	5		
Oxygen	**120**	**10**	**85**	**40**				**255**	642
Air			185	260	290	320	80	**0**	0

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

F-3. Tender Management Plan

Figure F-1 shows the tender management plan for one chamber run.



	0		30	60	180	210	390
Rescuees on Air	16	16	16	0	0	0	0
Rescuees on Oxygen	0	0	0	16	16	16	16
Tenders on Air	5	3	2	2	2	1	1
Tenders on Oxygen	0	0	0	0	0	2	0
Total Bodies	21	19	18	18	18	19	17

Figure F-1. Tender Management 40 FSW Rescue

Immediately prior to the mate of the first sortie, three transfer tenders lock into the SDC via the MTL. One transfer tender positions himself in the SDC while the other two enter the DTL. Upon mating, the two PRM attendants immediately leave the PRM and make their way to the MTL where they decompress to the surface on air without stops. They will be close to their 163 min no-decompression limit when they complete their nominal 150 min bottom time in the PRM. If they do not make the 163 min limit, they will breathe oxygen in the SDC according to Table 4-5, then surface in the MTL.

The three transfer tenders transfer the reescuees from the PRM to the SDC. This transfer nominally takes 30 min. The transfer tenders are in a no-decompression status and can exit the SDC via the MTL without taking decompression stops.

Just before the transfer tenders lock out, two pre-breathe tenders lock in. Their role is to teach the rescuees how to use the MBS 2000, and then assist them during the pre-breathing period. They spend a total of 170 min at 40 fsw: 5 min for lockin, 30 min for instructing the rescuees, and 135 min for the pre-breathe itself. The pre-breathe consists of two 60 min periods on oxygen separated by a 15 min air break. The pre-breathe tenders then ascend at 1 fsw/min to the first decompression stop at 30 fsw. Their total bottom time (including the 10 min ascent from 40 to 30 fsw) is 180 min. The pre-breathe tenders then breathe oxygen at 30 fsw for 3 min according to Table F-2. They then lock out no-stop via the MTL. The prebreathe tenders are allowed 3 min on air at 30 fsw prior to starting decompression on air in the MTL.

Table F-2. Pre-Breathe Tender Oxygen Decompression Schedules--40 fsw

Time at Depth (min)	Ascent Time (min)	Oxygen at 30 fsw (min)	Repetitive Group	Clean Time (min)
31.7 FSW				
170	1.7	0	L	966
180	1.7	0	M	1002
190	1.7	0	M	1037
35 FSW				
170	5	0	N	1062
180	5	0	N	1104
190	5	0	O	1140
40 FSW				
170	10	3	Z	1192
180	10	5	Z	1225
190	10	7	Z	1257

Upon arrival at 30 fsw, one terminal tender locks into the chamber to tend to the rescuees. He can ride the remaining portion of the decompression schedule to the surface with the rescuees while breathing air.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure F-2. The maximum number of personnel in the chamber is 21. During the terminal portion of the saturation decompression there are 17 people in the chamber.

F-4. Sortie/Chamber Loading Analysis

Table F-3 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression.

F-5. Repetitive Exposure of PRM Attendants and SDC Tenders

F-5.1. PRM Attendants

At 40 fsw, PRM attendants no longer serve as transfer tenders. Once the PRM is mated to the DTL, they immediately transfer to the SDC and begin breathing oxygen to satisfy their decompression obligation. Surface interval calculations for PRM attendants are based on the worst case scenario, two sorties with 4 hours under pressure on each.

Table F-3. 40 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	16	16	0	16	0	0
2	Ch. 2	16	16	0	15	1	0
3	Ch. 1	16	16	0	15	1	0
4	Ch. 2	16	16	0	15	1	0
5	Ch. 1	16	16	0	15	1	0
6	Ch. 2	16	16	0	15	1	0
7	Ch. 1	16	16	0	15	1	0
8	Ch. 2	16	16	0	16	0	0
9	Ch. 1	16	16	0	16	0	0
10	Ch. 2	11	11	2	11	0	2
Total:		155	155	2	149	6	2

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 10 sorties and 10 chamber runs. The last sortie and chamber run carries only 11 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Only 1 DET team is required at this depth and this team can be inserted on the first sortie and removed on the tenth. Ten sorties and 10 chamber runs are required with the 10th sortie and the 10th chamber load only carrying 13 personnel.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and a two-man DET team. Ten sorties and 10 chamber loads are required to execute this scenario with the last sortie and chamber run carrying 13 personnel. The 6 stretcher cases are carried one per sortie for the Sorties 2-7.

Attendants with a total bottom time of 240 min on the first dive will surface in Repetitive Group Z according to the Dive Planner. Table 9-8 indicates that Group Z has a clean time of 15h 50 min (950 min). The Dive Planner shows a total clean time of 1378 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 4 is 818 min, 132 min shorter than the Dive Manual clean time. The surface interval available between Sortie 1 and Sortie 5 is 1178 min, 228 min longer than the Dive Manual clean time and 200 min shorter than the Dive Planner clean time. If a second 240 min dive is made after a 1178 min surface interval, the second dive will require a 1 min stop on air at 10 fsw in addition to the oxygen breathing time at depth. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 4.323% to 4.776% by the NMRI 98 probabilistic model and from 3.043% to 3.331% by the BVM(3) probabilistic model. A dive with a predicted risk between 3 and 5% is considered moderate risk.

Therefore, for 6 hour sorties:

PRM attendants from the 1st sortie can dive again on the 5th, and 9th sorties.
PRM attendants from the 2nd sortie can dive again on the 6th, and 10th sorties.
PRM attendants from the 3rd sortie can dive again on the 7th, and 11th sorties.
PRM attendants from the 4th sortie can dive again on the 8th and 12th sorties

Two PRM attendants are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 8 attendants.

F-5.2. Transfer Tender

Three transfer tenders are required for each sortie. Each transfer tender is exposed to 40 fsw for 30 min. With a 6 hour sortie time, the surface interval between transfer tender dives is 330 min. This surface interval is more than adequate to allow the same transfer tender to be used repetitively on every sortie. It may be necessary to add a second set of transfer tenders to allow time for transfer tenders to eat and sleep during off duty time. The total number of transfer tenders required is 6.

F-5.3. Pre-breathe Tenders

Pre-breathe tenders will have a bottom time of 170 min at 40 fsw, ascend to 30 fsw at 1 fsw/min while breathing air, then start oxygen breathing at 30 fsw. The tenders will surface in Repetitive Group Z according to the Dive Planner. Table 9-8 of the Diving Manual indicates that Group Z has a clean time of 15h 50min (950 min). The Dive Planner shows a total clean time of 1200 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 4 is 893 min, 57 min shorter than the Dive Manual clean time and 307 min shorter than the Dive Planner clean time. The surface interval available between Sortie 1 and Sortie 5 is 1253 min, longer than both the Dive Manual and Dive Planner clean times. If an identical dive is made after a surface interval of 1253 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 3.067% to 3.423% by the NMRI 98 probabilistic model or from its baseline value of 2.280% to 2.536% by the BVM(3) probabilistic model. A dive with a predicted risk of 3% or less is considered low risk. A dive with a predicted risk between 3-5% is considered moderate risk. Note that the risk of the second dive increases even though the surface interval exceeds the Dive Planner clean time.

Therefore, for 6 hour sorties:

PBT from the 1st sortie/chamber run can repeat their dive on the 5th and 9th sorties.
PBT from the 2nd sortie/chamber run can repeat their dive on the 6th and 10th sorties.
PBT from the 3rd sortie/chamber run can repeat their dive on the 7th and 11th sorties.
PBT from the 4th sortie/chamber run can repeat their dive on the 8th and 12th sorties.

Two pre-breathe tenders are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 8 pre-breathe tenders.

F-5.4. Terminal Tender

The terminal tender locks into the SDC at 30 fsw and then rides to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is I by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group I has a clean time of 9h 44min (584 min). The Dive Planner shows a clean time of 754 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 3 is 530 min, 54 min shorter than the Dive Manual clean time and 224 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 530 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will not increase from its baseline (totally clean) value of 0.391% to 0.569% by the NMRI 98 probabilistic model or from its baseline value of 0.097% to 0.465% by the BVM(3) probabilistic model. The second dive is very low risk even though the surface interval is shorter than the Dive Manual clean time.

Therefore, for 6 hour sorties:

TT from the 1st sortie/chamber run can repeat their dive on the 3rd, 5th, 7th, and 9th sorties.
TT from the 2nd sortie/chamber run can repeat their dive on the 4th, 6th, 8th and 10th sorties.

There is one terminal tender on each sortie/chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 2 terminal tenders.

F-5.5. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above is:

PRM Attendants	8
Transfer Tenders	6
Pre-Breathe Tenders	8
Terminal Tenders	2
Total	24

Table F-4. 40 FSW Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)
40	60	O2	1:00
40	15	Air	1:15
40	60	O2	2:15
Travel 1 FPM to 3	10	Air	2:25
30	05	Air	2:30
30	10	O2	2:40
Travel 1 FPM to 25	5	O2	2:45
25	45	O2	3:30
25	15	Air	3:45
25	35	O2	4:20
Travel 1 FPM to 20	5	O2	4:25
20	20	O2	4:45
20	15	Air	5:00
20	15	O2	5:15
Travel 1 FPM to surface	20	Air	5:35

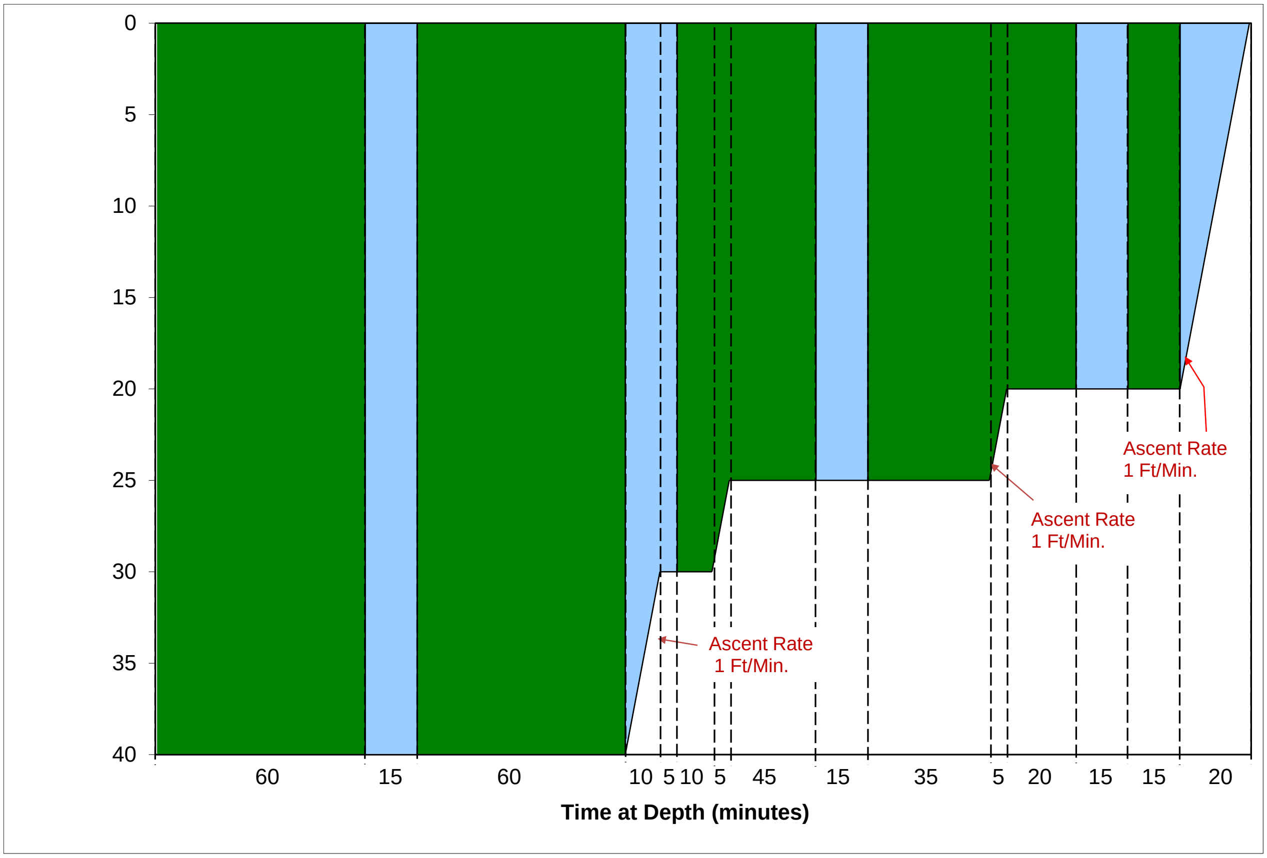


Figure F-2. 40 FSW Air/Oxygen Decompression Table with Air Breaks Included

Appendix G. Equivalent Air Saturation Depth 45 fsw

G-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (No Hold) mode when sortie times are 6 hours or more. Decompression is begun when the first load of 16 rescuees has been transferred to the SDC. Sortie times shorter than 6 hours will require the Dual Chamber (Hold) mode. Decompression will begin when 30+ rescuees are in the chamber.
2. All sorties go down unpressurized. This minimizes the bottom time of the PRM attendants. Each sortie launches with a fresh set of PRM attendants.
3. The No-Decompression time at 45 fsw is 125 min. The PRM attendants will be over the limit when they complete their nominal 150 min bottom time in the PRM. After mating, they immediately enter the SDC and begin breathing oxygen for the period specified in Table 4-5. At the completion of this time, they decompress to the surface on air via the MTL. Transfer of the rescuees from the PRM to the SDC is accomplished by three transfer tenders who lock in for this purpose. These transfer tenders are subsequently replaced by pre-breathe tenders and then by terminal tenders. Pre-breathe tenders will require a short period of oxygen breathing at depth prior to surfacing. The terminal tenders can ride to the surface on air with the rescuees without incurring a decompression obligation.
4. Rescuees pre-breathe oxygen for two hours in the SDC at the transfer depth to reduce the risk of bubble formation during the subsequent decompression to the surface on oxygen (Table 4-1). There is very little risk of CNS oxygen toxicity during the pre-breathing period at this depth.
5. DET members are not limited by pulmonary oxygen toxicity even if there has been no breathe down of the DISSUB oxygen level. They may lock into the DISSUB with the first sortie and be removed on the last.
6. PRM Attendants and SDC Tenders may perform repeat dives later in the rescue. Each attendant/tender is assigned a fixed role and repeats that exact role on subsequent chamber runs once the surface interval has been long enough not to increase the decompression obligation for the subsequent dive.

G-2. Rescuee Decompression Schedules

The schedules for decompressing rescuees at 45 fsw are shown in Table G-1. These basic tables are expanded to show all recommended air breaks in Tables G-5 and G-6 and in Figures G-2 and G-3.

Table G-1. Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)								O2 Stop Time (min)	CPTD (units)
	45	35	30	25	20	15	10	5		
Primary Oxygen	**120**	**20**	**105**	**115**	**50**				**410**	1044
Secondary Oxygen			**35**	**75**	**80**	**90**	**130**		**410**	719
Air			125	240	260	290	325	90	**0**	0

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

G-3. Tender Management Plan

Figure G-1 shows the tender management plan for one chamber run.

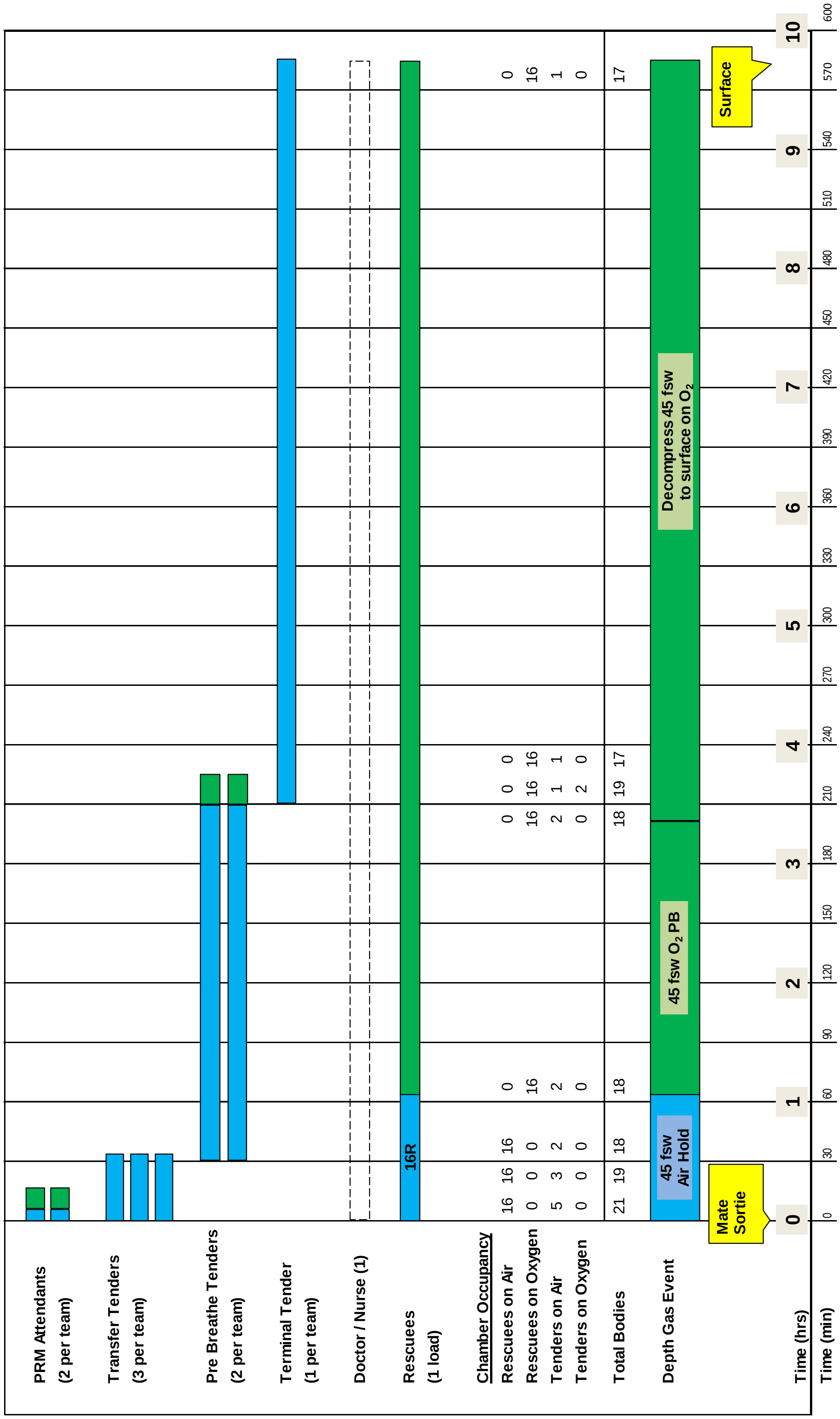


Figure G-1. Tender Management 45 FSW Rescue (PRM Attendant Time Under Pressure – 2.5 Hours)

Immediately prior to the mate of the first sortie, three transfer tenders lock into the SDC via the MTL. One transfer tender positions himself in the SDC while the other two enter the DTL. Upon mating, the two

PRM attendants immediately leave the PRM and make their way to the SDC. The PRM attendants will be over the 125 min no-decompression limit when they complete their nominal 150 min bottom time in the PRM. They breathe oxygen in the SDC for the period specified in Table 4-5. At the completion of this oxygen time, they decompress to the surface on air via the MTL.

The three transfer tenders transfer the reescuees from the PRM to the SDC. This transfer nominally takes 30 min. The transfer tenders are in a no-decompression status and can exit the SDC via the MTL without taking decompression stops.

Just before the transfer tenders lock out, two pre-breathe tenders lock in. Their role is to teach the rescuees how to use the MBS 2000, and then assist them during the pre-breathing period. They spend a total of 170 min at 45 fsw: 5 min for lockin, 30 min for instructing the rescuees, and 135 min for the pre-breathe itself. The pre-breathe consists of two 60 min periods on oxygen separated by a 15 min air break. The pre-breathe tenders then ascend at 1 fsw/min to the first decompression stop at 30 fsw.

The pre-breathe tender decompression schedules are given in Table G-2.

Table G-2. Pre-Breathe Tender Oxygen Decompression Schedules--45 fsw

Time at Depth (min)	Ascent Time (min)	Oxygen at 30 fsw (min)	Repetitive Group	Clean Time (min)
35.6 FSW				
170	0.6	0	N	1074
180	0.6	0	N	1115
190	0.6	0	O	1154
40 FSW				
170	5	3	Z	1188
180	5	5	Z	1222
190	5	7	Z	1254
45 FSW				
170	10	15	Z	1269
180	10	17	Z	1306
190	10	20	Z	1336

Table G-2 shows a range of depths because the pre-breathing takes place at the transfer depth which may be shallower than the equivalent air depth of the rescuees due to a breathe down of the DISSUB oxygen level. Enter the table at the depth that is exactly equal to or next deeper than the pre-breathe depth. Breathing down the oxygen level in the DISSUB can markedly reduce the pre-breathe depth and therefore the pre-breathe tender’s oxygen requirements.

For an exposure time of 170 min at a pre-breathe depth of 45 fsw, Table G-2 requires that the pre-breathe tenders breathe oxygen for a total of 15 min at 30 fsw. Bottom times of 180 and 190 min are also included in the pre-breathe tables in case the rescuees encounter difficulty with the pre-breathe and the bottom time at the pre-breathe depth has to be extended. Upon completion of their required oxygen time, the pre-breathe tenders lock out non-stop via the MTL. The pre-breathe tenders are allowed 3 min on air at 30 fsw prior to traveling to the surface on air at 30 fsw/min.

Before the pre-breathe tenders begin oxygen breathing at 30 fsw, one terminal tender locks into the chamber to tend to the rescuees. They can ride the remaining portion of the decompression schedule to the surface with the rescuees while breathing air.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure G-1. The maximum number of personnel in the chamber is 21. During the terminal portion of the saturation decompression there are 17 people in the chamber.

G-4. Sortie/Chamber Loading Analysis

Table G-3 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression.

Table G-3. 45 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	16	16	0	16	0	0
2	Ch. 2	16	16	0	15	1	0
3	Ch. 1	16	16	0	15	1	0
4	Ch. 2	16	16	0	15	1	0
5	Ch. 1	16	16	0	15	1	0
6	Ch. 2	16	16	0	15	1	0
7	Ch. 1	16	16	0	15	1	0
8	Ch. 2	16	16	0	16	0	0
9	Ch. 1	16	16	0	16	0	0
10	Ch. 2	11	11	2	11	0	2
Total:		155	155	2	149	6	2

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 10 sorties and 10 chamber runs. The last sortie and chamber run carries only 11 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Only 1 DET team is required at this depth and this team can be inserted on the first sortie and removed on the tenth. Ten sorties and 10 chamber runs are required with the 10th sortie and the 10th chamber load only carrying 13 personnel.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and a two-man DET team. Ten sorties and 10 chamber loads are required to execute this scenario with the last sortie and chamber run carrying 13 personnel. The 6 stretcher cases are carried one per sortie for the Sorties 2-7.

G-5. Abort of the Pre-Breathe Period due to CNS Oxygen Toxicity

It may be necessary to abort the pre-breathe period due to CNS oxygen toxicity in one or more of the rescuees, although this is very unlikely at a depth of 45 fsw. If an abort is required, the rescuees remain at depth on air until symptoms have abated. They then ascend at 1 fsw/min on air to the first decompression stop at 30 fsw. They remain on air for total of 15 min (including ascent time) before resuming oxygen breathing. See Table 4-2 and associated instructions for further details. Upon arrival at 30 fsw, one terminal tender locks in and the pre-breathe tenders begin oxygen breathing as required to satisfy their decompression obligation.

If an abort occurs, the pre-breathe tenders will require less oxygen breathing than if they remained at the pre-breathe depth for the full period. Table G-4 shows the oxygen requirement of pre-breathe tenders after an abort to 30 fsw. Enter the table at the bottom time that is equal to or next greater than the actual time spent at the pre-breathe depth.

Table G-4. Pre-Breathe Tender Oxygen Decompression Schedules for CNS O2 Toxicity Aborts to Secondary Rescuee Schedule--45 FSW

Time at Depth (min)	Ascent Time (min)	Oxygen at 30 fsw (min)	Repetitive Group	Clean Time (min)
35.6 FSW				
175	5.6	0	N	1108
40 FSW				
159	10	0	O	1166
175	10	4	Z	1217
45 FSW				
122	15	0	O	1105
140	15	6	O	1173
175	15	15	Z	1301

G-6. Repetitive Exposure of PRM Attendants and SDC Tenders

G-6.1. PRM Attendants

Once the PRM is mated to the DTL, the PRM attendants immediately transfer to the SDC and begin breathing oxygen to satisfy their decompression obligation. Surface interval calculations for PRM attendants are based on the worst case scenario, two sorties with 4 hours under pressure on each.

Attendants with a total bottom time of 240 min on the first dive will surface in Repetitive Group Z according to the Dive Planner. Table 9-8 indicates that Group Z has a clean time of 15h 50 min (950 min). The Dive Planner shows a total clean time of 1437 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 4 is 800 min, 150 min shorter than the Dive Manual clean time. The surface interval available between Sortie 1 and Sortie 5 is 1160 min, 210 min longer than the Dive Manual clean time and 277 min shorter than the Dive Planner clean time. If a second 240 min dive is made after a 1160 min surface interval, the second dive will not require any additional decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 4.717% to 5.265% by the NMRI 98 probabilistic model and from 3.344% to 3.721% by the BVM(3) probabilistic model. A dive with a predicted risk between 3 and 5% is considered moderate risk. A dive with a predicted risk greater than 5% is considered high risk.

Therefore, for 6 hour sorties:

PRM attendants from the 1st sortie can dive again on the 5th, and 9th sorties.
PRM attendants from the 2nd sortie can dive again on the 6th, and 10th sorties.
PRM attendants from the 3rd sortie can dive again on the 7th, and 11th sorties.
PRM attendants from the 4th sortie can dive again on the 8th and 12th sorties

Two PRM attendants are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 8 attendants.

G-6.2. Transfer Tenders

Two transfer tenders are required for each sortie. Each transfer tender is exposed to 45 fsw for 30 min. With a 6 hour sortie time, the surface interval between transfer tender dives is 330 min. This surface interval is more than adequate to allow the same transfer tender to be used repetitively on every sortie. It may be necessary to add a second set of transfer tenders to allow time for transfer tenders to eat and sleep during off duty time. The total number of transfer tenders required is 4.

G-6.3. Pre-breathe Tenders

Pre-breathe tenders will have a bottom time of 170 min at 45 fsw, ascend to 35 fsw at 1 fsw/min while breathing air, then start oxygen breathing at 35 fsw. The tenders will surface in Repetitive Group Z according to the Dive Planner. Table 9-8 of the Diving Manual indicates that Group Z has a clean time of 15h 50min (950 min). The Dive Planner shows a total clean time of 1269 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 4 is 800 min, 150 min shorter than the Dive Manual clean time and 469 min shorter than the Dive Planner clean time. The surface interval available between Sortie 1 and Sortie 5 is 1160 min, 210 min longer than the Dive Manual and 109 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 1160 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 3.506% to 3.910% by the NMRI 98 probabilistic model or from its baseline value of 2.280% to 2.562% by the BVM(3) probabilistic model. A dive with a predicted risk of 3% or less is considered low risk. A dive with a predicted risk between 3-5% is considered moderate risk.

Therefore, for 6 hour sorties:

PBT from the 1st sortie/chamber run can repeat their dive on the 5th and 9th sorties.
PBT from the 2nd sortie/chamber run can repeat their dive on the 6th and 10th sorties.
PBT from the 3rd sortie/chamber run can repeat their dive on the 7th and 11th sorties.
PBT from the 4th sortie/chamber run can repeat their dive on the 8th and 12th sorties.

Two pre-breathe tenders are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 8 pre-breathe tenders.

G-6.4. Terminal Tender

The terminal tender locks into the SDC at 35 fsw and then rides to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is M by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group M has a clean time of 13h 13min (793 min). The Dive Planner shows a clean time of 1209 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 4 is 705 min, 88 min shorter than the Dive Manual clean time and 504 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 705 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will not increase from its baseline (totally clean) value of 2.572% to 3.527% by the NMRI 98 probabilistic model or from its baseline value of 2.438% to 3.107% by the BVM(3) probabilistic model. A dive with a predicted risk of 3-5% is considered moderate risk.

Therefore, for 6 hour sorties:

TT from the 1st sortie/chamber run can repeat their dive on the 4th, 7th and 10th sorties.
TT from the 2nd sortie/chamber run can repeat their dive on the 5th, 8th, and 11th sorties.
TT from the 3rd sortie/chamber run can repeat their dive on the 6th, 9th, and 12th sorties.

There is one terminal tender on each sortie/chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 3 terminal tenders.

G-6.5. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above is:

PRM Attendants	8
Transfer Tenders	4
Pre-Breathe Tenders	8
Terminal Tenders	3
Total	23

Table G-5. 45 FSW Primary Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)
45	60	O2	1:00
45	15	Air	1:15
45	60	O2	2:15
Travel 1 FPM to 35	10	Air	2:25
35	5	Air	2:30
35	20	O2	2:50
Travel 1 FPM to 30	5	O2	2:55
30	35	O2	3:30
30	15	Air	3:45
30	60	O2	4:45
30	15	Air	5:00
30	5	O2	5:05
Travel 1 FPM to 25	5	O2	5:10
25	50	O2	6:00
25	15	Air	6:15
25	60	O2	7:15
Travel 1 FPM to 20	5	Air	7:20
20	10	Air	7:30
20	50	O2	8:20
Travel 1 FPM to surface	20	Air	8:40

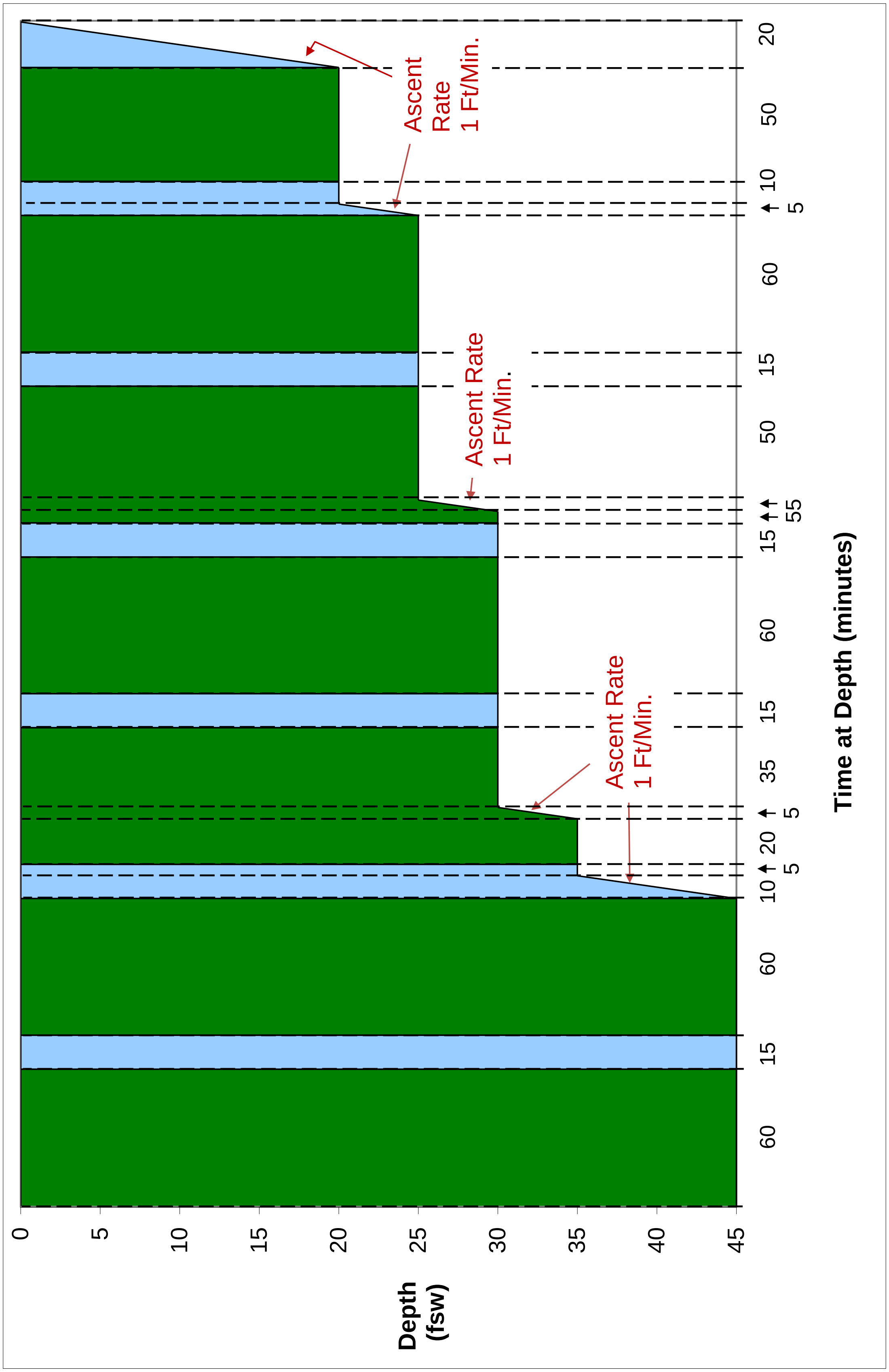


Figure G-2. Primary Air/Oxygen Decompression Table with Air Breaks Included

Table G-6. 45 FSW Secondary Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time (min)
45				
Travel 5 FPM to 30	3	Air	0:03	
30	35	O2	0:38	35
Travel 1 FPM to 25	5	O2	0:43	
25	20	O2	1:03	
25	15	Air	1:18	
25	50	O2	2:08	75
Travel 1 FPM to 20	5	O2	2:13	
20	5	O2	2:18	
20	15	Air	2:33	
20	60	O2	3:33	
20	15	Air	3:48	
20	10	O2	3:58	80
Travel 1 FPM to 15	5	O2	4:03	
15	45	O2	4:48	
15	15	Air	5:03	
15	40	O2	5:43	90
Travel 1 FPM to 10	5	O2	5:48	
10	15	O2	6:03	
10	15	Air	6:18	
10	60	O2	7:18	
10	15	Air	7:33	
10	50	O2	8:23	130
Travel 1 FPM to surface	10	Air	8:33	

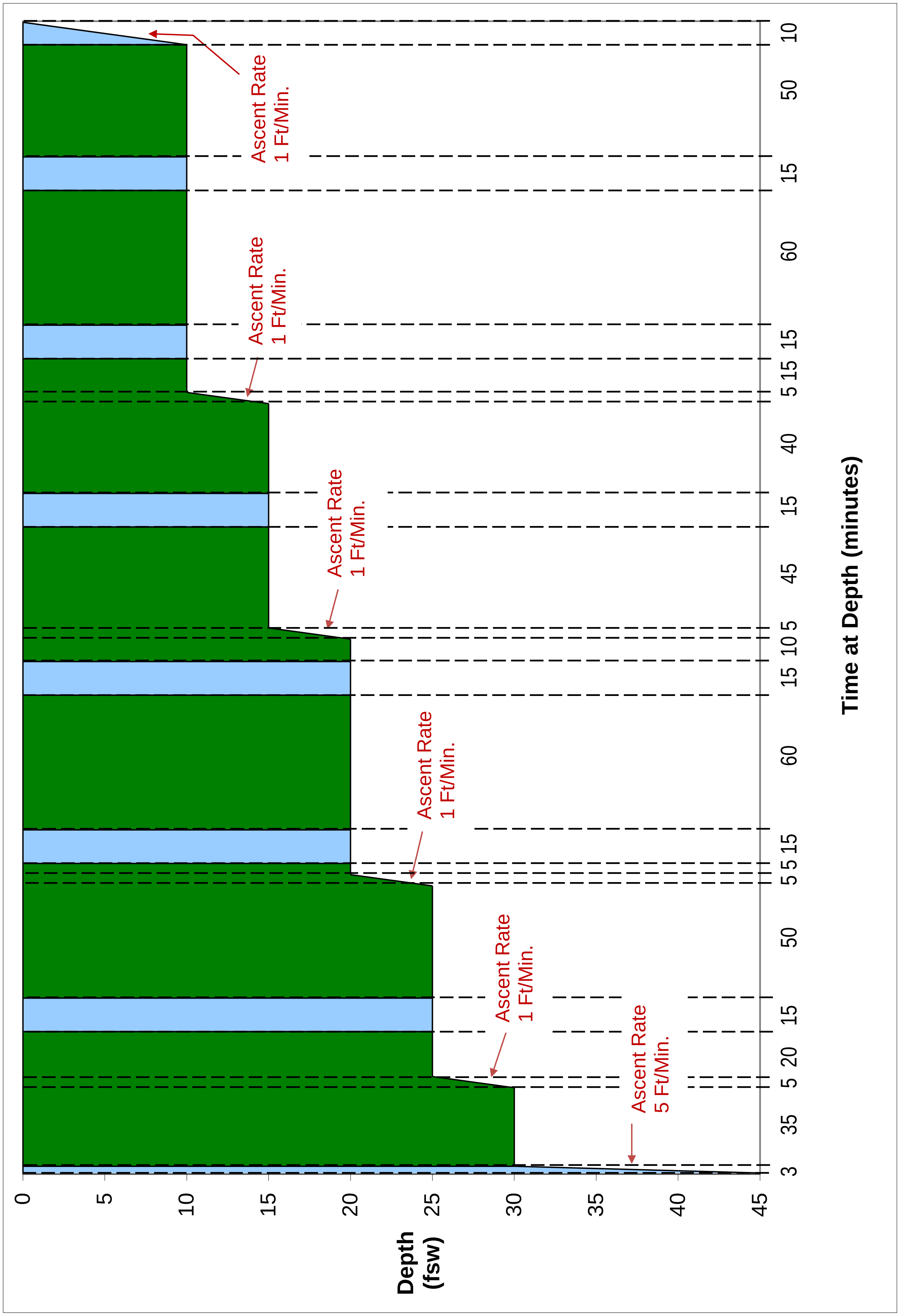


Figure G-3. 45 FSW Secondary Air/Oxygen Decompression Table with Air Breaks Included

Appendix H. Equivalent Air Saturation Depth 50 fsw

H-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (Hold) mode. Decompression will begin when 30+ rescuees are in the chamber.
2. All sorties go down unpressurized. This minimizes the bottom time of the PRM attendants. Each sortie launches with a fresh set of PRM attendants.
3. The No-Decompression time at 50 fsw is 92 min. The PRM attendants will be over the limit when they complete their nominal 150 min bottom time in the PRM. After mating, they immediately enter the SDC and begin breathing oxygen for the period specified in Table 4-5. At the completion of this time, they decompress to the surface on air via the MTL. This same process is repeated with the second set of PRM attendants when the second sortie mates. Transfer of the rescuees from the PRM to the SDC is accomplished by 2 transfer tenders and 1 custodial tender who lock in for this purpose. After the transfer tenders lock out, the custodial tender monitors the rescuees from the first sortie while the second sortie goes to recover the second load. These custodial tenders are replaced on a periodic basis. They breathe oxygen for a short period according to Table 4-5 and then lock out via the MTL. The final custodial tender is replaced by 3 pre-breathe tenders who supervise the pre-breathing. These pre-breathe tenders then replaced by 2 terminal tenders. The pre-breathe tenders breathe oxygen for a short period then lock out via the MTL. The terminal tenders can ride to the surface on air with the rescuees without incurring a decompression obligation.
4. Rescuees pre-breathe oxygen for two hours in the SDC at the transfer depth to reduce the risk of bubble formation during the subsequent decompression to the surface on oxygen (Table 4-1). There is a small risk of CNS oxygen toxicity during the pre-breathing period at this depth. A backup table (Table 4-2) is available if oxygen toxicity occurs during the pre-breathe period.
5. DET members are not limited by pulmonary oxygen toxicity even if there has been no breathe down of the DISSUB oxygen level. They may lock into the DISSUB with the first sortie and be removed on the last.
6. PRM Attendants and SDC Tenders may perform repeat dives later in the rescue. Each attendant/tender is assigned a fixed role and repeats that exact role on subsequent chamber runs once the surface interval has been long enough not to increase the decompression obligation for the subsequent dive.

H-2. Rescuee Decompression Schedules

The schedules for decompressing rescuees at 50 fsw are shown in Table H-1. These basic tables are expanded to show all recommended air breaks in Tables H-5 and H-6 and in Figures H-2 and H-3.

Table H-1. Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)								O2 Stop Time (min)	CPTD (units)
	50	35	30	25	20	15	10	5		
Primary Oxygen	**120**	**85**	**105**	**115**	**50**				**475**	1254
Secondary Oxygen		**25**	**65**	**75**	**80**	**95**	**135**		**475**	875
Air		75	215	240	260	295	325	100	**0**	0

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

H-3. Tender Management Plan

Figure H-1 shows the tender management plan for one chamber run.

Immediately prior to the mate of the first sortie, two transfer tenders and one custodial tender lock into the SDC via the MTL. The two transfer tenders position themselves in the DTL, while the custodial tender remains in the SDC. As soon as the PRM/DTL hatches are open, the two PRM attendants make their way into the SDC and begin breathing oxygen from the MBS 2000. Five minutes is allowed for the PRM attendants to exit the PRM, enter the SDC, and go on oxygen. Assuming, their bottom time in the PRM prior to transfer was 2.5h, they breathe oxygen according to the 50 fsw/160 min schedule in Table 4-5. This schedule requires 23 min on oxygen.

As soon as the PRM attendants have left the PRM, one of the transfer tenders enters the PRM to assist in the transfer of rescuees. The rescuees are passed from the PRM to the transfer tender in the DTL and then to the custodial tender in the SDC, who gets them seated. The transfer process takes 30 min after which the transfer tenders can lock out of the SDC via the MTL in a no-decompression status. The No-Decompression time at 50 fsw is 92 min.

The second sortie launches at +2h. During the intervening time, the first custodial tender ministers to the needs of the rescuees. His total bottom time is 130 min. A second custodial tender locks in at this point and the first custodial tender goes on oxygen to satisfy his decompression obligation. He breathes 13 min of oxygen according to the 50 fsw/130 min tender schedule (Table 4-5) then locks out of the SDC. The process is repeated with a third custodial tender.

The second sortie mates with the DTL at +6h. The same sequence with the PRM attendants and transfer tenders is repeated. Once the transfer tenders have locked out and the third custodial tender is ready to start oxygen breathing, three pre-breathe tenders lock in. Their role is to teach the rescuees how to use the MBS 2000, then assist them during the pre-breathing period. They spend a total of 170 min at 50 fsw: 5 min for lockin, 30 min for instructing the rescuees, and 135 min for the pre-breathe itself. The pre-breathe consists of four 30 min periods on oxygen separated by 5 min air breaks. The pre-breathe tenders then ascend at 1 fsw/min to the first decompression stop at 35 fsw and go on oxygen.

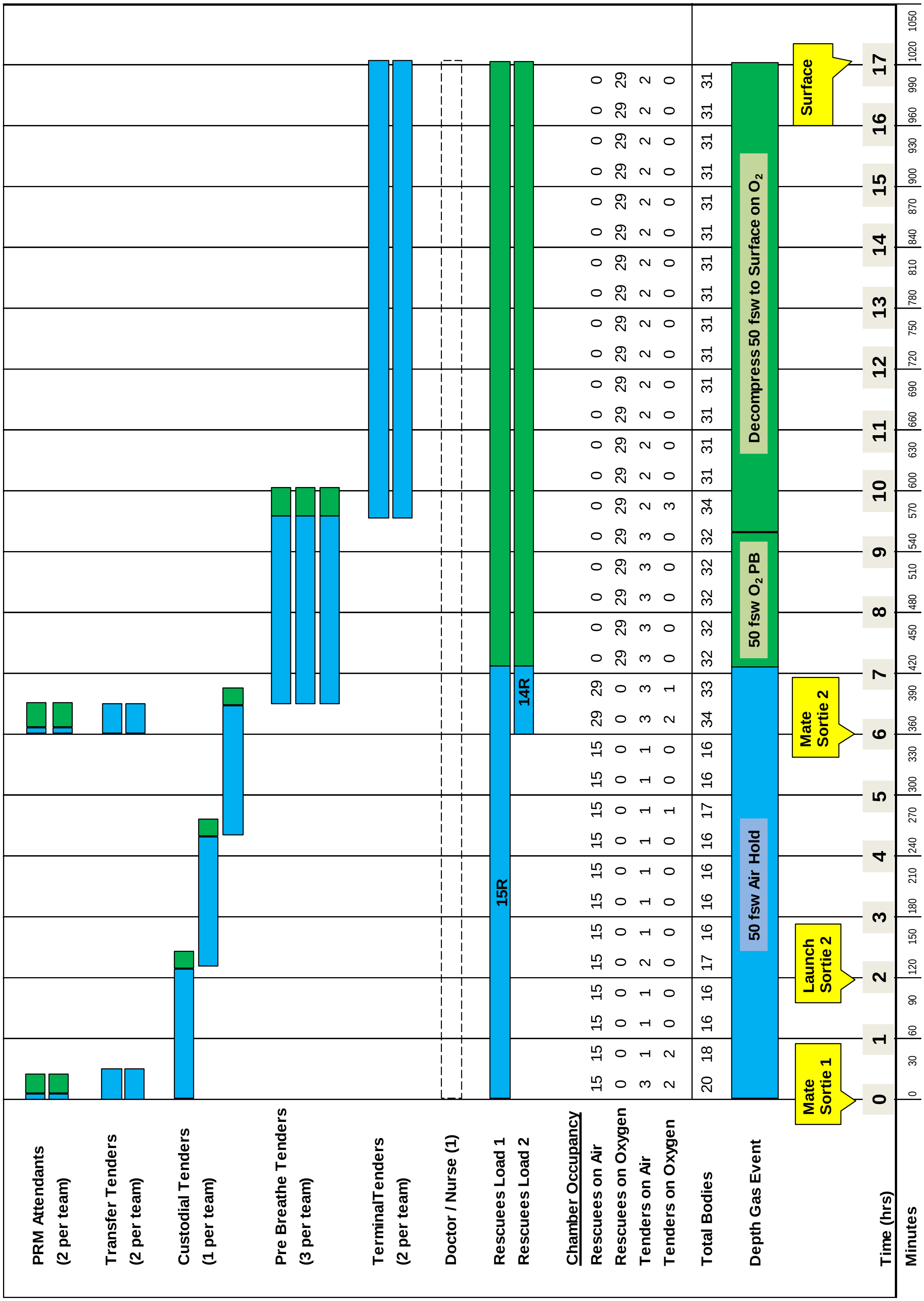


Figure H-1. Tender Management 50 FSW Rescue (PRM Attendant Time Under Pressure – 2.5 Hours)

The pre-breathe tender decompression schedules are given in Table H-2.

Table H-2. Pre-Breathe Tender Oxygen Decompression Schedules--50 fsw

Time at Depth (min)	Ascent Time (min)	Oxygen at 35 fsw (min)	Repetitive Group	Clean Time (min)
39.6 FSW				
170	4.6	2	O	1181
180	4.6	4	Z	1215
190	4.6	6	Z	1247
45 FSW				
170	10	15	Z	1269
180	10	17	Z	1306
190	10	20	Z	1336
50 FSW				
170	15	27	Z	1345
180	15	31	Z	1374
190	15	35	-	1401

Table H-2 shows a range of depths because the pre-breathing takes place at the transfer depth which may be shallower than the equivalent air depth of the rescuees due to a breathe down of the DISSUB oxygen level. Enter the table at the depth that is exactly equal to or next deeper than the pre-breathe depth. Breathing down the oxygen level in the DISSUB can markedly reduce the pre-breathe depth and therefore the pre-breathe tender's oxygen requirements.

For an exposure time of 170 min at a pre-breathe depth of 50 fsw, Table H-2 requires that the pre-breathe tenders breathe oxygen for a total of 27 min at 35 fsw. Bottom times of 180 and 190 min are also included in the pre-breathe tables in case the rescuees encounter difficulty with the pre-breathe and the bottom time at the pre-breathe depth has to be extended.

Before the pre-breathe tenders begin oxygen breathing at 35 fsw, two terminal tenders lock into the chamber to tend to the rescuees. They can ride the remaining portion of the decompression schedule to the surface with the rescuees while breathing air.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure H-1. The maximum number of personnel in the chamber is 34, with 2 breathing air and 32 breathing oxygen. During the terminal portion of the saturation decompression there are 31 people in the chamber.

H-4. Sortie/Chamber Loading Analysis

Table H-3 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression.

Table H-3. 50 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	15	15	0	15	0	0
2		14	14	0	14	0	0
3	Ch. 2	15	15	0	15	1	0
4		14	14	0	11	1	0
5	Ch. 1	15	15	0	15	1	0
6		14	14	0	11	1	0
7	Ch. 2	15	15	0	15	1	0
8		14	14	0	11	1	0
9	Ch. 1	15	15	0	15	0	0
10		14	14	0	14	0	0
11	Ch. 2	10	10	2	13	0	2
12		-	-	-	-	-	-
Total:		155	155	2	149	6	2

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 10 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Only 1 DET team is required at this depth and this team can be inserted on the first sortie and removed on the eleventh. Eleven sorties and 6 chamber loads are required with the 11th sortie and the 6th chamber load only carrying 12 personnel.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and a two-man DET team. Eleven sorties and 6 chamber loads are required to execute this scenario with the last sortie and the last chamber run carrying a total of 15 personnel. The 6 stretcher cases are carried one per sortie for Sorties 3-8.

H-5. Abort of the Pre-Breathe Period due to CNS Oxygen Toxicity

It may be necessary to abort the pre-breathe period due to CNS oxygen toxicity in one or more of the rescuees. This is more likely if no breathe-down of the DISSUB oxygen level has occurred and the pre-breathe depth is 50 fsw. If an abort is required, the rescuees remain at depth on air until symptoms have abated. They then ascend at 1 fsw/min on air to the first decompression stop. They remain on air for total of 15 min (including ascent time) before resuming oxygen breathing. See Table 4-2 and associated instructions for further details. Upon arrival at 35 fsw, two terminal tenders lock in and the pre-breathe tenders begin oxygen breathing as required to satisfy their decompression obligation.

If an abort occurs, the pre-breathe tenders will require less oxygen breathing than if they remained at the pre-breathe depth for the full period. Table H-4 shows the oxygen requirement of pre-breathe tenders after an abort to 35 fsw. Enter the table at the bottom time that is equal to or next greater than the actual time spent at the pre-breathe depth.

Table H-4. Pre-Breathe Tender Oxygen Decompression Schedules for CNS O2 Toxicity Aborts to Secondary Rescuee Schedule--50 FSW

Time at Depth (min)	Ascent Time (min)	Oxygen at 35 fsw (min)	Oxygen 35-30 fsw	Oxygen at 30 fsw (min)	Repetitive Group	Clean Time (min)
39.6 FSW						
163	4.6	0			O	1160
175	4.6	3			Z	1198
45 FSW						
122	10	0			O	1091
140	10	7			O	1156
175	10	16			Z	1288
50 FSW						
91	15	0			N	1008
105	15	4			O	1083
140	15	17			Z	1233
175	15	25	5	0	Z	1350

H-6. Repetitive Exposure of PRM Attendants and SDC Tenders

H-6.1. PRM Attendants

Once the PRM is mated to the DTL, the PRM attendants immediately transfer to the SDC and begin breathing oxygen to satisfy their decompression obligation. Surface interval calculations for PRM attendants are based on the worst case scenario, two sorties with 4 hours under pressure on each.

Attendants with a total bottom time of 240 min on the first dive will surface with the Repetitive Group Out-of-Range according to the Dive Planner. In this case, a surface interval of 24 hours (1440 min) is assumed. The Dive Planner shows a total clean time of 1437 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 5 is 1135 min, 302 min shorter than the Dive Planner clean time. The surface interval available between Sortie 1 and Sortie 6 is 1495 min, 58 min longer than the Dive Planner clean time. If a second 240 min dive is made after a 1495 min surface interval, the second dive will not require any additional decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 5.232% to 5.523% by the NMRI 98 probabilistic model and from 3.766% to 3.937% by the BVM(3) probabilistic model. A dive with a predicted risk between 3 and 5% is considered moderate risk. A dive with a predicted risk greater than 5% is considered high risk.

Therefore, for 6 hour sorties:

PRM attendants from the 1st sortie can dive again on the 6th and 11th sorties.
PRM attendants from the 2nd sortie can dive again on the 7th sorties and 12th sorties.
PRM attendants from the 3rd sortie can dive again on the 8th sortie.
PRM attendants from the 4th sortie can dive again on the 9th sortie.
PRM attendants from the 5th sortie can dive again on the 10th sortie.

Two PRM attendants are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 10 attendants.

H-6.2. Transfer Tenders

Two transfer tenders are required for each sortie. Each transfer tender is exposed to 50 fsw for 30 min. With a 6 hour sortie time, the surface interval between transfer tender dives is 330 min. This surface interval is more than adequate to allow the same transfer tender to be used repetitively on every sortie. It may be necessary to add a second set of transfer tenders to allow time for transfer tenders to eat and sleep during off duty time. The total number of transfer tenders required is 4.

H-6.3. Custodial Tenders

Three custodial tenders are required for each chamber load. Each custodial tender has a 130 min bottom time followed by oxygen breathing at depth to satisfy his decompression obligation. Upon surfacing, the repetitive group designator is O according to the Dive Planner. Table 9-8 of the Diving Manual indicates the Group O has a clean time of 14h 58min (898 min). The Dive Planner shows a total clean time of 1137 min for all tissues. The surface interval is too short to permit the custodial tenders to repeat their exposure on the second chamber run. The available surface interval for the 3rd chamber run is 1292 min, 155 min longer than the clean time according to the Dive Planner. If a second 240 min dive is made after a 1292 min surface interval, the second dive will not require any additional decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 3.367% to 3.650% by the NMRI 98 probabilistic model and from 1.750% to 1.966% by the BVM(3) probabilistic model. A dive with a predicted risk less than 3% is considered low risk. A dive with a predicted risk between 3 and 5% is considered moderate risk.

Therefore, for 6 hour sorties:

CT from the 1st chamber run can dive again on the 3rd and 5th chamber runs.
CT from the 2nd chamber run can dive again on the 4th and 6th chamber runs.

H-6.4. Pre-breathe Tenders

Pre-breathe tenders will have a bottom time of 170 min at 50 fsw, ascend to 35 fsw at 1 fsw/min while breathing air, then start oxygen breathing at 35 fsw. The tenders will surface in Repetitive Group Z according to the Dive Planner. Table 9-8 of the Diving Manual indicates that Group Z has a clean time of 15h 50min (950 min). The Dive Planner shows a total clean time of 1345 min for all tissues. With a sortie time of 6 hours, the surface interval available between Chamber Run 1 and Chamber Run 3 is 1224 min, 274 min longer than the Dive Manual clean time and 121 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 1345 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 3.506% to 3.910% by the NMRI 98 probabilistic model or from its baseline value of 2.280% to 2.562% by the BVM(3) probabilistic model. A dive with a predicted risk of 3% or less is considered low risk. A dive with a predicted risk between 3-5% is considered moderate risk.

Therefore, for 6 hour sorties:

PBT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber runs.
PBT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber runs.

Three pre-breathe tenders are needed for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 pre-breathe tenders.

H-6.5. Terminal Tenders

Terminal tenders lock into the SDC at 35 fsw and then ride to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is N by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group N has a clean time of 14h 5min (845 min). The Dive Planner shows a clean time of 1373 min for all tissues. With a sortie time of 6 hours, the surface interval available between Chamber Run 1 and Chamber Run 3 is 990 min, 145 min longer than the Dive Manual clean time and 383 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 990 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 4.162% to 4.789% by the NMRI 98 probabilistic model or from its baseline value of 3.720% to 4.109% by the BVM(3) probabilistic model. A dive with a predicted risk of 3-5% is considered moderate risk.

Therefore, for 6 hour sorties:

TT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber run.
TT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber run.

Two terminal tenders are required for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 4 terminal tenders.

H-6.6. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above is:

PRM Attendants	10
Transfer Tenders	4
Custodial Tenders	6
Pre-Breathe Tenders	6
Terminal Tenders	4
Total	30

Table H-5. 50 FSW Primary Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time (min)
50	30	O2	0:30	
50	5	Air	0:35	
50	30	O2	1:05	
50	5	Air	1:10	
50	30	O2	1:40	
50	5	Air	1:45	
50	30	O2	2:15	120
Travel 1 FPM to 35	15	Air	2:30	
35	60	O2	3:30	
35	15	Air	3:45	
35	25	O2	4:10	85
Travel 1 FPM to 30	5	O2	4:15	
30	30	O2	4:45	
30	15	Air	5:00	
30	60	O2	6:00	
30	15	Air	6:15	
30	10	O2	6:25	105
Travel 1FPM to 25	5	O2	6:30	
25	45	O2	7:15	
25	15	Air	7:30	
25	60	O2	8:30	
25	15	Air	8:45	
25	5	O2	8:50	115
Travel 1 FPM to 20	5	O2	8:55	
20	45	O2	9:40	50
Travel 1 FPM to surface	20	Air	10:00	

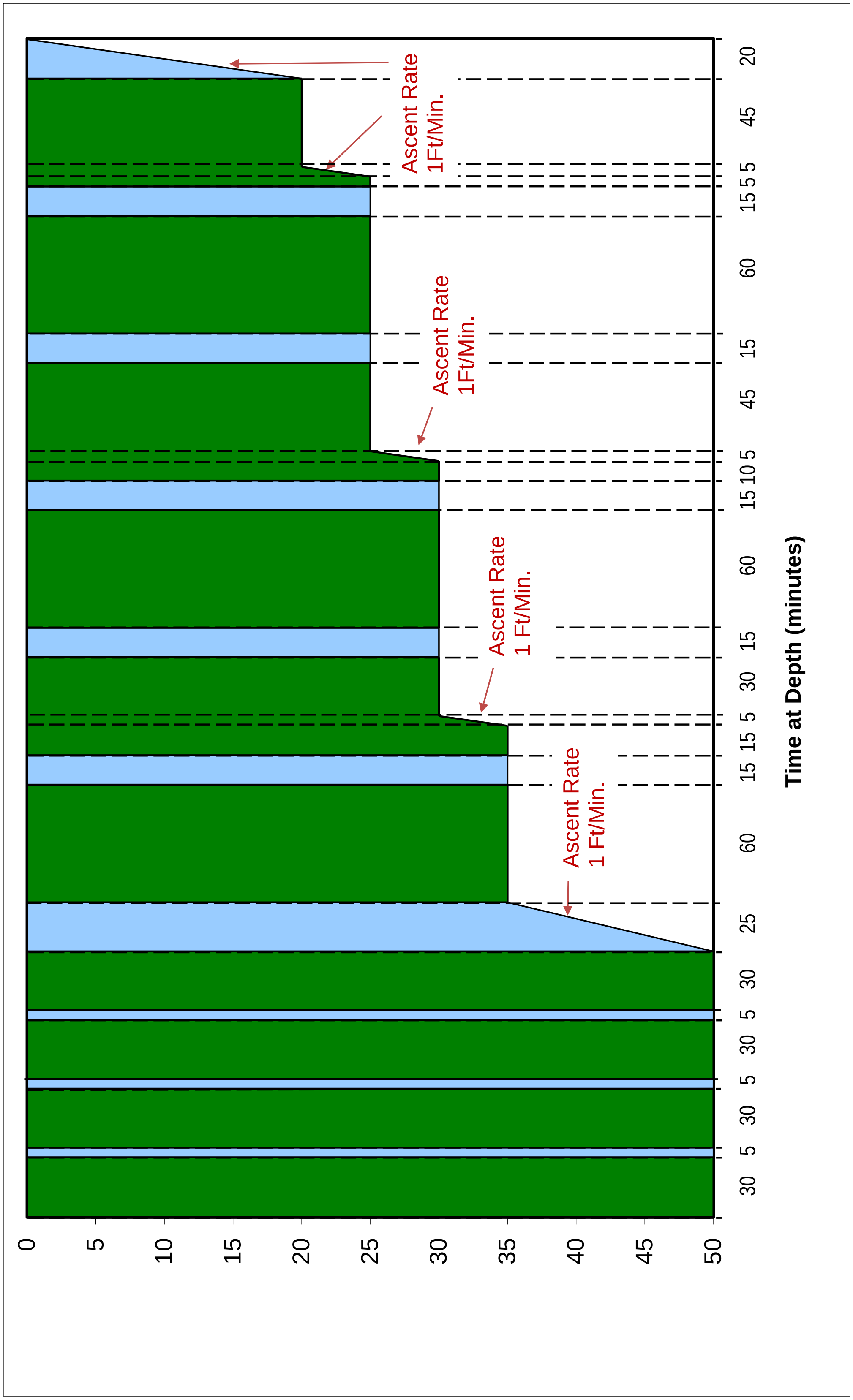


Figure H-2. 50 FSW Primary Air/Oxygen Decompression Table with Air Breaks Included

Table H-6. 50 FSW Secondary Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time (min)
50				
Travel 5 FPM to 35	3	Air	0:03	
35	25	O_2	0:28	25
Travel 1 FPM to 30	5	O_2	0:33	
30	30	O_2	1:03	
30	15	Air	1:18	
30	30	O_2	1:48	65
Travel 1FPM to 25	5	O_2	1:53	
25	25	O_2	2:18	
25	15	Air	2:33	
25	45	O_2	3:18	75
Travel 1 FPM to 20	5	O_2	3:23	
20	10	O_2	3:33	
20	15	Air	3:48	
20	60	O_2	4:48	
20	15	Air	5:03	
20	5	O_2	5:08	80
Travel 1 FPM to 15	5	O_2	5:13	
15	50	O_2	6:03	
15	15	Air	6:18	
15	40	O_2	6:58	95
Travel 1 FPM to 10	5	O_2	7:03	
10	15	O_2	7:18	
10	15	Air	7:33	
10	60	O_2	8:33	
10	15	Air	8:58	
10	55	O_2	9:53	135
Travel 1 FPM to surface	10	Air	10:03	

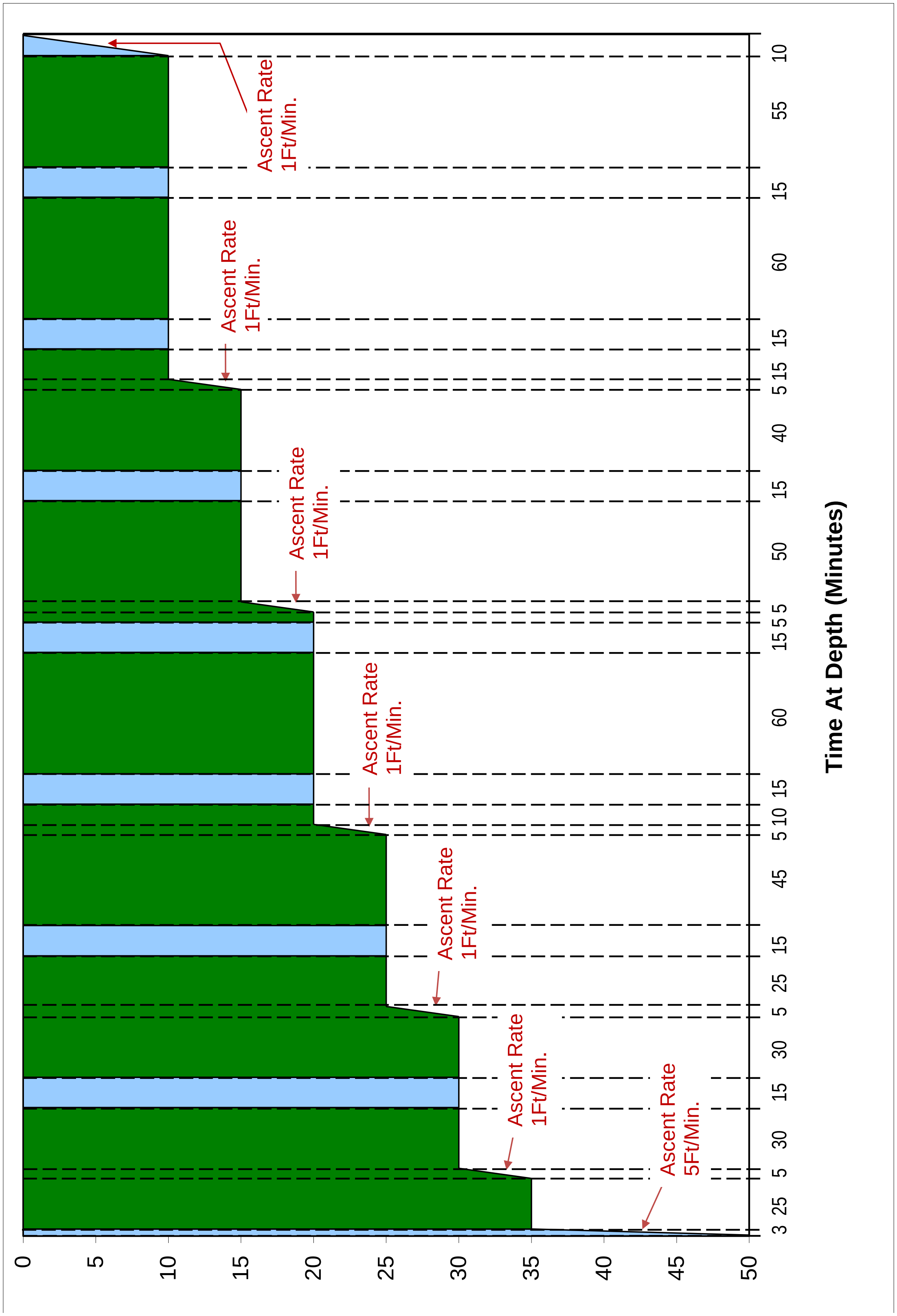


Figure H-3. 50 FSW Secondary Air/Oxygen Decompression Table with Air Breaks Included

Appendix I. Equivalent Air Saturation Depth 55 fsw

I-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (Hold) mode. Decompression will begin when 30+ rescuees are in the chamber.
2. All sorties go down unpressurized. This minimizes the bottom time of the PRM attendants. Each sortie launches with a fresh set of PRM attendants.
3. The No-Decompression time at 55 fsw is 74 min. The PRM attendants will be over the limit when they complete their nominal 150 min bottom time in the PRM. After mating, they immediately enter the SDC and begin breathing oxygen for the period specified in Table 4-5. At the completion of this time, they decompress to the surface on air via the MTL. This same process is repeated with the second set of PRM attendants when the second sortie mates. Transfer of the rescuees from the PRM to the SDC is accomplished by 2 transfer tenders and 1 custodial tender who lock in for this purpose. After the transfer tenders lock out, the custodial tender monitors the rescuees from the first sortie while the second sortie goes to recover the second load. These custodial tenders are replaced on a periodic basis. They breathe oxygen for a short period according to Table 4-5 and then lock out via the MTL. The final custodial tender is replaced by 3 pre-breathe tenders who supervise the pre-breathing. These pre-breathe tenders then replaced by 2 terminal tenders. The pre-breathe tenders breathe oxygen for a short period then lock out via the MTL. The terminal tenders can ride to the surface on air with the rescuees without incurring a decompression obligation.
4. Rescuees pre-breathe oxygen for two hours in the SDC at the transfer depth to reduce the risk of bubble formation during the subsequent decompression to the surface on oxygen (Table 4-1). There is a small risk of CNS oxygen toxicity during the pre-breathing period at this depth. A backup table (Table 4-2) is available if oxygen toxicity occurs during the pre-breathe period.
5. DET members are not limited by pulmonary oxygen toxicity even if there has been no breathe down of the DISSUB oxygen level. They may lock into the DISSUB with the first sortie and be removed on the last.
6. PRM Attendants and SDC Tenders may perform repeat dives later in the rescue. Each attendant/tender is assigned a fixed role and repeats that exact role on subsequent chamber runs once the surface interval has been long enough not to increase the decompression obligation for the subsequent dive.

I-2. Rescuee Decompression Schedules

The schedules for decompressing rescuees at 55 fsw are shown in Table I-1. These basic tables are expanded to show all recommended air breaks in Tables I-5 and I-6 and in Figures I-2 and I-3.

Table I-1. Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)									O2 Stop Time (min)	CPTD (units)
	55	40	35	30	25	20	15	10	5		
Primary Oxygen	**120**	**55**	**95**	**105**	**115**	**50**				**540**	1479
Secondary Oxygen		**10**	**60**	**70**	**75**	**80**	**95**	**140**		**530**	1019
Air		35	195	215	240	260	290	320	120	**0**	0

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

I-3. Tender Management Plan

Figure I-1 shows the tender management plan for one chamber run.

Immediately prior to the mate of the first sortie, two transfer tenders and one custodial tender lock into the SDC via the MTL. The two transfer tenders position themselves in the DTL, while the custodial tender remains in the SDC. As soon as the PRM/DTL hatches are open, the two PRM attendants make their way into the SDC and begin breathing oxygen from the MBS 2000. Five minutes is allowed for the PRM attendants to exit the PRM, enter the SDC, and go on oxygen. Assuming, their bottom time in the PRM prior to transfer was 2.5h, they breathe oxygen according to the 50 fsw/160 min schedule in Table 4-5. This schedule requires 35 min on oxygen. No air break is required.

As soon as the PRM attendants have left the PRM, one of the transfer tenders enters the PRM to assist in the transfer of rescuees. The rescuees are passed from the PRM to the transfer tender in the DTL and then to the custodial tender in the SDC, who gets them seated. The transfer process takes 30 min after which the transfer tenders can lock out of the SDC via the MTL in a no-decompression status. The No-Decompression time at 55 fsw is 74 min.

The second sortie launches at +2h. During the intervening time, the first custodial tender ministers to the needs of the rescuees. His total bottom time is 130 min. A second custodial tender locks in at this point and the first custodial tender goes on oxygen to satisfy his decompression obligation. He breathes 23 min of oxygen according to the 55 fsw/130 min tender schedule (Table 4-5) then locks out of the SDC. The process is repeated with a third custodial tender.

The second sortie mates with the DTL at +6h. The same sequence with the PRM attendants and transfer tenders is repeated. Once the transfer tenders have locked out and the third custodial tender is ready to start oxygen breathing, three pre-breathe tenders lock in. Their role is to teach the rescuees how to use the MBS 2000, then assist them during the pre-breathing period. They spend a total of 170 min at 55 fsw: 5 min for lockin, 30 min for instructing the rescuees, and 135 min for the pre-breathe itself. The pre-breathe consists of four 30 min periods on oxygen separated by 5 min air breaks. The pre-breathe tenders then ascend at 1 fsw/min to the first decompression stop at 40 fsw and go on oxygen.

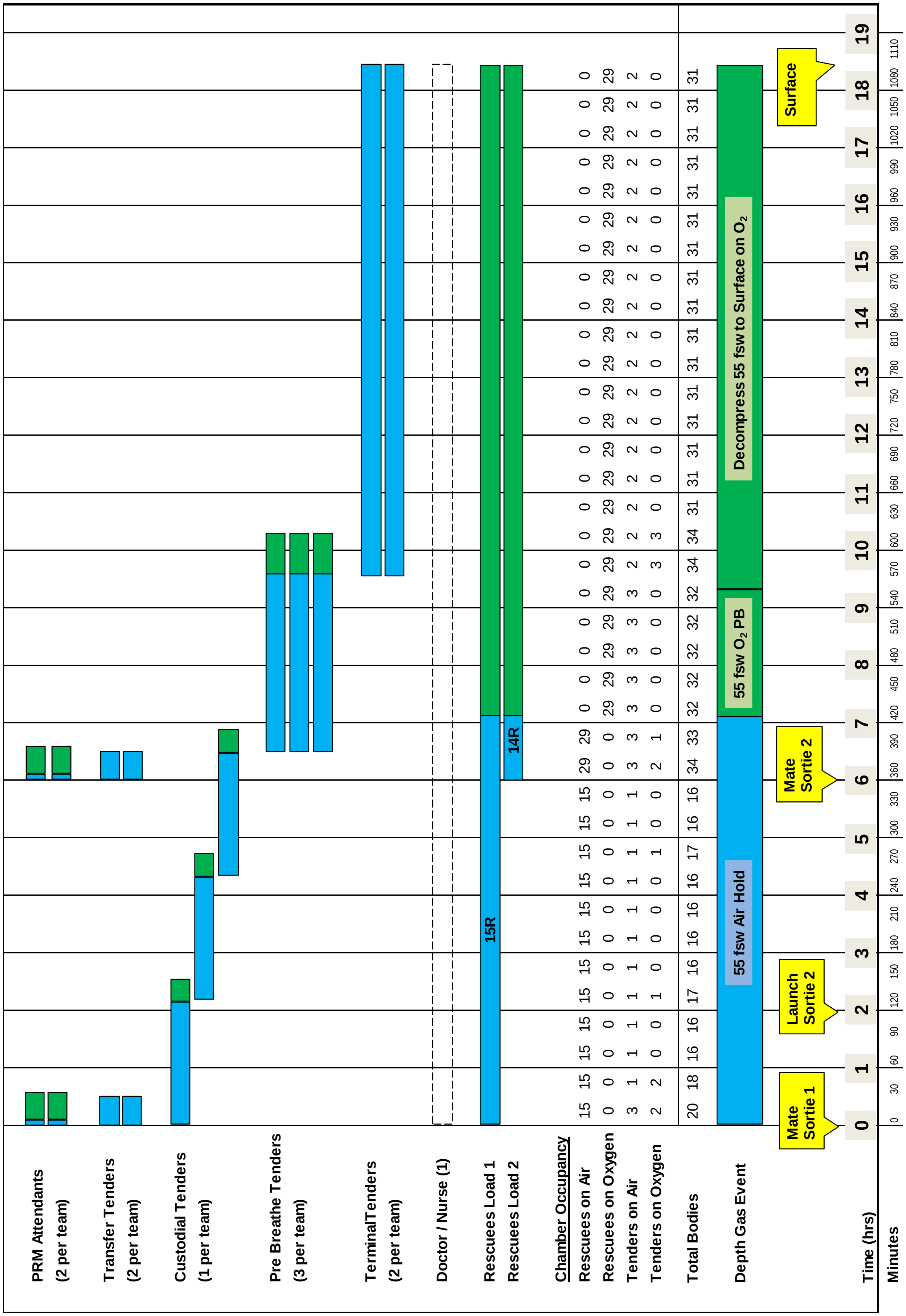


Figure I-1. Tender Management 55 FSW Rescue (PRM Attendant Time Under Pressure – 2.5 Hours)

The pre-breathe tender decompression schedules are given in Table I-2.

Table I-2. Pre-Breathe Tender Oxygen Decompression Schedules--55 fsw

Time at Depth (min)	Ascent Time (min)	Oxygen at 40 fsw (min)	Repetitive Group	Clean Time (min)
43.6 FSW				
170	3.6	12	Z	1230
180	3.6	14	Z	1268
190	3.6	16	Z	1303
45 FSW				
170	5	15	Z	1255
180	5	17	Z	1294
190	5	20	Z	1325
50 FSW				
170	10	27	Z	1335
180	10	32	Z	1360
190	10	36	Z	1388
55 FSW				
170	15	42	Z	1393
180	15	47	-	1419
190	15	51	-	1450

Table I-2 shows a range of depths because the pre-breathing takes place at the transfer depth which may be shallower than the equivalent air depth of the rescuees due to a breathe down of the DISSUB oxygen level. Enter the table at the depth that is exactly equal to or next deeper than the pre-breathe depth. Breathing down the oxygen level in the DISSUB can markedly reduce the pre-breathe depth and therefore the pre-breathe tender's oxygen requirements.

For an exposure time of 170 min at a pre-breathe depth of 55 fsw, Table I-2 requires that the pre-breathe tenders breathe oxygen for a total of 42 min at 40 fsw. Bottom times of 180 and 190 min are also included in the pre-breathe tables in case the rescuees encounter difficulty with the pre-breathe and the bottom time at the pre-breathe depth has to be extended.

Before the pre-breathe tenders begin oxygen breathing at 40 fsw, two terminal tenders lock into the chamber to tend to the rescuees. They can ride the remaining portion of the decompression schedule to the surface with the rescuees while breathing air.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure I-1. The maximum number of personnel in the chamber is 34, with 2 breathing air and 32 breathing oxygen. During the terminal portion of the saturation decompression there are 31 people in the chamber.

I-4. Sortie/Chamber Loading Analysis

Table H-3 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression.

Table I-3. 55 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	15	15	0	15	0	0
2		14	14	0	14	0	0
3	Ch. 2	15	15	0	15	1	0
4		14	14	0	11	1	0
5	Ch. 1	15	15	0	15	1	0
6		14	14	0	11	1	0
7	Ch. 2	15	15	0	15	1	0
8		14	14	0	11	1	0
9	Ch. 1	15	15	0	15	0	0
10		14	14	0	14	0	0
11	Ch. 2	10	10	2	13	0	2
12		-	-	-	-	-	-
Total:		155	155	2	149	6	2

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 10 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Only 1 DET team is required at this depth and this team can be inserted on the first sortie and removed on the eleventh. Eleven sorties and 6 chamber loads are required with the 11th sortie and the 6th chamber load only carrying 12 personnel.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and a two-man DET team. Eleven sorties and 6 chamber loads are required to execute this scenario with the last sortie and the last chamber run carrying a total of 15 personnel. The 6 stretcher cases are carried one per sortie for Sorties 3-8.

I-5. Abort of the Pre-Breathe Period due to CNS Oxygen Toxicity

It may be necessary to abort the pre-breathe period due to CNS oxygen toxicity in one or more of the rescuees. This is more likely if no breathe-down of the DISSUB oxygen level has occurred and the pre-breathe depth is 55 fsw. If an abort is required, the rescuees remain at depth on air until symptoms have abated. They then ascend at 1 fsw/min on air to the first decompression stop. They remain on air for total of 15 min (including ascent time) before resuming oxygen breathing. See table 4-2 and associated instructions for further details. Upon arrival at 40 fsw, two terminal tenders lock in and the pre-breathe tenders begin oxygen breathing as required to satisfy their decompression obligation.

If an abort occurs, the pre-breathe tenders will require less oxygen breathing than if they remained at the pre-breathe depth for the full period. Table I-4 shows the oxygen requirement of pre-breathe tenders after an abort to 40 fsw. Enter the table at the bottom time that is equal to or next greater than the actual time spent at the pre-breathe depth.

Table I-4. Pre-Breathe Tender Oxygen Decompression Schedules for CNS O2 Toxicity Aborts to Secondary Rescuee Schedule--55 FSW

Time at Depth (min)	Ascent Time (min)	Oxygen at 40 fsw (min)	Oxygen 40-35 fsw	Oxygen at 35 fsw (min)	Repetitive Group	Clean Time (min)
43.6 FSW						
132	3.6	0			O	1094
140	3.6	3			O	1123
175	3.6	13			Z	1249
45 FSW						
123	5	0			O	1078
140	5	6			O	1145
175	5	16			Z	1275
50 FSW						
88	10	0			M	967
105	10	3			O	1070
140	10	15	5	0	O	1201
175	10	15	5	9	Z	1346
55 FSW						
67	15	0			M	907
105	15	10	5		O	1122
140	15	10	5	12	Z	1292
175	15	10	5	28	-	1409

I-6. Repetitive Exposure of PRM Attendants and SDC Tenders

I-6.1. PRM Attendants

Once the PRM is mated to the DTL, the PRM attendants immediately transfer to the SDC and begin breathing oxygen to satisfy their decompression obligation. Surface interval calculations for PRM attendants are based on the worst case scenario, two sorties with 4 hours under pressure on each.

Attendants with a total bottom time of 240 min on the first dive will surface with the Repetitive Group Out-of-Range according to the Dive Planner. In this case, a surface interval of 24 hours (1440 min) is assumed. The Dive Planner shows a total clean time of 1577 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 6 is 1469 min, 29 min longer than the 24 hour clean time and 108 min shorter than the Dive Planner clean time. If a second 240 min dive is made after a 1465 min surface interval, the second dive will require a 1 min stop on air at 10 fsw in addition to the oxygen breathing time at depth. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 5.685% to 5.932% by the NMRI 98 probabilistic model and from 4.103% to 4.273% by the BVM(3) probabilistic model. A dive with a predicted risk between 3 and 5% is considered moderate risk. A dive with a predicted risk greater than 5% is considered high risk. While both dives carry substantial risk, the risk on the second dive is only slightly increased over the first dive.

Therefore, for 6 hour sorties:

PRM attendants from the 1st sortie can dive again on the 6th and 11th sorties.
PRM attendants from the 2nd sortie can dive again on the 7th sorties and 12th sorties.
PRM attendants from the 3rd sortie can dive again on the 8th sortie.
PRM attendants from the 4th sortie can dive again on the 9th sortie.
PRM attendants from the 5th sortie can dive again on the 10th sortie.

Two PRM attendants are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 10 attendants.

I-6.2. Transfer Tenders

Two transfer tenders are required for each sortie. Each transfer tender is exposed to 55 fsw for 30 min. With a 6 hour sortie time, the surface interval between transfer tender dives is 330 min. This surface interval is more than adequate to allow the same transfer tender to be used repetitively on every sortie. It may be necessary to add a second set of transfer tenders to allow time for transfer tenders to eat and sleep during off duty time. The total number of transfer tenders required is 4.

I-6.3. I-6.3 Custodial Tenders

Three custodial tenders are required for each chamber load. Each custodial tender has a 130 min bottom time followed by oxygen breathing at depth to satisfy his decompression obligation. Upon surfacing, the repetitive group designator is Z according to the Dive Planner. Table 9-8 of the Diving Manual indicates the Group Z has a clean time of 15h 50min (950 min). The Dive Planner shows a total clean time of 1192 min for all tissues. The surface interval is too short to permit the custodial tenders to repeat their exposure on the second chamber run. The available surface interval for the 3rd chamber run is 1282 min, 90 min longer than the clean time according to the Dive Planner. If a second 240 min dive is made after a 1282 min surface interval, the second dive will not require any additional decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 3.934% to 4.252% by the NMRI 98 probabilistic model and from 1.835% to 2.074% by the BVM(3) probabilistic model. A dive with a predicted risk less than 3% is considered low risk. A dive with a predicted risk between 3 and 5% is considered moderate risk.

Therefore, for 6 hour sorties:

CT from the 1st chamber run can dive again on the 3rd and 5th chamber runs.
CT from the 2nd chamber run can dive again on the 4th and 6th chamber runs.

Three custodial tenders are needed for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 custodial tenders.

I-6.4. Pre-breathe Tenders

Pre-breathe tenders will have a bottom time of 170 min at 55 fsw, ascend to 40 fsw at 1 fsw/min while breathing air, then start oxygen breathing at 35 fsw. The tenders will surface in Repetitive Group Z according to the Dive Planner. Table 9-8 of the Diving Manual indicates that Group Z has a clean time of 15h 50min (950 min). The Dive Planner shows a total clean time of 1393 min for all tissues. With a sortie time of 6 hours, the surface interval available between Chamber Run 1 and Chamber Run 3 is 1208 min, 258 min longer than the Dive Manual clean time and 185 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 1208 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 4.048% to 4.538% by the NMRI 98 probabilistic model or from its baseline value of 2.878% to 3.201% by the BVM(3) probabilistic model. A dive with a predicted risk of 3% or less is considered low risk. A dive with a predicted risk between 3-5% is considered moderate risk.

Therefore, for 6 hour sorties:

PBT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber runs.
PBT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber runs.

Three pre-breathe tenders are needed for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 pre-breathe tenders.

I-6.5. Terminal Tenders

Terminal tenders lock into the SDC at 40 fsw and then ride to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is O by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group O has a clean time of 14h 58min (898 min). The Dive Planner shows a clean time of 1517 min for all tissues. With a sortie time of 6 hours, the surface interval available between Chamber Run 1 and Chamber Run 4 is 1630 min, 732 min longer than the Dive Manual clean time and 113 min longer than the Dive Planner clean time. If an identical dive is made after a surface interval of 1630 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 5.842% to 6.028% by the NMRI 98 probabilistic model or from its baseline value of 5.009% to 5.106% by the BVM(3) probabilistic model. A dive with a predicted risk of greater 5% is considered high risk. Both the first and second dives are high risks, but the risks on the second dive are only slightly greater than on the first dive.

Therefore, for 6 hour sorties:

TT from the 1st chamber run can repeat their dive on the 4th chamber run.
TT from the 2nd chamber run can repeat their dive on the 5th chamber run.
TT from the 3rd chamber run can repeat their dive on the 6th chamber run.

Two terminal tenders are required for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 terminal tenders.

I-6.6. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above is:

PRM Attendants	10
Transfer Tenders	4
Custodial Tenders	6
Pre-Breathe Tenders	6
Terminal Tenders	6
Total	32

Table I-5. 55 FSW Primary Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time (min)
55	30	O2	0:30	
55	5	Air	0:35	
55	30	O2	1:05	
55	5	Air	1:10	
55	30	O2	1:40	
55	5	Air	1:45	
55	30	O2	2:15	120
Travel 1FPM to 40	15	Air	2:30	
40	55	O2	3:25	55
Travel 1 FPM to 35	5	O2	3:30	
35	15	Air	3:45	
35	60	O2	4:45	
35	15	Air	5:00	
35	30	O2	5:30	95
Travel 1 FPM to 30	5	O2	5:35	
30	25	O2	6:00	
30	15	Air	6:15	
30	60	O2	7:15	
30	15	Air	7:30	
30	15	O2	7:45	105
Travel 1FPM to 25	5	O2	7:50	
25	40	O2	8:30	
25	15	Air	8:45	
25	60	O2	9:45	
25	15	Air	10:00	
25	10	O2	10:10	115
Travel 1 FPM to 20	05	O2	10:15	
20	45	O2	11:00	50
Travel 1 FPM to surface	20	Air	11:20	

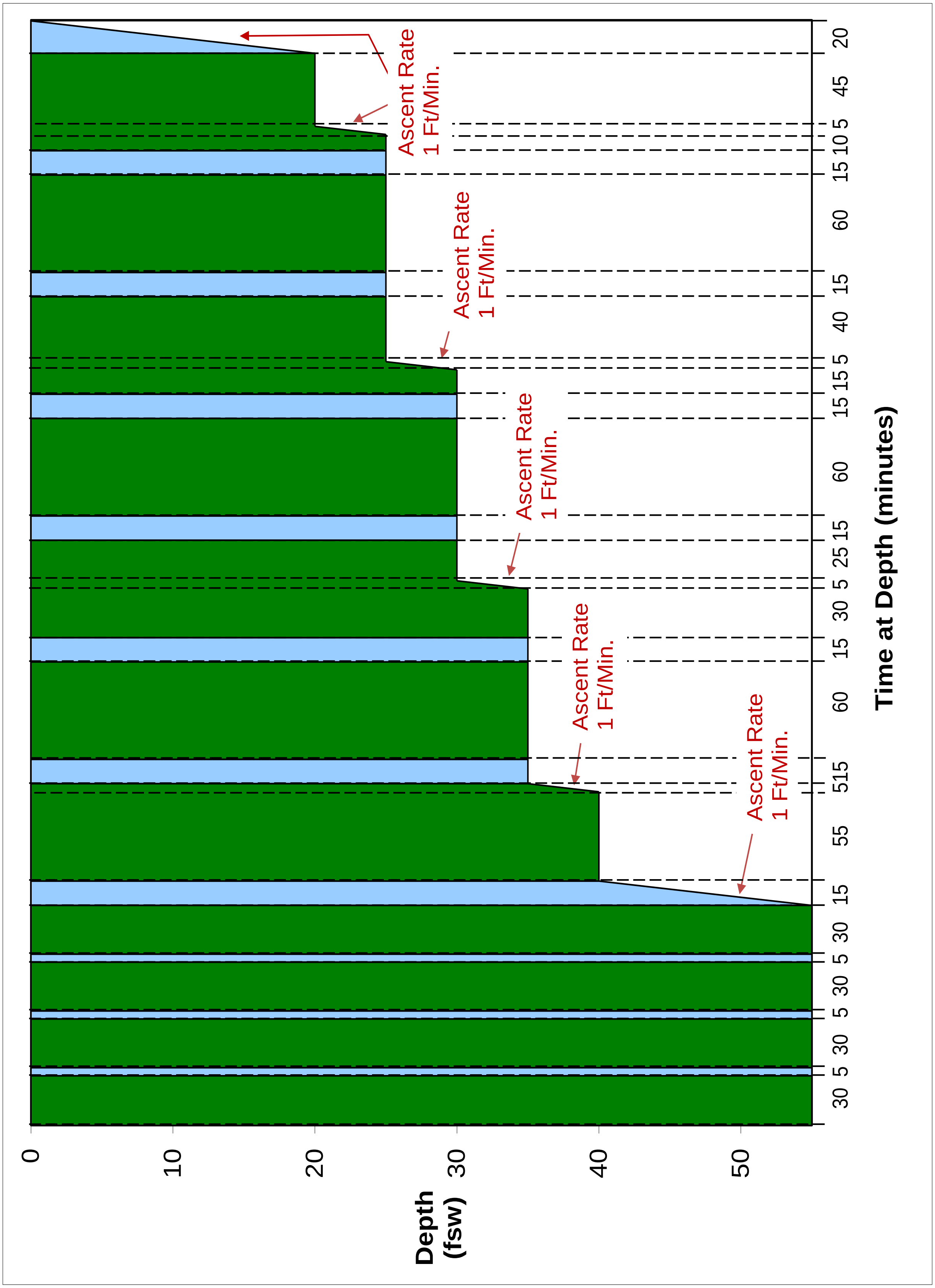


Figure I-2. 55 FSW Primary Air/Oxygen Decompression Table with Air Breaks Included

Table I-6. 55 FSW Secondary Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time (min)
55				
Travel 5FPM to 40	3	Air	0:03	
40	10	O2	0:13	10
Travel 1 FPM to 35	5	O2	0:18	
35	45	O2	1:03	
35	15	Air	1:18	
35	10	O2	1:28	60
Travel 1 FPM to 30	5	O2	1:33	
30	45	O2	2:18	
30	15	Air	2:33	
30	20	O2	2:53	70
Travel 1FPM to 25	5	O2	2:58	
25	35	O2	3:33	
25	15	Air	3:48	
25	35	O2	4:23	75
Travel 1 FPM to 20	5	O2	4:28	
20	20	O2	4:48	
20	15	Air	5:03	
20	55	O2	5:58	80
Travel 1FPM to 15	5	O2	6:03	
15	15	Air	6:18	
15	60	O2	7:18	
15	15	Air	7:33	
15	30	O2	8:03	95
Travel 1 FPM to 10	5	O2	8:08	
10	25	O2	8:33	
10	15	Air	8:48	
10	60	O2	9:48	
10	15	Air	10:03	
10	60	O2	11:03	
10	15	Air	11:18	
10	10	O2	11:28	140
Travel 1 FPM to surface	10	Air	11:38	

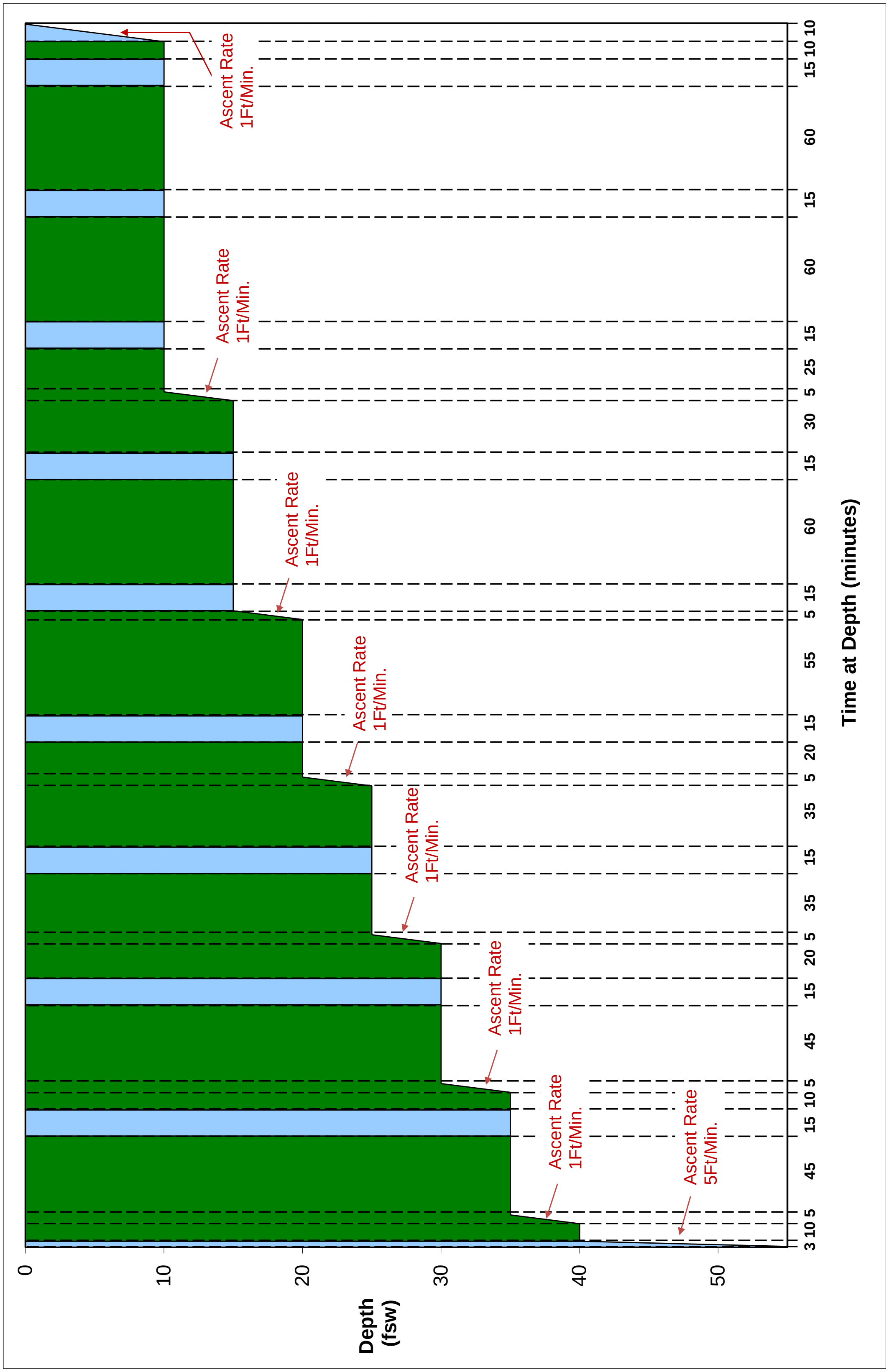


Figure I-3. 55 FSW Secondary Air/Oxygen Decompression Table with Air Breaks Included

Appendix J. Equivalent Air Saturation Depth 60 fsw

J-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (Hold) mode. Decompression begins when the chamber is fully loaded with 30+ rescuees.
2. All sorties go down unpressurized. This minimizes the bottom time of the PRM attendants. Each sortie launches with a fresh set of PRM attendants.
3. The No-Decompression time at 60 fsw is 60 min. The PRM attendants will be over the limit when they complete their nominal 150 min bottom time in the PRM. After mating, they immediately enter the SDC and begin breathing oxygen for the period specified in Table 4-5. At the completion of this time, they decompress to the surface on air via the MTL. This same process is repeated with the second set of PRM attendants when the second sortie mates. Transfer of the rescuees from the PRM to the SDC is accomplished by 2 transfer tenders and 1 custodial tender who lock in for this purpose. After the transfer tenders lock out, the custodial tender monitors the rescuees from the first sortie while the second sortie goes to recover the second load. These custodial tenders are replaced on a periodic basis. They breathe oxygen for a short period according to Table 4-5 and then lock out via the MTL. The final custodial tender is replaced by 3 pre-breathe tenders who supervise the pre-breathing. These pre-breathe tenders then replaced by 2 terminal tenders. The pre-breathe tenders breathe oxygen for a short period then lock out via the MTL. The terminal tenders can ride to the surface on air with the rescuees without incurring a decompression obligation.
4. Rescuees pre-breathe oxygen for two hours in the SDC at the transfer depth to reduce the risk of bubble formation during the subsequent oxygen decompression to the surface on oxygen (Table 4-1). There is a modest risk of CNS toxicity during the pre-breathing period at this depth. A backup table (Table 4-2) with lower oxygen doses is available if oxygen toxicity occurs during the pre-breathe period.
5. DET members are not limited by pulmonary oxygen toxicity even if there has been no breathe down of the DISSUB oxygen level. They may lock into the DISSUB with the first sortie and be removed on the last.
6. PRM Attendants and SDC Tenders may perform repeat dives later in the rescue. Each attendant/tender is assigned a fixed role and repeats that exact role on subsequent dives when the surface interval has been long enough not to increase the decompression obligation for the subsequent dive.

J-2. Rescuee Decompression Schedules

The schedules available for decompressing rescuees at 60 fsw are shown in Table J-1. These basic tables are expanded to show all recommended air breaks in Tables J-5 and J-6 and in Figures J-2 and J-3.

Table J-1. Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)										O2 Stop Time (min)	CPTD Units
	60	45	40	35	30	25	20	15	10	5		
Primary Oxygen	**120**	**30**	**85**	**95**	**105**	**115**	**50**				**600**	1700
Secondary Oxygen		**5**	**55**	**65**	**70**	**75**	**85**	**95**	**145**		**595**	1199
Air		5	170	200	215	240	260	290	325	120	**0**	0

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

J-3. Tender Management Plan

Figure J-1 shows the tender management plan for one chamber run.

Immediately prior to the mate of the first sortie, two transfer tenders and one custodial tender lock into the SDC via the MTL. The two transfer tenders position themselves in the DTL, while the custodial tender remains in the SDC. As soon as the PRM/DTL hatches are open, the two PRM attendants make their way into the SDC and begin breathing oxygen from the MBS 2000. Five minutes is allowed for the PRM attendants to exit the PRM, enter the SDC, and go on oxygen. Assuming, their bottom time in the PRM prior to transfer was 2.5h, they breathe oxygen according to the 60 fsw/160 min schedule in Table 4-5. This schedule requires 30 min on oxygen, 5 min on air, then 24 min on oxygen.

As soon as the PRM attendants have left the PRM, one of the transfer tenders enters the PRM to assist in the transfer of rescuees. The rescuees are passed from the PRM to the transfer tender in the DTL and then to the custodial tender in the SDC, who gets them seated. The transfer process takes 30 min after which the transfer tenders can lock out of the SDC via the MTL in a no-decompression status. The No-Decompression time at 60 fsw is 60 min.

The second sortie launches at +2h. During the intervening time, the first custodial tender ministers to the needs of the rescuees. His total bottom time is 130 min. A second custodial tender locks in at this point and the first custodial tender goes on oxygen to satisfy his decompression obligation. He breathes 33 min of oxygen according to the 60 fsw/130 min tender schedule (Table 4-5) then locks out of the SDC. The process is repeated with a third custodial tender.

The second sortie mates with the DTL at +6h. The same sequence with the PRM attendants and transfer tenders is repeated. Once the transfer tenders have locked out and the third custodial tender is ready to start oxygen breathing, three pre-breathe tenders lock in. Their role is to teach the rescuees how to use the MBS 2000, then assist them during the pre-breathing period. They spend a total of 170 min at 60 fsw: 5 min for lockin, 30 min for instructing the rescuees, and 135 min for the pre-breathe itself. The pre-breathe consists of four 30 min periods on oxygen separated by a 5 min air break. The pre-breathe tenders then ascend at 1 fsw/min to the first decompression stop at 45 fsw and go on oxygen.

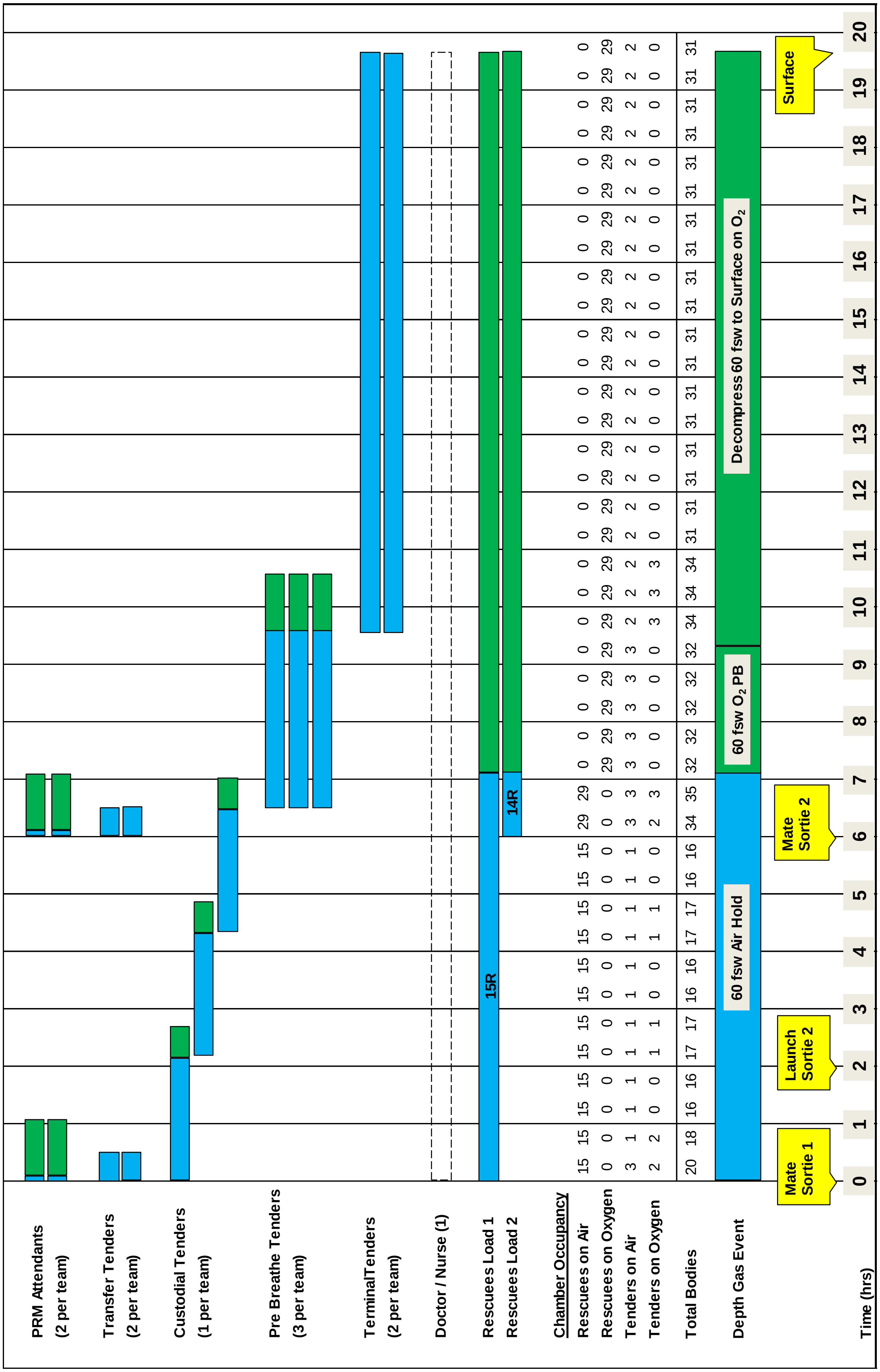


Figure J-1. Tender Management 60 FSW Rescue (PRM Attendant Time Under Pressure – 2.5 Hours)

The pre-breathe tender decompression schedules are given in Table J-2.

Table J-2. Pre-Breathe Tender Oxygen Decompression Schedules--60 fsw

Time at Depth (min)	Ascent Time (min)	Oxygen at 45 fsw (min)	Oxygen 45-40 fsw	Oxygen at 40 fsw	Repetitive Group	Clean Time (min)
47.5 FSW						
170	2.5	21	-	-	Z	1280
180	2.5	23	-	-	Z	1320
190	2.5	27	-	-	Z	1348
50 FSW						
170	5	27	-	-	Z	1321
180	5	30	5	-	Z	1327
190	5	30	5	-	Z	1365
55 FSW						
170	10	30	5	7	Z	1378
180	10	30	5	11	-	1411
190	10	30	5	15	-	1442
60 FSW						
170	15	30	5	21	-	1438
180	15	30	5	25	-	1474
190	15	30	5	30	-	1501

Table J-2 shows a range of depths because the pre-breathing takes place at the transfer depth which may be shallower than the equivalent air depth of the rescuees due to a breathe down of the DISSUB oxygen level. Enter the table at the depth that is exactly equal to or next deeper than the pre-breathe depth. Breathing down the oxygen level in the DISSUB can markedly reduce the pre-breathe depth and therefore the pre-breathe tender's oxygen requirements.

For an exposure time of 170 min at a pre-breathe depth of 60 fsw, Table J-2 requires that the pre-breathe tenders breathe oxygen for a total of 56 min (30 min at 45 fsw, 5 min during travel from 45 to 40 fsw, and 21 min at 40 fsw). Bottom times of 180 and 190 min are also included in the pre-breathe tables in case the rescuees encounter difficulty with the pre-breathe and the bottom time at the pre-breathe depth has to be extended.

Before the pre-breathe tenders begin oxygen breathing at 45 fsw, two terminal tenders lock into the chamber to tend to the rescuees. They can ride the remaining portion of the decompression schedule to the surface with the rescuees while breathing air.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure J-2. The maximum number of personnel in the chamber is 34, with 2 breathing air and 32 breathing oxygen. During the terminal portion of the saturation decompression there are 31 people in the chamber.

J-4. Sortie/Chamber Loading Analysis

Table J-3 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression.

Table J-3. 60 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	15	15	0	15	0	0
2		14	14	0	14	0	0
3	Ch. 2	15	15	0	15	1	0
4		14	14	0	11	1	0
5	Ch. 1	15	15	0	15	1	0
6		14	14	0	11	1	0
7	Ch. 2	15	15	0	15	1	0
8		14	14	0	11	1	0
9	Ch. 1	15	15	0	15	0	0
10		14	14	0	14	0	0
11	Ch. 2	10	10	2	13	0	2
12		-	-	-	-	-	-
Total:		155	155	2	149	6	2

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 10 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Only 1 DET team is required at this depth and this team can be inserted on the first sortie and removed on the eleventh. Eleven sorties and 6 chamber loads are required with the 11^{th} sortie and the 6^{th} chamber load only carrying 12 personnel.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and a two-man DET team. Eleven sorties and 6 chamber loads are required to execute this scenario with the last sortie and the last chamber run carrying a total of 15 personnel.

J-5. Abort of the Pre-Breathe Period due to CNS Oxygen Toxicity

It may be necessary to abort the pre-breathe period due to CNS oxygen toxicity in one or more of the rescuees. This is more likely if no breathe-down of the DISSUB oxygen level has occurred and the pre-breathe depth is 60 fsw. If an abort is required, the rescuees remain at depth on air until symptoms have abated. They then ascend at 1 fsw/min on air to the first decompression stop. They remain on air for total of 15 min (including ascent time) before resuming oxygen breathing. See Table 4-2 and associated instructions for further details. Upon arrival at 45 fsw, two terminal tenders lock in and the pre-breathe tenders begin oxygen breathing as required to satisfy their decompression obligation.

If an abort occurs, the pre-breathe tenders will require less oxygen breathing than if they remained at the pre-breathe depth for the full period. Table J-4 shows the oxygen requirement of pre-breathe tenders after an abort to 45 fsw. Enter the table at the bottom time that is equal to or next greater than the actual time spent at the pre-breathe depth.

TableJ-4. Pre-Breathe Tender Oxygen Decompression Schedules for CNS O2 Toxicity Aborts to Secondary Rescuee Schedule--60 FSW

Time at Depth (min)	Ascent Time (min)	Oxygen at 45 fsw (min)	Oxygen 45-40 fsw	Oxygen at 40 fsw (min)	Repetitive Group	Clean Time (min)
47.5 FSW						
102	2.5	0			N	983
140	2.5	12			O	1161
175	2.5	17.5	5	4	Z	1298
50 FSW						
88	5	0			M	942
105	5	4			N	1043
140	5	15	5	0	O	1183
175	5	15	5	8	Z	1337
55 FSW						
67	10	0			L	881
105	10	10	5	0	O	1102
140	10	10	5	12	Z	1277
175	10	10	5	29	Z	1393
60 FSW						
53	15	0			L	851
105	15	5	5	13	O	1177
140	15	5	5	29	Z	1342
175	15	5	5	48	-	1454

J-6. Repetitive Exposure of PRM Attendants and SDC Tenders

J-6.1. PRM Attendants

Once the PRM is mated to the DTL, the PRM attendants immediately transfer to the SDC and begin breathing oxygen to satisfy their decompression obligation. Surface interval calculations for PRM attendants are based on the worst case scenario, two sorties with 4 hours under pressure on each.

Attendants with a total bottom time of 240 min on the first dive will surface with the Repetitive Group Out-of-Range according to the Dive Planner. In this case, a surface interval of 24 hours (1440 min) is assumed. The Dive Planner shows a total clean time of 1621 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 6 is 1439 min, 1 min shorter than the 24 hour clean time and 182 min shorter than the Dive Planner clean time. If a second 240 min dive is made after a 1440 min surface interval, the second dive will require a 2 min stop on air at 10 fsw in addition to the oxygen breathing time at depth. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 5.919% to 6.193% by the NMRI 98 probabilistic model and from 4.352% to 4.462% by the BVM(3) probabilistic model. A dive with a predicted risk between 3 and 5% is considered moderate risk. A dive with a predicted risk greater than 5% is considered high risk. While both dives carry substantial risk, the risk on the second dive is only slightly increased over the first dive.

Therefore, for 6 hour sorties:

PRM attendants from the 1st sortie can dive again on the 6th and 11th sorties.
PRM attendants from the 2nd sortie can dive again on the 7th sorties and 12th sorties.
PRM attendants from the 3rd sortie can dive again on the 8th sortie.
PRM attendants from the 4th sortie can dive again on the 9th sortie.
PRM attendants from the 5th sortie can dive again on the 10th sortie.

Two PRM attendants are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 10 attendants.

J-6.2. Transfer Tenders

Two transfer tenders are required for each sortie. Each transfer tender is exposed to 60 fsw for 30 min. With a 6 hour sortie time, the surface interval between transfer tender dives is 330 min. This surface interval is more than adequate to allow the same transfer tender to be used repetitively on every sortie. It may be necessary to add a second set of transfer tenders to allow time for transfer tenders to eat and sleep during off duty time. The total number of transfer tenders required is 4.

J-6.3. Custodial Tenders

Three custodial tenders are required for each chamber load. Each custodial tender has a 130 min bottom time followed by oxygen breathing at depth to satisfy his decompression obligation. Upon surfacing, the repetitive group designator is Z according to the Dive Planner. Table 9-8 of the Diving Manual indicates the Group Z has a clean time of 15h 50min (950 min). The Dive Planner shows a total clean time of 1245 min for all tissues. The surface interval is too short to permit the custodial tenders to repeat their exposure on the second chamber run. The available surface interval for the 3rd chamber run is 1272 min, 27 min longer than the clean time according to the Dive Planner. If a second 240 min dive is made after a 1272 min surface interval, the second dive will not require any additional decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 4.487% to 4.842% by the NMRI 98 probabilistic model and from 2.089% to 2.346% by the BVM(3) probabilistic model. A dive with a predicted risk less than 3% is considered low risk. A dive with a predicted risk between 3 and 5% is considered moderate risk.

Therefore, for 6 hour sorties:

CT from the 1st chamber run can dive again on the 3rd and 5th chamber runs.
CT from the 2nd chamber run can dive again on the 4th and 6th chamber runs.

Three custodial tenders are needed for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 custodial tenders.

J-6.4. Pre-breathe Tenders

Pre-breathe tenders will have a bottom time of 170 min at 60 fsw followed by (1) decompression on air to 45 fsw at 1 fsw/min, (2) oxygen breathing at 45 fsw for 30 min, (3) decompression on oxygen to 40 fsw at 1 fsw/min, (4) oxygen breathing at 40 fsw for 21 min, (5) air breathing at 40 fsw for 3 min and finally (6) decompression on air to the surface at 30 fsw/min. The tenders will surface in Repetitive Group Z according to the Dive Planner. Table 9-8 of the Diving Manual indicates that Group Z has a clean time of 15h 50min (950 min). The Dive Planner shows a total clean time of 1438 min for all tissues. With a sortie time of 6 hours, the surface interval available between Chamber Run 1 and Chamber Run 3 is 1195 min, 245 min longer than the Dive Manual clean time and 243 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 1195 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 4.164% to 4.684% by the NMRI 98 probabilistic model or from its baseline value of 3.081% to 3.417% by the BVM(3) probabilistic model. A dive with a predicted risk of 3% or less is considered low risk. A dive with a predicted risk between 3-5% is considered moderate risk.

Therefore, for 6 hour sorties:

PBT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber runs.
PBT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber runs.

Three pre-breathe tenders are needed for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 pre-breathe tenders.

J-6.5. Terminal Tenders

Terminal tenders lock into the SDC at 45 fsw and then ride to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is O by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group O has a clean time of 14h 58min (898 min). The Dive Planner shows a clean time of 1635 min for all tissues. With a sortie time of 6 hours, the surface interval available between Chamber Run 1 and Chamber Run 4 is 1555 min, 657 min longer than the Dive Manual clean time and 80 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 1555 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 7.421% to 7.639% by the NMRI 98 probabilistic model or from its baseline value of 6.172% to 6.284% by the BVM(3) probabilistic model. A dive with a predicted risk of greater 5% is considered high risk. Both the first and second dives are high risk dives, but the risks on the second dive are only slightly greater than on the first dive. Nevertheless, these risks are substantially greater than the risks for terminal tenders at other depths. Consideration should be given to having the terminal tenders breathe 90% oxygen for 45 min at 20 fsw. This will reduce the risk of the initial dive to 4.241% by the NMRI 98 probabilistic model and to 3.888% by the BVM(3) probabilistic model.

Therefore, for 6 hour sorties:

TT from the 1st chamber run can repeat their dive on the 4th chamber run.
TT from the 2nd chamber run can repeat their dive on the 5th chamber run.
TT from the 3rd chamber run can repeat their dive on the 6th chamber run.

Two terminal tenders are required for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 terminal tenders.

J-6.6. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above is:

PRM Attendants	10
Transfer Tenders	4
Custodial Tenders	6
Pre-Breathe Tenders	6
Terminal Tender	6
Total	32

Table J-5. Primary Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time (min)
60	30	O2	0:30	
60	5	Air	0:35	
60	30	O2	1:05	
60	5	Air	1:10	
60	30	O2	1:40	
60	5	Air	1:45	
60	30	O2	2:15	120
Travel 1 FPM to 45	15	Air	2:30	
45	30	O2	3:00	30
Travel 1FPM to 40	5	O2	3:05	
40	25	O2	3:30	
40	15	Air	3:45	
40	55	O2	4:40	85
Travel 1 FPM to 35	5	O2	4:45	
35	15	Air	5:00	
35	60	O2	6:00	
35	15	Air	6:15	
35	30	O2	6:45	95
Travel 1 FPM to 30	5	O2	6:50	
30	25	O2	7:15	
30	15	Air	7:30	
30	60	O2	8:30	
30	15	Air	8:45	
30	15	O2	9:00	105
Travel 1FPM to 25	5	O2	9:05	
25	40	O2	9:45	
25	15	Air	10:00	
25	60	O2	11:00	
25	15	Air	11:15	
25	10	O2	11:25	115
Travel 1 FPM to 20	5	O2	11:30	
20	45	O2	12:15	50
Travel 1 FPM to surface	20	Air	12:35	

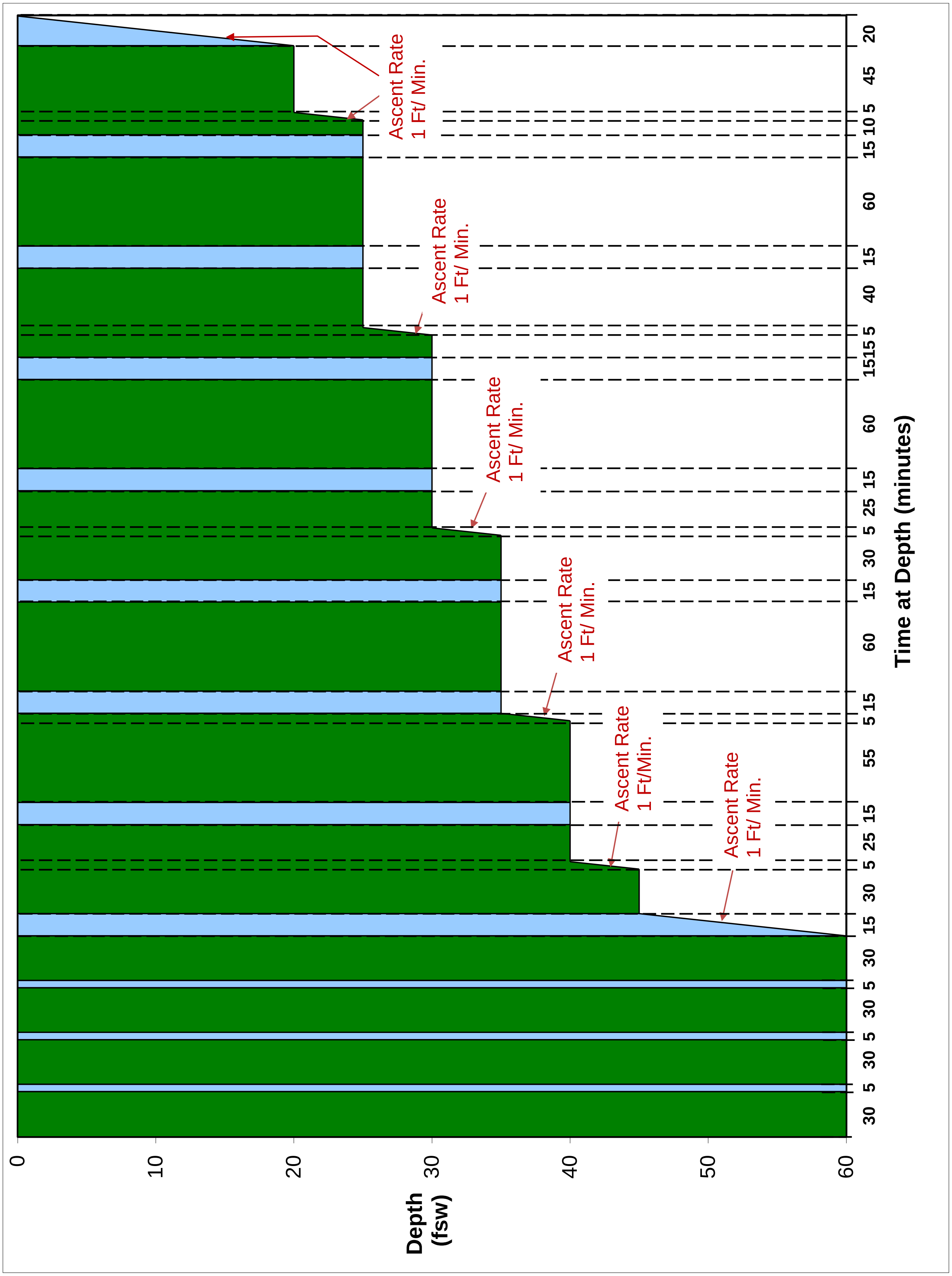


Figure J-2. Primary Air/Oxygen Decompression Table with Air Breaks Included

Table J-6. 60 FSW Secondary Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time (min)
60				
Travel 5 FPM to 45	3	Air	0:03	
45	5	O2	0:08	
Travel 1FPM to 40	5	O2	0:13	5
40	50	O2	1:03	
Travel 1 FPM to 35	05	Air	1:08	55
35	10	Air	1:18	
35	60	O2	2:18	
35	15	Air	2:33	
35	05	O2	2:38	
Travel 1 FPM to 30	05	O2	2:43	65
30	50	O2	3:33	
30	15	Air	3:48	
30	15	O2	4:03	
Travel 1FPM to 25	05	O2	4:08	70
25	40	O2	4:48	
25	15	Air	5:03	
25	30	O2	5:33	
Travel 1 FPM to 20	5	O2	5:38	75
20	25	O2	6:03	
20	15	Air	6:18	
20	55	O2	7:13	
Travel 1 FPM to 15	05	O2	7:18	85
15	15	Air	7:33	
15	60	O2	8:33	
15	15	Air	8:48	
15	30	O2	9:18	
Travel 1 FPM to 10	05	O2	9:23	95
10	25	O2	9:48	
10	15	Air	10:03	
10	60	O2	11:03	
10	15	Air	11:18	
10	55	O2	12:13	
Travel 1 FPM to surface	10	Air	12:23	145

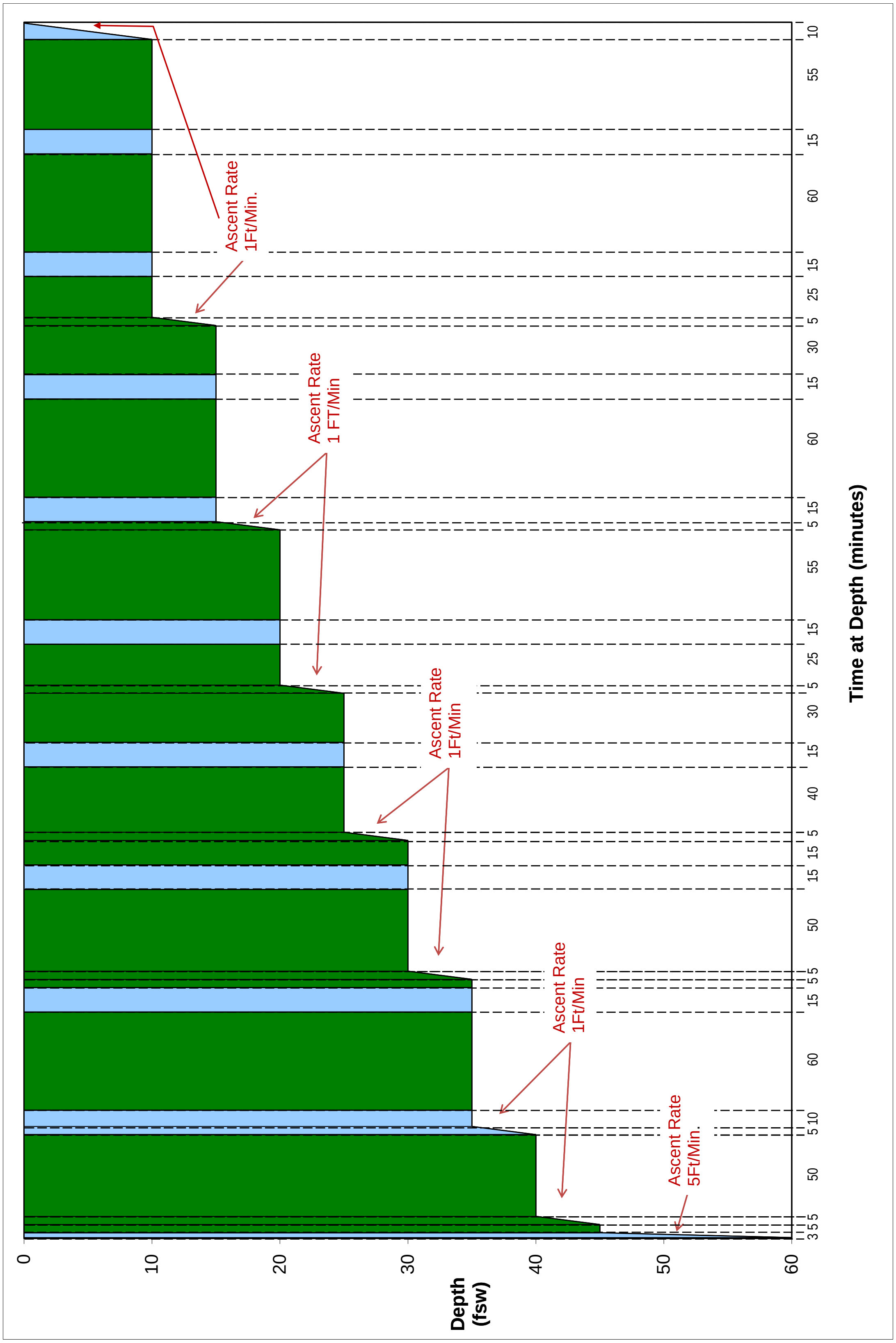


Figure J-3. Secondary Air/Oxygen Decompression Table with Air Breaks Included

Appendix K. Equivalent Air Saturation Depth 70 fsw

K-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (Hold) mode. Decompression will begin when 30+ rescuees are in the chamber.
2. Initially, all sorties go down unpressurized. This minimizes the bottom time of the PRM attendants and allows the 60 fsw PRM attendant management scheme to be continued to be used. Each sortie launches with a fresh set of PRM attendants. At some point, the HP gas racks may no longer be capable of replenishing the PRM air banks by cascading. At this point, the PRM attendants are used in a back-to-back mode. The PRM attendants enter the SDC with the first load of rescuees and remain there while the PRM is surfaced and replenished. The PRM/DTL complex is then re-pressurized to the transfer depth and the PRM attendants transfer to the PRM for the second run.
3. Rescuees are decompressed on Table 4-3. This table does not have a period of oxygen pre-breathing at depth. As the PRM is mated with the DTL, the pressure in the PRM is vented off to the first stop depth of 50 fsw. Transfer of rescuees to the SDC occurs at 50 fsw. The first batch of rescuees is then held at 50 fsw while the second sortie picks up the second batch who also decompress to 50 fsw prior to transfer to the SDC. Once all rescuees are in the chamber and instructed in the use of the MBS 2000, the rescuees begin breathing oxygen at 50 fsw and complete the remainder of the schedule from that point forward.
4. When the PRM attendants are used on a one time basis, they breathe oxygen at 50 fsw according to Table 4-6 and then lock out via the MTL. When they are used back-to-back, they ride with the rescuees to the surface and begin breathing oxygen with them at some later point in the decompression. The oxygen requirement of tenders in the back-to-back mode is substantially greater than in the one time use only mode.
5. When PRM attendants are used in the back-to-back mode, there is also a requirement to have one custodial tender in the chamber to attend to the first batch of rescuees while the PRM recovers the second batch. This custodial tender will also have to go on oxygen with the rescuees as some point later in the decompression. This point will be after the PRM attendants go on oxygen. At the point the PRM attendants go on oxygen, two terminal tenders lock into the chamber and ride the remainder of the schedule to the surface on air. They are not required to breathe oxygen.
6. DET members will be limited by pulmonary oxygen toxicity if there has been no breathe down of the DISSUB oxygen level. DET members lock into the DISSUB on the 1st sortie and are removed on the 7th. A second team is locked in on the 7th sortie and removed on the last (11th or 12th sortie)
7. PRM Attendants and SDC Tenders may perform repeat dives later in the rescue in the one sortie only mode. PRM attendants and the custodial tender in the back-to-back mode cannot perform repetitive dives later because of their prolonged oxygen exposure. DET members also cannot perform repetitive dives. Terminal tenders can perform repetitive dives.

K-2. Rescuee Decompression Schedules

The schedules for decompressing rescuees are shown in Table K-1. These basic tables are expanded to show all recommended air breaks in Table K-4 and Figure K-3.

Table K-1. 70 Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)										O2 Stop Time (min)	CPTD (units)
	50	45	40	35	30	25	20	15	10	5		
Oxygen	**25**	**55**	**60**	**65**	**70**	**80**	**85**	**95**	**150**		**685**	1482
Air	85	170	185	200	215	240	260	290	325	140	**0**	5

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

K-3. PrimaryTender Management Plan (Single Sortie by PRM Attendants)

Figure K-1 shows the tender management plan for one chamber run when PRM attendants perform only one sortie then exit the SDC after breathing oxygen at depth. This the primary tender management plan.

Once the PRM is in the deck cradle following the first sortie, the PRM is decompressed to 50 fsw, the first stop on the 70 fsw saturation decompression schedule. Immediately prior to completing the mate with the DTL which is also at 50 fsw, two transfer tenders and one custodial tender lock into the SDC via the MTL. The two transfer tenders position themselves in the DTL, while the custodial tender remains in the SDC. As soon as the PRM/DTL hatches are open, the two PRM attendants make their way into the SDC and begin breathing oxygen from the MBS 2000. Five minutes is allowed for the PRM attendants to exit the PRM, enter the SDC, and go on oxygen. Assuming, their bottom time in the PRM prior to transfer was 2.5h, they breathe oxygen according to the 70 fsw/160 min schedule in Table 4-6. This schedule requires 30 min on oxygen, followed by a 5 min air break, followed by 45 min on oxygen, for a total of 75 min on oxygen. All oxygen breathing takes place at 50 fsw.

As soon as the PRM attendants have left the PRM, one of the transfer tenders enters the PRM to assist in the transfer of rescuees. The rescuees are passed from the PRM to the transfer tender in the DTL and then to the custodial tender in the SDC, who gets them seated. The transfer process takes 30 min after which the transfer tenders can lock out of the SDC via the MTL in a no-decompression status. The No-Decompression time at 50 fsw is 92 min.

The second sortie launches at +2h. During the intervening time, the first custodial tender ministers to the needs of the rescuees. His total bottom time is 130 min. A second custodial tender locks in at this point and the first custodial tender goes on oxygen to satisfy his decompression obligation. He breathes 13 min of oxygen according to the 50 fsw/130 min tender schedule (Table 4-5) then locks out of the SDC. The process is repeated with a third custodial tender.

The second sortie mates with the DTL at +6h. The same sequence with the PRM attendants and transfer tenders is repeated. Once the transfer tenders have locked out and the third custodial tender is ready to start oxygen breathing, three pre-breathe tenders lock in. Their role is to teach the rescuees how to use the MBS 2000, then assist them during the initial periods of oxygen breathing on the decompression schedule. (Note: This is not oxygen pre-breathing in the strictest sense because the rescuees have already decompressed from 70 to 50 fsw before transferring to the SDC).

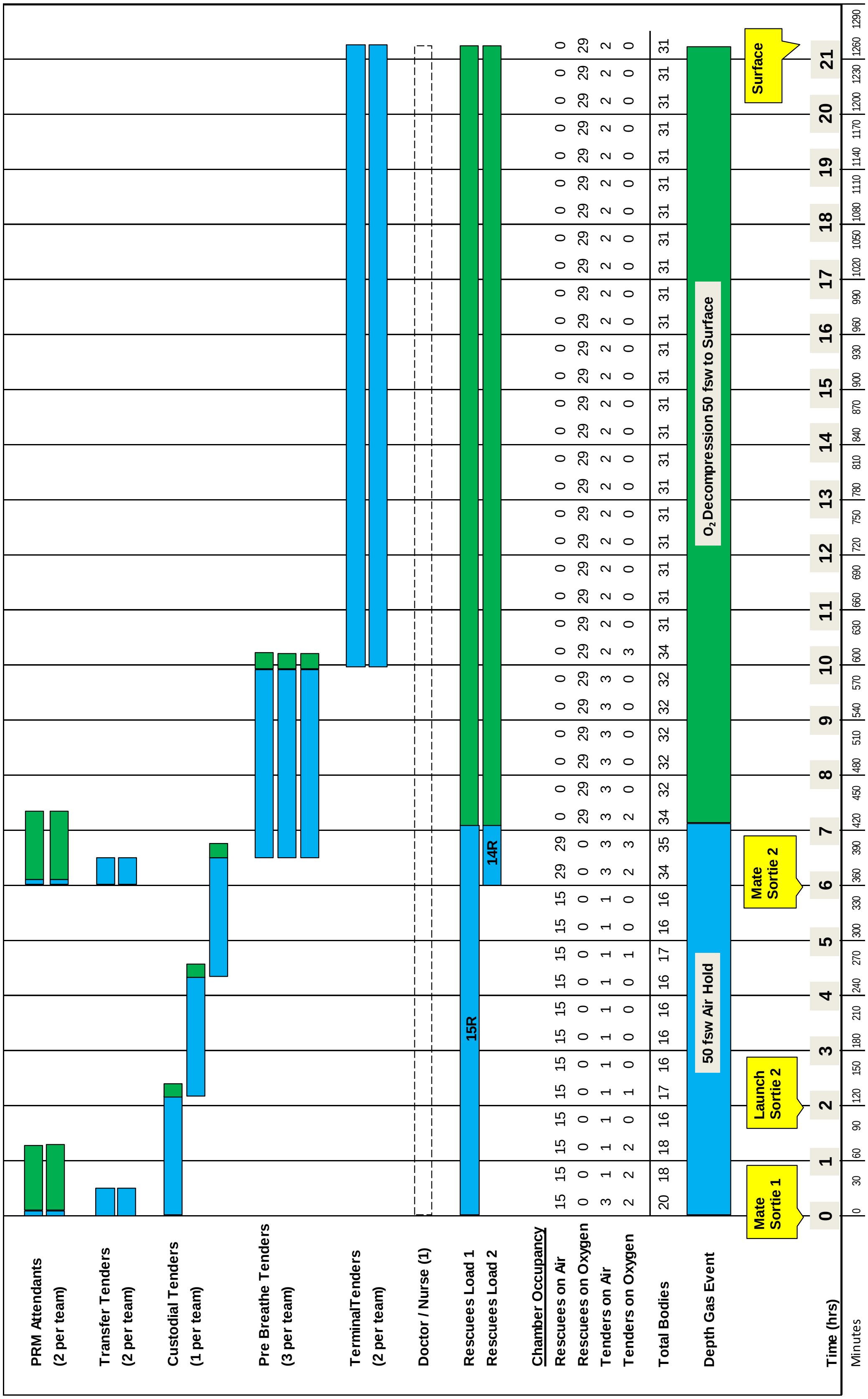


Figure K-1. Primary Tender Management 70 FSW Rescue

A total of 35 min is allowed for the pre-breathe tenders to lock into the chamber and instruct the rescuees in the use of the MBS 2000. The rescuees then begin the 25 min oxygen breathing period at 50 fsw. It is at this point that the decompression schedule officially begins. The rescuees continue to breathe oxygen and take air breaks in accordance with the Schedule K-4 until they arrive at the first 15 min air break at 35 fsw. Once they arrive at the 15 min air break, two terminal tenders lock into the chamber and the pre-breathe tenders begin breathing oxygen. The total exposure time for the pre-breathe tenders has been 205 min. They are required to breathe oxygen for 17 min at 35 fsw prior to locking out of the chamber. The terminal tenders can ride the remaining portion of the decompression schedule to the surface with the rescuees while breathing air. These tenders can later make repetitive dives.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure K-1. The maximum number of personnel in the chamber is 34, with 2 breathing air and 32 breathing oxygen. During the terminal portion of the saturation decompression there are 31 people in the chamber.

(Note: Decompression Table K-4 shows a 4 min ascent on air from 70 to 50 fsw and a 25 min stop on oxygen at the 50 fsw. In reality, time must be allotted upon arrival at 50 fsw to transfer the rescuees to the SDC and to instruct them in the use of the MBS 2000. Thirty minutes is allotted for the transfer and 35 min is allotted for the pre-breathe tenders to lock in and instruct the rescuees. This 65 min period is considered dead time. The 4-min ascent time from 70-50 fsw is considered part of the PRM exposure time for the PRM attendants).

K-4. Alternate Tender Management Plan (Back-to-Back Sorties by PRM Attendants)

Figure K-2 shows the tender management plan for one chamber when PRM attendants perform back-to-back sorties.

Once the PRM is in the deck cradle following the first sortie, the PRM is decompressed to 50 fsw, the first stop on the 70 fsw saturation decompression schedule. Immediately prior to completing the mate with the DTL, which is also at 50 fsw, one custodial tender locks into the SDC via the MTL. As soon as the PRM/DTL/SDC hatches are open, the two PRM attendants and the custodial tender assist in transferring the rescuees from the PRM to the SDC. The transfer process takes 30 min. The SDC hatch is then closed and the DTL and PRM are brought to the surface unmanned for resupply and refurbishment. The PRM attendants and custodial tender minister remain in the SDC to minister to the needs of the rescuees.

Once the PRM and DTL have been refurbished and recompressed back to 50 fsw, the PRM attendants reenter the PRM and prepare for launch. The second sortie launches at +2h.

The second sortie mates with the DTL at +6h. The PRM attendants and the custodial tender assist with the transfer of the rescuees into the SDC. The transfer process takes 30 min. The PRM attendants and custodial tender then train the rescuees and any DET members in the use of the MBS 2000 for the next 30 min. The rescuees and DET members then begin the oxygen breathing decompression schedule, starting with 25 min on oxygen at 50 fsw.

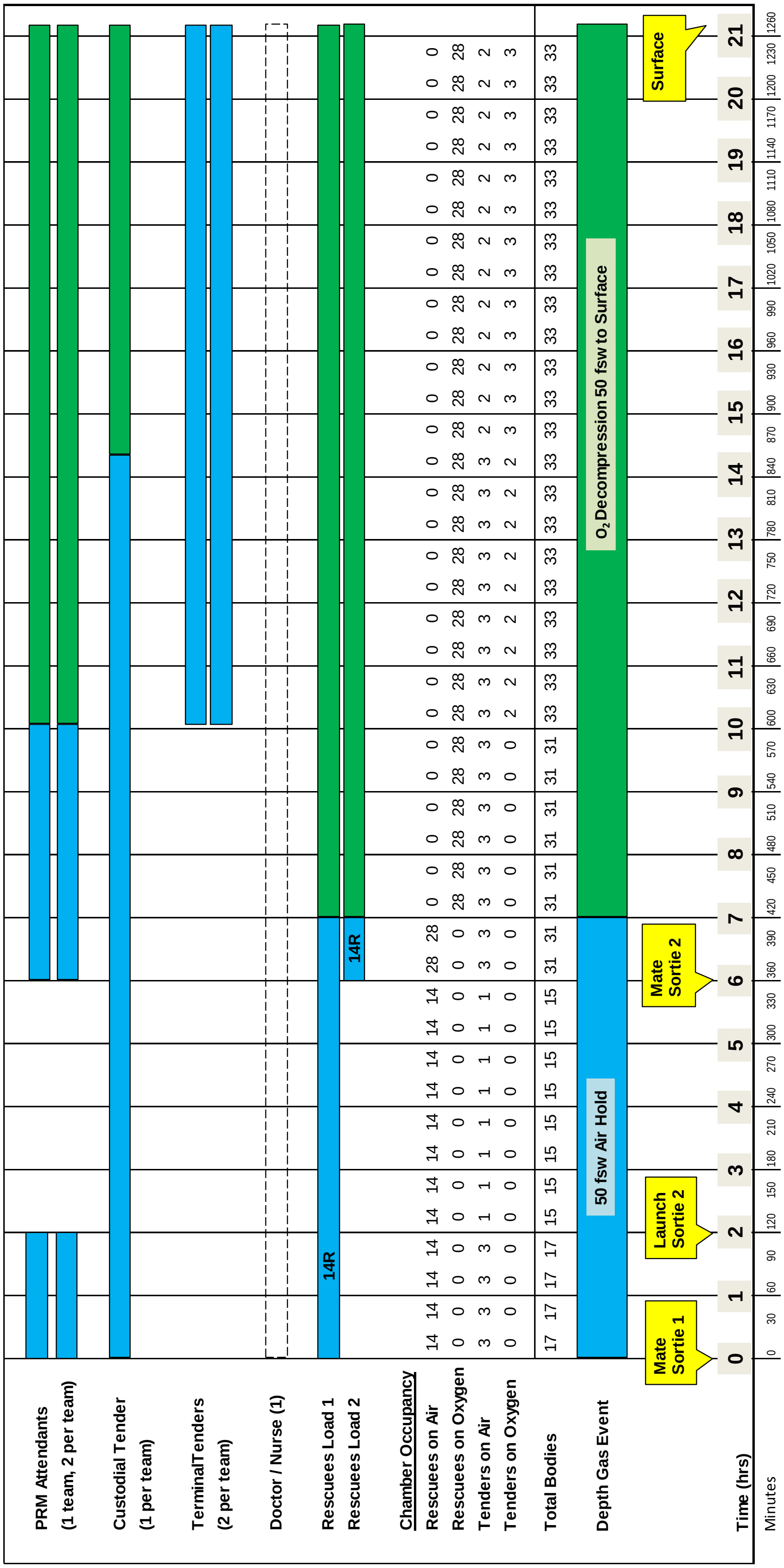


Figure K-2. Alternate Tender Management 70 FSW Rescue

Upon completion of the first 15 min air break at 35 fsw, two terminal tenders lock into the chamber and the PRM attendants go on oxygen and follow the same oxygen breathing schedule to the surface as the rescuees. The terminal tenders can ride the remainder of the decompression schedule to the surface on air.

Upon arrival at the 20 fsw stop, the custodial tender begins breathing oxygen and follows the same oxygen breathing schedule as the rescuees and PRM attendants from that point forward.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure K-2. The maximum number of personnel in the chamber is 33, with 2 breathing air and 31 breathing oxygen.

K-5. Sortie/Chamber Loading Analysis (Single Sortie by PRM Attendants)

Table K-2 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression when PRM attendants perform a single sortie.

Table K-2. 70 FSW Sortie/Chamber Loading Analysis (Single Sortie)

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (148 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	15	15	0	15	0	0
2		14	14	0	14	0	0
3	Ch. 2	15	15	0	15	1	0
4		14	14	0	11	1	0
5	Ch. 1	15	15	0	15	1	0
6		14	14	0	11	1	0
7	Ch. 2	15	13	2	13	0	2
8		14	14	0	14	0	0
9	Ch. 1	15	15	0	15	1	0
10		14	14	0	11	1	0
11	Ch. 2	10	12	2	14	0	2
12		-	-	-	-	-	-
Total:		155	155	4	148	6	4

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 10 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Two DET teams are required at this depth. The first team is removed on the 7th sortie and the second team is removed on the 11th. Eleven sorties and 6 chamber loads are required with the 11th sortie and the 6th chamber load only carrying 14 personnel.

Scenario 3 involves 148 ambulatory rescuees, 6 stretcher cases, and 2 two-man DET teams. Eleven sorties and 6 chamber loads are required to execute this scenario with the last sortie and the last chamber run carrying a total of 16 personnel. Only 148 rescuees can be handled in this scenario because the PRM cannot have more than 18 occupants, the number of available EBS masks. This number would be exceeded if 15 rescuees were transported during the last sortie.

K-6. Sortie/Chamber Loading Analysis (Back-to-Back Sorties by PRM Attendants)

Table K-3 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression when PRM attendants perform back-to-back sorties.

Table K-3. 70 FSW Sortie/Chamber Loading Analysis (Back-to-back Sorties)

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	14	14	0	14	0	0
2		14	14	0	14	0	0
3	Ch. 2	14	14	0	12	1	0
4		14	14	0	12	1	0
5	Ch. 1	14	14	0	12	1	0
6		14	14	0	12	1	0
7	Ch. 2	14	12	2	12	0	2
8		14	14	0	14	0	0
9	Ch. 1	14	14	0	12	1	0
10		14	14	0	12	1	0
11	Ch. 2	15	15	0	15	0	0
12		-	2	2	8	0	2
Total:		155	155	4	149	6	4

Note: The chamber load also includes two PRM attendants and one Custodial Tender decompressing on oxygen along with the rescuees.

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 15 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Two DET teams are required at this depth. The first team is removed on the 7th sortie and the second team is removed on the 12th.

Twelve sorties and 6 chamber loads are required. The last sortie transports only 2 rescuees and 2 DET members. The 6th chamber load carries 17 rescuees and 2 DET members.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and 2 two-man DET teams. Twelve sorties and 6 chamber loads are required to execute this scenario. The last sortie transports 8 rescuees plus 2 DET members. The last chamber load carries 23 rescuees plus 2 DET members.

K-7. Repetitive Exposure of PRM Attendants and SDC Tenders

K-7.1. PRM Attendants

Once the PRM is mated to the DTL, the PRM attendants immediately transfer to the SDC and begin breathing oxygen to satisfy their decompression obligation. Surface interval calculations for PRM attendants are based on the worst case scenario, two sorties with 4 hours under pressure on each.

Attendants with a total bottom time of 240 min on the first dive will surface with the Repetitive Group Out-of-Range according to the Dive Planner. In this case, a surface interval of 24 hours (1440 min) is assumed. The Dive Planner shows a total clean time of 1692 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 6 is 1404 min, 36 min shorter than the 24 hour clean time and 288 min shorter than the Dive Planner clean time. If a second 240 min dive is made after a 1404 min surface interval, the second dive will require an 11 min stop on air at 10 fsw in addition to the oxygen breathing time at depth. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 5.849% to 5.870% by the NMRI 98 probabilistic model and from 4.646% to 4.651% by the BVM(3) probabilistic model. A dive with a predicted risk between 3 and 5% is considered moderate risk. A dive with a predicted risk greater than 5% is considered high risk. While both dives carry substantial risk, the risk on the second dive is only slightly increased over the first dive. . If the terminal oxygen period at 50 fsw is increased from 37 to 43 min, the 11 min stop can be avoided. This risk of the dive with an additional 6 min of oxygen is 5.833% by the NMRI 98 probabilistic model and 4.568% by the BVM(3) probabilistic model.

Therefore, for 6 hour sorties:

PRM attendants from the 1st sortie can dive again on the 6th and 11th sorties.
PRM attendants from the 2nd sortie can dive again on the 7th sorties and 12th sorties.
PRM attendants from the 3rd sortie can dive again on the 8th sortie.
PRM attendants from the 4th sortie can dive again on the 9th sortie.
PRM attendants from the 5th sortie can dive again on the 10th sortie.

Two PRM attendants are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 10 attendants.

K-7.2. Transfer Tenders

Two transfer tenders are required for each sortie. Each transfer tender is exposed to 50 fsw for 30 min. With a 6 hour sortie time, the surface interval between transfer tender dives is 330 min. This surface interval is more than adequate to allow the same transfer tender to be used repetitively on every sortie. It may be necessary to add a second set of transfer tenders to allow time for transfer tenders to eat and sleep during off duty time. The total number of transfer tenders required is 4.

K-7.3. Custodial Tenders

Three custodial tenders are required for each chamber load. Each custodial tender has a 130 min bottom time followed by oxygen breathing at depth to satisfy his decompression obligation. Upon surfacing, the repetitive group designator is O according to the Dive Planner. Table 9-8 of the Diving Manual indicates the Group O has a clean time of 14h 58min (898 min). The Dive Planner shows a total clean time of 1117 min for all tissues. The surface interval is too short to permit the custodial tenders to repeat their exposure on the second chamber run. The available surface interval for the 3rd chamber run is 1292 min, 175 min longer than the clean time according to the Dive Planner. If a second 240 min dive is made after a 1292 min surface interval, the second dive will not require any additional decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 3.367% to 3.650% by the NMRI 98 probabilistic model and from 1.750% to 1.966% by the BVM(3) probabilistic model. A dive with a predicted risk less than 3% is considered low risk. A dive with a predicted risk between 3 and 5% is considered moderate risk.

Therefore, for 6 hour sorties:

CT from the 1st chamber run can dive again on the 3rd and 5th chamber runs.
CT from the 2nd chamber run can dive again on the 4th and 6th chamber runs.

Three custodial tenders are needed for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 custodial tenders.

K-7.4. Pre-breathe Tenders

Pre-breathe tenders will have a bottom time of 60 min at 50 fsw followed by (1) decompression on air to 45 fsw at 1 fsw/min, (2) air breathing at 45 fsw for 30 min, (3) decompression on air to 40 fsw at 1 fsw/min, (4) air breathing at 40 fsw for 70 min, (5) decompression on air to 35fsw at 1 fsw/min, (6) air breathing at 35 fsw for 5 min, (7) oxygen breathing at 35 fsw for 17 min, (8) air breathing at 35 fsw for 3 min, and finally (9) decompression on air to the surface at 30 fsw/min. The tenders will surface in Repetitive Group Z according to the Dive Planner. Table 9-8 of the Diving Manual indicates that Group Z has a clean time of 15h 50min (950 min). The Dive Planner shows a total clean time of 1345 min for all tissues. With a sortie time of 6 hours, the surface interval available between Chamber Run 1 and Chamber Run 3 is 1214 min, 264 min longer than the Dive Manual clean time and 131 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 1214 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 3.904% to 4.381% by the NMRI 98 probabilistic model or from its baseline value of 2.778% to 3.097% by the BVM(3) probabilistic model. A dive with a predicted risk of 3% or less is considered low risk. A dive with a predicted risk between 3-5% is considered moderate risk.

Therefore, for 6 hour sorties:

PBT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber runs.
PBT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber runs.

Three pre-breathe tenders are needed for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 pre-breathe tenders.

K-7.5. Terminal Tenders

Terminal tenders lock into the SDC at 35 fsw and then ride to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is H by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group H has a clean time of 8h 52min (532 min). The Dive Planner shows a clean time of 1039 min for all tissues. With a sortie time of 6 hours, the surface interval available between Chamber Run 1 and Chamber Run 3 is 760 min, 228 min longer than the Dive Manual clean time and 279 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 760 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 1.899% to 2.318% by the NMRI 98 probabilistic model or from its baseline value of 1.971% to 2.235% by the BVM(3) probabilistic model. A dive with a predicted risk of 0-3% is considered low risk.

Therefore, for 6 hour sorties:

TT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber run.
TT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber run.

When PRM attendants perform back-to-back sorties rather than single sorties, the terminal tenders have a shorter decompression time in the SDC. Therefore their risk for decompression sickness risk is lower.

Two terminal tenders are required for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 4 terminal tenders.

K-7.6. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above is:

PRM Attendants	10
Transfer Tenders	4
Custodial Tenders	6
Pre-Breathe Tenders	6
Terminal Tenders	4
Total	30

Table K-4. Air Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time (min)
70				
Travel 5 FPM to 50	4	Air	0:04	
50	25	O2	0:29	25
Travel 1 FPM to 45	5	O2	0:34	
45	5	Air	0:39	
45	50	O2	1:29	55
Travel 1 FPM to 40	5	O2	1:34	
40	5	O2	1:39	
45	15	Air	1:54	
45	50	O2	2:44	60
Travel 1FPM to 35	5	O2	2:49	
35	5	02	2:54	
35	15	Air	3:09	
35	55	O2	4:04	65
Travel 1 FPM to 30	5	O2	4:09	
30	15	Air	4:24	
30	60	O2	5:24	
30	15	Air	5:39	
30	5	O2	5:44	70
Travel 1 FPM to 25	5	O2	5:49	
25	50	O2	6:39	
25	15	Air	6:54	
25	25	O2	7:19	80
Travel 1FPM to 20	5	O2	7:24	
20	30	O2	7:54	
20	15	Air	8:09	
20	50	O2	8:59	85
Travel 1 FPM to 15	5	O2	9:04	
15	5	O2	9:09	
15	15	Air	9:24	
15	60	O2	10:24	
15	15	Air	10:39	
15	25	O2	11:04	95
Travel 1FPM to 10	5	O2	11:09	
10	30	O2	11:39	
10	15	Air	11:54	
10	60	O2	12:54	
10	15	Air	13:09	
10	55	O2	14:04	150
Travel 1 FPM to surface	10	Air	14:14	

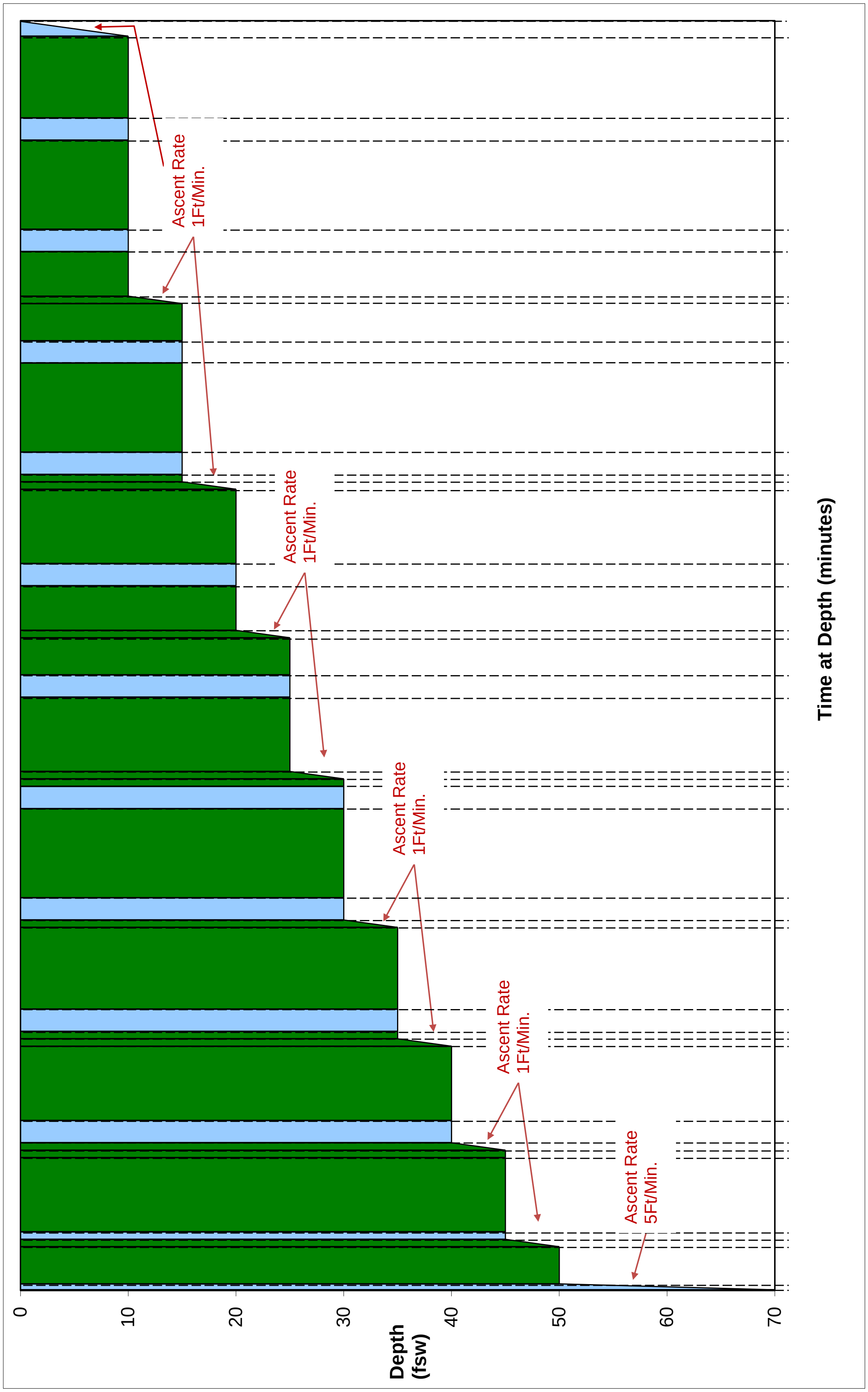


Figure K-3, Air Oxygen Decompression Table with Air Breaks

Appendix L. Equivalent Air Saturation Depth 80 fsw

L-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (Hold) mode. Decompression will begin when 30+ rescuees are in the chamber.
2. Initially, all sorties go down unpressurized. This minimizes the bottom time of the PRM attendants and allows the 60 fsw PRM attendant management scheme to be used. Each sortie launches with a fresh set of PRM attendants. At some point, the HP gas racks may no longer be capable of replenishing the PRM air banks by cascading. At this point, the PRM attendants are used in a back-to-back mode. Attendants are also used in the back-to-back mode if their bottom time (including ascent time from 80 to 60 fsw) exceeds 145 min on the first sortie. The PRM attendants enter the SDC with the first load of rescuees and remain there while the PRM is surfaced and replenished. The PRM/DTL complex is then re-pressurized to the transfer depth and the PRM attendants transfer to the PRM for the second run.
3. Rescuees are decompressed on Table 4-3. This table does not have a period of oxygen pre-breathing at depth. As the PRM is mated with the DTL, the pressure in the PRM is vented off to the first stop depth of 60 fsw. Transfer of rescuees to the SDC occurs at 60 fsw. The first batch of rescuees is then held at 60 fsw while the second sortie picks up the second batch who also decompress to 60 fsw prior to transfer to the SDC. Once all rescuees are in the chamber and instructed in the use of the MBS 2000, the rescuees begin breathing oxygen at 60 fsw and complete the remainder of the schedule from that point forward.
4. When the PRM attendants are used on a one time basis, they breathe oxygen at 60 fsw according to Table 4-6 and then lock out via the MTL. When they are used back-to-back, they ride with the rescuees to the surface and begin breathing oxygen with them at some later point in the decompression. The oxygen requirement of tenders in the back-to-back mode is substantially greater than in the one time use only mode.
5. When PRM attendants are used in the back-to-back mode, there is also a requirement to have one custodial tender in the chamber to attend to the first batch of rescuees while the PRM recovers the second batch. This custodial tender will also have to go on oxygen with the rescuees as some point later in the decompression. This point will be after the PRM attendants go on oxygen. At the point the PRM attendants go on oxygen, two terminal tenders lock into the chamber and ride the remainder of the schedule to the surface on air. They are not required to breathe oxygen.
6. DET members will be limited by pulmonary oxygen toxicity if there has been no breathe down of the DISSUB oxygen level. DET members lock into the DISSUB on the 1st sortie and are removed on the 6th. A second team is locked in on the 6th sortie and removed on the 11th. A third team, if required, is locked in on the 11th sortie and removed on the 12th.
7. PRM Attendants and SDC Tenders may perform repeat dives later in the rescue in the one sortie only mode. PRM attendants and the custodial tender in the back-to-back mode cannot perform repetitive dives later because of their prolonged oxygen exposure. Terminal tenders can perform repeat dives.

L-2. Rescuee Decompression Schedules.

The schedules for decompressing rescuees are shown in Table L-1. These basic tables are expanded to show all recommended air breaks in Table L-4 and Figure L-3.

Table L-1. 80 Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)												O2 Stop Time (min)	CPTD (units)
	60	55	50	45	40	35	30	25	20	15	10	5		
Oxygen	**10**	**45**	**50**	**55**	**60**	**65**	**75**	**75**	**85**	**90**	**155**		**765**	1782
Air	20	145	160	170	185	200	220	235	260	285	325	155	**0**	30

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

L-3. PrimaryTender Management Plan (Single Sortie by PRM Attendants)

Figure L-1 shows the tender management plan for one chamber run when PRM attendants perform only one sortie then exit the SDC after breathing oxygen at depth. This the primary tender management plan.

Once the PRM is in the deck cradle following the first sortie, the PRM is decompressed to 60 fsw, the first stop on the 80 fsw saturation decompression schedule. Immediately prior to completing the mate with the DTL which is also at 60 fsw, two transfer tenders and one custodial tender lock into the SDC via the MTL. The two transfer tenders position themselves in the DTL, while the custodial tender remains in the SDC. As soon as the PRM/DTL hatches are open, the two PRM attendants make their way into the SDC and begin breathing oxygen from the MBS 2000. Five minutes is allowed for the PRM attendants to exit the PRM, enter the SDC, and go on oxygen. Assuming, their bottom time in the PRM prior to transfer was 145 min, they breathe oxygen according to the 80 fsw/150 min schedule in Table 4-6. This schedule requires 30 min on oxygen, 5 min on air, 30 min on oxygen, 5 min on air, 30 min on oxygen, 5 min on air, and finally 14 min on oxygen for a total of 104 min on oxygen. For the first set of PRM attendants, all oxygen breathing takes place at 60 fsw. For the second set of PRM attendants, some the later oxygen breathing periods will have to be conducted at a shallower depth as decompression of the rescues will have begun before the required oxygen time can be completed. The final 14 min oxygen period at 60 fsw can be replaced with a 9-min stop on oxygen at 20 fsw if the MTL is available for decompression purposes.

As soon as the PRM attendants have left the PRM, one of the transfer tenders enters the PRM to assist in the transfer of rescuees. The rescuees are passed from the PRM to the transfer tender in the DTL and then to the custodial tender in the SDC, who gets them seated. The transfer process takes 30 min after which the transfer tenders can lock out of the SDC via the MTL in a no-decompression status. The No-Decompression time at 60 fsw is 60 min.

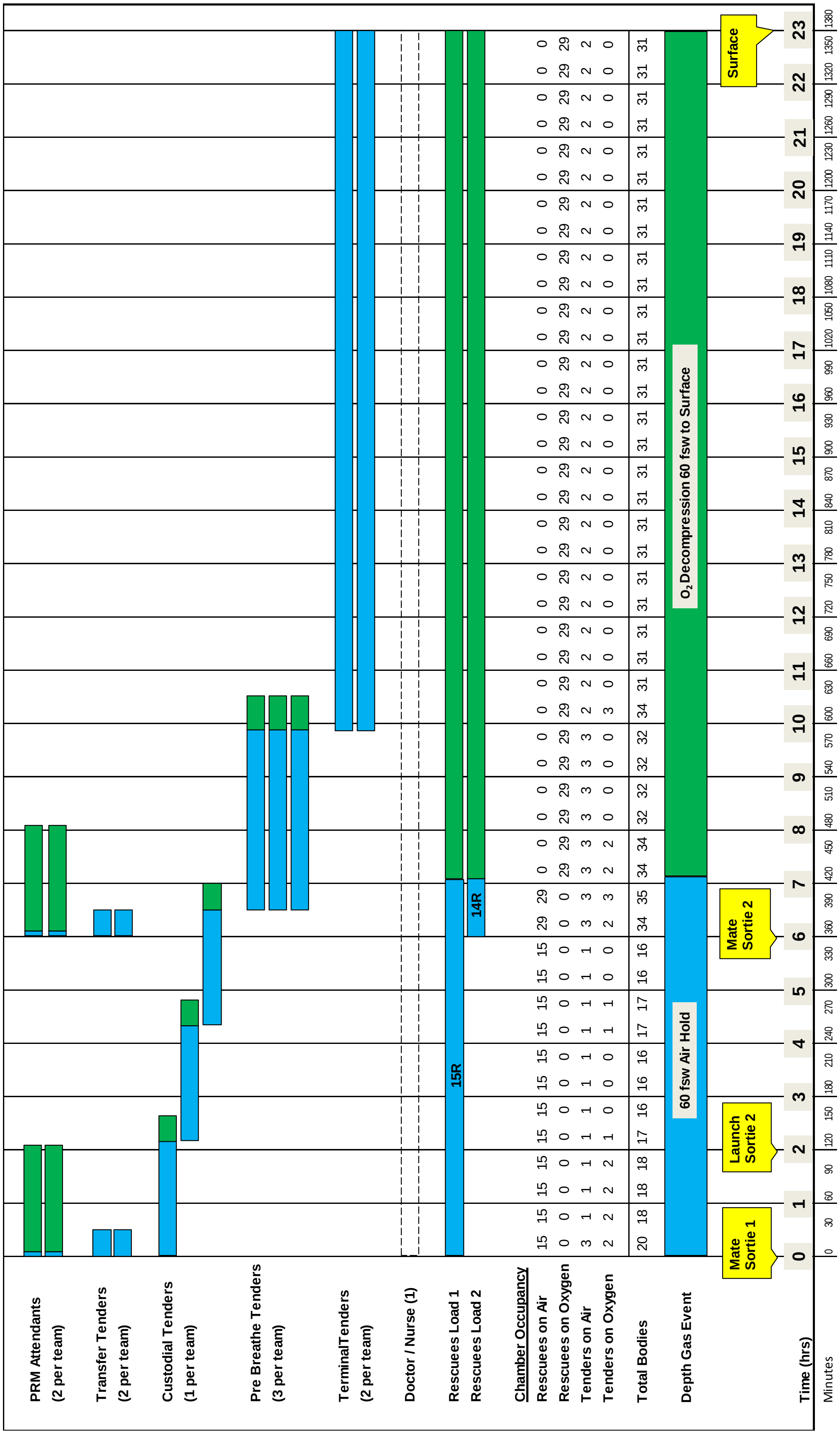


Figure L-1. Tender Management 80 FSW Rescue

The second sortie launches at +2h. During the intervening time, the first custodial tender ministers to the needs of the rescuees. His total bottom time is 130 min. A second custodial tender locks in at this point and the first custodial tender goes on oxygen to satisfy his decompression obligation. He breathes 33 min of oxygen according to the 60 fsw/130 min tender schedule (Table 4-5) then locks out of the SDC. The process is repeated with a third custodial tender.

The second sortie mates with the DTL at +6h. The same sequence with the PRM attendants and transfer tenders is repeated. Once the transfer tenders have locked out and the third custodial tender is ready to start oxygen breathing, three pre-breathe tenders lock in. Their role is to teach the rescuees how to use the MBS 2000, then assist them during the initial periods of oxygen breathing on the decompression schedule. (Note: This is not oxygen pre-breathing in the strictest sense because the rescuees have already decompressed from 80 to 60 fsw before transferring to the SDC).

A total of 35 min is allowed for the pre-breathe tenders to lock into the chamber and instruct the rescuees in the use of the MBS 2000. The rescuees then begin the 10 min oxygen breathing period at 60 fsw. It is at this point that the decompression schedule officially begins. The rescuees continue to breathe oxygen and take air breaks in accordance with the Schedule L-4 until they arrive at the first 15 min air break at 45 fsw. Once they arrive at the 15 min air break, two terminal tenders lock into the chamber and the pre-breathe tenders begin breathing oxygen. The total exposure time for the pre-breathe tenders has been 200 min. They are required to breathe oxygen for 25 min at 45 fsw, for 5 min during ascent from 45 to 40 fsw, and for 10 min at 40 fsw. They can then lock out of the chamber. The pre-breathe tenders surface in repetitive group Z. The terminal tenders can ride the remaining portion of the decompression schedule to the surface with the rescuees while breathing air. These tenders can later make repetitive dives.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure L-1. The maximum number of personnel in the chamber is 34, with 2 breathing air and 32 breathing oxygen. During the terminal portion of the saturation decompression there are 31 people in the chamber.

(Note: Decompression Table L-4 shows a 4 min ascent on air from 80 to 60 fsw and a 10 min stop on oxygen at the 60 fsw. In reality, time must be allotted upon arrival at 60 fsw to transfer the rescuees to the SDC and to instruct them in the use of the MBS 2000. Thirty minutes is allotted for the transfer and 35 min is allotted for the pre-breathe tenders to lock in and instruct the rescuees. This 65 min period is considered dead time. The 4-min ascent time from 80-60 fsw is considered part of the PRM exposure time for the PRM attendants).

L-4. Alternate Tender Management Plan (Back-to-Back Sorties by PRM Attendants)

Figure L-2 shows the tender management plan for one chamber when PRM attendants perform back-to-back sorties.

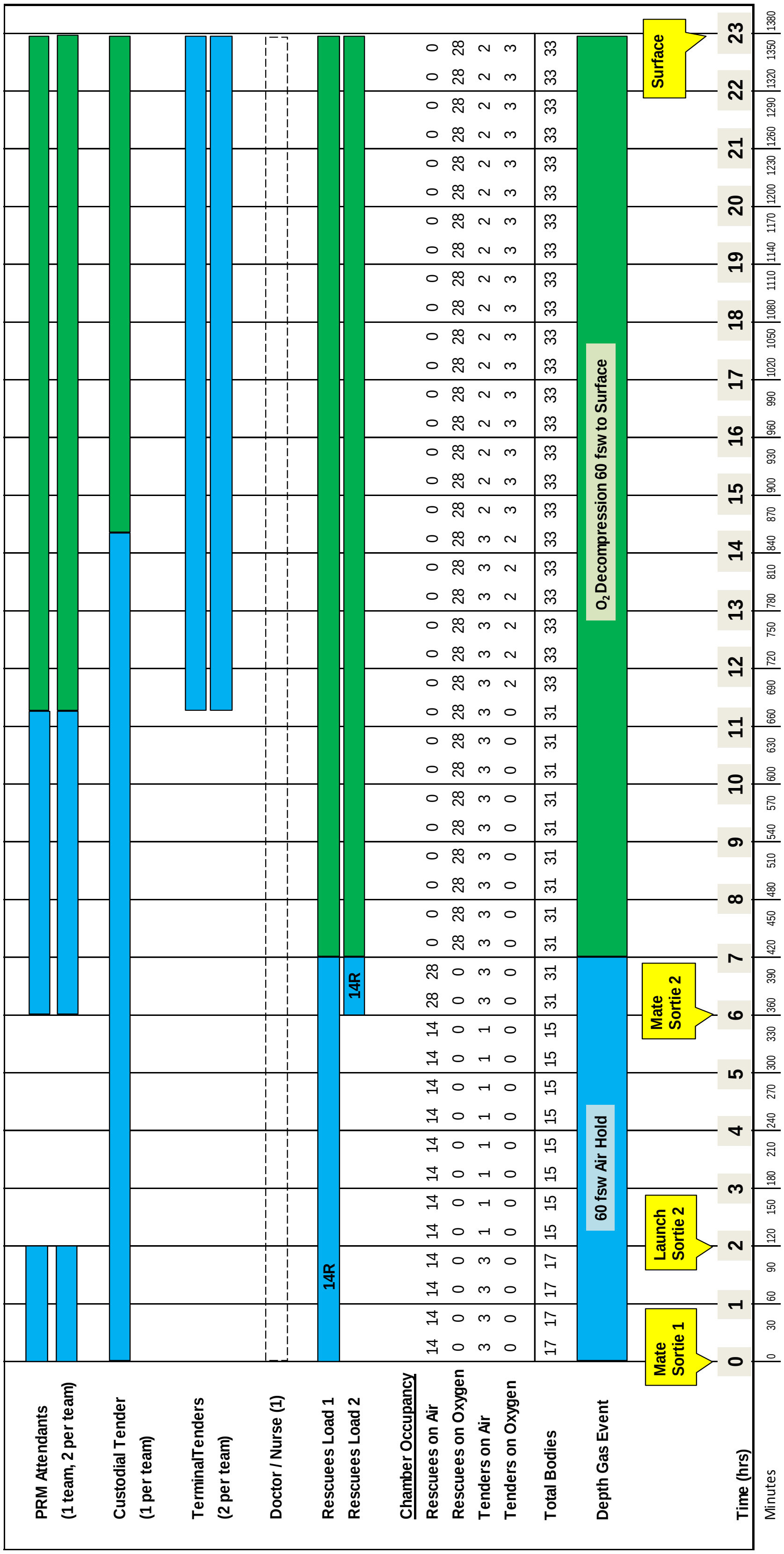


Figure L-2. Alternate Tender Management 80 FSW Rescue

Once the PRM is in the deck cradle following the first sortie, the PRM is decompressed to 60 fsw, the first stop on the 80 fsw saturation decompression schedule. Immediately prior to completing the mate with the DTL, which is also at 60 fsw, one custodial tender locks into the SDC via the MTL. As soon as the PRM/DTL/SDC hatches are open, the two PRM attendants and the custodial tender assist in transferring the rescuees from the PRM to the SDC. The transfer process takes 30 min. The SDC hatch is then closed and the DTL and PRM are brought to the surface unmanned for resupply and refurbishment. The PRM attendants and custodial tender remain in the SDC to minister to the needs of the rescuees.

Once the PRM and DTL have been refurbished and recompressed back to 60 fsw, the PRM attendants reenter the PRM and prepare for launch. The second sortie launches at +2h.

The second sortie mates with the DTL at +6h. The PRM attendants and the custodial tender assist with the transfer of the rescuees into the SDC. The transfer process takes 30 min. The PRM attendants and custodial tender then train the rescuees and any DET members in the use of the MBS 2000 for the next 30 min. The rescuees and DET members then begin the oxygen breathing decompression schedule, starting with 10 min on oxygen at 60 fsw.

Upon completion of the first 15 min air break at 40 fsw, two terminal tenders lock into the chamber and the PRM attendants go on oxygen and follow the same oxygen breathing schedule to the surface as the rescuees. The terminal tenders can ride the remainder of the decompression schedule to the surface on air.

The custodial tender begins breathing oxygen upon arrival at the first 25 min oxygen period at 25 fsw and follows the same oxygen breathing schedule as the rescuees and PRM attendants from that point forward.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lock ins by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure K-2. The maximum number of personnel in the chamber is 33, with 2 breathing air and 31 breathing oxygen.

L-5. Sortie/Chamber Loading Analysis (Single Sortie by PRM Attendants)

Table L-2 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression when PRM attendants perform a single sortie.

L-6. Sortie/Chamber Loading Analysis (Back-to-Back Sorties by PRM Attendants)

Table L-3 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression when PRM attendants perform back-to-back sorties.

Table L-2. 80 FSW Sortie/Chamber Loading Analysis (Single Sortie)

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (148 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	15	15	0	15	0	0
2		14	14	0	14	0	0
3	Ch. 2	15	15	0	15	1	0
4		14	14	0	11	1	0
5	Ch. 1	15	15	0	15	1	0
6		14	12	2	9	1	2
7	Ch. 2	15	15	0	15	1	0
8		14	14	0	11	1	0
9	Ch. 1	15	15	0	15	0	0
10		14	14	0	14	0	0
11	Ch. 2	10	12	2	14	0	2
12		-	-	-	-	-	-
Total:		155	155	4	148	6	4

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 10 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Two DET teams are required at this depth. The first team is removed on the 6th sortie and the second team is removed on the 11th. Eleven sorties and 6 chamber loads are required with the 11th sortie and the 6th chamber load only carrying 14 personnel.

Scenario 3 involves 148 ambulatory rescuees, 6 stretcher cases, and 2 two-man DET teams. Eleven sorties and 6 chamber loads are required to execute this scenario with the last sortie and the last chamber run carrying a total of 16 personnel. Only 148 rescuees can be handled in this scenario because the PRM cannot have more than 18 occupants, the number of available EBS masks. This number would be exceeded if 15 rescuees were transported during the last sortie.

Table L-3. 80 FSW Sortie/Chamber Loading Analysis (Back-to-back Sorties)

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	14	14	0	14	0	0
2		14	14	0	14	0	0
3	Ch. 2	14	14	0	12	1	0
4		14	14	0	12	1	0
5	Ch. 1	14	14	0	14	0	0
6		14	12	2	12	0	2
7	Ch. 2	14	14	0	12	1	0
8		14	14	0	12	1	0
9	Ch. 1	14	14	0	12	1	0
10		14	14	0	12	1	0
11	Ch. 2	15	14	2	14	0	2
12		-	3	2	9	0	2
Total:		155	155	6	149	6	6

Note: The chamber load also includes two PRM attendants and one Custodial Tender decompressing on oxygen along with the rescuees.

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 15 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Three DET teams are required at this depth. The first team is removed on the 6th sortie, the second on the 11th and the last on the 12th. Twelve sorties and 6 chamber loads are required. The last sortie transports only 3 rescuees and 2 DET members. The 6th chamber load carries 17 rescuees and 4 DET members.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and 3 two-man DET teams. Twelve sorties and 6 chamber loads are required to execute this scenario. The last sortie transports 9 rescuees plus 2 DET members. The last chamber load carries 23 rescuees plus 4 DET members.

L-7. Repetitive Exposure of PRM Attendants and SDC Tenders

L-7.1. PRM Attendants

Once the PRM is mated to the DTL, the PRM attendants immediately transfer to the SDC and begin breathing oxygen to satisfy their decompression obligation. Surface interval calculations for PRM attendants at this depth are based a maximum bottom time of 140 min. Sortie bottom time is limited because of the 90 min limit on oxygen breathing time at the first stop depth of 60 fsw. With 6 hour sortie cycling, there will be a 7 min delay in the launch of the 5th and 9th sorties.

Attendants with a total bottom time of 140 min on the first dive will surface with the Repetitive Group Out-of-Range according to the Dive Planner. In this case, a surface interval of 24 hours (1440 min) is assumed. The Dive Planner shows a total clean time of 1502 min for all tissues. With a sortie time of 6 hours, the surface interval available between Sortie 1 and Sortie 6 is 1449 min, 9 min longer than the 24 hour clean time and 53 min shorter than the Dive Planner clean time. If a second 240 min dive is made after a 1449 min surface interval, the second dive will not require any additional decompression beyond the oxygen breathing time at depth. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 5.001% to 5.319% by the NMRI 98 probabilistic model and from 3.365% to 3.560% by the BVM(3) probabilistic model. A dive with a predicted risk between 3 and 5% is considered moderate risk. A dive with a predicted risk greater than 5% is considered high risk. While both dives carry substantial risk, the risk on the second dive is only slightly increased over the first dive.

Therefore, for 6 hour sorties:

PRM attendants from the 1st sortie can dive again on the 6th and 11th sorties.
PRM attendants from the 2nd sortie can dive again on the 7th sorties and 12th sorties.
PRM attendants from the 3rd sortie can dive again on the 8th sortie.
PRM attendants from the 4th sortie can dive again on the 9th sortie.
PRM attendants from the 5th sortie can dive again on the 10th sortie.

Two PRM attendants are needed for each sortie. With repetitive diving as outlined above, the whole evolution requires a total of 10 attendants.

L-7.2. Transfer Tenders

Two transfer tenders are required for each sortie. Each transfer tender is exposed to 60 fsw for 30 min. With a 6 hour sortie time, the surface interval between transfer tender dives is 330 min. This surface interval is more than adequate to allow the same transfer tender to be used repetitively on every sortie. It may be necessary to add a second set of transfer tenders to allow time for transfer tenders to eat and sleep during off duty time. The total number of transfer tenders required is 4.

L-7.3. Custodial Tenders

Three custodial tenders are required for each chamber load. Each custodial tender has a 130 min bottom time at 60 fsw followed by oxygen breathing at depth to satisfy his decompression obligation. Upon surfacing, the repetitive group designator is Z according to the Dive Planner. Table 9-8 of the Diving Manual indicates the Group Z has a clean time of 15h 50min (950 min). The Dive Planner shows a total clean time of 1420 min for all tissues. The surface interval is too short to permit the custodial tenders to repeat their exposure on the second chamber run. The available surface interval for the 3rd chamber run is 1279 min, 141 min shorter than the clean time according to the Dive Planner. If a second 240 min dive is made after a 1279 min surface interval, the second dive will not require any additional decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 4.487% to 4.837% by the NMRI 98 probabilistic model and from 2.089% to 2.432% by the BVM(3) probabilistic model. A dive with a predicted risk less than 3% is considered low risk. A dive with a predicted risk between 3 and 5% is considered moderate risk.

Therefore, for 6 hour sorties:

CT from the 1st chamber run can dive again on the 3rd and 5th chamber runs.
CT from the 2nd chamber run can dive again on the 4th and 6th chamber runs.

Three custodial tenders are needed for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 custodial tenders.

L-7.4. Pre-breathe Tenders

Pre-breathe tenders will have a bottom time of 45 min at 60 fsw followed by (1) decompression on air to 55 fsw at 1 fsw/min, (2) air breathing at 55 fsw for 45 min, (3) decompression on air to 50 fsw at 1 fsw/min, (4) air breathing at 50 fsw for 55 min, (5) decompression on air to 45fsw at 1 fsw/min, (6) air breathing at 45 fsw for 40 min, (7) oxygen breathing at 45 fsw for 25 min, (8) decompression on oxygen to 40 fsw at 1 fsw/min, (9) oxygen breathing at 40 fsw for 10 min, (10) air breathing at 40 fsw for 3 min, and finally (11) decompression on air to the surface at 30 fsw/min. The tenders will surface in Repetitive Group Z according to the Dive Planner. Table 9-8 of the Diving Manual indicates that Group Z has a clean time of 15h 50min (950 min). The Dive Planner shows a total clean time of 1420 min for all tissues. With a sortie time of 6 hours, the surface interval available between Chamber Run 1 and Chamber Run 3 is 1202 min, 252 min longer than the Dive Manual clean time and 218 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 1202 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 4.354% to 4.870% by the NMRI 98 probabilistic model or from its baseline value of 3.127% to 3.462% by the BVM(3) probabilistic model. A dive with a predicted risk between 3-5% is considered moderate risk.

Therefore, for 6 hour sorties:

PBT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber runs.
PBT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber runs.

Three pre-breathe tenders are needed for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 6 pre-breathe tenders.

L-7.5. Terminal Tenders

Terminal tenders lock into the SDC at 45 fsw and then ride to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is H by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group H has a clean time of 8h 52min (532 min). The Dive Planner shows a clean time of 1129 min for all tissues. With a sortie time of 6 hours, the surface interval available between Chamber Run 1 and Chamber Run 3 is 657 min, 125 min longer than the Dive Manual clean time and 472 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 657 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 3.020% to 3.564% by the NMRI 98 probabilistic model or from its baseline value of 2.815% to 3.137% by the BVM(3) probabilistic model. A dive with a predicted risk of less than 3% is considered low risk. A dive with a predicted risk of 3-5% is considered moderate risk.

Therefore, for 6 hour sorties:

TT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber run.
TT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber run.

When PRM attendants perform back-to-back sorties rather than single sorties, the terminal tenders have a shorter decompression time in the SDC. Therefore their risk for decompression sickness risk is lower.

Two terminal tenders are required for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 4 terminal tenders.

L-7.6. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above is:

PRM Attendants	10
Transfer Tenders	4
Custodial Tenders	6
Pre-Breathe Tenders	6
Terminal Tenders	4
Total	30

Table L-4. 80 FSW Air Oxygen Decompression Table with Air Breaks

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time (min)
80				
Travel 5 FPM to 60	4	Air	0:04	
60	10	O2	0:14	10
Travel 1FPM to 55	5	O2	0:19	
55	15	O2	0:34	
55	5	Air	0:39	
55	25	O2	1:04	45
Travel 1 FPM to 50	5	O2	1:09	
50	5	Air	1:14	
50	30	O2	1:44	
50	5	Air	1:49	
50	15	O2	2:04	50
Travel 1 FPM to 45	5	O2	2:09	
45	40	O2	2:49	
45	15	Air	3:04	
45	10	O2	3:14	55
Travel 1 FPM to 40	5	O2	3:19	
40	45	O2	4:04	
40	15	Air	4:19	
40	10	O2	4:29	60
Travel 1FPM to 35	5	O2	4:34	
35	45	O2	5:19	
35	15	Air	5:34	
35	15	O2	5:49	65
Travel 1 FPM to 30	5	O2	5:54	
30	40	O2	6:34	
30	15	Air	6:49	
30	30	O2	7:19	
Travel 1 FPM to 25	5	O2	7:24	
25	25	O2	7:49	
25	15	Air	8:04	
25	45	O2	8:49	75
Travel 1FPM to 20	5	O2	8:54	
20	10	O2	9:04	
20	15	Air	9:19	
20	60	O2	10:19	
20	15	Air	10:34	
20	10	O2	10:44	85
Travel 1 FPM to 15	5	O2	10:49	
15	45	O2	11:34	
15	15	Air	11:49	
15	40	O2	12:29	90
Travel 1FPM to 10	5	O2	12:34	
10	15	O2	12:49	
10	15	Ai	13:04	
10	60	O2	14:04	
10	15	Air	14:19	
10	60	O2	15:19	
10	15	Air	15:34	
10	15	O2	15:49	155
Travel 1 FPM to surface	10	Air	15:59	

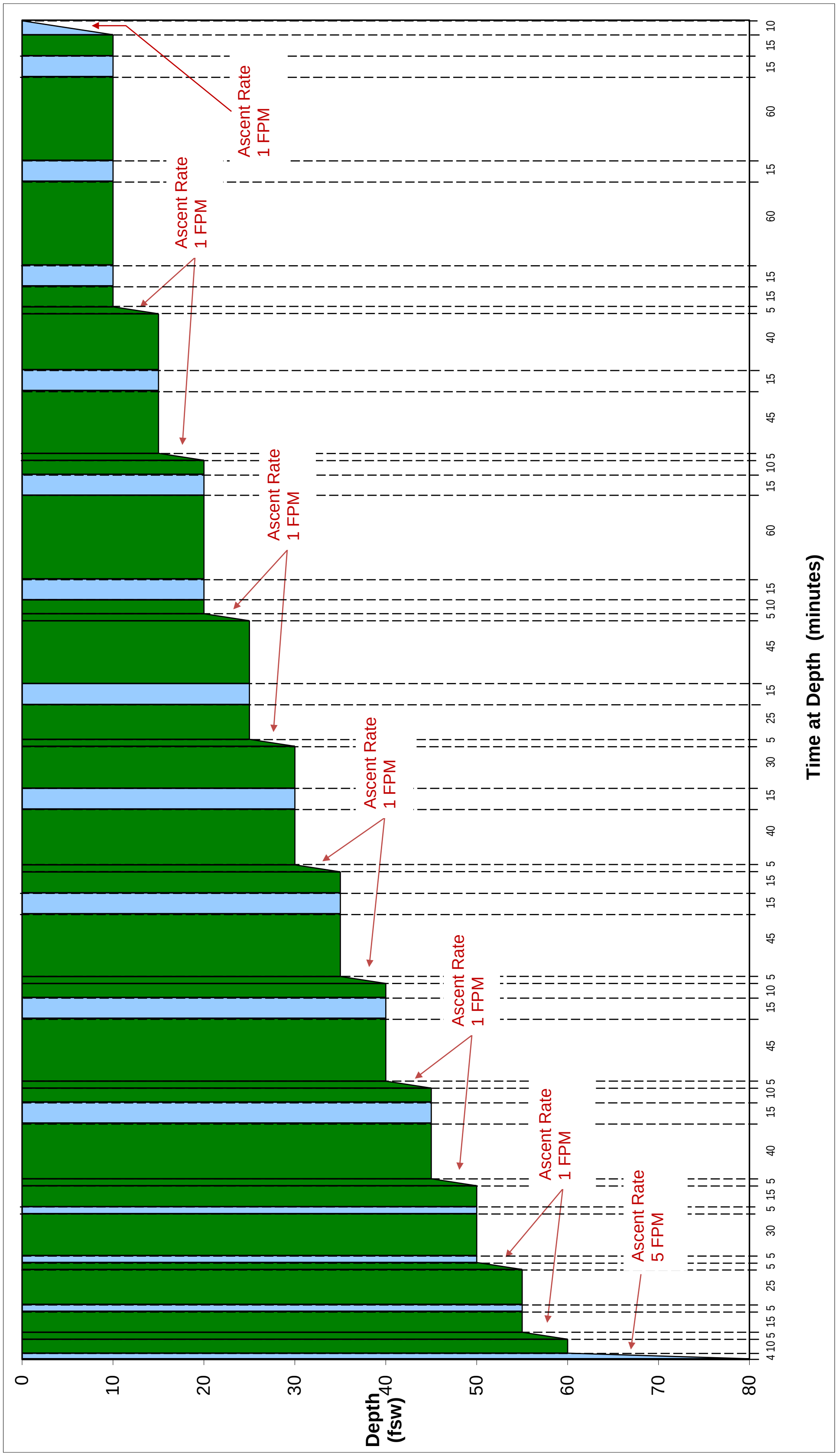


Figure L-3. 80 FSW Air Oxygen Decompression Table with Air Breaks

Appendix M. Equivalent Air Saturation Depth 90 fsw

M-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (Hold) mode. Decompression will begin when 30+ rescuees are in the chamber.
2. The first sortie goes down unpressurized. All subsequent sorties go down pre-pressurized to the first stop depth in the schedule (Table 4-3). After mating with the DISSUB the pressure in the PRM is increased to equalize with the DISSUB using on board HP air supplies.
3. The PRM attendants are used in a back-to-back mode. The PRM attendants enter the SDC with the first load of rescuees and remain there while the PRM is surfaced and replenished. The PRM/DTL complex is then re-pressurized to the transfer depth and the PRM attendants transfer to the PRM for the second run.
4. Rescuees are decompressed on Table 4-3. This table does not have a period of oxygen pre-breathing at depth. As the PRM is mated with the DTL, the pressure in the PRM is vented off to the first stop depth of 65 fsw. Transfer of rescuees to the SDC occurs at 65 fsw. The first batch of rescuees is then held at 65 fsw while the second sortie picks up the second batch who also decompress to 65 fsw prior to transfer to the SDC. Once all rescuees are in the chamber, decompression on air is begun. During the air decompression period, the rescuees are instructed in the use of the MBS 2000. When the oxygen stops are reached, the rescuees begin breathing oxygen and complete the remainder of the schedule on oxygen from that point forward. During ascent to the first oxygen stop, 4 seats can be converted to 2 bunks to allow PRM attendants and the custodial tender to lie down and get some rest. Only 1 tender is required to be on duty during this time. Upon arrival at the first oxygen stop, the 2 bunks are converted back to 4 seats so all individuals breathing oxygen can be seated.
5. The PRM attendants ride with the rescuees to the surface and begin breathing oxygen with them at some later point in the decompression.
6. There is a requirement to have one custodial tender in the chamber to attend to the first batch of rescuees while the PRM recovers the second batch. This custodial tender will also have to go on oxygen with the rescuees as some point later in the decompression. This will be after the PRM attendants go on oxygen. At the point the PRM attendants go on oxygen, two terminal tenders lock into the chamber and ride the remainder of the schedule to the surface on air. They are not required to breathe oxygen.
7. DET members will be limited by pulmonary oxygen toxicity if there has been no breathe down of the DISSUB oxygen level. DET members lock into the DISSUB on the 1st sortie and are removed on the 4th. A second team is locked in on the 4th sortie and removed on the 7th. A third team is locked in on the 7th sortie and removed on the 9th. A fourth team, if required, is locked in on the 9th sortie and removed on the 12th.
8. PRM attendants and the custodial tender cannot perform repetitive dives later because of their prolonged oxygen exposure. Terminal tenders can perform repetitive dives.

M-2. Rescuee Decompression Schedules

The schedules for decompressing rescuees are shown in Table M-1. These basic tables are expanded to show all recommended air breaks in Table M-3 and Figures M-2 and M-3.

Table M-1. 90 Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)													O2 Stop Time (min)	CPTD (units)
	65	60	55	50	45	40	35	30	25	20	15	10	5		
Air/Oxygen	95	140	**50**	**55**	**55**	**60**	**65**	**70**	**75**	**85**	**95**	**160**		**770**	1830
Air	95	140	150	160	170	185	200	215	235	260	290	325	165	**0**	76

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

M-3. Tender Management Plan

Figure M-1 shows the tender management plan for one chamber run.

Once the PRM is in the deck cradle following the first sortie, the PRM is decompressed to 65 fsw, the first stop on the 90 fsw saturation decompression schedule. Immediately prior to completing the mate with the DTL, which is also at 65 fsw, one custodial tender locks into the SDC via the MTL. As soon as the PRM/DTL/SDC hatches are open, the two PRM attendants and the custodial tender assist in transferring the rescuees from the PRM to the SDC. The transfer process takes 30 min. The SDC hatch is then closed and the DTL and PRM are brought to the surface unmanned for resupply and refurbishment. The PRM attendants and custodial tender remain in the SDC to minister to the needs of the rescuees.

Once the PRM and DTL have been refurbished and recompressed back to 65 fsw, the PRM attendants reenter the PRM and prepare for launch. The second sortie launches at +2h.

The second sortie mates with the DTL at +6h. The PRM attendants and the custodial tender assist with the transfer of the rescuees into the SDC. The transfer process takes 30 min. The PRM attendants and custodial tender then have 235 min of air decompression time to settle the rescuees and train them and any DET members in the use of the MBS 2000. The rescuees and DET members begin the oxygen breathing portion of the decompression schedule upon arrival 55 fsw.

Upon arrival of the chamber at 40 fsw, two terminal tenders lock into the chamber and the PRM attendants go on oxygen and follow the same oxygen breathing schedule to the surface as the rescuees from that point forward. The terminal tenders can ride the remainder of the decompression schedule from 40 fsw to the surface on air.

The custodial tender begins breathing oxygen upon arrival at 30 fsw and follows the same oxygen breathing schedule as the rescuees and PRM attendants from that point forward.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lockins and lockouts by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure M-1. The maximum number of personnel in the chamber is 33, with 2 breathing air and 31 breathing oxygen.

M-4. Sortie/Chamber Loading Analysis

Table M-3 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression when PRM attendants perform back-to-back sorties.

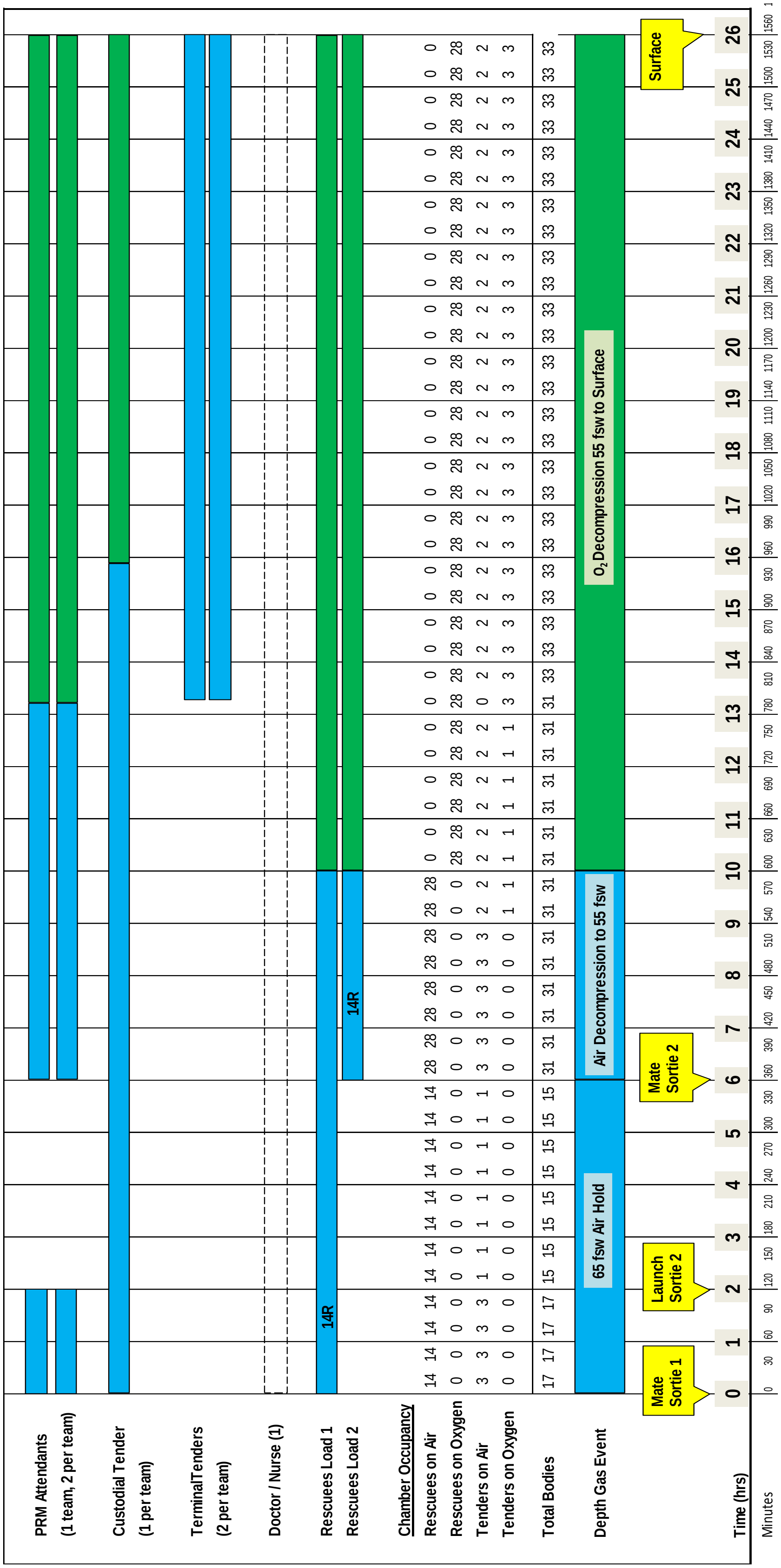


Figure M-1. Tender Management 90 FSW Rescue

Table M-2. 90 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	14	14	0	14	0	0
2		14	14	0	14	0	0
3	Ch. 2	14	14	0	12	1	0
4		14	12	2	10	1	2
5	Ch. 1	14	14	0	12	1	0
6		14	14	0	12	1	0
7	Ch. 2	14	12	2	10	1	2
8		14	14	0	12	1	0
9	Ch. 1	14	12	2	12	0	2
10		14	14	0	14	0	0
11	Ch. 2	15	14	0	16	0	0
12		-	7	2	11	0	2
Total:		155	155	8	149	6	8

Note: The chamber load also includes two PRM attendants and one Custodial Tender decompressing on oxygen along with the rescuees.

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 15 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Four DET teams are required at this depth. The first team is removed on the 4th sortie, the second on the 7th, the third on the 9th and the last on the 12th. Twelve sorties and 6 chamber loads are required. The last sortie transports only 7 rescuees and 2 DET members. The 6th chamber load carries 21 rescuees and 2 DET members.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and 4 two-man DET teams. Twelve sorties and 6 chamber loads are required to execute this scenario. The last sortie transports 11 rescuees plus 2 DET members. The last chamber load carries 27 rescuees plus 2 DET members.

M-5. Repetitive Exposure of PRM Attendants and SDC Tenders

M-5.1. Terminal Tenders

At the 90 fsw depth, only terminal tenders are allowed to perform repetitive dives. All others will have a long exposure to hyperbaric oxygen that precludes repetitive diving.

Terminal tenders lock into the SDC at 40 fsw and then ride to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is H by the Dive Planner. Table 9-8 of the Diving

Manual indicates that Group H has a clean time of 8h 52min (532 min). The Dive Planner shows a clean time of 1084 min for all tissues. With a sortie time of 6 hours and a 3.22 hour delay between Sorties 4 and 5, the surface interval available between Chamber Run 1 and Chamber Run 3 is 868 min, 336 min longer than the Dive Manual clean time and 216 min shorter than the Dive Planner clean time. If an identical dive is made after a surface interval of 868 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 2.591% to 2.931% by the NMRI 98 probabilistic model or from its baseline value of 2.490% to 2.688% by the BVM(3) probabilistic model. A dive with a predicted risk of less than 3% is considered low risk.

Therefore, for 6 hour sorties:

TT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber run.
TT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber run.

Two terminal tenders are required for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 4 terminal tenders.

M-5.2. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above (6 chamber runs) is:

PRM Attendants	12
Transfer Tenders	0
Custodial Tender	6
Pre-Breathe Tenders	0
Terminal Tenders	4
Total	22

Table M-3. 90 FSW Air Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time (min)	Depth (fsw)
90					
Travel 5 FPM to 65	5	Air	0:05		
65	95	Air	1:40	95	Air
Travel 1 FPM to 60	5	Air	1:45		
60	135	Air	4:00	140	Air
Travel 1 FPM to 55	5	Air	4:05		
55	30	O2	4:35		
55	5	Air	4:40		
55	20	O2	5:00	50	O2
Travel 1 FPM to 50	5	O2	5:05		
50	5	O2	5:10		
50	5	Air	5:15		
50	30	O2	5:45		
50	5	Air	5:50		
50	15	O2	6:05	55	O2
Travel 1 FPM to 45	5	O2	6:10		
45	40	O2	6:50		
45	15	Air	7:05		
45	10	O2	7:15	55	O2
Travel 1 FPM to 40	5	O2	7:20		
40	45	O2	8:05		
40	15	Air	8:20		
40	10	O2	8:30	60	O2
Travel 1FPM to 35	5	O2	8:35		
35	45	O2	9:20		
35	15	Air	9:35		
35	15	O2	9:50	65	O2
Travel 1 FPM to 30	5	O2	9:55		
30	35	O2	10:30		
30	15	Air	10:45		
30	30	O2	11:15	70	O2
Travel 1 FPM to 25	5	O2	11:20		
25	25	O2	11:45		
25	15	Air	12:00		
25	45	O2	12:45	75	O2
Travel 1FPM to 20	5	O2	12:50		
20	10	O2	13:00		
20	15	Air	13:15		
20	60	O2	14:15		
20	15	Air	14:30		
20	10	O2	14:40	85	O2
Travel 1 FPM to 15	5	O2	14:45		
15	45	O2	15:30		
15	15	Air	15:45		
15	45	O2	16:30	95	O2
Travel 1FPM to 10	5	O2	16:35		
10	10	O2	16:45		
10	15	Air	17:00		
10	60	O2	18:00		
10	15	Air	18:15		
10	60	O2	19:15		
10	15	Air	19:30		
10	25	O2	19:55	160	O2
Travel 1 FPM to surface	10	Air	20:05		

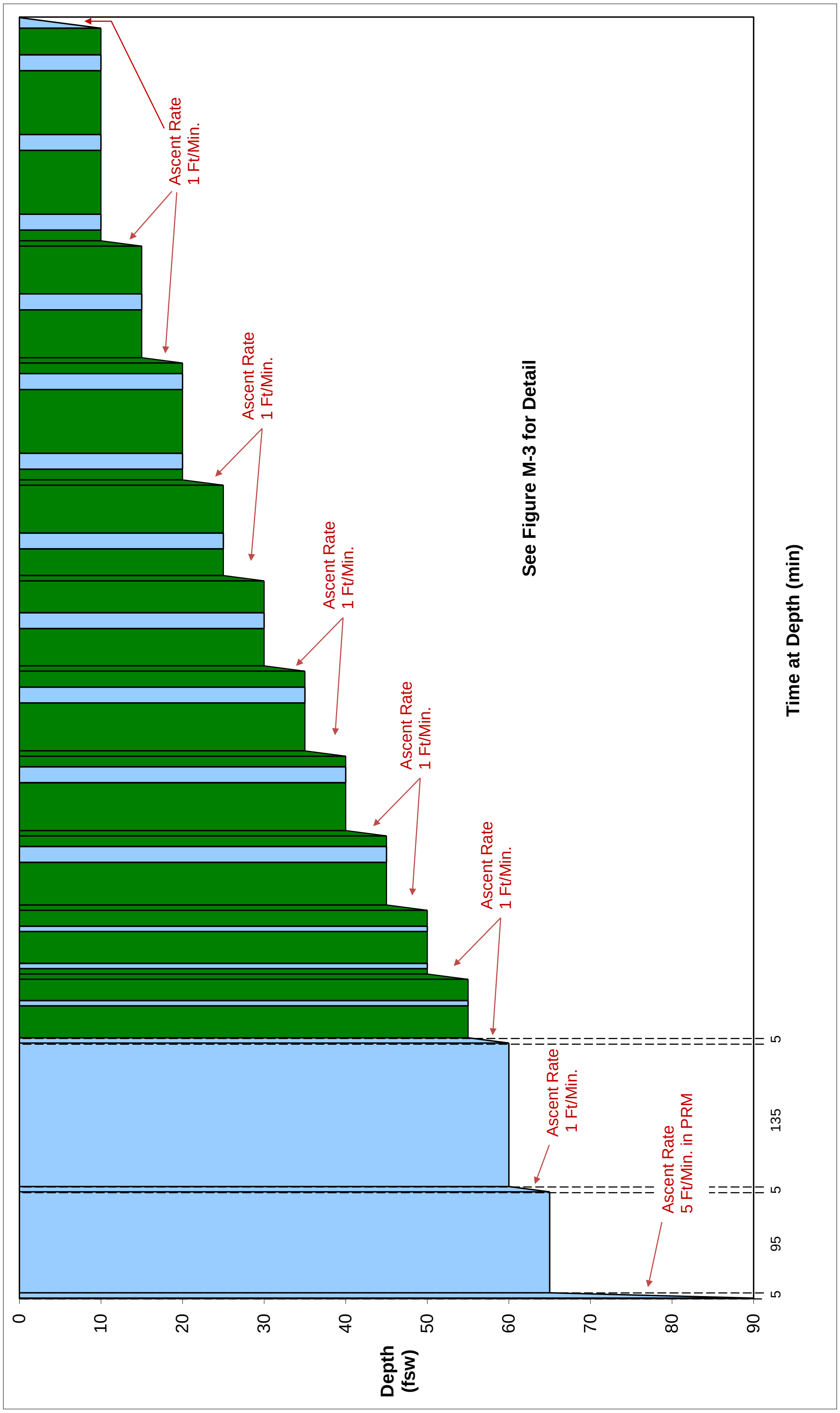


Figure M-2. 90 FSW Air / Oxygen Saturation Decompression Table.

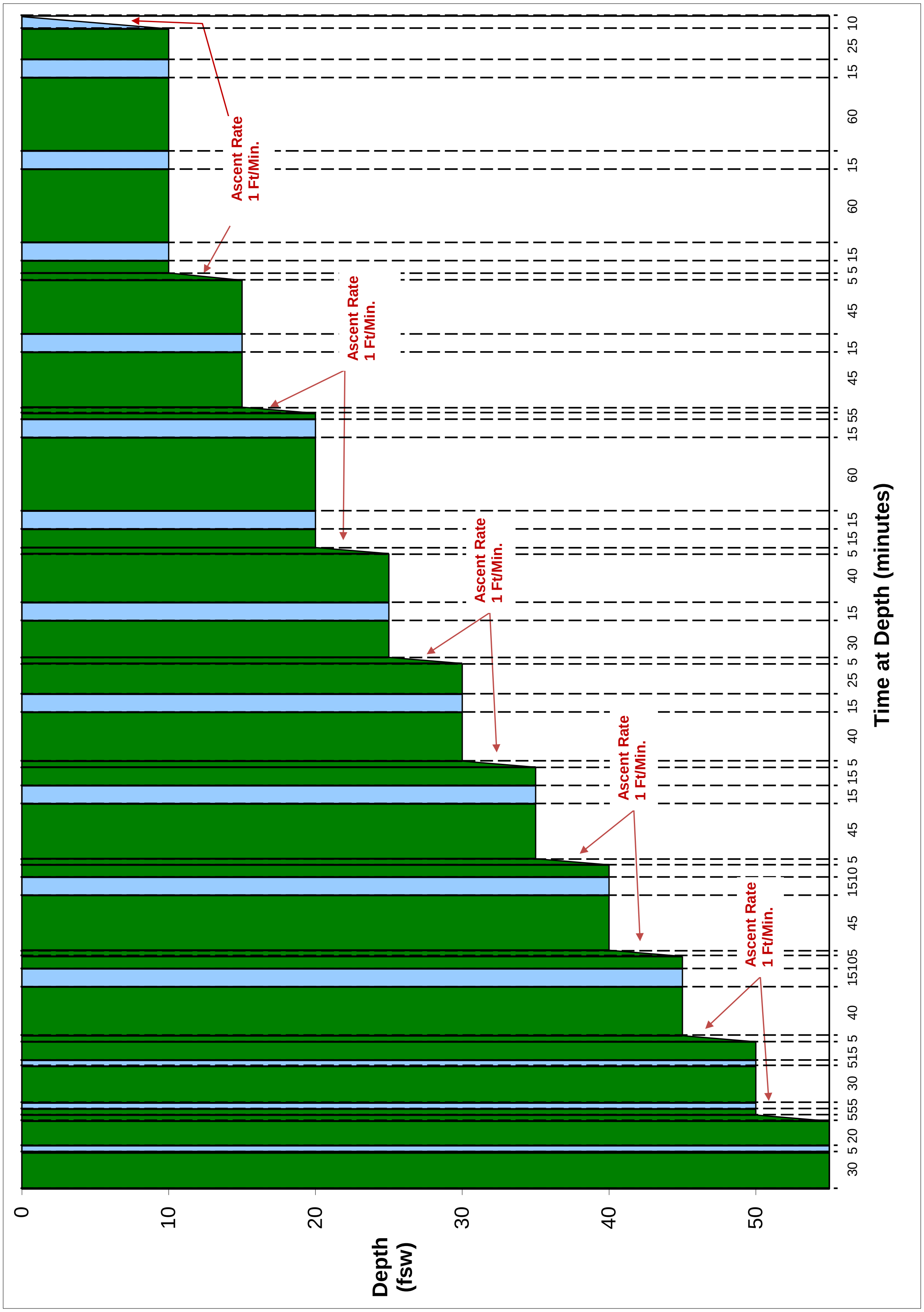


Figure M-3. 90 FSW Submarine Rescue Oxygen Decompression Table (SDC Oxygen Breathing Only).

Appendix N. Equivalent Air Saturation Depth 100 fsw

N-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (Hold) mode. Decompression will begin when 30+ rescuees are in the chamber.
2. The first sortie goes down pre-pressurized at the pressure specified in Table 3-5. Remember that the DISSUB internal pressure may differ from the Equivalent Air Saturation Depth. All subsequent sorties go down pre-pressurized to the first stop depth in the schedule (Table 4-3). After mating with the DISSUB the pressure in the PRM is increased to equalize with the DISSUB using on board HP air supplies.
3. The PRM attendants are used in a back-to-back mode. The PRM attendants enter the SDC with the first load of rescuees and remain there while the PRM is surfaced and replenished. The PRM/DTL complex is then re-pressurized to the transfer depth and the PRM attendants transfer to the PRM for the second run.
4. Rescuees are decompressed on Table 4-3. This table does not have a period of oxygen pre-breathing at depth. As the PRM is mated with the DTL, the pressure in the PRM is vented off to the first stop depth of 75 fsw. Transfer of rescuees to the SDC occurs at 75 fsw. The first batch of rescuees is then held at 75 fsw while the second sortie picks up the second batch who also decompress to 75 fsw prior to transfer to the SDC. Once all rescuees are in the chamber, decompression on air is begun. During the air decompression period, the rescuees are instructed in the use of the MBS 2000. When the oxygen stops are reached, the rescuees begin breathing oxygen and complete the remainder of the schedule on oxygen from that point forward. During ascent to the first oxygen stop, 4 seats can be converted to 2 bunks to allow PRM attendants and the custodial tender to lie down and get some rest. Only 1 tender is required to be on duty during this time. Upon arrival at the first oxygen stop, the 2 bunks are converted back to 4 seats so all individuals breathing oxygen can be seated.
5. The PRM attendants ride with the rescuees to the surface and begin breathing oxygen with them at some later point in the decompression.
6. There is a requirement to have one custodial tender in the chamber to attend to the first batch of rescuees while the PRM recovers the second batch. This custodial tender will also have to go on oxygen with the rescuees as some point later in the decompression. This will be after the PRM attendants go on oxygen. At the point the PRM attendants go on oxygen, two terminal tenders lock into the chamber and ride the remainder of the schedule to the surface on air. They are not required to breathe oxygen.
7. DET members will be limited by pulmonary oxygen toxicity if there has been no breathe down of the DISSUB oxygen level. DET members lock into the DISSUB on the 1st sortie and are removed on the 4th. A second team is locked in on the 4th sortie and removed on the 5th. There is a 10h delay in rescue between the 4th and 5th sorties. A third team is locked in on the 5th sortie and removed on the 8th. A fourth team is locked in on the 8th sortie and removed on the 9th. There is a 10h delay in rescue between the 8th and 9th sorties. A fifth team, if required, is locked in on the 9th sortie and removed on the 12th.
8. PRM attendants and the custodial tender cannot perform repetitive dives later because of their prolonged oxygen exposure. Terminal tenders can perform repetitive dives.

N-2. Rescuee Decompression Schedules

The schedules for decompressing recsuees are shown in Table N-1. These basic tables are expanded to show all recommended air breaks in Table N-3 and Figures N-2 and N-3.

Table N-1. 100 Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)															O2 Stop Time (Min)	CPTD (units)
	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5		
Air/Oxygen	35	130	130	145	150	165	**55**	**60**	**65**	**75**	**80**	**85**	**95**	**160**		**675**	1559
Air	35	130	130	145	150	165	170	180	200	215	235	265	290	325	165	**0**	140

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

N-3. Tender Management Plan

Figure N-1 shows the tender management plan for one chamber run.

Once the PRM is in the deck cradle following the first sortie, the PRM is decompressed to 75 fsw, the first stop on the 100 fsw saturation decompression schedule. Immediately prior to completing the mate with the DTL, which is also at 75 fsw, one custodial tender locks into the SDC via the MTL. As soon as the PRM/DTL/SDC hatches are open, the two PRM attendants and the custodial tender assist in transferring the rescuees from the PRM to the SDC. The transfer process takes 30 min. The SDC hatch is then closed and the DTL and PRM are brought to the surface unmanned for resupply and refurbishment. The PRM attendants and custodial tender remain in the SDC to minister to the needs of the rescuees.

Once the PRM and DTL have been refurbished and recompressed back to 75 fsw, the PRM attendants reenter the PRM and prepare for launch. The second sortie launches at +2h.

The second sortie mates with the DTL at +6h. The PRM attendants and the custodial tender assist with the transfer of the rescuees into the SDC. The transfer process takes 30 min. The PRM attendants and custodial tender then have 755 min of air decompression time to settle the rescuees and train them and any DET members in the use of the MBS 2000. The rescuees and DET members begin the oxygen breathing portion of the decompression schedule upon arrival 45 fsw.

When 25 min remain at the 40 fsw stop, two terminal tenders lock into the chamber and the PRM attendants go on oxygen and follow the same oxygen breathing schedule to the surface as the rescuees from that point forward. The terminal tenders can ride the remainder of the decompression schedule from 40 fsw to the surface on air.

The custodial tender begins breathing oxygen at the beginning of the first 60 min oxygen breathing period at 30 fsw and follows the same oxygen breathing schedule as the rescuees and PRM attendants from that point forward.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lockins and lockouts by medical personnel is shown as a dotted bar across the duration of the chamber run.

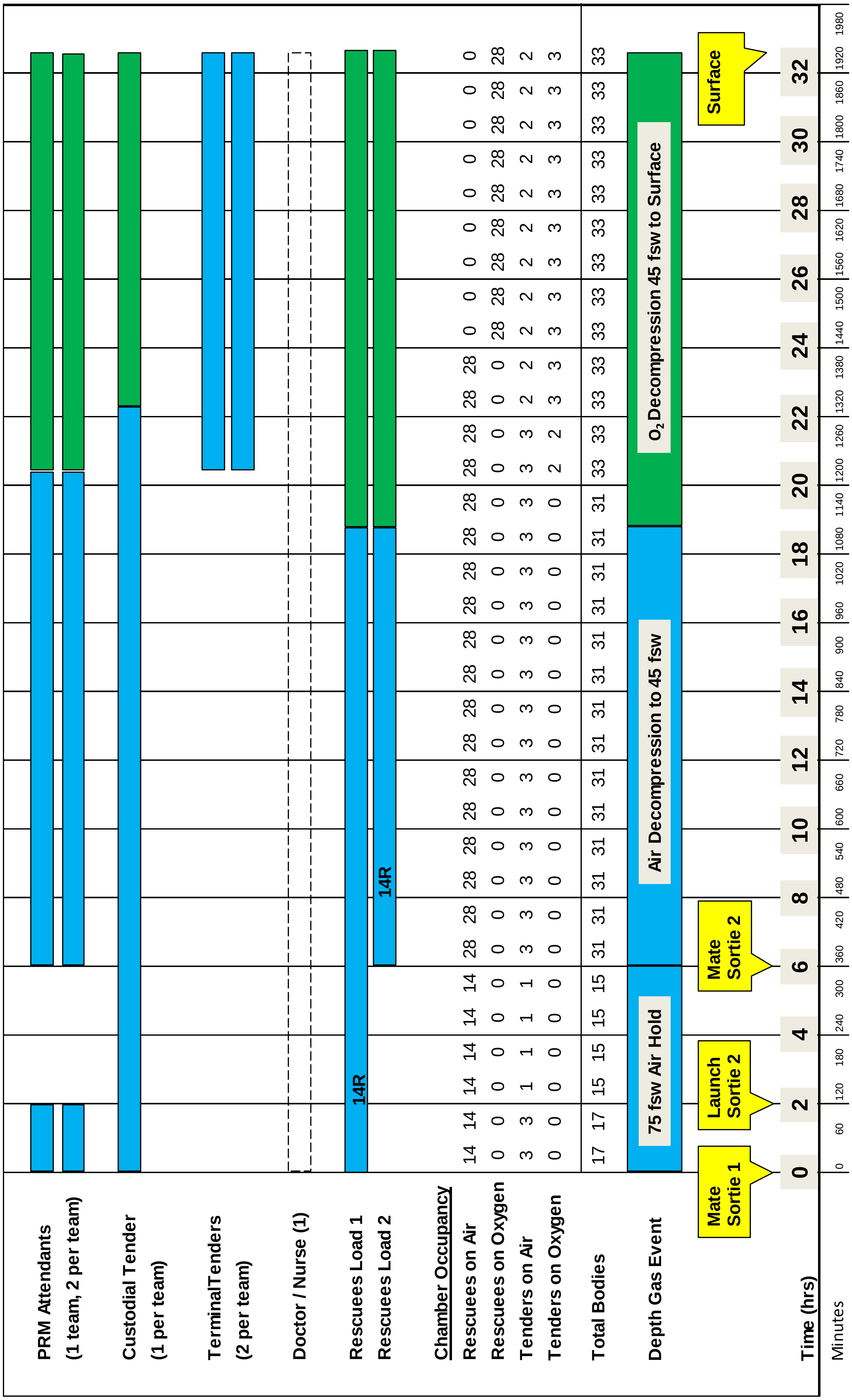


Figure N-1. Tender Management 100 FSW Rescue

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure N-1. The maximum number of personnel in the chamber is 33, with 2 breathing air and 31 breathing oxygen.

N-4. Sortie/Chamber Loading Analysis

Table N-2 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression when PRM attendants perform back-to-back sorties.

Table N-2. 100 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	14	14	0	14	0	0
2		14	14	0	14	0	0
3	Ch. 2	14	14	0	12	1	0
4		14	12	2	10	1	2
5	Ch. 1	14	12	2	10	1	2
6		14	14	0	12	1	0
7	Ch. 2	14	14	0	12	1	0
8		14	12	2	10	1	2
9	Ch. 1	14	12	2	12	0	2
10		14	14	0	14	0	0
11	Ch. 2	15	14	0	14	0	0
12		-	9	2	12	0	2
13	Ch. 1	-	-	-	3	0	2
14		-	-	-	-	-	-
Total:		155	155	10	149	6	12

Note: The chamber load also includes two PRM attendants and one Custodial Tender decompressing on oxygen along with the rescuees.

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 15 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Five DET teams are required at this depth. The first team is removed on the 4th sortie, the second on the 5th because of the 10 h delay between the 4th and 5th sorties, the third on the 8th and the last on the 12th. Twelve sorties and 6 chamber loads are required. The last sortie transports only 9 rescuees and 2 DET members. The 6th chamber load carries 23 rescuees and 2 DET members.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and 6 two-man DET teams. Thirteen sorties and 7 chamber loads are required to execute this scenario. There is a 10 h delay in the launch of the 13th sortie. The sixth DET can enter the DISSUB on the 12th sortie and be removed on the 13th sortie. The 13th sortie and the last chamber load transports only 3 rescuees plus the last two DET members. The need for a 13th sortie is eliminated if there are only 146 rather than 149 rescuees.

N-5. Repetitive Exposure of PRM Attendants and SDC Tenders

N-5.1. Terminal Tenders

At the 100 fsw depth, only terminal tenders are allowed to perform repetitive dives. All others will have a long exposure to hyperbaric oxygen that precludes repetitive diving.

Terminal tenders lock into the SDC at 40 fsw and then ride to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is H by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group H has a clean time of 8h 52min (532 min). The Dive Planner shows a clean time of 1051 min for all tissues. With a sortie time of 6 hours and a 10.0 hour delay between Sorties 4 and 5, the surface interval available between Chamber Run 1 and Chamber Run 3 is 1300 min, 768 min longer than the Dive Manual clean time and 249 min longer than the Dive Planner clean time. If an identical dive is made after a surface interval of 1300 min, the second dive will not require any extra decompression time. The risk of decompression sickness on the second dive will increase from its baseline (totally clean) value of 2.207% to 2.343% by the NMRI 98 probabilistic model or from its baseline value of 2.195% to 2.270% by the BVM(3) probabilistic model. A dive with a predicted risk of less than 3% is considered low risk.

Therefore, for 6 hour sorties:

TT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber run.
TT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber run.

Two terminal tenders are required for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 4 terminal tenders.

N-5.2. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above (6 chamber runs) is:

PRM Attendants	12
Transfer Tenders	0
Custodial Tenders	6
Pre-Breathe Tenders	0
Terminal Tenders	4
Total	22

Table N-3. 100 FSW Air/Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time
100				
Travel 5 FPM to 75	5	Air	:05	
75	35	Air	:40	35
Trvael 1 FPM to 70	5	Air	:45	
70	125	Air	2:50	130
Travel 1 FPM to 65	05	Air	2:55	
65	125	Air	5:00	130
Travel 1 FPM to 60	5	Air	5:05	
60	140	Air	7:25	145
Travel 1 FPM to 55	5	Air	7:30	
55”	145	Air	9:55	150
Travel 1 FPM to 50	5	Air	10:00	
50	160	Air	12:40	165
Travel 1 FPM to 45	5	Air	12:45	
45	55	O2	13:40	55
Travel 1 FPM to 40	5	O2	13:45	
40	15	Air	14:00	
40	55	O2	14:55	60
Travel 1FPM to 35	5	O2	15:00	
35	15	Air	15:15	
35	60	O2	16:15	65
Travel 1 FPM to 30	5	Air	16:20	
30	10	Air	16:30	
30	60	O2	17:30	
30	15	Air	17:45	
30	15	O2	18:00	75
Travel 1 FPM to 25	5	O2	18:05	
25	40	O2	18:45	
25	15	Air	19:00	
25	30	O2	19:30	75
Travel 1FPM to 20	5	O2	19:35	
20	25	O2	20:00	
20	15	Air	20:15	
20	55	O2	21:10	85
Travel 1 FPM to 15	5	O2	21:15	
15	15	Air	21:30	
15	60	O2	22:30	
15	15	Air	22:45	
15	30	O2	23:15	95
Travel 1FPM to 10	5	O2	23:20	
10	25	O2	23:45	
10	15	Air	24:00	
10	60	O2	25:00	
10	15	Air	25:15	
10	60	O2	26:15	
10	15	Air	26:30	
10	10	O2	26:40	160
Travel 1 FPM to surface	10	Air	26:50	

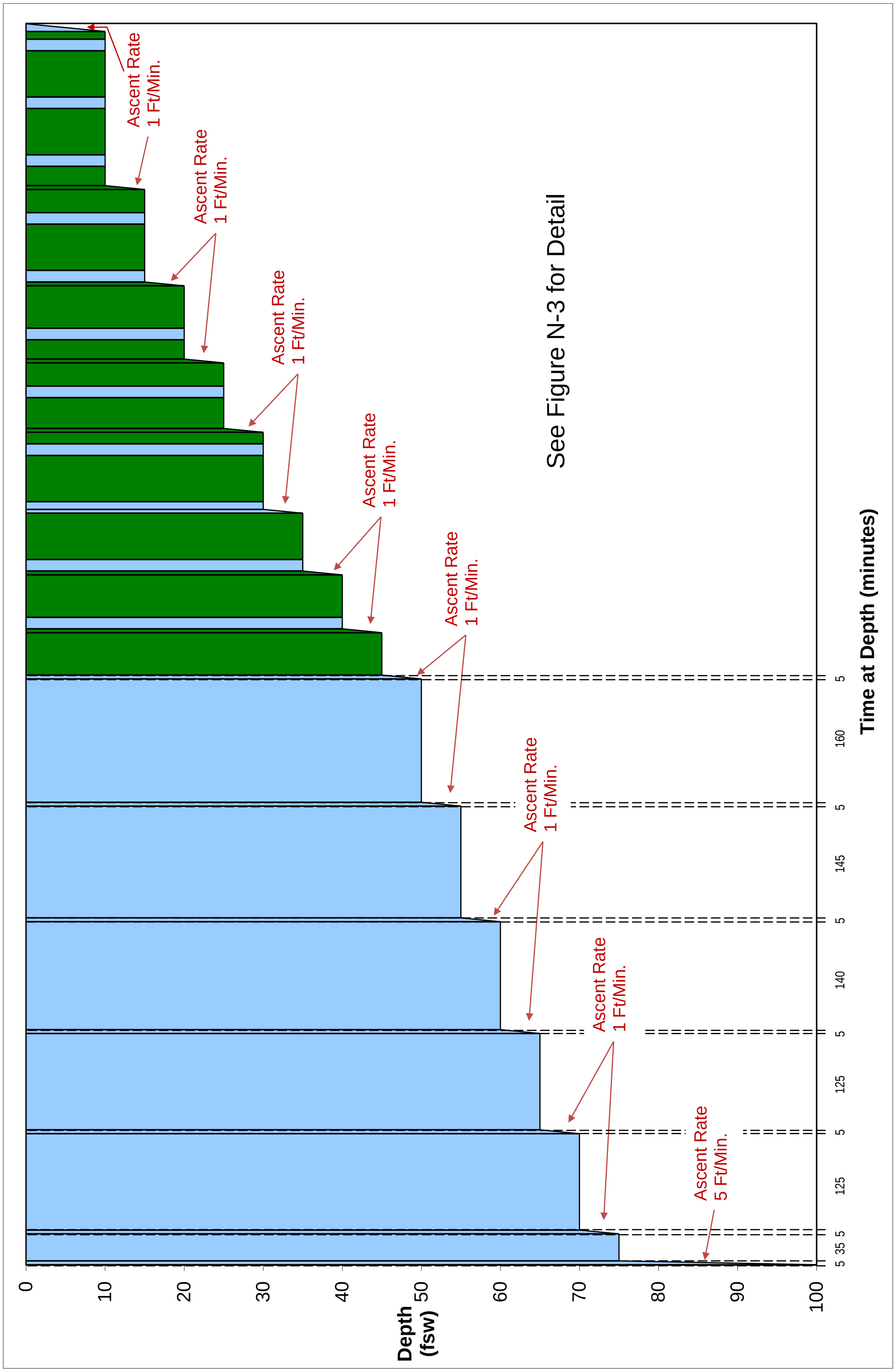


Figure N-2. 100 FSW Air/Oxygen Saturation Decompression Table

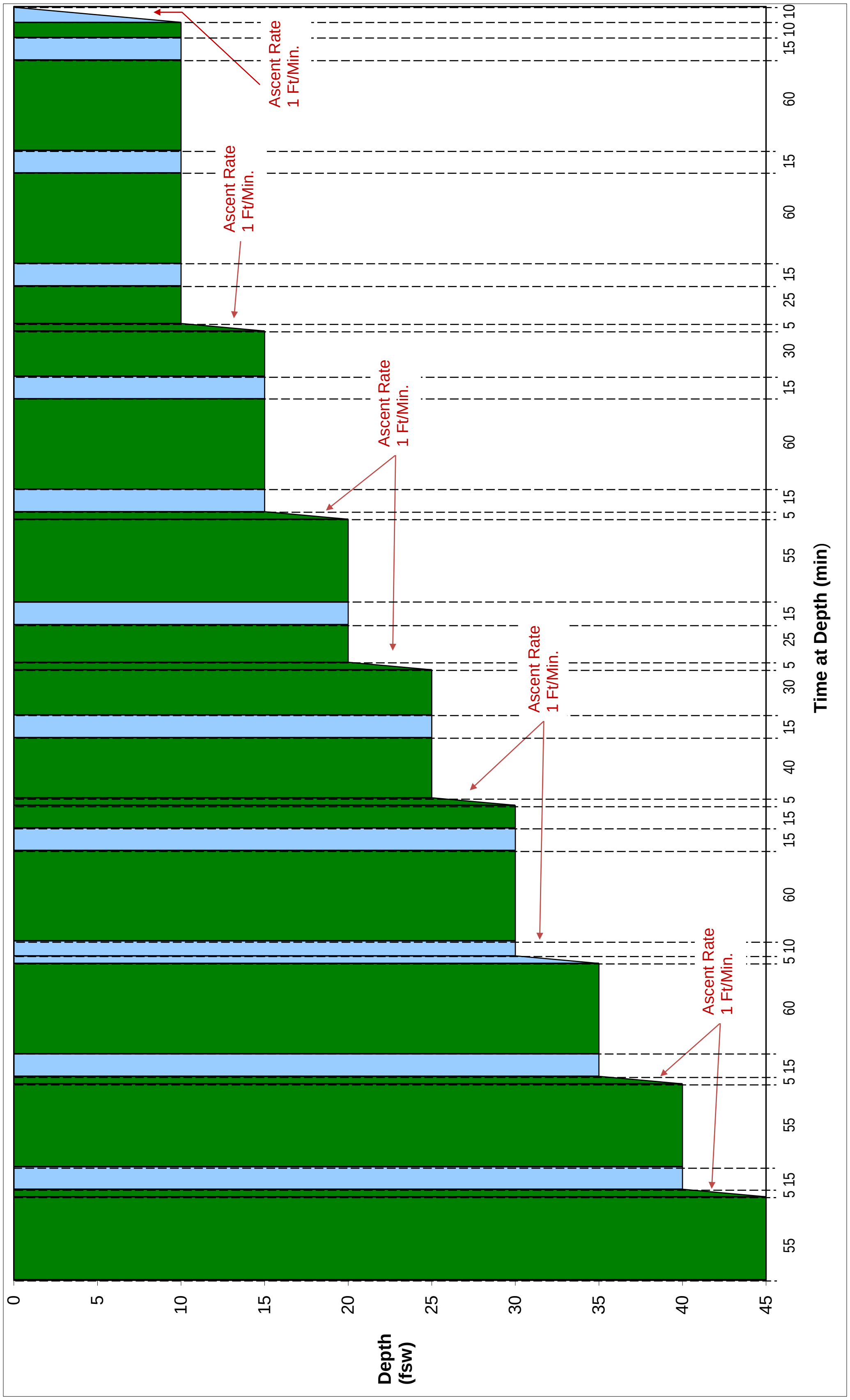


Figure N-3. Air Oxygen Decompression Table with Air Breaks (O_2 Portion Only)

Appendix O. Equivalent Air Saturation Depth 110 fsw

O-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (Hold) mode. Decompression will begin when 30+ rescuees are in the chamber.
2. The first sortie goes down pre-pressurized at the pressure specified in Table 3-5. Remember that the DISSUB internal pressure may differ from the Equivalent Air Saturation Depth. All subsequent sorties go down pre-pressurized to the first stop depth in the schedule (Table 4-3). After mating with the DISSUB the pressure in the PRM is increased to equalize with the DISSUB using on board HP air supplies.
3. The PRM attendants are used in a back-to-back mode. The PRM attendants enter the SDC with the first load of rescuees and remain there while the PRM is surfaced and replenished. The PRM/DTL complex is then re-pressurized to the transfer depth and the PRM attendants transfer to the PRM for the second run.
4. Rescuees are decompressed on Table 4-3. This table does not have a period of oxygen pre-breathing at depth. As the PRM is mated with the DTL, the pressure in the PRM is vented off to the first stop depth of 80 fsw. Transfer of rescuees to the SDC occurs at 80 fsw. The first batch of rescuees is then held at 80 fsw while the second sortie picks up the second batch who also decompress to 80 fsw prior to transfer to the SDC. Once all rescuees are in the chamber, decompression on air is begun. During the air decompression period, the rescuees are instructed in the use of the MBS 2000. When the oxygen stops are reached, the rescuees begin breathing oxygen and complete the remainder of the schedule on oxygen from that point forward. During ascent to the first oxygen stop, 4 seats can be converted to 2 bunks to allow PRM attendants and the custodial tender to lie down and get some rest. Only 1 tender is required to be on duty during this time. Upon arrival at the first oxygen stop, the 2 bunks are converted back to 4 seats so all individuals breathing oxygen can be seated.
5. The PRM attendants ride with the rescuees to the surface and begin breathing oxygen with them at some later point in the decompression.
6. There is a requirement to have one custodial tender in the chamber to attend to the first batch of rescuees while the PRM recovers the second batch. This custodial tender will also have to go on oxygen with the rescuees as some point later in the decompression. This will be after the PRM attendants go on oxygen. At the point the PRM attendants go on oxygen, two terminal tenders lock into the chamber and ride the remainder of the schedule to the surface on air. They are not required to breathe oxygen.
7. DET members will be limited by pulmonary oxygen toxicity if there has been no breathe down of the DISSUB oxygen level. DET members lock into the DISSUB on the 1st sortie and are removed on the 3rd. A second team is locked in on the 3rd sortie and removed on the 4th. There is a 13.3 h rescue delay between the 4th and 5th sorties. It will not be possible to have a DET in the DISSUB during this time. A third team is locked in on the 5th sortie and removed on the 7th. A fourth team is locked in on the 7th sortie and removed on the 8th. There is a second 13.3 h delay between the 8th and 9th sorties. It will not be possible to have a DET in the DISSUB during this time. A fifth team is locked in on the 9th sortie and removed on the 11th. A sixth team, if required is locked in on the 11th sortie and removed on the 12th.

O-2. Rescuee Decompression Schedules

The schedules for decompressing rescuees are shown in Table O-1. These basic tables are expanded to show all recommended air breaks in Table O-3 and Figures O-2 and O-3.

Table O-1. 110 Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)																O2 Stop Time (Min)	CPTD (units)
	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5		
Air/Oxygen	100	120	125	135	140	150	160	**60**	**60**	**65**	**75**	**80**	**85**	**95**	**160**		**680**	1650
Air	100	120	125	135	140	150	160	170	185	200	220	235	260	290	325	175	**0**	214

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

O-3. Tender Management Plan

Figure O-1 shows the tender management plan for one chamber run.

Once the PRM is in the deck cradle following the first sortie, the PRM is decompressed to 80 fsw, the first stop on the 110 fsw saturation decompression schedule. Immediately prior to completing the mate with the DTL, which is also at 85 fsw, one custodial tender locks into the SDC via the MTL. As soon as the PRM/DTL/SDC hatches are open, the two PRM attendants and the custodial tender assist in transferring the rescuees from the PRM to the SDC. The transfer process takes 30 min. The SDC hatch is then closed and the DTL and PRM are brought to the surface unmanned for resupply and refurbishment. The PRM attendants and custodial tender remain in the SDC to minister to the needs of the rescuees.

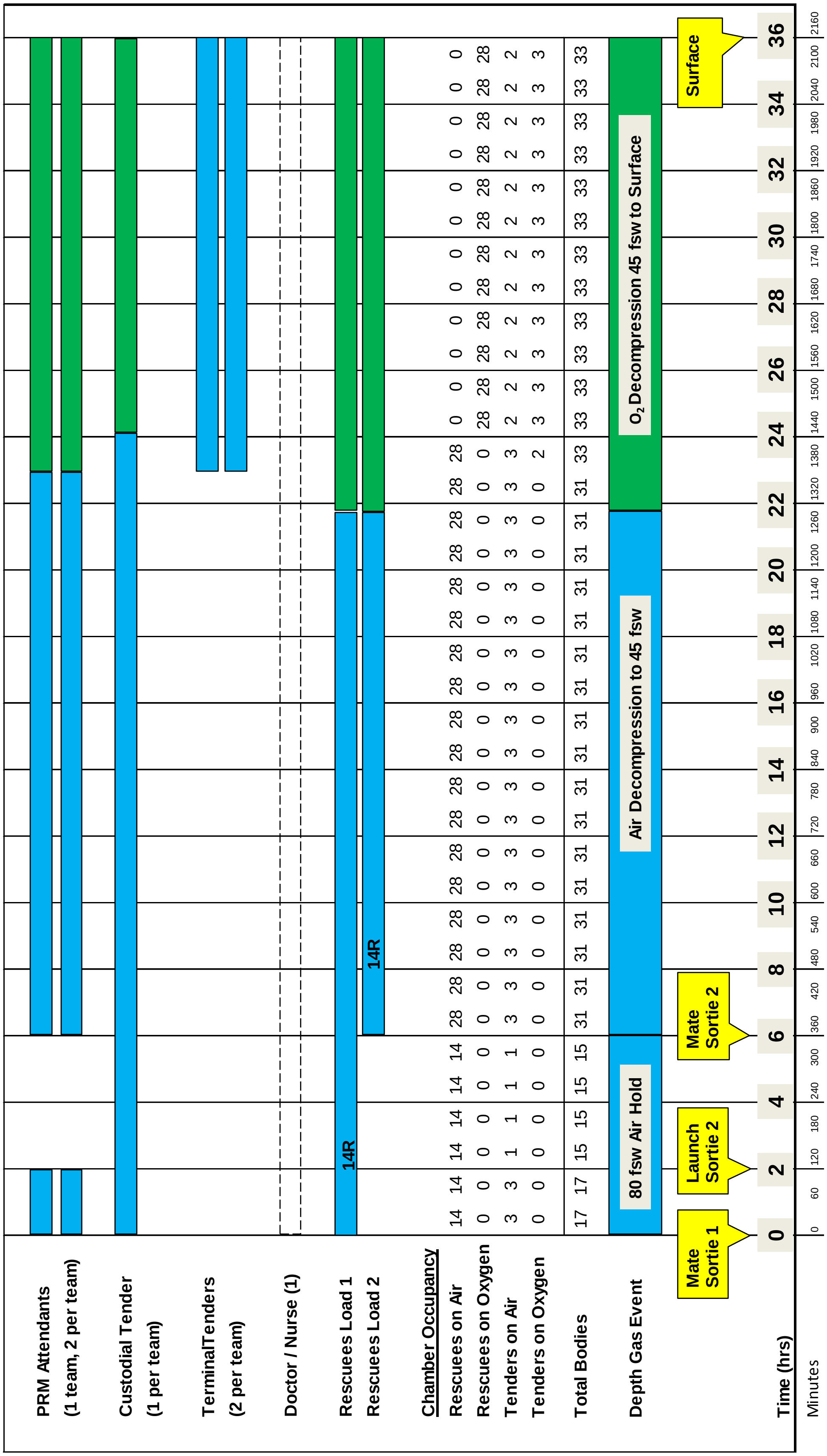
Once the PRM and DTL have been refurbished and recompressed back to 80 fsw, the PRM attendants reenter the PRM and prepare for launch. The second sortie launches at +2h.

The second sortie mates with the DTL at +6h. The PRM attendants and the custodial tender assist with the transfer of the rescuees into the SDC. The transfer process takes 30 min. The PRM attendants and custodial tender then have 15.5 hours of air decompression time to settle the rescuees and train them and any DET members in the use of the MBS 2000. The rescuees and DET members begin the oxygen breathing portion of the decompression schedule upon arrival 45 fsw.

The PRM attendants go on oxygen at the beginning of the first 60 min oxygen breathing period at 40 fsw and follow the same oxygen breathing schedule to the surface as the rescuees from that point forward. Immediately beforehand, two terminal tenders lock into the chamber to attend to the rescuees and the PRM attenants breathing oxygen. The terminal tenders can ride the remainder of the decompression schedule from 40 fsw to the surface on air.

The custodial tender begins breathing oxygen at the beginning of the first 60 min oxygen breathing period at 35 fsw and follows the same oxygen breathing schedule as the rescuees and PRM attendants from that point forward.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lockins and lockouts by medical personnel is shown as a dotted bar across the duration of the chamber run.



Chamber Occupancy (Minutes)	0	60	120	180	240	300	360	420	480	540	600	660
Rescuees on Air	14	14	14	14	14	14	28	28	28	28	28	28
Rescuees on Oxygen	0	0	0	0	0	0	0	0	0	0	0	0
Tenders on Air	3	3	1	1	1	1	3	3	3	3	3	3
Tenders on Oxygen	0	0	0	0	0	0	0	0	0	0	0	0
Total Bodies	17	17	15	15	15	15	31	31	31	31	31	31

Chamber Occupancy (Minutes)	720	780	840	900	960	1020	1080	1140	1200	1260	1320	1380
Rescuees on Air	28	28	28	28	28	28	28	28	28	28	28	28
Rescuees on Oxygen	0	0	0	0	0	0	0	0	0	0	0	0
Tenders on Air	3	3	3	3	3	3	3	3	3	3	3	3
Tenders on Oxygen	0	0	0	0	0	0	0	0	0	0	0	2
Total Bodies	31	31	31	31	31	31	31	31	31	31	31	33

Chamber Occupancy (Minutes)	1440	1500	1560	1620	1680	1740	1800	1860	1920	1980	2040	2100
Rescuees on Air	0	0	0	0	0	0	0	0	0	0	0	0
Rescuees on Oxygen	28	28	28	28	28	28	28	28	28	28	28	28
Tenders on Air	2	2	2	2	2	2	2	2	2	2	2	2
Tenders on Oxygen	3	3	3	3	3	3	3	3	3	3	3	3
Total Bodies	33	33	33	33	33	33	33	33	33	33	33	33

Figure O-1. Tender Management 110 FSW Rescue

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure O-1. The maximum number of personnel in the chamber is 33, with 2 breathing air and 31 breathing oxygen.

O-4. Sortie/Chamber Loading Analysis

Table O-2 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression when PRM attendants perform back-to-back sorties.

Table O-2. 110 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	14	14	0	12	1	0
2		14	14	0	12	1	0
3	Ch. 2	14	12	2	12	0	2
4		14	12	2	12	0	2
5	Ch. 1	14	14	0	12	1	0
6		14	14	0	12	1	0
7	Ch. 2	14	12	2	12	0	2
8		14	12	2	12	0	2
9	Ch. 1	14	14	0	12	1	0
10		14	14	0	12	1	0
11	Ch. 2	15	12	2	12	0	2
12		-	11	2	12	0	2
13	Ch. 1	-	-	-	5	0	0
14		-	-	-	-	-	-
Total:		155	155	12	149	6	12

Note: The chamber load also includes two PRM attendants and one Custodial Tender decompressing on oxygen along with the rescuees.

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 15 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Six DET teams are required at this depth. The first team is removed on the 3th sortie, the second on the 4th because of the 13.3 h delay between the 4th and 5th sorties, the third on the 7th , the fourth on the 8th, the fifth on the 11th and the last on the 12th. Twelve sorties and 6 chamber loads are required. The last sortie transports only 11 rescuees and 2 DET members. The 6th chamber load carries 23 rescuees and 4 DET members.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and 6 two-man DET teams. Thirteen sorties and 7 chamber loads are required to execute this scenario. There is a 13.3 h delay in the launch of the 13th sortie. A DET member cannot be in the DISSUB during this interval because of the excessive oxygen exposure. The 13th sortie and the last chamber load transports only 5 rescuees. The need for a 13th sortie is eliminated if there are only 144 rather than 149 ambulatory rescuees.

O-5. Repetitive Exposure of PRM Attendants and SDC Tenders

O-5.1. Terminal Tenders

At the 110 fsw depth, only terminal tenders are allowed to perform repetitive dives. All others will have a long exposure to hyperbaric oxygen that precludes repetitive diving.

Terminal tenders lock into the SDC at 40 fsw and then ride to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is H by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group H has a clean time of 8h 52min (532 min). The Dive Planner shows a clean time of 1076 min for all tissues. With a sortie time of 6 hours and a 13.27 hour delay between Sorties 4 and 5, the surface interval available between Chamber Run 1 and Chamber Run 3 will be sufficiently long than a second dive will have no greater risk that the first dive. The risk of both dives is 2.558% by the NMRI probabilistic model and 2.456% by the BVM(3) probabilistic model. A dive with a predicted risk of less than 3% is considered low risk.

Therefore, for 6 hour sorties:

TT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber run.
TT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber run.

Two terminal tenders are required for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 4 terminal tenders.

O-5.2. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above (6 chamber runs) is:

PRM Attendants	12
Transfer Tenders	0
Custodial Tenders	6
Pre-Breathe Tenders	0
Terminal Tenders	4
Total	22

Table O-3. 110 FSW Air / Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time
110				
Travel 5 FPM to 80	6	Air	:06	
80	100	Air	1:46	100
Travel 1 FPM to 75	05	Air	1:51	
75	115	Air	3:46	120
Travel 1 FPM to 70	5	Air	3:51	
70	125	Air	5:56	130
Travel 1 FPM to 65	5	Air	6:01	
65	125	Air	8:06	130
Travel 1 FPM to 60	5	Air	8:11	
60	140	Air	10:31	145
Travel 1 FPM to 55	5	Air	10:36	
55	145	Air	13:01	150
Travel 1 FPM to 50	5	Air	13:06	
50	155	Air	15:41	160
Travel 1 FPM to 45	5	Air	15:46	
45	60	O2	16:46	60
Travel 1 FPM to 40	5	Air	16:51	
40	10	Air	17:01	
40	60	O2	17:56	60
Travel 1FPM to 35	5	Air	18:01	
35	10	Air	18:16	
35	60	O2	19:16	
35	15	Air	19:31	
35	5	O2	19:36	65
Travel 1 FPM to 30	5	O2	19:41	
30	50	O2	20:31	
30	15	Air	20:46	
30	20	O2	21:06	75
Travel 1 FPM to 25	5	O2	21:11	
25	35	O2	21:46	
25	15	Air	22:01	
25	40	O2	22:41	80
Travel 1FPM to 20	5	O2	22:46	
20	15	O2	23:01	
20	15	Air	23:16	
20	60	O2	24:16	
20	15	Air	24:31	
20	5	O2	24:36	85
Travel 1 FPM to 15	5	O2	24:41	
15	50	O2	25:31	
15	15	Air	25:46	
15	40	O2	26:26	95
Travel 1FPM to 10	5	O2	26:31	
10	15	O2	26:46	
10	15	Air	27:01	
10	60	O2	28:01	
10	15	Air	28:16	
10	60	O2	29:16	
10	15	Air	29:31	
10	20	O2	29:51	160
Travel 1 FPM to surface	10	Air	30:01	

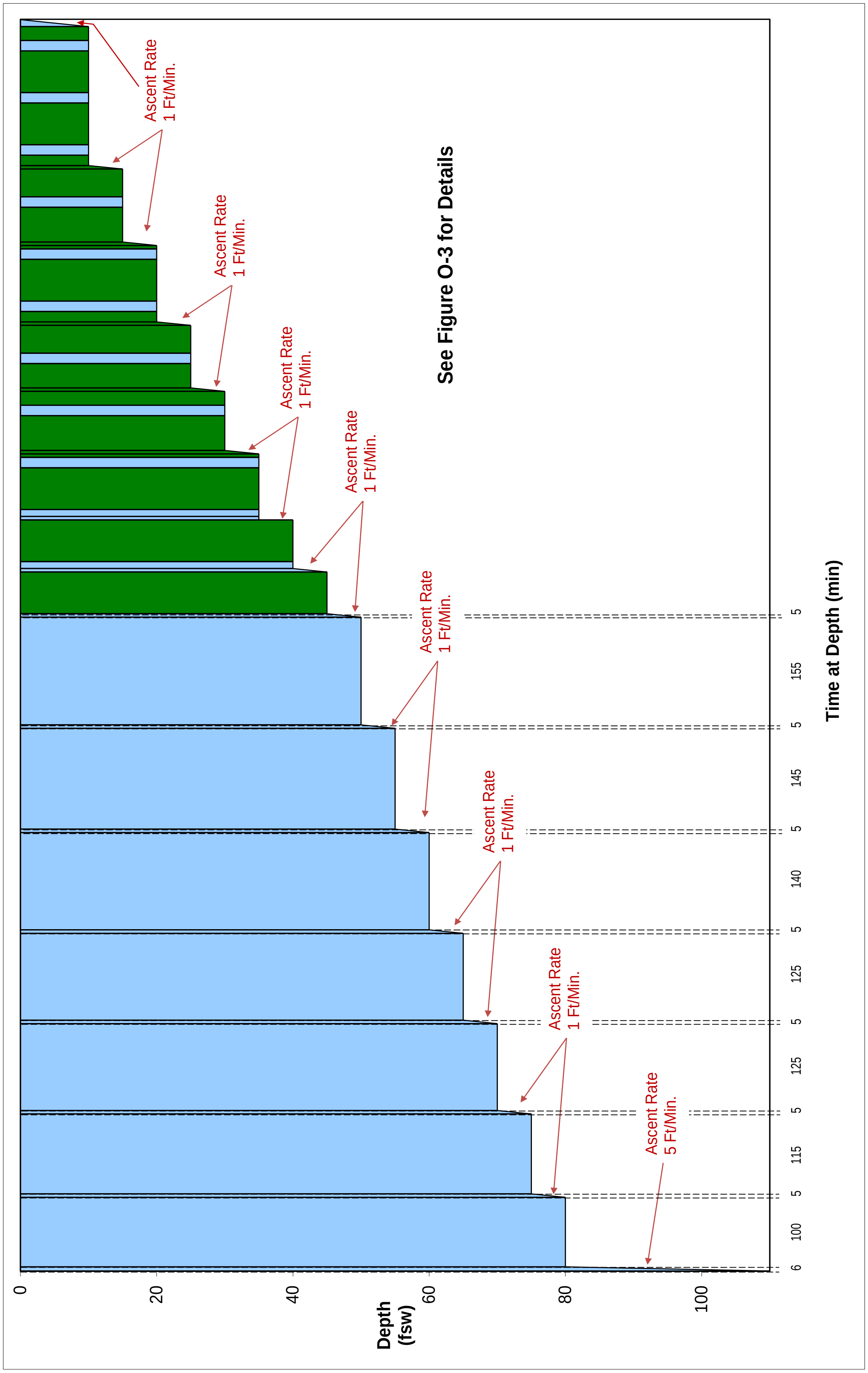


Figure O-2. 110 FSW Air/Oxygen Saturation Decompression Table

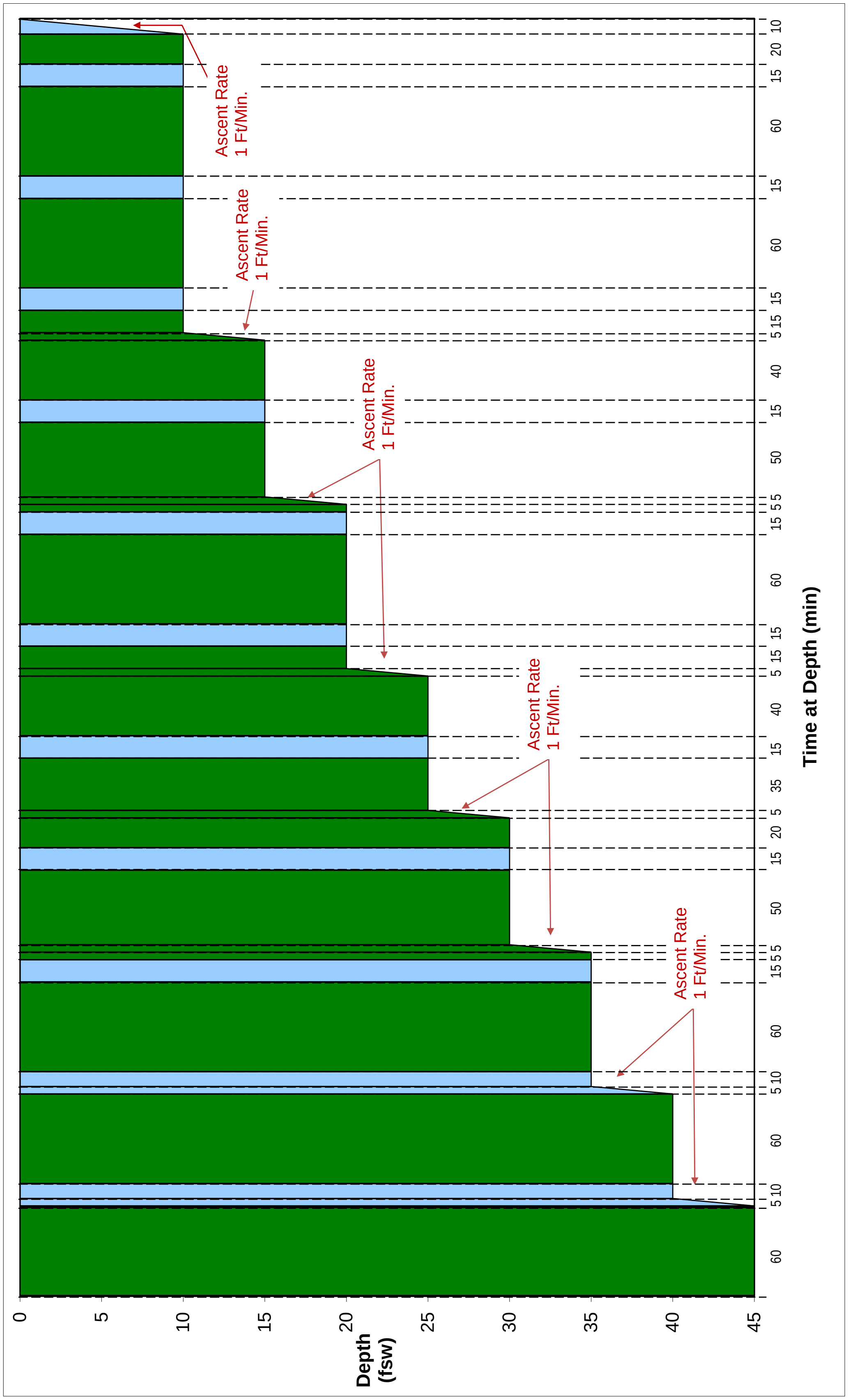


Figure O-3. 110 FSW Air Oxygen Decompression Table with Air Breaks (O_2 Portion Only)

Appendix P. Equivalent Air Saturation Depth 120 fsw

P-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (Hold) mode. Decompression will begin when 30+ rescuees are in the chamber.
2. The first sortie goes down pre-pressurized at the pressure specified in Table 3-5. Remember that the DISSUB internal pressure may differ from the Equivalent Air Saturation Depth. All subsequent sorties go down pre-pressurized to the first stop depth in the schedule (Table 4-3). After mating with the DISSUB the pressure in the PRM is increased to equalize with the DISSUB using on board HP air supplies.
3. The PRM attendants are used in a back-to-back mode. The PRM attendants enter the SDC with the first load of rescuees and remain there while the PRM is surfaced and replenished. The PRM/DTL complex is then re-pressurized to the transfer depth and the PRM attendants transfer to the PRM for the second run.
4. Rescuees are decompressed on Table 4-3. This table does not have a period of oxygen pre-breathing at depth. As the PRM is mated with the DTL, the pressure in the PRM is vented off to the first stop depth of 85 fsw. Transfer of rescuees to the SDC occurs at 85 fsw. The first batch of rescuees is then held at 85 fsw while the second sortie picks up the second batch who also decompress to 85 fsw prior to transfer to the SDC. Once all rescuees are in the chamber, decompression on air is begun. During the air decompression period, the rescuees are instructed in the use of the MBS 2000. When the oxygen stops are reached, the rescuees begin breathing oxygen and complete the remainder of the schedule on oxygen from that point forward. During ascent to the first oxygen stop, 4 seats can be converted to 2 bunks to allow PRM attendants and the custodial tender to lie down and get some rest. Only 1 tender is required to be on duty during this time. Upon arrival at the first oxygen stop, the 2 bunks are converted back to 4 seats so all individuals breathing oxygen can be seated.
5. The PRM attendants ride with the rescuees to the surface and begin breathing oxygen with them at some later point in the decompression.
6. There is a requirement to have one custodial tender in the chamber to attend to the first batch of rescuees while the PRM recovers the second batch. This custodial tender will also have to go on oxygen with the rescuees as some point later in the decompression. This will be after the PRM attendants go on oxygen. At the point the PRM attendants go on oxygen, two terminal tenders lock into the chamber and ride the remainder of the schedule to the surface on air. They are not required to breathe oxygen.
7. DET members will be limited by pulmonary oxygen toxicity if there has been no breathe down of the DISSUB oxygen level. DET members lock into the DISSUB on the 1st sortie and are removed on the 3rd. A second team is locked in on the 3rd sortie and removed on the 4th. There is a 16.1 h rescue delay between the 4th and 5th sorties. It will not be possible to have a DET in the DISSUB during this time. A third team is locked in on the 5th sortie and removed on the 7th. A fourth team is locked in on the 7th sortie and removed on the 8th. There is a second 16.1 h delay between the 8th and 9th sorties. It will not be possible to have a DET in the DISSUB during this time. A fifth team is locked in on the 9th sortie and removed on the 11th. A sixth team, if required is locked in on the 11th sortie and removed on the 12th.

P-2. Rescuee Decompression Schedules

The schedules for decompressing rescuees are shown in Table P-1. These basic tables are expanded to show all recommended air breaks in Table P-3 and Figures P-2 and P-3.

Table P-1. 120 Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)																	O2 Stop Time (Min)	CPTD (units)
	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5		
Air/Oxygen	150	115	120	130	130	145	150	160	**60**	**60**	**70**	**75**	**80**	**85**	**95**	**165**		**690**	1753
Air	150	115	120	130	130	145	150	160	175	180	200	220	235	260	295	330	175	**0**	297

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

P-3. Tender Management Plan

Figure P-1 shows the tender management plan for one chamber run.

Once the PRM is in the deck cradle following the first sortie, the PRM is decompressed to 85 fsw, the first stop on the 120 fsw saturation decompression schedule. Immediately prior to completing the mate with the DTL, which is also at 85 fsw, one custodial tender locks into the SDC via the MTL. As soon as the PRM/DTL/SDC hatches are open, the two PRM attendants and the custodial tender assist in transferring the rescuees from the PRM to the SDC. The transfer process takes 30 min. The SDC hatch is then closed and the DTL and PRM are brought to the surface unmanned for resupply and refurbishment. The PRM attendants and custodial tender remain in the SDC to minister to the needs of the rescuees.

Once the PRM and DTL have been refurbished and recompressed back to 85 fsw, the PRM attendants reenter the PRM and prepare for launch. The second sortie launches at +2h.

The second sortie mates with the DTL at +6h. The PRM attendants and the custodial tender assist with the transfer of the rescuees into the SDC. The transfer process takes 30 min. The PRM attendants and custodial tender then have 18.3 hours of air decompression time to settle the rescuees and train them and any DET members in the use of the MBS 2000. The rescuees and DET members begin the oxygen breathing portion of the decompression schedule upon arrival 45 fsw.

The PRM attendants go on oxygen at the beginning of the first 60 min oxygen breathing period at 40 fsw and follow the same oxygen breathing schedule to the surface as the rescuees from that point forward. Immediately beforehand, two terminal tenders lock into the chamber to attend to the rescuees and the PRM attendants breathing oxygen. The terminal tenders can ride the remainder of the decompression schedule from 40 fsw to the surface on air.

The custodial tender begins breathing oxygen at the beginning of the first 60 min oxygen breathing period at 35 fsw and follows the same oxygen breathing schedule as the rescuees and PRM attendants from that point forward.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lockins and lockouts by medical personnel is shown as a dotted bar across the duration of the chamber run.

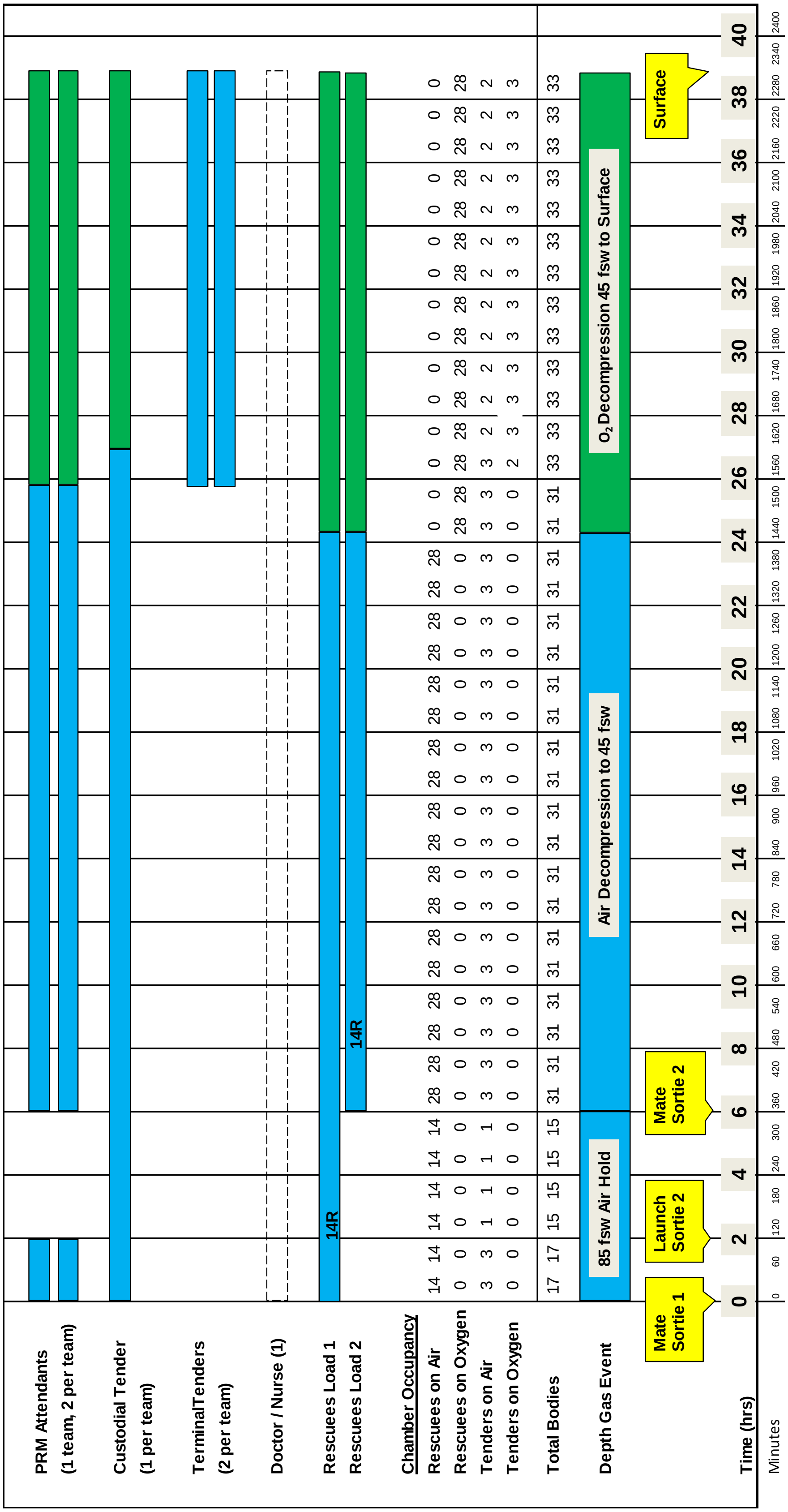


Figure P-1. Tender Management 120 FSW Rescue

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure P-1. The maximum number of personnel in the chamber is 33, with 2 breathing air and 31 breathing oxygen.

P-4. Sortie/Chamber Loading Analysis

Table P-2 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression when PRM attendants perform back-to-back sorties.

Table P-2. 120 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	14	14	0	12	1	0
2		14	14	0	12	1	0
3	Ch. 2	14	12	2	12	0	2
4		14	12	2	12	0	2
5	Ch. 1	14	14	0	12	1	0
6		14	14	0	12	1	0
7	Ch. 2	14	12	2	12	0	2
8		14	12	2	12	0	2
9	Ch. 1	14	14	0	12	1	0
10		14	14	0	12	1	0
11	Ch. 2	15	12	2	12	0	2
12		-	11	2	12	0	2
13	Ch. 1	-	-	-	5	0	0
14		-	-	-	-	-	-
Total:		155	155	12	149	6	12

Note: The chamber load also includes two PRM attendants and one Custodial Tender decompressing on oxygen along with the rescuees.

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 15 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Six DET teams are required at this depth. The first team is removed on the 3th sortie, the second on the 4th because of the 16.1 h delay between the 4th and 5th sorties, the third on the 7th , the fourth on the 8th, the fifth on the 11th and the last on the 12th. Twelve sorties and 6 chamber loads are required. The last sortie transports only 11 rescuees and 2 DET members. The 6th chamber load carries 23 rescuees and 4 DET members.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and 6 two-man DET teams. Thirteen sorties and 7 chamber loads are required to execute this scenario. There is a 16.1 h delay in the launch of the 13th sortie. A DET member cannot be in the DISSUB during this interval because of the excessive oxygen exposure. The 13th sortie and the last chamber load transports only 5 rescuees. The need for a 13th sortie is eliminated if there are only 144 rather than 149 ambulatory rescuees.

P-5. Repetitive Exposure of PRM Attendants and SDC Tenders

P-5.1. Terminal Tenders

At the 120 fsw depth, only terminal tenders are allowed to perform repetitive dives. All others will have a long exposure to hyperbaric oxygen that precludes repetitive diving.

Terminal tenders lock into the SDC at 40 fsw and then ride to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is H by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group H has a clean time of 8h 52min (532 min). The Dive Planner shows a clean time of 1090 min for all tissues. With a sortie time of 6 hours and a 16.12 hour delay between Sorties 4 and 5, the surface interval available between Chamber Run 1 and Chamber Run 3 will be sufficiently long than a second dive will have no greater risk that the first dive. The risk of both dives is 2.705% by the NMRI probabilistic model and 2.570% by the BVM(3) probabilistic model. A dive with a predicted risk of less than 3% is considered low risk.

Therefore, for 6 hour sorties:

TT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber run.
TT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber run.

Two terminal tenders are required for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 4 terminal tenders.

P-5.2. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above (6 chamber runs) is:

PRM Attendants	12
Transfer Tenders	0
Custodial Tenders	6
Pre-Breathe Tenders	0
Terminal Tenders	4
Total	22

Table P-3. 120 FSW Air / Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time
120				
Travel 5 FPM to 85	7	Air	:07	
85	120	Air	2:37	150
Travel 1 FPM to 80	5	Air	2:42	
80	110	Air	4:32	115
Travel 1 FPM to 75	5	Air	4:37	
75	115	Air	6:32	120
Travel 1 FPM to 70	5	Air	6:37	
70	125	Air	8:42	130
Travel 1 FPM to 65	5	Air	8:47	
65	125	Air	10:52	130
Travel 1 FPM to 60	5	Air	10:57	
60	140	Air	13:17	145
Travel 1 FPM to 55	5	Air	13:22	
55	145	Air	15:47	150
Travel 1 FPM to 50	5	Air	15:52	
50	155	Air	18:27	160
Travel 1 FPM to 45	5	Air	18:32	
45	60	O2	19:32	60
Travel 1 FPM to 40	5	Air	19:37	
40	10	Air	19:47	
40	60	O2	20:47	60
Travel 1FPM to 35	05	Air	20:52	
35	10	Air	21:02	
35	60	O2	22:02	
35	15	Air	22:17	
35	10	O2	22:27	70
Travel 1 FPM to 30	5	O2	22:32	
30	45	O2	23:17	
30	15	Air	23:32	
30	25	O2	23:57	75
Travel 1 FPM to 25	05	O2	24:02	
25	30	O2	24:32	
25	15	Air	24:47	
25	45	O2	25:32	80
Travel 1FPM to 20	5	O2	25:37	
20	10	O2	25:47	
20	15	Air	26:02	
20	60	O2	27:02	
20	15	Air	27:17	
20	10	O2	27:27	85
Travel 1 FPM to 15	5	O2	27:32	
15	45	O2	28:17	
15	15	Air	28:32	
15	45	O2	29:17	95
Travel 1FPM to 10	5	O2	29:22	
10	10	O2	29:32	
10	15	Air	29:47	
10	60	O2	30:47	
10	15	Air	31:02	
10	60	O2	32:02	
10	15	Air	32:17	
10	30	O2	32:47	165
Travel 1 FPM to surface	10	Air	32:57	

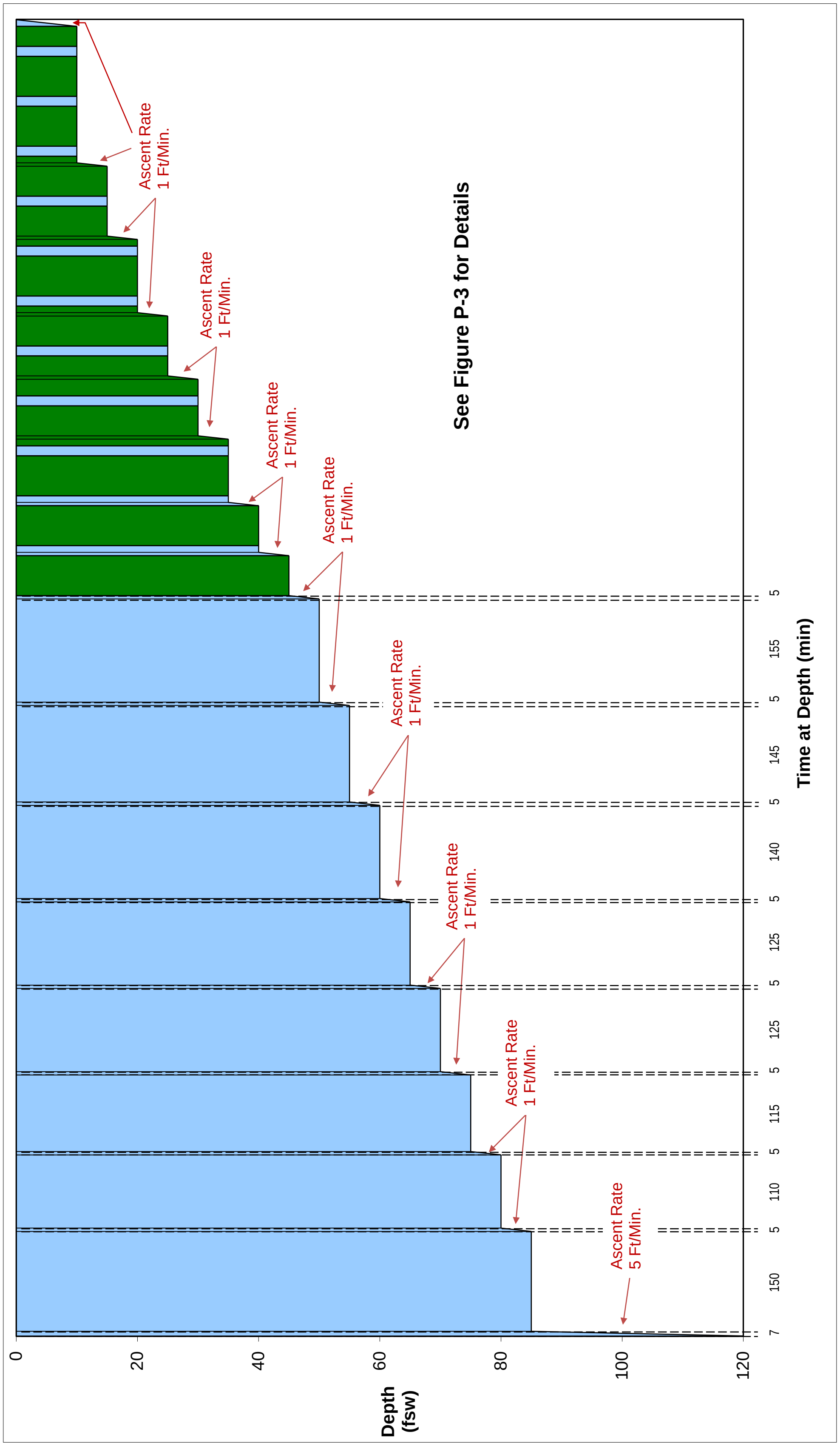


Figure P-2. 120 FSW Air/Oxygen Saturation Decompression Table

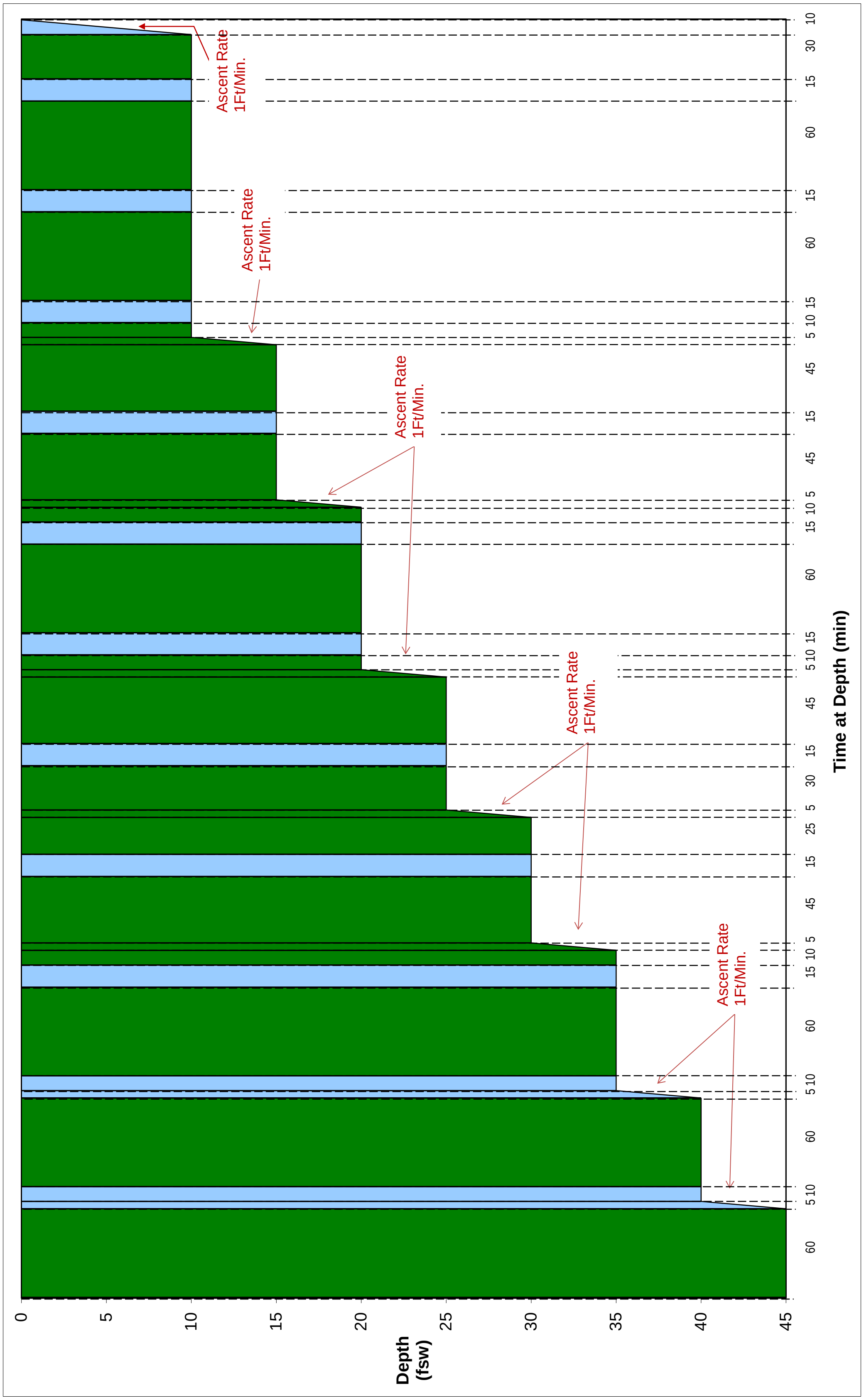


Figure P-3. 120 FSW Air Oxygen Decompression Table with Air Breaks (O2 Portion Only)

Appendix Q. Equivalent Air Saturation Depth 132 fsw

Q-1. Concept of Operation

1. SDC's are operated in the Dual Chamber (Hold) mode. Decompression will begin when 30+ rescuees are in the chamber.
2. The first sortie goes down pre-pressurized at the pressure specified in Table 3-5. Remember that the DISSUB internal pressure may differ from the Equivalent Air Saturation Depth. All subsequent sorties go down pre-pressurized to the first stop depth in the schedule (Table 4-3). After mating with the DISSUB the pressure in the PRM is increased to equalize with the DISSUB using on board HP air supplies.
3. The PRM attendants are used in a back-to-back mode. The PRM attendants enter the SDC with the first load of rescuees and remain there while the PRM is surfaced and replenished. The PRM/DTL complex is then re-pressurized to the transfer depth and the PRM attendants transfer to the PRM for the second run.
4. Rescuees are decompressed on Table 4-3. This table does not have a period of oxygen pre-breathing at depth. As the PRM is mated with the DTL, the pressure in the PRM is vented off to the first stop depth of 85 fsw. Transfer of rescuees to the SDC occurs at 85 fsw. The first batch of rescuees is then held at 85 fsw while the second sortie picks up the second batch who also decompress to 85 fsw prior to transfer to the SDC. Once all rescuees are in the chamber, decompression on air is begun. During the air decompression period, the rescuees are instructed in the use of the MBS 2000. When the oxygen stops are reached, the rescuees begin breathing oxygen and complete the remainder of the schedule on oxygen from that point forward. During ascent to the first oxygen stop, 4 seats can be converted to 2 bunks to allow PRM attendants and the custodial tender to lie down and get some rest. Only 1 tender is required to be on duty during this time. Upon arrival at the first oxygen stop, the 2 bunks are converted back to 4 seats so all individuals breathing oxygen can be seated.
5. The PRM attendants ride with the rescuees to the surface and begin breathing oxygen with them at some later point in the decompression.
6. There is a requirement to have one custodial tender in the chamber to attend to the first batch of rescuees while the PRM recovers the second batch. This custodial tender will also have to go on oxygen with the rescuees as some point later in the decompression. This will be after the PRM attendants go on oxygen. At the point the PRM attendants go on oxygen, two terminal tenders lock into the chamber and ride the remainder of the schedule to the surface on air. They are not required to breathe oxygen.
7. DET members will be limited by pulmonary oxygen toxicity if there has been no breathe down of the DISSUB oxygen level. At this depth, it will not be possible to have a DET in the DISSUB between the 2nd and 3rd, 6th and 7th, or 10th and 11th sorties. It will also not be possible to have a DET in the DISSUB during the 19.5 h rescue delay between the 4th and 5th sorties and the 8th and 9th sorties. Different DISSUB entry teams will lock into the DISSUB on Sorties 1, 3, 5, 7, 9, and 11 and be removed on the subsequent sortie, i.e., Sorties 2, 4, 6, 8, 10 and 12.
8. PRM attendants and the custodial tender cannot perform repetitive dives later because of their prolonged oxygen exposure. Terminal tenders can perform repetitive dives.

Q-2. Rescuee Decompression Schedules

The schedules for decompressing rescuees are shown in Table Q-1. These basic tables are expanded to show all recommended air breaks in Table Q-3 and Figures Q-2 and Q-3.

Table Q-1. 120 Rescuee Decompression Schedules

Schedule	Decompression Stop Time (min)																	O2 Stop Time (Min)	CPTD (units)
	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5		
Air/Oxygen	305	115	125	130	135	145	150	165	**60**	**65**	**70**	**75**	**80**	**90**	**100**	**180**		**720**	1887
Air	305	115	125	130	135	145	150	165	175	190	205	225	245	275	305	345	215	**0**	378

Note 1: Oxygen times shown in bold print; air breaks during oxygen breathing not shown
Note 2: CPTD by Harabin method assuming 90% oxygen in the MBS 2000

Q-3. Tender Management Plan

Figure Q-1 shows the tender management plan for one chamber run.

Once the PRM is in the deck cradle following the first sortie, the PRM is decompressed to 85 fsw, the first stop on the 132 fsw saturation decompression schedule. Immediately prior to completing the mate with the DTL, which is also at 85 fsw, one custodial tender locks into the SDC via the MTL. As soon as the PRM/DTL/SDC hatches are open, the two PRM attendants and the custodial tender assist in transferring the rescuees from the PRM to the SDC. The transfer process takes 30 min. The SDC hatch is then closed and the DTL and PRM are brought to the surface unmanned for resupply and refurbishment. The PRM attendants and custodial tender remain in the SDC to minister to the needs of the rescuees.

Once the PRM and DTL have been refurbished and recompressed back to 85 fsw, the PRM attendants reenter the PRM and prepare for launch. The second sortie launches at +2h.

The second sortie mates with the DTL at +6h. The PRM attendants and the custodial tender assist with the transfer of the rescuees into the SDC. The transfer process takes 30 min. The PRM attendants and custodial tender then have 21.2 hours of air decompression time to settle the rescuees and train them and any DET members in the use of the MBS 2000. The rescuees and DET members begin the oxygen breathing portion of the decompression schedule upon arrival 45 fsw.

The PRM attendants go on oxygen for the last 20 min of the 60 min oxygen breathing period at 45 fsw and follow the same oxygen breathing schedule to the surface as the rescuees from that point forward. Immediately beforehand, two terminal tenders lock into the chamber to attend to the rescuees and the PRM attendants breathing oxygen. The terminal tenders can ride the remainder of the decompression schedule from 45 fsw to the surface on air.

The custodial tender goes on oxygen for the last 20 of the 60 min oxygen breathing period at 40 fsw and follows the same oxygen breathing schedule as the rescuees and PRM attendants from that point forward.

The requirement for medical tenders inside the chamber will vary with the condition of the rescuees and cannot be predicted in advance. The potential for lockins and lockouts by medical personnel is shown as a dotted bar across the duration of the chamber run.

The breakdown of personnel inside the chamber at any given point, including those on air and those on oxygen, is shown in the lower half of Figure Q-1. The maximum number of personnel in the chamber is 33, with 2 breathing air and 31 breathing oxygen.

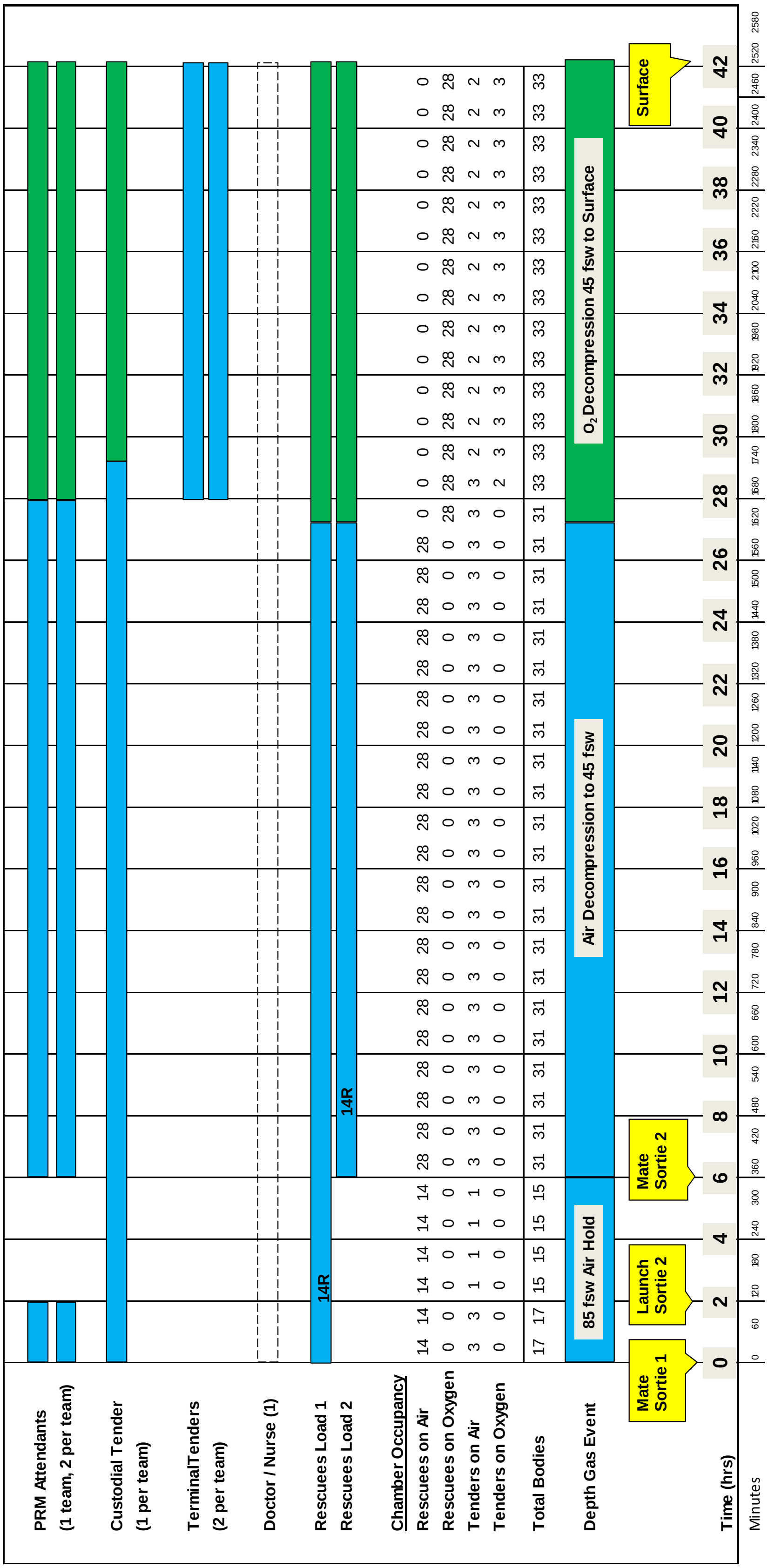


Figure Q-1. Tender Management 132 FSW Rescue

Q-4. Sortie/Chamber Loading Analysis

Table O-2 shows the number of rescuees and DET members transported with each sortie and the chamber in which they perform their decompression when PRM attendants perform back-to-back sorties.

Table Q-2. 132 FSW Sortie/Chamber Loading Analysis

		Scenario I (155 AR)	Scenario II (155 AR + 2 DET)		Scenario III (149 AR + 6 ST + 2 DET)		
Sortie #	Chamber	AR	AR	DET	AR	ST	DET
1	Ch. 1	14	14	0	14	0	0
2		14	12	2	12	0	2
3	Ch. 2	14	14	0	12	1	0
4		14	12	2	10	1	2
5	Ch. 1	14	14	0	12	1	0
6		14	12	2	10	1	2
7	Ch. 2	14	14	0	12	1	0
8		14	12	2	10	1	2
9	Ch. 1	14	14	0	14	0	0
10		14	12	2	12	0	2
11	Ch. 2	15	14	0	14	0	0
12		-	11	2	12	0	2
13	Ch. 1	-	-	-	5	0	0
14		-	-	-	-	-	-
Total:		155	155	12	149	6	12

Note: The chamber load also includes two PRM attendants and one Custodial Tender decompressing on oxygen along with the rescuees.

Scenario 1 is the Base Case for system design, testing and certification. One hundred and fifty-five ambulatory rescuees (AR) can be transported to the surface in 11 sorties and 6 chamber runs. The last sortie and chamber run carries only 15 rescuees.

Scenario 2 involves 155 ambulatory rescuees and a two-man DET team. Six DET teams are required at this depth. The first team is inserted on 1st sortie and removed on the 2th sortie, the second is inserted on the 3rd sortie and removed on the 4th, etc. because the high PO2 in the DISSUB allows a maximum exposure time of only 12 h. Twelve sorties and 6 chamber loads are required to execute this scenario. The last sortie transports only 11 rescuees and 2 DET members. The 6th chamber load carries 25 rescuees and 4 DET members.

Scenario 3 involves 149 ambulatory rescuees, 6 stretcher cases, and 6 two-man DET teams. Thirteen sorties and 7 chamber loads are required to execute this scenario. There is a 19.5 h delay in the launch of the 13th sortie. A DET member cannot be in the DISSUB during this interval because of the excessive oxygen exposure. The 13th sortie and the last chamber load transports only 5 rescuees. The need for a 13th sortie is eliminated if there are only 144 rather than 149 ambulatory rescuees.

Q-5. Repetitive Exposure of PRM Attendants and SDC Tenders

Q-5.1. Terminal Tenders

At the 120 fsw depth, only terminal tenders are allowed to perform repetitive dives. All others will have a long exposure to hyperbaric oxygen that precludes repetitive diving.

Terminal tenders lock into the SDC at 45 fsw and then ride to the surface with the rescuees while breathing air. Upon surfacing the repetitive group designator is H by the Dive Planner. Table 9-8 of the Diving Manual indicates that Group H has a clean time of 8h 52min (532 min). The Dive Planner shows a clean time of 1107 min for all tissues. With a sortie time of 6 hours and a 19.45 hour delay between Sorties 4 and 5, the surface interval available between Chamber Run 1 and Chamber Run 3 will be sufficiently long than a second dive will have no greater risk that the first dive. The risk of both dives is 3.076% by the NMRI probabilistic model and 2.824% by the BVM(3) probabilistic model. A dive with a predicted risk of less than 3% is considered low risk.

Therefore, for 6 hour sorties:

TT from the 1st chamber run can repeat their dive on the 3rd and 5th chamber run.
TT from the 2nd chamber run can repeat their dive on the 4th and 6th chamber run.

Two terminal tenders are required for each chamber run. With repetitive diving as outlined above, the whole evolution requires a total of 4 terminal tenders.

Q-5.2. Manpower Requirements

The requirement for PRM attendants and SDC tenders for the whole evolution using the repetitive dive schedules outlined above (6 chamber runs) is:

PRM Attendants	12
Transfer Tenders	0
Custodial Tenders	6
Pre-Breathe Tenders	0
Terminal Tenders	4
Total	22

Table Q-3. 132 FSW Air / Oxygen Decompression Table with Air Breaks Included

Depth (fsw)	Time (min)	Gas	Elapsed Time (hr:min)	Oxygen Stop Time
132				
Travel 5 FPM to 85	9.4	Air	:10	10 Rounded up to nearest minute
85 Transfer to SDC	30	Air	:40	
85	275	Air	5:15	305 Air
Travel 1 FPM to 80	5	Air	5:20	
80	110	Air	7:10	115 Air
Travel 1 FPM to 75	5	Air	7:15	
75	120	Air	9:15	125 Air
Travel 1 FPM to 70	5	Air	9:20	
70	125	Air	11:25	130 Air
Travel 1 FPM to 65	5	Air	11:30	
65	130	Air	13:40	135 Air
Travel 1 FPM to 60	5	Air	13:45	
60	140	Air	16:05	145 Air
Travel 1 FPM to 55	5	Air	16:10	
55	145	Air	18:35	150 Air
Travel 1 FPM to 50	5	Air	18:40	
50	155	Air	21:15	160 Air
Travel 1 FPM to 45	5	Air	21:20	
45	60	O2	22:20	60 O2
Travel 1 FPM to 40	5	Air	22:25	
40	10	Air	22:35	
40	60	O2	23:35	
40	15	Air	23:50	
40	5	O2	23:55	65 O2
Travel 1FPM to 35	5	O2	24:00	
35	50	O2	24:50	
35	15	Air	25:05	
35	15	O2	25:20	70 O2
Travel 1 FPM to 30	5	O2	25:25	
30	40	O2	26:05	
30	15	Air	26:20	
30	30	O2	26:50	75 O2
Travel 1 FPM to 25	5	O2	26:55	
25	25	O2	27:20	
25	15	Air	27:35	
25	50	O2	28:25	80 O2
Travel 1FPM to 20	5	O2	28:30	
20	10	O2	28:40	
20	15	Air	28:55	
20	60	O2	29:55	
20	15	Air	30:10	
20	15	O2	30:25	90 O2
Travel 1 FPM to 15	5	O2	30:30	
15	40	O2	31:10	
15	15	Air	31:25	
15	55	O2	32:20	100 O2
Travel 1FPM to 10	5	O2	32:25	
10	15	Air	32:40	
10	60	O2	33:40	
10	15	Air	33:55	
10	60	O2	34:55	
10	15	Air	35:10	
10	55	O2	36:05	180 O2
Travel 1 FPM to surface	10	Air	36:15	

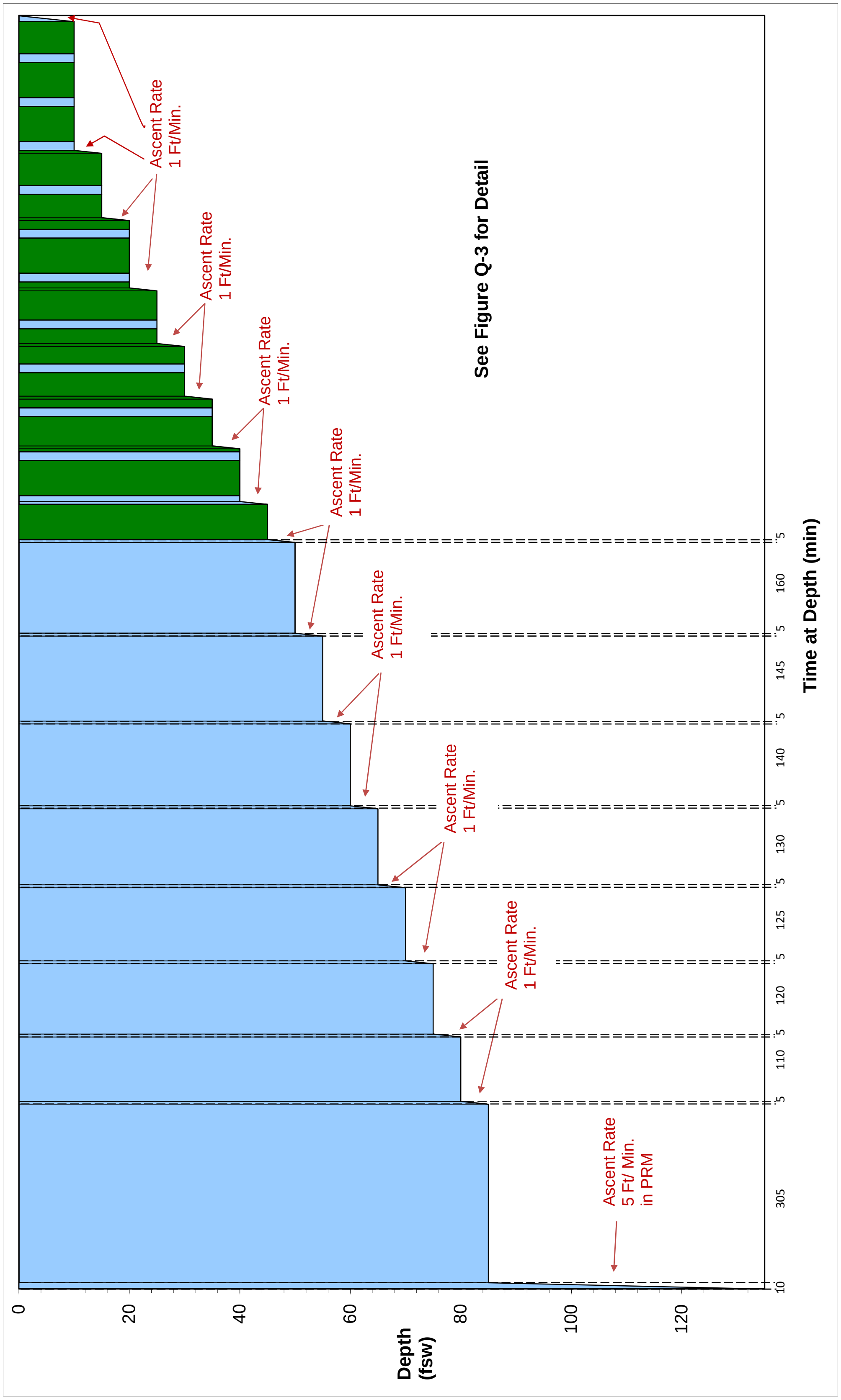


Figure Q-2. 132 FSW Air/Oxygen Saturation Decompression Table

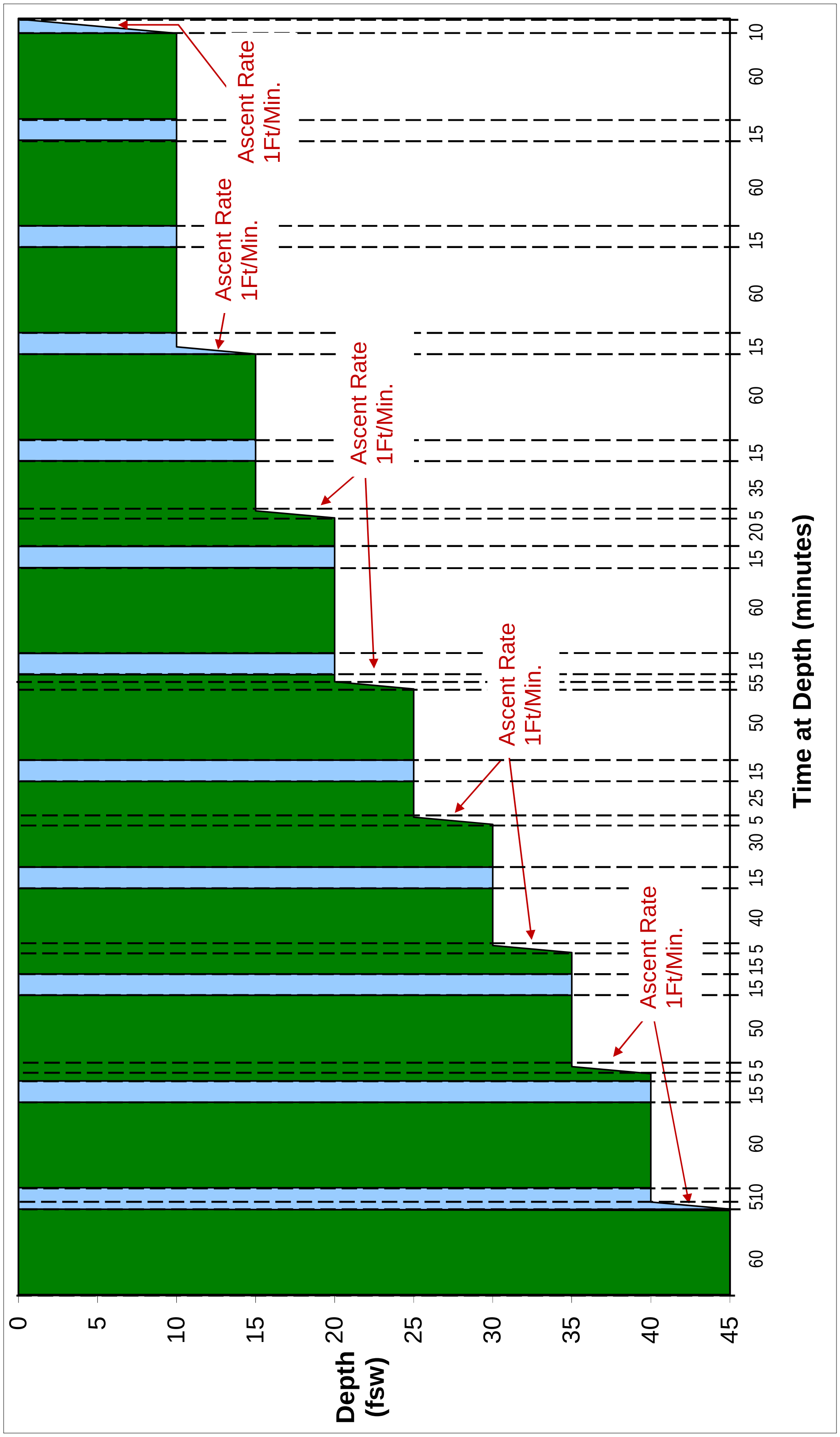


Figure Q-3. 132 FSW Submarine Rescue Oxygen Decompression Table (SDC Oxygen Breathing Only)

Ref: NAVSEAINST 4160.3 NAVSEA S0005-AA-PRO-010/TMMP

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