NATIONAL UNDERSEA RESEARCH PROGRAM Technical Report 88-1B

REPEX Habitat Diving Procedures: Repetitive Vertical Excursions, Oxygen Limits, and Surfacing Techniques

R.W. Hamilton, D.J. Kenyon,
and R.E. Peterson

May 1988

U.S. DEPARTMENT OF COMMERCE
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U.S. DEPARTMENT OF COMMERCE
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National Oceanic and Atmospheric Administration
William E. Evans, Under Secretary

Oceanic and Atmospheric Research
Joseph O. Fletcher, Assistant Administrator

Office of Undersea Research
David B. Duane, Director

FOREWORD

The National Oceanic and Atmospheric Administration (NOAA) has the largest diving complement of any civilian Federal agency. Under the aegis of NOAA's Undersea Research Program (NURP), the agency also directly assists a large cadre of marine research scientists to conduct their scientific activities under the sea. This research is accomplished using manned submersibles, remotely operated vehicles, and compressed-air scuba, mixed-gas, and saturation mode diving. Additionally, the NURP assists all divers of the nation through research undertaken in accordance with the terms of Sec. 21(e) of the Outer Continental Shelf Lands Act of 1978 (PL 95-372; 43 USC 1331 et seq.). This statute requires NOAA, under authority delegated by the Secretary of Commerce, to "...conduct studies of underwater diving techniques and equipment suitable for protection of human safety and improvement of diver performance. Such studies shall include, but need not be limited to, decompression and excursion table development and improvements and all aspects of diver physiological restraints and protective gear for exposure to hostile environments."

The Technical Report series published by the NURP is intended to provide the marine community with the results of NURP-sponsored research sooner than is normally possible through professional society journals and to do so in greater detail by presenting all of the relevant data developed in the course of the research. Results reported in NURP's Technical Report series may be preliminary or require further development, refinement, or validation, and this additional research may be beyond the scope or mission of NURP. Results of research or development are reported quickly through the Technical Report series to enhance the awareness of members of the marine science and engineering community. Accordingly, the reports in this series do not carry any endorsement or approbation on the part of the NURP, nor can the NURP accept any liability for damage resulting from incorrect or incomplete information.

A research project designed to improve diver performance and safety was recently completed for the NURP by scientists from Hamilton Research, Ltd., of Tarrytown, New York. In that research, the investigators "...focused on decompression aspects of habitat operations, especially excursions, and on breathing mixtures based on nitrogen as the inert gas." A consequence of this research was the development of an improved diving technology, the REPEX tables, for decompression using NITROX gas mixtures in saturation habitat operations. This technology includes both a computational concept (or model) and explicit operating procedures (decompression tables). REPEX has had, in the words of its developers, "modest" validation in hyperbaric chamber tests.

REPEX: Development of Repetitive Excursions, Surfacing Techniques, and Oxygen Procedures for Habitat Diving, a report prepared by R. W. Hamilton, D. J. Kenyon, R. E. Peterson, G. J. Butler, and D. M. Beers and submitted to NURP under the terms of

Contract NA-84-DGC-00152, with Hamilton Research, Ltd., is herein reprinted in its entirety. It is presented in two volumes: REPEX: Development of Repetitive Excursions, Surfacing Techniques, and Oxygen Procedures for Habitat Diving, NURP TR 88-1A; and REPEX Habitat Diving Procedures: Repetitive Vertical Excursions, Oxygen Limits, and Surfacing Techniques, NURP TR 88-1B.

Comments on the report are welcome. They should be directed to:

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Rockville, MD 20852

Rockville, Maryland
May 1988

David B. Duane
Director

PREFACE, Volume 1B

The procedures described in this document have been prepared by Hamilton Research, Ltd., for the NOAA Office of Undersea Research, U.S. Department of Commerce, under Contract NA-84-DGC-00152. Please note that this is not intended as a procedures manual for field use, but rather as a report to NOAA of procedures developed under the contract.

The excursion tables were calculated with Hamilton Research's Decompression Computation and Analysis Program (DCAP), using the Haldane-Workman-Schreiner computational model designated Tonawanda II. Ascent limiting M values for the excursions were conservatively derived from those used for the original NOAA OPS tables published in the first and second editions of the NOAA Diving Manual. The new procedures for decompression from saturation are based on extensive commercial, laboratory, and scientific experience using M values and Peterson's "Delta-P time" factor for determining ascent limits. New oxygen procedures are based on an analysis of relevant commercial and laboratory experience, some of it quite recent.

All procedures have been worked out in close collaboration with NOAA's Office of Undersea Research and with the cognizance of NOAA's Diving Office. However, the procedures have not been subjected to review by NOAA, so this manual should be regarded as a Contract Report submitted to the Office of Undersea Research and nothing more. The procedures are intended to serve as physiological limits, not specifically as diving rules or regulations; those are the responsibility of the agency using the procedures.

Many of the procedures in this report have been submitted to limited operational evaluation under controlled conditions in a dry pressure chamber with satisfactory results. **No amount of testing can completely rule out the possibility of decompression sickness or accidents.** Therefore, until field experience in their use has accumulated, the decompression procedures should be implemented by trained diving teams who know and understand them and the principles involved, who have competent supervision, and who are working under conditions that allow for prompt and adequate treatment of decompression sickness and/or embolism should they occur in any part of the operation. Accurate records of diving activities should be kept, including as a minimum the time, depth, and breathing gas profile for each diver, and any symptoms or unusual events.

A companion report by NOAA[1] provides background information with

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[1] Hamilton RW, Kenyon DJ, Peterson RE, Butler GJ, Beers DM. Repex: Development of repetitive excursions, surfacing techniques, and oxygen procedures for habitat diving. Technical Report 88-1A. Rockville, MD: NOAA Office of Undersea Research, May 1988.

references about the diving methods, covers details of how the procedures were developed, and describes the operational validation program that was carried out.

These procedures have been prepared using the best available techniques and information. However, because we have no control over their use, Hamilton Research, Ltd., disclaims responsibility for the results of any use of these procedures in any way. While we can bear no responsibility, we are nevertheless extremely interested in hearing about all experiences with the procedures, whether good or bad, and we expect all users to share this information with us.

The programming and production assistance of Frank R. Lofaro and David M. Beers is gratefully acknowledged. We are also indebted to Dr. Andrew A. Pilmanis and the staff of Catalina Marine Science Center, Dr. William Schane of NOAA's Carribean Laboratory, St. Croix, U.S.V.I., Dr. Morgan Wells of NOAA's Diving Office, and of course the staff of the Office of Undersea Research for operational guidance and many helpful suggestions. Dr. Walter Sterk has supplied us promptly with new data on oxygen toxicity as fast as it was obtained. We greatly appreciate the counsel of Dr. C.J. Lambertsen in preparing the treatment procedures. As consultants Dr. James W. Miller provided a strong historical review of habitat diving, and Ronald Y. Nishi assisted us in drawing on key data from CANDID, the diving data base at DCIEM, Toronto; his colleagues Brian Eatock and Peter Tikuisis shared a penetrating insight into bubble physics. Many helpful suggestions came from the divers and topside crew at IUC's North American Hyperbaric Center during the validation program directed and managed by Glenn J. Butler.

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The contract report to NURP which has been incorporated into this report is:

Hamilton RW, Kenyon DJ, Peterson RE. Repex habitat diving procedures: Repetitive vertical excursions, oxygen limits, and surfacing techniques. Procedures report to Office of Undersea Research, NOAA, U.S. Dept. of Commerce, under contract NA-84-DGC-00152. Tarrytown, NY: Hamilton Research Ltd.

Hamilton Research, Ltd.

STATEMENT OF RISK

It is well established that a risk of **decompression sickness** and/or **embolism** exists under any but the very slightest exposures of humans to excess pressure, such as occurs in diving, when such exposure is followed by a subsequent pressure reduction. No decompression procedures of any sort, no matter what their theoretical basis or degree of validation testing, can guarantee that these conditions will not occur. The only way to avoid this risk completely is to avoid exposure to pressure.

These decompression procedures were formulated with the best available techniques and experience, but the authors or Hamilton Research, Ltd. cannot be responsible for any direct or consequential damage that may result from their use.

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I.
ABSTRACT

Hamilton RW, Kenyon DJ, Peterson RE. Repex habitat diving procedures: Repetitive vertical excursions, oxygen limits, and surfacing techniques. Technical Report 88-1B. Rockville, MD: NOAA Office of Undersea Research, May 1988.

These procedures--designated "Repex"--are designed for divers, diver-scientists particularly, working out of seafloor habitats. They cover habitat depths from 30 to 120 fsw (feet of sea water), with the habitat filled with a nitrogen-oxygen mixture (nitrox) at a PO_2 of 0.3 to 0.35 atm. The established "NOAA OPS" procedures for performing descending excursions with divers breathing air have been improved. Longer times and repetitive excursions are allowed, but some specific excursions are shorter. Excursions cover the range 65 to 240 fsw, but with only short excursions deeper than 200 fsw. Repetitive dive intervals range between 1/2 and 16 hours; a new sequence starts after 16 hours. The number of the repetitive dive in a sequence and the interval since the last dive determine the repetitive excursion time. Provision is also made to adjust for an excursion following one that uses less than its maximum allowable time. "One-stop" dives with a primary decompression stop 15 ± 5 fsw deeper than the habitat provide for longer excursion times; these require a 2-min preliminary stop. A new approach is taken toward oxygen exposure limits. Prevailing USN/NOAA rules to prevent CNS toxicity are used deeper than 200 fsw; shallower than this the limits are based on pulmonary and chronic O_2 toxicity. These allow a daily dose (using the CPTD method of counting the dose) that varies with overall mission duration, and they are just as safe and much less restrictive than earlier rules. Procedures for ascent from saturation require slower ascent rates for deeper dives, and may start at a depth deeper than storage to account for excursions in the last 36 hours. A representative decompression time--after excursions--from saturation at 80 fsw is just over 51 hours. Several plans for surfacing are given, for the different types of equipment that might be used, and for emergencies. Procedures provided for treatment of decompression sickness in habitat diving are based on accepted practices and consider the operational limitations. [Procedures report to Office of Undersea Research, NOAA, U.S. Dept. of Commerce, under contract NA-84-DGC-00152. Tarrytown, NY: Hamilton Research Ltd., 30 Sep 1987.]

SATURATION DIVING / DECOMPRESSION / EXCURSION DIVING / HABITAT DIVING / NITROGEN / REPETITIVE DIVING / THERAPY / OXYGEN TOXICITY / OXYGEN EXPOSURE LIMITS / AIR / CPTD / DECOMPRESSION TABLES

II.
INTRODUCTION

The first and second editions of the NOAA Diving Manual contain procedures for nitrox saturation-excursion diving. These originated with a program involving analysis of past experience and laboratory validation, sometimes called "NOAA OPS," for "NOAA OPerationS." The NOAA OPS procedures have been used extensively in the field, in NOAA operations, in commercial diving, and in laboratories worldwide. Those procedures have two important limitations to their use in scientific diving--they do not allow for efficient repetitive excursions, and they do not provide realistic limitations in dealing with possible oxygen toxicity. Also needed are longer allowable excursion times, defined methods of surfacing, and procedures for treatment of DCS (decompression sickness).

The present procedures--designated "Repex," for REPetitive EXcursions--are intended to eliminate these operational restrictions. They have the objectives of providing a means of performing repetitive no-stop excursions, allowing longer excursions by means of stops, improving the methods of dealing with oxygen exposure, and offering new saturation decompression and other ascent techniques. Provision is made for reducing the repetitive penalty after excursions shorter than their allowable time. Also included are procedures for treatment of decompression sickness in habitat diving.

These procedures address most specifically the needs of the scientific diver, who is likely to live in a seafloor habitat and excurse to one or more work sites several times each day. This is in contrast to the commercial diver who generally will put in the full day's work at a single site on a single excursion, and will probably "commute" to the worksite in a closed diving bell from his (or her, always implied if not stated) pressurized living chamber located at the surface. Another difference is that the commuter type operation allows the storage depth in the living chamber to be placed at an even depth increment, while the depth of a seafloor habitat will generally be fixed by the terrain. The Repex procedures should be entirely acceptable for use in the commercial type situation, but they are optimized for scientific diving.

The following chapter tells what the new tables and procedures are like and what capabilities they provide, and describes their limits and format. The next three chapters tell how to perform excursions, methods for returning to the surface, and how to treat decompression sickness should it occur. A summary of the procedures, some reference charts, and the tables comprise the final chapters.

Details of how these procedures were developed and validated are covered in the companion report cited in the preface.

III.
DESCRIPTION AND SCOPE

This manual provides a new set of general procedures for managing decompression in nitrox saturation-excursion diving, identified by the name "Repex". Decompression tables are provided for ascending and descending excursions, and for saturation decompression; the tables allow for repetitive excursions. Air is the breathing gas on all excursions. Procedures are also given for handling oxygen exposure, treating of decompression sickness, and for different methods of bringing divers to the surface. This chapter describes the material presented.

A. Description of the tables and procedures

1. Tables for no-stop excursions and repetitive excursions

Established decompression tables for divers to perform vertical excursions while breathing air from a saturated condition in a habitat containing a nitrox mixture are included in the NOAA Diving Manual. These new procedures use the same general techniques, but allow for longer excursions, 480 minutes instead of the older maximum of 360 minutes, and over most of their range are slightly more conservative. However, by allowing for repetitive excursions, longer excursions with stops, and better oxygen management, the overall capabilities are greatly expanded.

Like the earlier "NOAA OPS" procedures, these give specific depth/time combinations for the various excursions that can be made from a given storage depth. They allow for storage depths that fall between the usual 5 or 10 fsw increments. Each "no-stop" table includes times for descending excursions--the maximum time allowed at each excursion depth for a return to habitat depth without decompression stops--and a set of allowable times for repetitive excursions. The repetitive excursions are also "no-stop," but the time allowed may be shorter if required by the effect of the previous excursion. For these procedures a repetitive excursion is one performed within 16 hours of the end of the preceding excursion.

The factors having the greatest effect on the next dive in a sequence of several repetitive dives are the **number** the dive is in the sequence, and the time **interval** between the dives. These are used in determining the "penalty" or reduction of allowable excursion time for the second and subsequent dives in a series.

Accordingly, the choice of the allowable time for a repetitive no-stop excursion is based on the number a repetitive dive is in its sequence (first, second, third, etc.), and the duration of the diver's interval in the habitat between dives in a repetitive sequence (this is equivalent to the "surface interval" in conventional diving). There are three categories of "number," the first, the second, and all dives after the second (called "3+" in the tables). Intervals are broken down between 1/2 and 16 hours.

2. Procedures for Submaximal excursions

For no-stop dives a method is described for determining a reduced repetitive "penalty" if the preceding dive is less than the maximum time allowed. This is basically an interpolation, whereby the effect of the unused portion of the allowable time of the first dive is deducted from the penalty (shortening) of the next dive.

While the concept is straightforward, the calculation involves several interactive steps with several opportunities for error. Our description of the calculation involves the use of several cumbersome terms invented for the purpose. A worksheet is provided in the appendix for performing this calculation, or it can be done using a commercial spreadsheet program. Even so, the only really satisfactory method for optimizing repetitive excursion diving is to do on-line, real-time calculations specific for the dive being conducted.

3. One-stop excursions

An additional set of tables provides for a moderate extension of excursion time--two to three times as much--by the use of a set of "one-stop" procedures. These procedures provide for a primary decompression stop lasting for up to about one hour at a depth nominally 15 fsw deeper than the habitat (15±5 fsw, or anywhere in the range 10 to 20 fsw). This stop can be carried out in a "way station" or using an air supply provided specifically for decompression. An earlier, preliminary 2-minute inwater stop 10 fsw deeper than the primary stop is also required on all "one-stop" excursions.

The one-stop tables are a series of excursion bottom times useable in specified depth ranges. Each bottom time is matched with a single stop time; the time for the stop is to be spent at the selected location about 15 fsw deeper than the habitat. The 2-minute preliminary stop is not shown in the tables because it is the same for all one-stop dives.

Limited provision is made for doing repetitive one-stop excursions. They may be mixed in with normal no-stop excursions, but the one-stop has to be either the first excursion in a sequence (that is, it follows a 16-hour interval) or must follow its preceding dive by 2 hours or more. "Submaximal" procedures are not available for one-stop dives.

4. Ascending excursions

This project did not include new procedures for "ascending" (upward) excursions to depths shallower than the habitat depth. Additional testing has confirmed that the original NOAA OPS procedures are appropriate, and these are included here for completeness. The times allowed for ascending excursions are given for each habitat depth. These are the same times as those in the NOAA manual. They are presented in a chart for each storage depth range. The chart shows the actual depth ranges that can be used for

excursions with the excursion time allowable for a dive to each depth range. Differential excursion distances are not included, in order to avoid possible confusion and because the diver's reference is to absolute depth.

Descending excursions are considered by these procedures to be unaffected by a preceding ascending excursion, but a 24-hour interval is required after a descending excursion before making an upward excursion. An ascending excursion can follow another ascending excursion after 4 hours. Because of these limitations it will be most effective to place the storage depth at the highest point in the depth range to be dived.

5. **Oxygen management**

Saturation-excursion techniques make it possible for divers--breathing air--to spend so much time at great enough depths that the exposure to oxygen in the air being breathed has to be taken into account. Two general categories of oxygen toxicity are considered. The more serious in a diving situation is the acute CNS (Central Nervous System) toxicity which can result in a convulsion. There is also a more slowly developing syndrome currently referred to as "pulmonary" oxygen toxicity but which can also affect the whole person in a variety of ways.

Pulmonary toxicity develops gradually, and its effects are reversible. There is considerable variation in susceptibility between individuals. Symptoms of pulmonary oxygen toxicity are tracheal irritation, chest pain or discomfort, coughing, inability to take a deep breath without pain or coughing, and development of fluid in the lungs. In addition to these, some other slowly developing non-pulmonary symptoms may be noted after a number of days of exposure at marginally toxic levels. Some such symptoms are headache, paresthesia, numb fingertips, and excessive fatigue unrelated to exercise. This is now being referred to as the "chronic oxygen toxicity syndrome." Also, after many days of exposure to increased oxygen a reduction of hemoglobin and red blood cells and reduction of aerobic capacity has been noted in some divers (this is a normal adaptive response).

These procedures provide guidelines for protecting the divers from oxygen toxicity while allowing maximum utilization of the possible excursion times. Some previous habitat operations have been restricted by oxygen limits that were developed for other purposes and are neither appropriate nor efficient for saturation-excursion diving. The prime example is the set of limits used by the U.S. Navy for deep, mixed-gas diving; these are the ones included in the NOAA Diving Manual.

The new approach taken here recognizes the inefficiency of the prevailing limits and offers new limits based on physiological principles and relevant laboratory and field data. The essence of the approach is to observe only pulmonary/chronic toxicity limits in the exposure range of less than 1.5 atm PO_2, (depths from the surface to about 200 fsw when breathing air), and to use CNS limits when deeper. Oxygen convulsions (acute CNS toxicity) with air as the breathing gas are extremely rare shallower than this level, but pulmonary/chronic oxygen toxicity could develop from an

excessive exposure to the oxygen in air. Deeper than 200 fsw, or at a PO_2 above 1.5 atm, these procedures incorporate the traditional and quite appropriate US Navy limits that are designed to avoid acute CNS toxicity.

This technique for preventing pulmonary/chronic oxygen toxicity is to keep account of each diver's exposure to elevated oxygen, and not to allow this to exceed a given "dose." The method of accounting for oxygen exposure uses the established "CPTU" (Cumulative Pulmonary Toxicity Unit) to accumulate the Dose (CPTD) over a time interval. One unit (CPTU) is defined as being equivalent to an exposure to one atmosphere of oxygen for one minute; the pulmonary effects of exposure at other than 1.0 atm PO_2 are determined from an experimentally derived equation.

The method used here for managing the slowly-developing "pulmonary/chronic" oxygen toxicity is to set daily exposure limits based on the total oxygen dose and the time period over which it happens. These are presented as allowable daily doses for various mission durations (number of days of exposure). The tolerable daily dose has to be reduced as the exposure duration is increased. Tables giving the rate of accumulation of CPTU's and the doses allowed for various mission durations are provided in the reference section (section VII.B, Tables VII-3 and VII-4).

Acute CNS oxygen toxicity is avoided by severely restricting the time allowed when working at depths where its occurrence is at all likely. Breathing air, this limit is considered to be deeper than 200 fsw. In that area the classical USN limits are used, interpreted so as to allow a maximum exposure of 29 minutes at 220 fsw and 16 minutes at 240 fsw. Shallower than 200 fsw (<e.g., 1.5 atm PO_2), only the pulmonary and general toxicity limits need be considered. The likelihood of either type of oxygen toxicity is reduced by maintaining the "storage" oxygen level in the habitat in the relatively low range of 0.3 to 0.35 atm in saturations where either of the oxygen exposure limits might be approached.

6. **The "Oxygen Window" unrestricted excursion range**

When a diver saturated at the relatively low oxygen range of 0.3-0.35 atm PO_2 switches to air breathing, the nitrogen partial pressure (PN_2) in the inspired gas will be reduced (because of the higher oxygen fraction in air). It is possible for the diver to descend until the inspired PN_2 is equal to the storage depth PN_2 level without incurring any additional inert gas uptake. As a result, since there is no additional inert gas uptake, the diver can freely move over this depth range without time limit, and without affecting subsequent excursions. This is referred to as the "oxygen window" range. Oxygen window ranges exist for each available storage depth; the allowable unrestricted excursion range is deeper from deeper storage depths.

An oxygen window range is given in the procedures for each storage depth. The oxygen window applies to descending excursions only; ascents are controlled by the ascending excursion procedures. If the habitat gas is air the same oxygen window prevails. In this range, inert gas would not exceed what is presumed to be present.

7. Saturation decompression

Every saturation-excursion mission must someday come to an end, and this means decompression from saturation will be necessary. Decompression from nitrox saturation is slow and difficult; nitrogen is highly soluble and unloads very slowly. These procedures include a general set of nitrox saturation decompression profiles to supplement those in the current NOAA manual. The profiles are specifically designed to cover all the saturation depths used, and they take excursions into account. They are based on extensive and up to date experience from NOAA, laboratories, and commercial activities worldwide. In particular the new saturation decompression procedures take into account the empirical observation that slower ascent rates are necessary for ascent from the deeper depths, and that a substantial adjustment in the ascent profile is necessary to deal with excursions. The Repex procedures do not require breathing oxygen by mask.

A separate saturation decompression profile is provided for each storage depth, and is included with the other tables for that storage depth. These tables are designed for staging at 5 fsw intervals, but can be used with linear ascent or the "continuous bleed" technique if that is desired. For this purpose ascent rates for each 5 fsw staging interval are given in the tables. These are given in units of minutes per fsw; because these are inverse or reciprocal rates they are designated "rrates."

An additional more conservative ascent procedure is provided for divers who have been excursing deeper than the oxygen window range. Saturation decompression of these divers begins at a **"starting depth"** deeper than the habitat. Divers on the last excursion return briefly to the habitat and the habitat is then pressurized to the starting depth and a **"precursory"** ascent back to the starting depth is begun. The intent is to prevent or reduce bubble formation resulting from the last excursions; this is a more definitive approach than just waiting in the habitat for many hours. The starting depth for the precursory ascent is a function of the storage depth and the deepest downward excursion performed during the last 36 hours. An alternative and in fact preferred method, if it can be done, is to start the precursory ascent while returning from the last excursion of the mission.

Air is used as the breathing gas on all saturation decompressions. From the deeper depths air all the way would mean too much oxygen exposure, so in those cases a "break" at a PO_2 of 0.5 atm is provided for a period of 4 stops, a few hours after beginning ascent.

8. Diving Limits

The Repex procedures impose certain broad limits on a diving operation, primarily to protect against unusual combinations of activities and conditions that may not have been taken into account. A diver is allowed no more than 12 hours in the water deeper than the oxygen window during each 24-hour period. (The "oxygen window," mentioned earlier, is the range through which a diver can excurse without increasing his or her inert gas

loading). A diver is allowed up to 14 excursions in a repetitive sequence, or 4 of the one-stop type. A new repetitive sequence starts after a 16-hour interval in the habitat, and there are other limits applicable to the sequence of excursions.

Because of the possibility of both acute CNS **oxygen toxicity** and operationally significant **nitrogen narcosis**, air excursions in the range deeper than 200 fsw are sharply curtailed. Only excursions of 29 minutes at 220 fsw and 16 minutes at 240 fsw are allowed. Because of the possibility of chronic oxygen toxicity, limits for the total diving exposure of each diver are recommended for different mission durations. These are based on the cumulative pulmonary toxicity dose over various exposure periods.

9. **Format**

The technique for performing vertical excursions from an undersea habitat is not changed, but the presentation of these tables is new. Most information needed for conducting saturation-excursion operations from a given storage depth is displayed on a set of two pages specific to a range of storage depths. Reference materials needed for oxygen management are included, as well as the tables for conducting ascending, oxygen window, no-stop, and one-stop repetitive descending excursions, plus the saturation decompression profile from each storage depth range.

Each pair of pages covers a 5-fsw range of storage depths, and the functions on those pages apply to any storage depth in that range.

B. Summary scope of the tables and procedures

Habitat atmosphere: Nitrox, PO_2 0.30 to 0.35 atm, balance nitrogen
Excursion breathing gas: Air, 20.5 to 22.0 % oxygen, balance nitrogen

1. **Saturation storage depths**

- Range of habitat depths: 30 to 120 fsw, every 5 fsw
- Storage (or habitat) depths given in 5-fsw ranges, e.g. 60-64 fsw inclusive, or more precisely 60.0 to 64.9 fsw. (The deepest range is 115-120 fsw)

2. **Ascending excursions**

- Times allowed: 5 min to "unlimited" (not over 12 hours)
- Range for unlimited duration ascent distances: 15 to 25 fsw shallower than habitat (range is longer at deeper storage depths)

- Range of time-limited ascent distances: 20 to 60 fsw from storage
- Ascending excursions follow descending excursions by 24 hours, and can be made 4 hours following another ascending excursion

3. **Oxygen window unrestricted excursion range**

- Range of oxygen window descent distances (differential depths) deeper than habitat, 4 to 27 fsw (range is longer at deeper storage depths)
- No time limits except contribution to daily CPTD (see Table VII-3)

4. **No-stop repetitive excursions**

- Accessible depth range: 65 to 240 fsw (every 5 fsw to 160, then every 10 fsw to 200, plus 220 and 240 fsw; see Table VII-1)
- Allowable bottom times, 5 to 480 min, depending on depths involved; (29 and 16 min at 220 and 240 fsw respectively)
- Repetitive excursions in a sequence: 1st, 2nd, 3+ (3+ is for 3rd or any subsequent excursion)
- Repetitive intervals: >16 hr
  8 - 16 hr
  4 - 8 hr
  2 - 4 hr
  1 - 2 hr
  1/2 - 1 hr
- Maximum number of excursions in any repetitive sequence: 14
- Excursions following another excursion that is submaximal can be adjusted with a formula to compensate for unused allowable time

5. **One-stop excursions**

- Accessible range: 80 to 240 fsw (See Table VII-2)
- Allowable bottom times: 10, 20, 30, 45, 60, 90, 120, 150, 180, 210, 240 min (29 and 16 min maximum at 220 and 240 fsw)
- Two repetitive intervals: >16 hr and 2-16 hr
- Stop depth normally 15 fsw deeper than habitat, range 10-20 fsw
- Preliminary 2-minute stop 10 fsw deeper required on all "one-stop" excursions

- Maximum number of one-stop excursions in any repetitive sequence: 4
- One-stop and no-stop excursions may be mixed in the same sequence (in this case 1 one-stop counts as 3 no-stops in figuring the total of 14)
- No submaximal procedures for one-stop excursions

6. **Surfacing techniques from seafloor habitats**

- Decompression in habitat with swim-up (the Hydro-Lab pattern): Maximum operational habitat depth 50 fsw; requires proper habitat design
- Ascent in bell: Required if habitat is deeper than 50 fsw and cannot be surfaced under pressure; depends on equipment
- Surfacing the pressurized habitat and decompressing it to surface: Depends on equipment capability
- Emergency surfacing procedures are available for situations outside these limits, with varying degrees of estimated risk

7. **Saturation decompression**

- General plan: Divers who have not exceeded the oxygen window depth in last 36 hr begin decompression from storage depth. Divers who have done any descending excursions outside the oxygen window in the last 36 hours use a precursory table before starting saturation ascent.
- Ascent rates: Variable, specific to the starting depth; ascent profiles use slower rates for decompression from deeper storage depths. Tables show 5 fsw stops but one-fsw stops can be used, or "continuous bleed". Range of stop times 100 to 450 min per 5 fsw, or 20 to 90 min/fsw (these are reciprocal rates, or "RRates").
- Ascent following excursions:
  - + A special "precursory" ascent profile is used for first part of saturation ascent, from starting depth to storage depth.
  - + Each storage depth has a "starting depth" based on the deepest excursion in the last 36 hours. Divers recompress so as to begin the first precursory decompression stop at the starting depth, or pick it up by stopping at that depth while returning from the last excursion.
  - + Standard ascent procedures for that storage depth are used thereafter.

- Breathing gas is air, with a defined break at 0.5 atm PO_2 during saturation decompressions from 105 fsw and deeper

- Total times for saturation decompression are given on each table and in a summary list in Table VII-5. The time for 30 fsw is 36 hr and the time for 120 is 101 hr, when deep excursions have been made.

8. **Oxygen exposure limits**

Breathing gas on all excursions is air (20.5 - 22.0% O_2 in N_2)

- Pulmonary/chronic oxygen toxicity limits: Surface to 200 fsw
  - + Limits based on CPTD (CPTU/day)
  - + Daily limits are a function of mission duration (Table VII-4):

Exposure (mission) duration, (inc dec)	Avg daily dose	Total this mission
1	850	850
2	700	1400
3	620	1860
4	525	2100
5	460	2300
6	420	2520
7	380	2660
8	350	2800
9	330	2970
10	310	3100
11	300	3300
12	300	3600
13	300	3900
14	300	4200
15-30	300	n/a

- CNS limits, beyond 200 fsw:
  - + Based on USN/NOAA prevailing rules:
  - + Time in range 200-220 fsw, 29 min max
  - + Time at range 220-240 fsw, 16 min max

IV.
USING THE TABLES

This chapter describes the format of the tables and procedures, and gives instructions on how to use them.

These decompression tables and procedures are organized so that all the information specific to a single 5-fsw range of storage or habitat depths is included in a set of two pages. The set of pages for each range of storage depths comprises six sections; the first page contains reference information on **breathing atmospheres and oxygen**, and tables for **ascending excursions**, **oxygen window excursions**, and **no-stop excursions**; the second page contains **one-stop excursions** and **saturation decompression** from that range of storage depths. These 36 table pages are in section VII.D, and have page numbers T-1 through T-36.

Terms like "allowed" and "permissible" refer to **physiologically acceptable actions** within the ranges of these procedures; they do not constitute **rules** or **operating procedures** unless so designated by the responsible authority.

To help in planning, Table VII-6 converts between **hours and minutes** and running **minutes**.

A. General instructions

1. **Maximum daily dive time**

The **maximum time** during any 24-hour period that a diver is allowed to excurse beyond the "oxygen window" limit is **12 hours** (the oxygen window is discussed in III.A.6 and IV.D).

2. **Compression procedure**

Compression or descent to working depth can be at **any convenient rate.** Excursions can begin as soon as divers are operationally ready.

To get the prescribed **range of oxygen** the chamber can be **compressed with air** to between 14 and 22 fsw, with the balance of the compression (to any depth) with pure nitrogen. Mix well. Take **precautions** when using inert gases not containing sufficient oxygen to support normal respiration!

3. **Changing habitat depth**

If the operation is being conducted out of a living chamber on the surface or a mobile habitat, it may be necessary or desirable to **change** the storage depth.

To change a crew of saturated divers to a **deeper** depth pressurize (with nitrogen) to the desired new depth at a convenient rate, maintaining proper oxygen. Both descending and ascending excursions may begin immediately. Resume normal procedures at the new storage depth.

A change to a **shallower** storage depth that is within the range for unlimited duration ascending excursions may be made in a single step at a rate no faster than 30 fsw/min. Wait at least 72 hours before making another such change.

For a **greater change** to a shallower depth or after a first one made within the unlimited ascent range as mentioned above, proceed as for a saturation decompression. Use the "main table" ascent rates for the original storage depth.

After a change to a shallower storage depth, temporarily use the previous storage depth as the basis for calculating excursions. Do it this way for the next **16** hours when performing **descending** excursions from the new depth, and for the next **48** hours when selecting allowable times for **ascending** excursions. Use the normal times thereafter.

4. **Background gas**

These procedures are based on the use of **nitrogen** as the background gas, and use with prominent fractions of any other inert gas is not recommended without further study.

5. **Units**

The primary pressure and depth unit of the entire set of tables is the foot of sea water, **fsw**, defined as 1/33 of a standard atmosphere, or 3.0705 kPa.

Note that if the conversion is made to metres of sea water, msw, the independently derived definition of a metre of sea water as 1/10 of a bar should be used. The relation between these units is **1 msw = 3.2568** fsw, which is not the same as the conversion between metres and feet when they are used as linear units.

Where practical, the values for feet of sea water, **fsw**, are in **boldface** type in the tables to help keep the depth values distinct from those for time.

B. Oxygen management

Oxygen management information is given in this section and on the first page of the pair covering each storage depth.

1. **Habitat oxygen levels**

During missions with extensive excursion diving the recommended **level for PO_2** in the habitat is **0.3 to 0.35 atm.** This rather low level for saturation storage is intended to keep the oxygen exposure of divers while they are in the habitat as low as practical.

Long-duration exposures to higher levels of up to **0.45 atm** are acceptable physiologically, and these levels have some operational and safety advantages if the mission does not require significant oxygen exposure during excursions. The effects of these higher storage levels on the **tolerance** of the divers to excess oxygen exposure on excursions is not certain, but tolerance is likely to be somewhat lower than when using the lower storage levels given here. The higher habitat oxygen levels should be used only if the daily oxygen exposure will be substantially less than the limits given here.

For saturations at habitat depths of **50 fsw or less** it is acceptable to use **air** as the habitat gas. In this case any CPTD accumulated during storage should be considered as part of the daily dose. Special **fire safety** precautions should be taken when using air.

The procedures make no provision for adjusting the excursion or saturation tables to account for the higher habitat oxygen level that would result from using air. Consequently, the oxygen window remains valid.

2. **The OXYGEN MANAGEMENT section for each storage depth**

As a convenience, the **pressure** of each storage depth is expressed in several **units.**

The recommended **oxygen composition** of the habitat gas is given in both partial pressure units (atmospheres or atm) and as percentages.

Next on the page are some representative **CPTD** accumulation rates for monitoring the oxygen exposure when excursing on air in the **oxygen window range** in the vicinity of the habitat. These can be helpful when the saturation storage depth is close to the worksite and descending excursions are not used.

3. Instructions for managing long-duration oxygen exposure

Oxygen exposure over a saturation-excursion mission is managed by **keeping track of** and if necessary **limiting** daily exposure to increased oxygen tensions. The allowable "dose" depends on the mission duration (actually the duration of the hyperoxic exposure). A higher average daily dose can be used for shorter missions of a few days duration, but as mission duration increases lower average daily doses are required. Table VII-4 shows the allowable doses.

The doses given are **average** doses over the mission. The average daily doses for shorter missions are much higher than those for longer missions, but this does **not** mean that a diver can start with those high values and then taper off later to the lower values; the **mission total** has to be used for determining the average over the **duration** of high PO_2.

The average dose is for the whole mission, and daily averages can exceed the average dose if neighboring days have lower totals. There is no rigid rule on how this averaging is to be done, but in general the oxygen dose should be acceptable when averaged over any period of 5 to 7 days.

During predive **planning** the oxygen exposure dose for each excursion is noted and these are totaled for each day, averaged if appropriate, and the dive plan checked against the chart. The diver or mission supervisor logs the CPTD each day as the mission proceeds and confirms that it is within the limits or makes necessary adjustments.

Cumulative pulmonary toxicity doses (CPTD) can be determined from the **oxygen management section** of the table pages and the chart of pulmonary toxicity doses breathing air, Table VII-3. The formula used for CPTD and other details on oxygen toxicity are given in the Underwater Handbook (Shilling, Werts, and Schandelmeier, 1976, pp 154-175).

Example: Can a diver stored at 64 fsw (PO_2 < 0.5) excurse to 90 fsw for 6 hours and spend 1 hour at the limit of the oxygen window range every day of a 7-day mission and still be within the limits? Each hour at 90 fsw involves 37 CPTU (from Table VII-3, or, because 90 fsw is within the storage depth range, from the 90-94 fsw table pages, p. T-25) for a daily total of 6*37=222 and each hour at the limit of the oxygen window from that storage depth (64 + 12 = 76 fsw, from the table page for 60-64 fsw) is 27 units, for a total of 249 per day. The diver is well under the limit of 380 units/day allowed for a 7-day mission (Table VII-4).

Pulmonary and "chronic" oxygen exposure limits are approximate and very much a matter of **individual sensitivity**; the effects on the lungs of excess oxygen exposure develop gradually (at low dose levels) and are reversible. They should be adjusted downward (toward a lower exposure) if any symptoms develop (symptoms are mentioned in section III.A.3, and in the Underwater Handbook reference). If considerable experience (weeks of diving) shows no problems whatsoever in a given individual, that person may cautiously increase his daily limits by say 20 units for a few days, and continue at

the higher level as long as no symptoms are noted. A diving medical doctor should monitor this practice.

4. **Instructions for managing CNS oxygen toxicity**

Protection against **CNS toxicity** is built into the tables, with times limited for excursions deeper than 200 fsw; 29 minutes are allowed in the range 200 to 220 fsw, and 16 minutes in the range 220 to 240 fsw. The diver is warned that this is a zone of significant nitrogen narcosis.

5. **Preparations for saturation decompression**

The **peak** of the **oxygen stress** during a mission will normally be the first day of saturation decompression. To minimize problems at this time it is advisable to **check the CPTD** for the first part of the ascent profile and possibly **curtail excursions** during the hours before that, if indicated.

C. Ascending excursions

An ascending excursion is one to a depth **shallower** than the saturation storage or habitat depth. The tables for ascending excursions have the same values as those in the Second Edition of the NOAA Diving Manual, and the procedures are essentially unchanged. They are included here so the information needed for excursions from each storage depth will be as complete as possible.

1. **Format of the ASCENDING EXCURSION tables**

An **ascending excursion** table is included for each range of storage depths; The values are the ones for the **deepest** part of that range. For example, the table for ascending excursions for the 60-64 fsw range is the same as those in the NOAA Diving Manual (1976, Table 12-7) for ascending excursions made from 65 fsw; these are the appropriate values to use for excursions made from depths between 60 and 65 fsw.

This little table gives the **time limits** for ascending excursions made from this storage depth. The top double row of figures is the "target" or planned **depth range** of the ascending excursion; the lower row is the **maximum time** allowed in that depth range when excursing from this storage depth.

The leftmost depth in most cases uses the "less than" symbol (**<**) to indicate that excursions are not allowed to that depth or to any shallower depth; that is, the allowed excursion time is **zero.**

The rightmost depth indicates that all depths equal to or greater than that value (**>=**) can be accessed **without time limit.** (The 12-hour maximum inwater time still applies.)

The depths given are "absolute" depths, as measured **from the surface** rather than from the habitat. No provision is given here for extending the range of ascending excursions when a higher PO_2 than 0.35 is used in the habitat.

2. Instructions for ascending excursions

A diver is allowed to make an ascending excursion dive to an excursion depth for the time shown in the table.

2.a. Timing

Begin **timing** an ascending excursion on departing the habitat, and plan the excursion so as to be back at the habitat depth (or within the oxygen window range) **by the end** of the allowed excursion time. Thus the ascending excursion time is "hatch-to-hatch."

2.b. Depths falling between values in the table

For an ascending excursion depth **between** the listed depths, use the more conservative choice. That is, for an excursion depth falling between two listed depths use the **shorter** time limit, that of the shallower depth.

2.c. Rates of travel

The recommended **ascent rate** should be relatively slow, 10 to 30 fsw/min, and descent can be 30 to 75 fsw/min. Precise rate control is not critical as long as the timing (IV.C.2.a, above) is correct.

2.d. DCS symptoms

If **symptoms** of decompression sickness occur during the excursion, return to storage depth according to Treatment Chart ASC, section VI.H and VI.J.2. Treat if necessary. The divers and crew should know and understand the treatment procedures before making ascending excursions.

3. Relation to other dives

Ascending excursions have little or no impact on descending excursions that follow, but they may be affected by prior dives.

3.a. Ascending excursion following descending excursion

Wait 24 hours after returning from a full-time descending excursion before making an ascending excursion.

An ascending excursion made **less than 24 hours** after a descending excursion can be made using the depth of the deepest descending excursion in the last 24 hours as the "storage depth" for determining the allowable ascending excursion time; if this is not possible then the second ascent should not be made.

Following **submaximal** no-stop descending excursions, the "submaximal" procedures may be used to **reduce** the 24 hour wait to as little as 12 hours. (See section IV.F.3).

3.b. Descending excursion following ascending excursion

Ascending excursions **do not prejudice** subsequent descending excursions, and do not require the use of repetitive procedures. Time spent at depths shallower than the habitat on ascending excursions can be regarded in the same way as time spent in the oxygen window range.

3.c. Ascending excursion following another ascending excursion

Wait **4 hours** after returning to storage depth before beginning another ascending excursion. This time may be spent in the oxygen window range, deeper than the habitat. **Submaximal** procedures are not applicable here.

4. **Habitat placement**

Except when they are in the unlimited duration range, ascending excursions are usually not as easy or efficient as descending excursions. It is preferable to **place the habitat** in relation to the work site so that most excursions are of the descending type.

D. Oxygen window excursions

The term "oxygen window" as used here is the **vertical depth range** over which a diver may excurse downward and not increase the inert gas loading beyond that prevailing when in saturation storage. It works because air has a higher fraction of oxygen than the habitat atmosphere. The term does not relate to monitoring of oxygen exposure; its relevance is only to **decompression**. The "oxygen window" depth is calculated to give the same nitrogen partial pressure when breathing air as that present in the habitat gas.

The oxygen window value is given on each pair of table pages as a separate item on the first page. It is a **differential depth**. For example, from the 60-64 fsw storage depth range the differential is 12 fsw. Thus the oxygen window range for a habitat at 60 fsw would be 60-72 fsw, and for a habitat at 63 fsw the range would be 63-75 fsw. The oxygen window applies to **descent only**; ascents are covered by the ascending excursion procedures.

The purpose of identifying the oxygen window values is to allow diving in the vicinity of the habitat depth to be performed without affecting any subsequent diving. This would include:

(1) Determining the **12-hour dive time limit** (per 24 hours). Excursions within the oxygen window need not be counted in figuring this limit. See IV.A.1.

(2) Determining the **16-hour interval** for starting a new repetitive sequence. Time within the oxygen window range is equivalent to time in the habitat.

(3) The **repetitive effect** on a subsequent excursion. Time spent within the oxygen window is equivalent to habitat time, except that when the stop of a one-stop excursion falls within the oxygen window; in that case begin timing the interval at the end of the stop.

Inwater time spend **shallower** than the habitat during ascending excursions can be counted in the same way as time in the oxygen window range. Thus there is a **"free zone"** between the unlimited ascending excursion depth and the oxygen window depth that does not affect the decompression aspects of subsequent diving.

E. No-stop excursions

1. Format of the NO-STOP EXCURSION tables

The no-stop excursion table contains the **allowable times** for all standard and repetitive no-stop descending excursions permissible from this storage depth range.

The header shows the date when this calculation was made and the DCAP "Base Case" used for the calculation. This is included to document the source of the figures in the table, and to keep track of updates.

There are two table blocks in each set; the second is merely a continuation of the first.

The values in the table are the **maximum allowable times** in minutes for each of the excursions. The target excursion depths in **fsw** are given across the top of each table. On the left side of the table are given first the sequential excursion numbers, and then the "habitat intervals" in hours applicable to each place in the sequence.

There are three sequential categories or **excursion numbers** (the "excn#" column on the table) for repetitive excursion diving. An excursion is a **1st** excursion if it starts more than 16 hours after the end of the preceding excursion. A **2nd** excursion is the next one in a sequence; it follows less than 16 hours after a **1st** excursion. Any and all excursions following this

are "3+" excursions until there is another 16-hour break. This follows without regard to days and nights, work cycles, etc.

The **times** given in the top data row (for the 1st excursion and interval of >16 hr) are the standard no-stop (or NOAA OPS) non-repetitive excursion time limits in minutes equivalent to those in the NOAA Manual (but the values are not necessarily the same).

There are 5 interdive habitat time **intervals** (the "Intrvl" column) in addition to the ">16 hr" interval which starts a new sequence. These refer to the elapsed time in hours between the end of the preceding excursion dive and the start of the current one, and are equivalent to the "surface interval" in conventional repetitive diving. The shortest interval for a repetitive excursion is 1/2 hour.

2. Instructions for no-stop excursions

A diver is allowed to **excurse** to a target excursion depth deeper than the saturation storage or habitat depth, for the time shown in the table and according to his repetitive status.

2.a. Determining repetitive status

A diver's **repetitive status** for a given excursion dive depends on his previous excursions during this saturation, specifically which dive it is in the sequence of dives, and the time interval spent in the habitat since the last dive.

2.b. Dive number in a sequence

If **16 hours** or more have elapsed since the last excursion (or if it is the beginning of the saturation) then a dive is considered to be a **"1st"** excursion. If the diver has done **one excursion** since the last 16-hr break, then the coming one would be a **"2nd"** excursion. If he has done two or more excursions since the last full 16-hr break then the dive is a "3+" (or "subsequent") excursion. The section of the table for the appropriate excursion number is used.

2.c. Time interval since the last excursion

Use the time the diver has spent at habitat depth or within the oxygen window depth range (defined in IV.D) as the **interval** for selecting the (horizontal) row of the table to be used. Timing of the interval may begin when the diver leaves bottom in a no-stop excursion, or at the end of the stop of a one-stop excursion. A preferred method is to begin timing the interval when the diver returns to the habitat.

2.d. Continuation excursions

If a following excursion starts **less than 1/2 hour** after the one before it, it has to be considered as an extension of the same excursion or a "continuation" excursion and must fall within the same total excursion time. The time spent in the habitat in such a case is included as excursion time; that is, the timing of the excursion continues through the short habitat interval.

2.e. Choosing allowable time for the depth of a descending excursion

The allowable **excursion time** is chosen from the row defined by excursion number and interval, in the column headed by the depth of the excursion.

For target depths falling **between values** in the table, use the time allowed for the next deeper depth.

2.f. Rates of travel to and from excursions

Descent (compression) to the excursion depth may be at any convenient rate. Ascent (decompression) back to the habitat should be ideally 30 fsw/min, but in any case should fall within the range **10 to 60 fsw/min.**

2.g. Timing

Timing of a no-stop excursion normally begins when the diver descends deeper than habitat depth. As an option it may begin when the diver passes the deeper limit of the oxygen window depth range, but it is recommended that timing begin on departing the habitat. Begin ascent no later than the end of the allowable time.

See section IV.F for the adjustment for a submaximal excursion.

2.h. Limits

A maximum of **14 no-stop excursions** are allowed in a given sequence. A new sequence is started after a period of 16 or more hours spent in the habitat and/or inside the oxygen window depth range. No-stop and one-stop excursions may be **mixed** in the same sequence, in which case **each one-stop** excursion is counted as **3 no-stops** in calculating the limit of 14.

F. Submaximal no-stop excursions

If the **duration** of a given descending no-stop excursion is **less than** the total allowed time, this becomes a "submaximal" excursion. Then the excursion that follows (here called the "**post-submaximal**" excursion) can be

longer than the time given in the table. The relationships are proportional and the calculation of this adjustment is straightforward, but it requires several steps. The calculation is an adjustment of the "**penalty**" due to the preceding excursion; the penalty is the normal repetitive reduction in time of a subsequent excursion as a result of the excursion or excursions before it in a sequence. The submaximal adjustment is illustrated in Figure IV-1.

The new excursion thus falls between the full penalty (reduction in allowable time) due to the preceding excursion had it been full, and the time that would have been allowed if that excursion (the submaximal) had not taken place at all.

The hours to minutes conversion table, Table VII-6 may be helpful in converting times.

1. Rule for submaximal excursions

The following equation describes how the adjustment for a dive following a submaximal excursion is calculated. t = time; * = multiply

adjusted t = t:min + (max:penalty * F:unused)

Or, the same equation may be written:

adjusted t = t:min + {(t:max - t:min) * (t:allowed - t:used) / (t:allowed)}

Definitions:

adjusted t is allowed time of the new dive (t:adj).

max:penalty is the reduction in allowable time, where the preceding excursion is for the full allowable time (i.e., not a submaximal).

F:unused is the unused fraction of allowable time on the submaximal excursion; it is equal to: (T:allowed - T:used) / t:allowed.

t:min is the minimum time allowed on the new dive, as if the submaximal dive had gone its full time; this is taken from the tables, and considers the sequence of the dives as well as the intervals.

t:max is the maximum time that could be allowed for the new dive had the submaximal dive not taken place at all; this is taken from the tables and considers the sequence of the dives as well as the intervals.

t:allowed is the time that could have been used on the submaximal dive had it not been submaximal.

t:used is the actual time used on the submaximal excursion.

submaximal excursion: The excursion that used less than its full allowable time.

preceding excursion: The one before the submaximal excursion.

post-submaximal excursion: The one after the submaximal excursion.

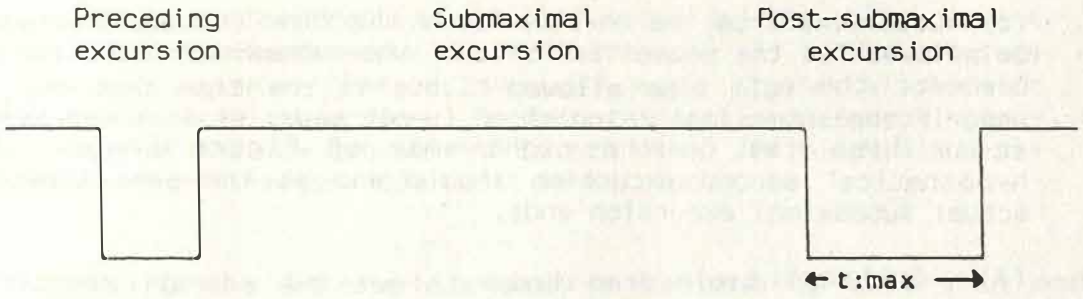


Figure IV-1A. Hypothetical sequence in which the submaximal excursion was not done at all, and the new excursion (t:max) is then based on the preceding one.

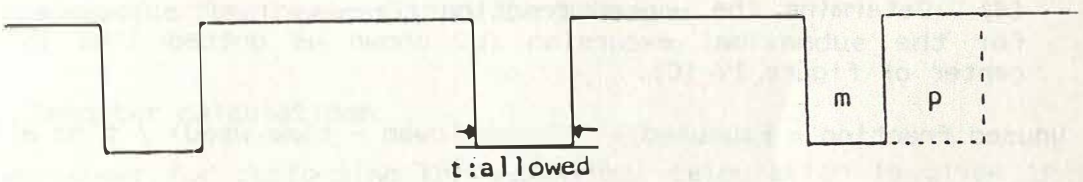


Figure IV-1B. Hypothetical sequence in which the submaximal excursion is for the full allowable time (t:allowed) and the new dive, t:min (shown as "m") has the full "max:penalty" (shown as "p").

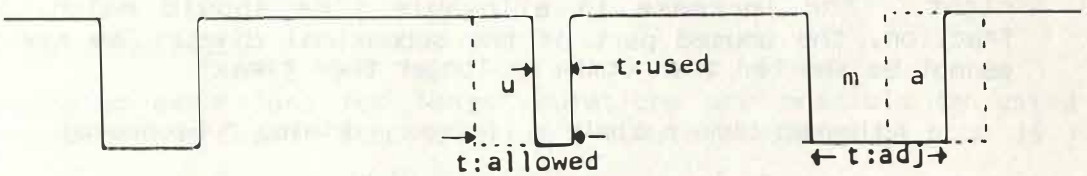


Figure IV-1C. Adjusted excursion follows a submaximal excursion. The allowed time (t:adj) is now equal to the minimal time ("m") plus the portion ("a") of the full penalty that corresponds to the unused part of the submaximal dive ("u"), which is added back.

Figure IV-1. Diagram of adjustment for submaximal excursion

2. Calculation of an excursion following a submaximal excursion

(1) Determine from the no-stop table the time (**t:max**) that would be allowed for the postsubmaximal excursion if the submaximal excursion had **not taken place at all.** This may require choosing a new excursion sequence number as well as a new interval, then reading the time from the table. This is shown in the top figure, IV-1A.

(2) Determine from the no-stop table the time (**t:min**) that would be allowed for the sequential dive if the submaximal excursion had been for the **full time allowed.** This is the time that will be used if the submaximal calculation is not made; it is shown as the solid line (m) on the right side of Figure IV-1B. The hypothetical second excursion should end at the same time the actual submaximal excursion ends.

(3) Subtract **t:min** from **t:max** to get the overall repetitive **max:penalty** which is going to be adjusted. This is the difference in repetitive effect between the preceding "submaximal" excursion not being done at all and being a full-time excursion. It (p) is shown as dots on the right of the second figure, IV-1B.

(4) Determine the **unused fraction** (f:unused) of allowable time for the submaximal excursion (u, shown as dotted line in the center of figure IV-1C).

Unused fraction = F:unused = (time allowed - time used) / time allowed

(5) Multiply the **max:penalty** (t:max-t:min) by the unused **fraction** (F:unused) to get a new penalty in minutes (hatched areas at right of 3rd figure).

(6) Add this to the time (t:min) determined in (2) to get the **new** allowable time. **Check it** by inspection to make sure it looks right. The **increase** in allowable time should match, as a fraction, the **unused** part of the submaximal dive. The new time cannot be shorter than t:min or longer than t:max!

Adjusted time = t:min + {(t:max - t:min) * F:unused}

Example: Consider a "1st" excursion from storage at 60 fsw (p. T-13) to 115 fsw for 140 minutes followed 3 hours later by another "subsequent" excursion (the one to be adjusted). The table would allow 420 minutes for the 1st excursion, and for a 2nd excursion 2-4 hours after a full-length excursion the normal allowable time would be 244 min.

(1) If the first dive had not been done the post-submaximal dive would have been a "1st" dive (t:max) with an allowable time of 420 min.

(2) If the first (submaximal) dive is for only 140 minutes, the proportion of the allowable time not used is (420-140)/420, or a fraction (F:unused) of 0.667 of the allowable time.

(3) A 2nd excursion 2-4 hours after a full excursion would have a normal time (t:min) of 244 min.

(4) Subtract to get the difference in penalties, 420 - 244 = 176.

(5) Multiply by the fraction, 176 * 0.667 = 117 min. This amount is added to the normal sequential dive time in (2) of 244 minutes, to yield an adjusted time of 244 + 117 = 361 minutes allowed for the 2nd sequential excursion. By inspection this is approximately two thirds of the way between the "worst case" 244 minutes and the "1st excursion" time of 420, so it looks right.

3. Reducing the interval between a descending excursion and a subsequent ascending excursion

Normally an ascending excursion cannot be done until 24 hours after a descending excursion. If the descending excursion is submaximal, the 24 hours can be reduced appropriately: New time = 24 * t:used / t:allowed. In no case should the time be less than 12 hours.

4. Computer calculations

A worksheet for performing the submaximal calculation is given in the Appendix, after the tables. However, a better way of dealing with this problem would be to calculate all excursions on a real time basis; this is strongly recommended if many diverse excursions are to be made and excursion efficiency is needed.

G. One-stop excursions

Descending excursions for longer durations are possible by using a single timed decompression stop after a 2-minute preliminary stop 10 fsw deeper.

1. Format of the ONE-STOP EXCURSIONS

At the top of the second page of each set are two tables for **"one-stop"** excursions. The two tables are for the two interdive habitat intervals applicable to one-stop excursions. The upper one is for one-stop excursions that follow a **16 hour interval** since the last dive. The lower is for one-stop excursions to be carried out **between 2 and 16 hours** after the end of the last excursion. There are no schedules for one-stop excursions less than 2 hours after the preceding excursion.

No "sequence number" information is given, because every one-stop excursion dive is regarded as a **3+** in the sequence. Likewise, any no-stop excursion following a one-stop must also be considered to be a 3+, unless it follows by more than 16 hours.

The column headings (in **boldface**) are the **"target" depths** in **fsw** accessible from the current storage depth. For intermediate depths the next deeper depth is used in the familiar way.

Two figures constitute each entry. The number on the **left** is the excursion **"bottom" time**; each one covers the period between it and the next shorter one (the one above it) in the usual way. That is, for an excursion of 190 minutes, which falls between 180 and 210 minutes, the 210 minute bottom time is the proper choice.

The number on the **right** in each pair is the primary **stop time** for that bottom time. This time is to be spent at a point **15 fsw deeper** than the habitat or storage depth. This is the nominal and desired stop point, but any depth between 10 and 20 fsw deeper than the habitat is acceptable.

A **2-minute preliminary stop** is made 10 fsw deeper than the primary stop on **ALL** one-stop excursions, but this stop is not shown on the tables. It is **required** on all of this type excursion.

2. Instructions for one-stop excursions

2.a. Choosing a one-stop ascent table

Choose the table appropriate to the **interdive interval** between the end of the preceding descending excursion (whether no-stop or one-stop) and the start of the next one. The upper table is for intervals of more than 16 hours, the lower is for intervals of 2-16 hours. One-stop excursions are not allowed sooner than 2 hours after another descending excursion.

All one-stop excursions are considered as **"3+,"** as if they were after the second in a sequence; any descending no-stop excursions that follow one-stop excursions are 3+ as well.

2.b. Choosing the schedule

Select the **target depth** (excursion depth) column on the table equal to or for the depth next deeper than the maximum depth of the excursion. Select the next longer **bottom time** from the **left** entry in that column. The time to its **right** is the **stop time** to use.

2.c. The preliminary stop

A **required "preliminary" stop** of 2 minutes is taken 10 fsw deeper than the indicated stop depth on all one-stop excursions.

2.d. The primary stop

The **primary stop** is to be performed at a depth ideally 15 fsw deeper than the storage depth. The acceptable range is 10 to 20 fsw. Do not use the oxygen window as the habitat depth in this case, use the actual storage depth. The stop depth may fall within the oxygen window range, but the time must still be spent at the specified stop depth.

Air is breathed during the stop. After the stop time is complete at the prescribed depth the diver may make oxygen window excursions.

2.e. Ascent rate

Ascent is ideally **30 fsw/min**, but the range 10 to 60 fsw/min is acceptable.

2.f. Timing

Begin **timing** the excursion on departing the habitat, and depart bottom depth by the end of the allowed excursion time. Start timing each stop **on arrival** at the stop depth, and begin ascent **after** the required duration of the stop has elapsed. Note that this timing procedure for stops is **different** from others; the reason is to ensure a full 2 minutes in the preliminary stop. Begin timing the next interval at the end of the stop.

If it is more convenient, timing of the **descent** may begin on departing the deeper end of the oxygen window range.

2.g. Repetitive status

One-stop excursions may be used **interchangeably** in the same repetitive pattern aas the no-stop excursions, with the two limitations that all one-stops and the dives that follow are 3+, and only two intervals are available for use with one-stop excursions.

2.h. Limits

No more than **4** one-stop excursions are allowed in any repetitive sequence. A sequence is a series of repetitive excursions without a break; a 16-hour break starts a new sequence.

As stated, one-stop and no-stop excursions may be **mixed together** in a sequence. If this is done, count **each one-stop** excursion as equal to **3 no-stops**, and use 14 excursions as the upper limit for a sequence.

2.i. Submaximal excursions

There is **no** provision for using "**submaximal**" procedures with one-stop excursions to reduce the penalty to the next excursion.

H. Saturation decompression

Tables are provided for decompression from saturation for each storage depth range; each has its own ascent rates. The tables use a special procedure for preventing or minimizing the picking up of gas and/or bubbles during excursions; divers who have made excursions outside the oxygen window range during the 36 hours preceding the start of saturation decompression begin the decompression at a "starting depth" that is deeper than storage. This "precursory" starting depth is a function of the storage depth and the depth of the deepest excursion performed in the last 36 hours.

1. **Format of the SATURATION DECOMPRESSION procedures**

There are two tables for each depth range. The 7-column table on the right is the **main table** for decompression from storage depth, and the one on the left is a **precursory** table for use in ascending to storage depth after excursions. Above these tables is a two-line chart used for selecting the proper precursory starting depth following excursions, and below the tables is a breakdown of the total ascent times in hours and minutes and a CPTD summary.

The two tables are laid out with the same column headings. On the title line of the main table is the **"k" value** which was used in calculating the table. The k is not used in normal operations, but it can be helpful in calculating contingency ascent profiles at higher oxygen levels and still maintain the same table reliability. This is covered in section V.D.3.c.

The seven **columns** in each table show the stop depth, the time remaining at the beginning of the stop, the stop time at that depth, the average "RRate" of ascent between this stop and the next, the gas mixture to be breathed, the correct oxygen partial pressure to be breathed during that stop, and the CPTD (oxygen dose) for the stop.

The **depth** column shows the depths of the stops in 5-fsw increments. In the main table (on the right) the first stop is the shallow end of the storage depth range for that table. Decompression begins with an ascent from storage to that depth. In the precursory table (on the left) the stops are starting depths for decompressions that follow descending excursions.

The **"Time to go"** column gives the total time in minutes remaining in the decompression from the moment ascent to that stop begins, and is thus the total decompression time from that point.

The **stop time** shows the time to be spent at that stop, in minutes, when the staged method is used.

The fourth column shows the (inverse) linear **ascent "RRate"** in minutes per fsw between that depth and the next, if decompression is by continuous bleed instead of in 5 msw stops. The term "RRate" stands for "reciprocal

rate," the expression of ascent in minutes per fsw. This is not properly a rate, which would be feet per hour, but it is a more convenient unit to use.

The next column is the **gas mixture** to be breathed throughout the stop. This is included to show when the mixture of nitrogen and oxygen has the composition of air or when it should be a specific oxygen partial pressure. All but the four deepest tables (105-120 fsw) use air as the breathing gas throughout the decompression.

The sixth column is the **oxygen partial pressure** (in atmospheres) that should be breathed at that stop depth. Normally this is the PO_2 of air, but for tables 105 fsw and deeper there is a period of four stops (about 12 hours) with the PO_2 lowered to 0.5 atm to reduce oxygen stress.

The final column gives the **CPTD** accumulated during the stop.

Each saturation table is the appropriate one for the **deeper** end of the saturation storage depth range. That is, the table for the storage depth range designated "60-64 fsw" is actually the table for decompression from 65 fsw.

2. Instructions for saturation decompression

2.a. Ascent pattern

The decompression may be carried out in **5 fsw stages** or by a continuous **linear** "bleed" type of ascent. The procedures are given first for the **staged** ascent, with differences required for **linear** ascent noted in section IV.H.2.j. If conducted properly there should be no difference in either time or results between the two methods.

2.b. Choosing the decompression table

The saturation tables on the set of pages for a given storage depth range are the correct ones to use for depths falling **within that range.** However, if storage is at an **exact** increment of 5 fsw (60, 65, etc.) then the saturation table for the next shallower storage depth range--which has that depth as its deepest point--may be used. The **ascent distance** to the first stop must be **5 fsw or less.**

For example, a saturation at exactly 65 fsw uses the table for the storage depth 60-64 fsw, and begins with an ascent to 60 fsw. However, a habitat stored at exactly 30 fsw has to use the 35 fsw table because there is not one for the 25-29 fsw range.

Excursions have a **big effect** on the table to be used; these are covered in the next section.

2.c. Effect of excursions

If **any diver** in a team to be decompressed together has been on a descending excursion deeper than the oxygen window range during the last 36 hours, the decompression should begin at a **starting depth** deeper than storage, using the **precursory** table. Ascending excursions have no effect on saturation decompression.

2.d. Starting procedures, no excursions in last 36 hours

Change the habitat **atmosphere** to air before commencing decompression. This change is made by raising the oxygen level to the required value. **Begin decompression** by ascending (reducing pressure) to the first stop. Rate of ascent can be any convenient rate; a good rate is to take one minute to ascend. If linear ascent is used, ascend to the first stop (in about 1 min), then immediately begin the specified linear ascent rate to the second and subsequent stops.

2.e. Starting procedures, after excursions

For divers who have been **excursing** during the 36 hours before the start of saturation decompression, the saturation decompression is preceded by a **"precursory"** decompression from a starting depth that is determined by the **deepest excursion** during the past 36 hours. Even if only the end of an excursion falls within the past 36 hours it should be counted. Using this "maximum excursion depth," select the **starting depth** from the two-line "Selecting precursory starting depth" chart. Using the precursory table (at left), the decompression **begins at the depth specified** in the starting depth chart, taking the time given in the table for the selected starting depth as the first stop. If the dive depth falls between listed excursion depths use the next deeper depth to select the starting depth. The precursory table is continued to its end and then the main table (on the right) is followed to the surface.

There is **no hold** or wait after the last excursion before beginning saturation decompression using these procedures.

The normal method is for the divers to **return** to the habitat, then the habitat is **pressurized to the starting depth** and the atmosphere changed to air. Compression should be started as soon as practical, but always within 5 minutes. The rate of travel to the starting depth is not critical, but should be faster than 10 fsw/min, preferably 30 fsw/min. The net oxygen fraction of the compression gas can be adjusted so as to result in an air atmosphere when starting depth is reached.

The starting depth is selected for the **deepest** excursion made by any member of the team to be decompressed together during the 36-hour period, **not** necessarily the last excursion. Normally the **entire dive team** will be recompressed to the starting depth.

An alternative method if the equipment permits is to have the habitat pressurized to **meet the divers** at the end of the last excursion. This is possible if they can lock into the habitat while it has a pressure greater than the ambient water. In this case any divers in the habitat who were not on the last excursion are pressurized to meet those returning from the last excursion. This method may be better if the rate of compression of the lock is faster than that of the habitat.

When operations are being conducted from a surface-located living chamber with travel to the worksite in a **closed** (pressurized) **bell**, the habitat or living chamber should be switched to air and pressurized to the starting depth during the last excursion, and the divers on the last excursion locked in at starting depth pressure to begin the precursory decompression. This method avoids having the divers return to storage depth and then be recompressed, so is physiologically advantageous. As before, the timing of the first precursory stop begins when all divers are at starting depth and at the PO_2 of air.

Example: Divers saturated at 77 fsw and using the 75-79 fsw storage depth range (p. T-20) have made an excursion to 113 fsw. Enter the precursory starting depth selection chart at 115, the next deeper depth, and find 95 fsw just beneath it as the starting depth. The divers take their first stop of 60 minutes at 95 fsw, breathing air. This depth may be reached by stopping there on return from 113 fsw, or by returning to the habitat at 77 fsw and recompressing to 95 fsw within 5 minutes.

2.f. Timing and rates

Begin timing a stop the moment **ascent** from the preceding stop depth begins. That is, **travel time** is taken from the **next stop.**

The first stop on the precursory table begins as soon as all divers are **at the pressure** of the starting depth.

Rate of depressurization between stops is not critical, but a time of about one minute for a 5-fsw ascent is desirable.

Recompression of the habitat to the starting depth should be as fast as practical, ideally **10 to 30** fsw/min.

2.g. Oxygen levels during saturation decompression

Two oxygen patterns are used. For all saturations shallower than the 100-104 fsw range the breathing gas throughout the decompression is **air** (i.e., the nitrogen-oxygen mixture equivalent to air). For the 100-104 fsw and deeper storage depths there is a period of **4 stops** at a PO_2 of **0.5 atm** beginning two stops after the start of decompression. This is to provide a low-oxygen break at the point of potentially high oxygen exposure.

The proper gases and PO_2's are given in the tables. The initial oxygen level should be set by the time decompression timing begins.

For these purposes air is **defined** as 20.5 to 22.0% oxygen, balance nitrogen. A nominal PO_2 of 0.5 atm can range between 0.50 and 0.52 atm.

2.h. Sleep stops

No sleep stops are used; decompression continues through the night. Although opinion is not unanimous, some authorities recommend or require that divers **get up and stretch**, moving all joints and muscles, for one or two minutes **every 2 hours** during the decompression. This may seem tedious, but should be regarded as a lot less trouble than performing a treatment for decompression sickness.

2.i. Deviations

If during ascent it is noted that ascent is **too slow**, continue **from that point** at the prescribed rate given in the table. If it is noted that ascent is **too fast, recompress** to the proper depth for the current time and continue ascent. In the former case the schedule is changed and the divers will reach the surface later than planned; in the latter case the original schedule is not changed.

Example: In decompressing from 74 fsw (without excursions; p. T-18) it is noted at 300 minutes after beginning ascent, 1990 to go, that the depth is 55 fsw instead of 60. The table for a storage depth of 70-74 fsw shows ascent from 60 to 55 fsw at 1960 minutes to go, so the divers are ahead of schedule or shallower than they should be. They should recompress back to 60 fsw and complete the stop there, which is scheduled to be over at 1990 to go or 330 minutes after starting ascent. The stops to follow will occur at the originally scheduled times.

Example: It is noted that at 300 minutes elapsed time since the start of decompression from 74 fsw (1990 to go) the depth is now 65 fsw. The depth should be 60 fsw, so the divers are 85 minutes behind (they should have ascended at 2075). They should ascend immediately to 60 and begin the normal stop time there and follow the remainder of the table. No adjustments are made in depths or rates, but the schedule has to be reset and the divers will reach the surface 85 minutes later than originally planned.

2.j. Using linear ascent

Decompression may be by **linear ascent** instead of by 5-fsw staging. Different linear ascent rates are used between the five foot intervals; these rates are given in the tables.

Preparation procedures are the **same** regarding choice of table, effect of excursions, setting the decompression oxygen values, and the starting procedures.

Begin linear saturation decompression by a **step ascent** to the first stop depth, just as for the staging method. Ascent travel time is optional, or 1 **min** for the travel to the first stop. On reaching the first stop depth begin the linear decompression, changing ascent rate to the linear rate given in the table. Adjust rate so as to pass through the depth of the second stop at the "time-to-go" indicated in the table, at which point the rate is changed again according to the table. Continue on, passing each stop and assuming each new rate at the listed time. The chamber should reach surface pressure at the time given for ascent from the last stop.

Each rate listed with a stop is used for travel from **that stop** to the **next**.

2.k. Oxygen toxicity symptoms during decompression

If a diver develops oxygen toxicity **symptoms** during the decompression that are prominent enough to require some action, the following procedure could be used. Stop the ascent and **reduce the oxygen** level to below a PO_2 of 0.5, down to 0.3 if deemed necessary. **Hold** for 12-24 hours, depending on the diver's condition. When recovery is significant, prepare to resume ascent.

Before resuming decompression, **raise the PO_2** back to the level of air as given in the table. Allow chamber pressure to increase during the addition of oxygen, and resume the decompression at the resulting pressure or the next shallower stop depth, using the appropriate stop time. Take a **full stop** after oxygen has been raised and before ascending.

A profile using reduced oxygen levels and slower rates can be calculated if necessary, but it may be less reliable. See section V.D.3.c for the method.

2.l. Bends watch and flying after saturation decompression

Divers are to refrain from **travelling by air** or otherwise ascending to altitudes greater than 1500 feet above the dive site for a minimum of **48 hours** after reaching surface pressure. A longer period is recommended.

Decompression sickness following nitrox saturation decompression has been observed to occur up to several days following surfacing, so a chamberside **"bends watch"** of only a few hours may be inadequate. Accordingly, it is recommended that divers remain within 2 hours travel time of a treatment **chamber** for 24 hours and in **contact** with the project's responsible person for a minimum of 72 hours.

V.
SURFACING PROCEDURES

This chapter covers several of the alternatives for recovering the divers from the pressurized subsea habitat to sea level. These include two operational methods that depend on having the right equipment, one method good only for relatively shallow habitat depths, and two plans for contingencies and emergencies. A method for accelerating decompression is also given.

A. Ascent in pressurized bell and decompression in DDC

1. Description of bell ascent method

The standard (and preferred) method for recovery of divers from a seafloor habitat is for them to travel in a **pressurized diving bell** (or "SDC" or "PTC") to the surface, and to be transferred under pressure into a surface chamber ("DDC") for decompression. Many operational details need to be settled, but this method requires nothing in the way of special decompression techniques. Decompression may be carried out in the habitat with transfer to the surface in the bell; see section V.B.

2. Conditions for use

This is the recommended method for all habitat operations, but it is the only fully acceptable method for work **deeper than 50 fsw.** It requires a "closed" bell, one that can be pressurized, moved under pressure, and mated to a chamber suitable for saturation decompression.

3. Procedures

The divers enter the bell at a pressure deeper than the **unlimited ascending excursion depth** (which may be storage depth, following excursions), and this or a higher pressure is maintained until saturation decompression procedures are started. Either wet or dry transfer can be used. Saturation decompression should be started at the appropriate starting depth or the saturation storage pressure, not at the ascending excursion depth. **Oxygen** procedures for storage or saturation are followed as they apply.

B. Surfacing the habitat under pressure

This method may seem unlikely or impractical at first glance, because it depends on having a very special set of hardware. However, several

serious conceptual designs have proposed it and it will undoubtedly be used eventually. The method requires that the **"habitat"** (which may be a lockout submersible) be taken physically **to the surface** by the time decompression ends, so the divers can step from the chamber into atmospheric pressure. It imposes no decompression requirements not already covered in the standard procedures. Decompression procedures are the same as those for a pressurized bell and DDC, section V.A.

C. Recompression and "swim up" or dry transfer

1. Description of "seabed decompression and swim-up" method

This method requires the divers to **decompress in the habitat** while it is in place on the sea floor, then **repressurize** to ambient pressure at that depth, lock out, and **swim** to the surface. This method has been used for hundreds of successful decompressions from Hydro-Lab.

An alternative is to use the same decompression pattern, decompresssing in the habitat to sea level pressure and then transfer the divers to the surface in the bell. The bell has to be able to take external pressure.

2. Conditions for use

This "swim-up" method is considered fully acceptable operationally for normal recovery from storage depths to **50 fsw.** It requires three things: (a) The capability to **decompress** the habitat **in place;** (b) the capacity to **recompress** it within a time limit that depends on the depth; and (c) a surface decompression **chamber** (in case of need) close--ideally within 5 minutes--to the place where the divers will surface.

The recompression has to be fast enough for the divers to repressurize and begin ascent within the **no-decompression limits** (such as those of USN) for the depth of the habitat. The standard no-decompression tables are all right to use after a saturation decompression. Slower pressurizations and ascents with stops are possible but are not covered here.

3. Procedures

The dive team completes a normal saturation decompression **in the habitat** all the way to surface pressure. As soon as the last stop is finished in the habitat, **recompression** with air back to ambient water pressure may begin. There is only a minor benefit to the final decompression for the divers to wait in the habitat (at the last stop or at surface pressure) before beginning repressurization, but stay at surface pressure of any duration may be made optionally. A period (up to about one hour) of **oxygen breathing** would be beneficial, however, prior to ascent.

Without haste but without wasting time, as soon as pressurization is complete the divers **lock out** and swim to the surface. After surfacing no

further recompression/decompression is necessary unless there are problems or symptoms. The normal post-saturation protocol is followed.

For normal ascents the pressurization time plus the time for the divers to leave the habitat and begin the swim-up should not exceed the **no-decompression time limit** for that depth. If pressurization is prompt for the depth involved there may be no time urgency.

Ascent rates are 30 to 60 fsw/minute; 60 fsw is specified in the USN no-d procedures, but 30 fsw is preferable if it can be managed.

When a bell is available, after decompression the divers make a dry transfer at sea level pressure at their leisure.

D. Emergency surfacing

1. **Why procedures may be required**

Under most circumstances the above procedures will meet all operational contingencies. However, it is prudent to have methods on hand to deal with **unexpected** operational conditions **before** they occur. The procedures here deal with situations where it is impossible to surface the habitat under pressure and no bell is available, and the habitat is at a depth too great or there is not enough time for normal use of the "Hydro-Lab" method of seabed decompression.

A procedure is also given for **speeding up** the final few feet of a decompression if it needs to be done at the cost of higher oxygen exposure.

2. **Approaches and conditions**

2.a. Seabed decompression and swim-up from deeper than 50 fsw

This method would be used when transfer under pressure methods are for some reason not available (e.g., the bell lifting wire has been condemned by ABS) and there is **need to surface** the divers without it, but there is no time urgency. Planning missions in advance to use this method deeper than 50 fsw is not allowed under these procedures.

Using the USN no-decompression limits as a guide for the post-recompression ascent, the degree of reliability would depend on the **time** it takes to recompress. This can be done with safety equivalent to the no-decompression limits if the following formula is true:

(Repressurization time / 2) + time to exit < USN No-D time

The "**time to exit**" is the time it takes to get out of the habitat and begin ascent. As an example, at 80 fsw (standard no-d time of 40 minutes) it

could take 60 minutes to repressurize the habitat and there would still be 10 minutes available for lockout (60/2 + 10 = 40).

In situations where the conditions of the formula are not met, the same risks and responses as surfacing with "omitted decompression" are applicable. Briefly, the "no-d" limits can be exceeded with relatively little risk of lasting damage if **recompression** therapy is immediately available at the surface.

2.b. Direct ascent and surface decompression

This method requires the divers to **exit** the habitat and **swim** to the surface, then transfer to a **surface chamber** for recompression and saturation decompression. It has been used successfully from 45 fsw in the FLARE project, and tests have shown that ascents from the 50 fsw range allow as much as 15 minutes for divers to enter the chamber and begin recompression. This method is not recommended for routine operational use, but it offers a viable escape method when needed, especially if the saturation is shallow.

For the habitat depth range to 55 fsw the ascending excursion tables allow sufficient **time for transfer** to a convenient chamber. For the range 60 fsw and deeper, very little experimental data are available and it is unlikely that much will be generated in the future. However, some reasonable speculation suggests some general limits, Table V-1. The **"transfer time"** is that required to begin recompression in a chamber equipped for saturation decompression. Note that the ranges are large and should be interpreted as being estimates and very general. The gaps are there as a reminder not to use this chart literally; it is a guide only.

Table V-1 Emergency surfacing risk estimates

Saturation depth	Transfer time	Risk analysis
30-40 fsw	30 min	Safe, but repressurization advised ASAP
60-75 fsw	=<5 min	Minimal risk; could be used for operational contingency
	10-20 min	Small risk, use if facing serious loss or injury
	>30 min	Emergency only
80-90 fsw	5 min	Small risk, use for serious problems only
	>10 min	Moderate risk of DCS
100-120 fsw	<5 min	Slight risk
	>10 min	Emergency only

Keep in mind that these are proposed for ideal conditions. The situation that causes the emergency in the first place is likely to make meeting the transfer time more difficult.

3. **Procedures for emergency ascent and recompression**

This section covers planned emergency ascent. Unplanned (inadvertent or accidental) surfacing is covered in the Treatment chapter, Section VI.J.

3.a. Seabed decompression and swim-up from deeper than 50 fsw

Follow the steps given in V.C.3, above.

3.b. Direct ascent and surface decompression

Everything should be **ready** both in the habitat and topside before initiating ascent. Divers should use the best and most convenient **breathing gear** available.

If possible divers should **breathe oxygen** for the last few minutes prior to ascent (during ascent also, if equipment permits this to be done safely), otherwise breathe air. Oxygen times before ascent should be 8 minutes between 60 and 80 fsw, 4 minutes at 80-90 fsw, and 2 minutes if deeper than 90 fsw. This is of no benefit to normal decompression, but if the lungs are filled with oxygen instead of air the effects of an embolism would be minimized; the times are for optimal lung washout and minimal risk of CNS toxicity.

Ascent rate in the water should be deliberate and slow enough to minimize chance of embolism, 30 fsw/min if possible.

Make the **transfer** carefully but as promptly as possible. Recompress to 30 fsw **deeper** than the original habitat depth and begin saturation decompression from that point. If symptoms develop during the ascent process and resolve on recompression, breathe 2 cycles of treatment mix at surface pressure (see VI.H). If symptoms persist after recompression treat as DCS occurring following a descending excursion, (Chapter VI, Chart EX1 or EX2).

3.c. Speeding up the final stages of decompression

If circumstances dictate that accelerating the decompression slightly is **worth the risk** or **consequences** of increased oxygen exposure, this can be done using the "k" values on the saturation decompression tables.

To get a faster ascent rate first select the **oxygen level** that can presumably be tolerated. This will depend on the history of the exposure and the present condition of the divers, plus the risk of possible oxygen

toxicity that can be justified under the circumstances, and fire safety considerations.

Oxygen exposure limits are **complex** at best and based on limited data. Table VII-4 shows conservative oxygen limits that can be used as a guide, and the rate of accumulation of oxygen dose is shown in Table VII-3. Consider also that 1200 CPTU/day has led to fulminating, debilitating (but eventually reversible) lung toxicity after six days. Exposure to 65 CPTU/hr (CPTD 1560/day) for 48 hours has caused significant toxicity symptoms that took many days to reverse. An exposure of 90 CPTU/hr led subjects to quit in 15 hours when the CPTD was 1350. Thus it would appear that the dose could be **tolerated** at much higher than the prescribed level for a couple of days if there were sufficient incentive; this could result in a considerable time saving. After selecting a new PO_2, calculate the **new rate** as follows:

$$\text{Stop time (min)} = 300 / (K * PO_2)$$

where k is given in the table in fsw/hr per atm of PO_2, and PO_2 is in atm. Stop time is as used in the tables, with 5 fsw staging; round stop times off to the next even multiple of 5 min. Use the same criteria for selecting the table (excursions, storage depth, etc.) as would normally be done, and use the k appropriate to that table. This technique does not apply to the **precursory** table.

Note that the k cannot be used for calculating a **slower** ascent using a lower PO_2 without the possibility of reducing the reliability of the table. This is because the total duration of a saturation decompression affects the ascent rates uses, and in effect requires the use of a smaller k value. Using a lower PO_2 would make the table longer and thus less reliable.

Some tables in the first and second editions of the NOAA Diving Manual allow faster ascent than the ones given here, but with the requirement for extensive oxygen breathing.

VI.
TECHNIQUES FOR TREATMENT OF DECOMPRESSION SICKNESS IN HABITAT DIVING

R.W. Hamilton, R.E. Peterson, and C.J. Lambertsen

This chapter offers guidelines for management of decompression sickness (DCS) and embolism occurring in habitat diving. It reviews the resources needed, discusses diagnosis and therapy techniques, and includes flow charts, treatment charts, and tables for returning to storage depth or to the surface. The objectives are to take care of the affected diver, to avoid endangering others, and to get back to diving.

If you are in a hurry to begin a treatment skip to Section VI.G, then come back and reread the rest while decompressing.

A. General considerations

1. Equipment requirements

The full treatment of the decompression casualty requires the following capabilities:

(a) Chamber/habitat with life support capable of being compressed to pressures greater than ambient water depth, 230 fsw or 8 atm abs maximum (differential will be less)
(b) Breathing system for treatment mix
(c) Treatment mixes, PO_2 1.5 to 2.5 atm at all relevant depths; the best method of supplying treatment mix is via a gas "blender" or closed circuit rebreather
(d) Ability to change habitat atmosphere to air and back to normoxic
(e) Medical kit in habitat with iv fluids and appropriate drugs should know how to use the key items
(f) Dive crew capable of carrying out treatment and giving iv's, drugs
(g) Communication with Duty Doctor
(h) A surface-based recompression chamber capable of saturation decompression
(i) USN or other procedures for (1) Treatment at surface; and (2) Neurological exam

2. Problems to anticipate

On the basis of past experience the occurrence of DCS from a descending excursion is **relatively unlikely.** Barring overt accidents, the most likely occurrence of DCS would be in the latter stages of saturation decompression or after surfacing. There is some likelihood of symptoms occurring on

ascending excursions, but these usually resolve immediately on return to the habitat.

There is always the chance of **embolism,** possibly combined with DCS; it may result from some loss of control of depth or pressure.

In any ongoing habitat diving operation the possibility always exists that a saturated diver will show up at the surface, and plans to deal with such an eventuality should be well thought out and thoroughly rehearsed.

More likely to be encountered but far less serious is the development of chronic **oxygen toxicity.** This is covered in other parts of this manual (see VI.B.1.d.). It is of special concern here when its symptoms (such as numb fingertips) might be confused with those of DCS or embolism, or if it limits DCS treatment.

3. Approach to therapy

This manual has few innovations; it attempts to show how **standard practice** for treatment of DCS can be applied to the habitat situation.

DCS management consists primarily of **diagnosis, therapy, and return.**

Diagnosis is observing and acknowledging the familiar signs and symptoms (and not trying to explain them away). **Therapy** is administered primarily as pressure, oxygen, and support with drugs and fluids. **Return** is reliably decompressing back to the original storage depth or to the surface.

4. Medical coverage

It is not the purpose of these procedures to dictate personnel policy, but some common sense recommendations relevant to the management of pressure-related problems are mentioned in this section.

4.a. Preexisting arrangement

It is presumed that the habitat operation has an **arrangement** with a knowledgeable medical doctor **trained** in diving medicine who is **medically responsible** for this specific habitat operation as the **"Facility Doctor."** The Facility Doctor will be concerned with medical preparations, relevant crew training, and will participate in the setting of medical policy.

There should at all times during a habitat diving operation be a **"Duty Doctor"** on call to monitor treatments, give advice, and assume medical management of difficult cases. This need not be the same person as the Facility Doctor, but lines of responsibility should be clearly understood in advance of need. The procedures **do not require** that a doctor be **on site** during an operation.

4.b. Notification of a treatment

These procedures allow the Supervisor and the dive team to conduct a treatment for routine pain-only DCS without the moment-by-moment advice of a doctor. However, the Duty Doctor should be **notified** that a treatment is taking place; the purpose of this is to **establish contact** in the event that the treatment does not go well.

In extremely **serious** or life threatening cases, the Duty Doctor is expected to **take charge** of a treatment.

Common practice is for the control of and responsibility for the operation to be maintained by the Diving Supervisor (or equivalent), and he/she acts under the advice and consultation of the Duty Doctor. This relationship should be spelled out in local procedures.

4.c. Deviation from these procedures

The Duty Doctor or the Diving Supervisor acting on behalf of the Duty Doctor, may at his discretion deviate from these procedures. The consequences of compression beyond depths given here should be taken into account with respect to the other dive team members, range of available decompression tables, logistic limitations, etc.

5. **Logging**

For several very good reasons it is important that all details of a treatment be logged. This should as a minimum be the time-depth-gas profile, with time and description of symptoms, and symptom changes.

B. Diagnosis

The **traditional** signs and symptoms of DCS all apply in the habitat situation. Apparently "mild" or "minor" symptoms are still an indication of DCS.

1. **Signs and symptoms**

1.a. Pain-only symptoms

Joint pains, muscle pains, swelling of the thoracic lymph nodes, and the less serious of the **skin** manifestations of itching and rash are regarded as pain-only or Type I symptoms.

1.b. Serious or Type II symptoms

Serious, Type II, or **neurological** symptoms most commonly include numbness, tingling, paresthesia, and minor weakness. Extreme **fatigue** is a distinct symptom. Severe pain and excessive skin symptoms are considered as serious symptoms. Even minor neurological symptoms are serious; if you see a little (neurological DCS), you have found a lot.

The more significant of the serious symptoms include major sensory loss, weakness, unconsciousness, loss of a bodily function (such as bladder control), and paralysis. For these to be seen in a habitat diving situation will normally require exceptional pressure changes; if they do occur they may be the result of embolism (pulmonary barotrauma) rather than simple DCS.

1.c. Skin symptoms

Normally DCS limited to skin **itching** is not treated by recompression, but breathing of two or more cycles of treatment mix may be used. Rashes and intense itching may be treated as pain-only DCS, while marbling or dark purple rashes, raised welts, or severe itching are treated as serious DCS.

1.d. Comparison with oxygen toxicity

Oxygen toxicity can **imitate** some of the DCS symptoms. This could include numbness and tingling of the skin, especially in the toes and fingertips. More general effects such as chest pain, nausea, headache, fatigue, visual disturbances, and coughing are typical of the general oxygen toxicity syndrome.

Oxygen symptoms are normally of a "**systematic**" nature, affecting several parts of the body, whereas DCS effects can normally be **isolated** to the results of a single lesion. Oxygen does not cause weakness.

1.e. Embolism

Embolism is usually responsible for major sensory losses, unconsciousness, and effects on the brain. The "history" of what has happened to the diver, such as uncontrolled ascents or other events that could lead to pulmonary barotrauma, may be a clue to the presence of embolism.

2. **Neurological exam**

A neurological exam should be performed in **all** DCS cases. The exam will normally be performed during the air break after the first cycle of breathing treatment mix, but if signs and symptoms are weak and or vague enough that the proper treatment path cannot clearly be chosen it is appropriate to perform all or part of the exam before initial recompression.

The USN Diving Manual has procedures for a neurological exam, but the Facility Doctor will normally define the preferred procedures and train the crew in their use. The results of exams should be reported to the Duty Doctor.

3. **Depth of onset**

In the traditional way, the **depth of onset** is the depth at which the symptoms were first noted. Recompression steps in saturation decompression are based on depth of onset.

C. Description of therapy procedures for nitrox saturation-excursion diving

This section provides background information about the treatment procedures. Details of how to conduct a treatment are given in VI.G and subsequent sections.

1. **Treatment and flow charts**

The procedures are summarized in a primary TMT flow chart for selecting the treatment, two selection and treatment charts (ASC and ISD) for ascending excursions and inadvertently surfaced divers, and 4 treatment charts (EX1, EX2, SAT1, SAT2) covering pain-only and serious DCS after excursions and in saturation decompression.

2. **Recompression**

Treatment begins with recompression to the "depth of relief." These procedures provide a sequential compression plan intended to give definitive therapeutic compression steps and to remain at each step long enough to evaluate its effect, thus reducing the amount of medical judgement needed to approach an optimal treatment.

The compression **steps** coincide with timed **cycles** of breathing treatment mix (see VI.C.3, next). Evaluation is done during air breaks, and compression is continued if needed, up to a specified **maximum** pressure.

The initial compression steps are based on the situation, and range from 10 fsw to as much as halfway to the bottom depth of the excursion just completed. For pain-only symptoms initial compression is 30 fsw, or approximately 1/3 of the excursion distance if that turns out to be greater than 30 fsw. For serious symptoms initial compression is 60 fsw, or about 1/2 the distance of the recent excursion, whichever is greater. Example: If pain-only DCS followed an excursion to 200 fsw from storage at 50 fsw, the initial compression should be 1/3 of the difference between 50 and 200 fsw, or 50 fsw; the first cycle of breathing treatment mix would be at 100 fsw.

If relief is **not complete** during the first cycle at the depth of the first compression step, the diver is compressed an **additional** 10 fsw for breathing the second 25-min cycle. These steps are continued, spending one cycle at each step until relief is complete or substantially complete, or until the maximum depth in the chart has been reached. In treating **serious symptoms**, the diver is compressed an **additional step** (10 fsw) beyond the one where relief was complete. The **maximum** depth to be used in any treatment under these procedures is **230 fsw.**

If for some reason the pressurization and breathing of treatment mix cannot both be started immediately, for example if there is a delay in bringing the treatment mix on line, it is best to **go ahead** with what can be done, and then start timing the first cycle when both pressurization **and** breathing of treatment mix are underway.

3. Breathing gases

A **treatment** involves recompression and having the affected diver breathe at least **6 cycles** of treatment mix.

A **cycle** is 20 minutes breathing treatment mix by mask, followed by 5 minutes breathing chamber atmosphere (which should normally be air).

Treatment mix is a mixture of oxygen and nitrogen that gives an oxygen partial pressure (PO_2) of 1.5 to 2.5 atm at the pressure of the diver. If there is a choice, 2.0 atm is preferred. At pressures of 60 fsw or less pure oxygen is used as "treatment mix;" this gives a PO_2 of 2.8 atm at 60 fsw.

Air is defined as a nitrogen-oxygen mixture having an oxygen fraction of 0.205 to 0.22 (20.5 to 22.0%).

4. Chamber atmosphere

During breathing of treatment mix, as soon as practical the chamber atmosphere is **switched** to the composition of **air.** This can be done by adding oxygen during compression, or by compressing with air and then flushing with oxygen after arriving at the first treatment step. Air is used during decompressions also.

When a "hold" of several hours is called for in the chart the atmosphere should be switched back to 0.3 to 0.5 atm PO_2, called **"normoxic"** in the charts. This is performed by flushing with nitrogen or a low-oxygen mix. It is solely for prevention of oxygen toxicity; at the discretion of the Duty Doctor the air atmosphere may be maintained during treatment holds.

During the breathing of **high oxygen mixtures** it is important not to allow the oxygen level in the habitat to go above the **fire safety limit.** This limit is based on oxygen percentage (or fraction; not partial pressure) and should be not exceed any more than necessary the oxygen composition of

air (21%; some standards allow 23%). Unless an "overboard dump system" is available the easiest way to use oxygen and still maintain a fire safe atmosphere is to have plenty of **nitrogen** available for dilution. The section on fire safety in the Underwater Handbook (Shilling, et al., 1976, pp. 646-664) gives additional information.

5. Supportive therapy

Serious and life-threatening DCS and embolism call for **fluid replacement** and sometimes other **drugs**, which should be on hand in the habitat on all missions. The choice of drugs and fluids is made by the Facility Doctor, and it is presumed that the method of administering them, the supplies to have on hand, and training of personnel, have been prearranged. It is considered important not to let a DCS/embolism patient become **dehydrated.**

A low dose of **aspirin** (one 5-grain tablet every 12 hr) as an anti-inflammatory agent is recommended in all cases. Starting an **iv infusion** for fluids and drugs is recommended early in the treatment of severe cases.

6. Use of heliox

If the Duty Doctor and the topside team are **experienced** in the use of heliox for nitrox saturation treatment, the Doctor may call for a switch to heliox for difficult cases. The primary hazard here is deep tissue isobaric counterdiffusion, which can cause growth of existing bubbles.

D. Returning to storage or saturation decompression

1. Return tables

An essential part of any treatment is the procedure for **returning** to either the starting point--the habitat storage depth--or the surface. Two tables are included for this purpose, the RN71 and the "Contingency Return." The return tables require that the diver breathe **air**; they are found after the treatment charts, in Section M.

2. Hold and use regular table

At the discretion of the Duty Doctor there are options for ascending to the surface using a standard Repex saturation decompression table after a specified holding period of at least 24 or 48 hours at treatment depth. A table for a deeper depth may be used for added conservatism; where a deeper table is specified, if there is no deeper table the deepest one available (e.g., 120 fsw) should be used.

Where circumstances are right this option provides a possibility for the **other divers** on the mission to **continue working**, with the treated diver remaining in the habitat or within the oxygen window until the final decompression.

E. Role of other divers during a treatment

1. Decompression of companion divers

Any other divers following the treatment profiles will be **properly decompressed** as long as they breathe the prescribed chamber atmosphere. No treatment mix or oxygen breathing is needed.

In the event of a USN Table 6 or similar treatment after surfacing from saturation decompression, if a diver from the same saturation serves as a tender he should breathe all the oxygen called for in the treatment table.

2. Carrying on with the mission

If the habitat system has a lock permitting divers to **lock out** while the treatment chamber is pressurized to deeper than ambient pressure and other operational factors are under control, the other divers can continue to make excursions. They should follow the procedures for change of **habitat depth**, and consider that their new storage depth is now the present pressure of the habitat during treatment. Depending on the habitat pressure, it might be necessary to make an **ascending excursion** in order to lock out, and this may require a wait of 24 hours after the end of the last descending excursion (IV.C).

F. Resuming diving

In keeping with standard practice these procedures consider that it is all right for divers **successfully** and **promptly** treated for **pain-only DCS** to **resume** excursing during the same mission, after a one-day break. The criterion for prompt relief is the time, i.e., the number of cycles of breathing treatment mix, for complete relief. The procedures allow a diver completely cured in less than 2 full cycles (left path, EX1) to resume diving during the mission; if cure takes between 2 and 4 cycles (center path, EX1), the Duty Doctor may approve the return to diving. A **full 24-hour** break is required before diving again.

If a diver develops and is successfully treated for **serious** DCS it is not necessary to abort the mission and decompress the entire crew. The treated diver, however, is not allowed to excurse outside of the oxygen window pressure range for the remainder of the current mission.

G. Performing a normal treatment

This section provides instructions to go with the charts in performing a treatment; additional details are given above in the earlier description of the procedures, Section VI.C. The treatment charts follow at the end of the chapter.

1. Choosing the chart

Use the **operational situation** at the time DCS/embolism occurs and the **symptoms** to choose the treatment as is summarized in Chart TMT, Section VI.K. The flow charts are:

- Flow Chart **TMT**, for **selecting** the treatment to use.
- Treatment/flow Chart **ASC**, for use with **ascending excursions.**
- Treatment/flow Chart **ISD**, for an inadvertently **surfaced diver.**

The treatment charts are found in Section VI.L:

- Treatment Chart **EX1**, for pain-only DCS or significant skin symptoms occurring during or following an excursion.
- Treatment Chart **EX2**, for serious, neurological, or Type II symptoms or embolism during or following an excursion, or for suspected embolism in saturation decompression.
- Treatment Chart **SAT1**, for pain-only and significant skin DCS occurring during saturation decompression.
- Treatment Chart **SAT2**, for serious or Type II DCS occurring during saturation decompression.

The standard USN Table 6 is recommended for treating DCS occurring after surfacing (VI.I).

2. Compression steps and cycles

As soon as possible after DCS is recognized, begin compression and breathing of treatment mix. **Recompress** in defined steps, with a 20 minute cycle of **treatment mix** and a 5 minute **evaluation** period at each step. **Continue** these steps until the diver is completely relieved of symptoms or has been recompressed to the specified limit. For **serious** symptoms carry the compression **one step (10 fsw) deeper** than the depth of relief and complete the 6 cycles. (See VI.C.3 for mix definitions.)

3. Chamber atmosphere

Switch chamber atmosphere to the composition of **air** as soon as practical after the initiation of a treatment. Choosing appropriate compression gases can help implement this switch. Maintain oxygen/fire safety.

If the diver requires a hold and an additional session of treatment mix, convert the atmosphere to normoxic for the hold period. Switch back to air or the appropriate PO_2 for saturation decompression.

4. Evaluation and relief

Evaluate the diver's condition at **each cycle**, doing a neurological exam in the break following the first cycle (if not earlier), and again when cure seems complete. **Log** the findings and report them to the Duty Doctor.

If the neurological exam discloses **serious signs or symptoms** during a pain-only treatment that is already underway, compress the diver to the proper depth as if the serious symptoms had been noted initially. In this case it is not necessary to repeat any completed cycles.

If after the required recompression and first 6 cycles there is no improvement the normal DCS case should be **reevaluated** in consultation with the Duty Doctor to consider if the symptoms might be due to something other than DCS. The chart allows the Doctor to call for a return (decompression) to storage and possibly to diving if the problem turns out not to have been DCS. If it is DCS, further treatment is called for. **If in doubt,** continue to **treat** for DCS.

The charts may call for a 12-hr hold and 6 more cycles of treatment mix. The hold is to allow the diver to recover enough to tolerate the additional oxygen. If oxygen breathing is well tolerated, the Duty Doctor may add cycles while holding or during ascent, and in an intractable case may consider further compression.

5. DCS in the water

For DCS occurring on a stop in the water, **complete all inwater stops** and return to the habitat, then immediately begin the treatment from storage depth. Treat such a case as for **serious symptoms**, compressing 60 fsw or 1/2 the distance of the excursion. **Consult** the Duty Doctor.

6. Recurrence

If symptoms recur, **reenter** the chart from the present position with the new symptoms. After a 6-cycle treatment the depth of the original excursion is no longer relevant. **Consult** the Duty Doctor.

7. Pulmonary or chronic oxygen toxicity

If during a treatment the diver being treated begins to develop signs or symptoms of **oxygen toxicity**, try to finish any required cycles, then convert the atmosphere to normoxic (0.3 to 0.5 PO_2) and wait 12 hours or until symptoms are relieved enough to continue. Restore the decompression atmosphere (air) and proceed, or use the "Contingency Return" table at 0.5 or 0.6 atm. **Consult** the Duty Doctor.

8. Involving the Duty Doctor

The chart calls for two levels of **involvement** of the Duty Doctor. For a pain-only treatment **contact** the doctor after the neurological exam. For a treatment with serious symptoms at any time, or when relief is not complete in 4 cycles, or when DCS occurs in the water, or on recurrence of symptoms, or in the case of oxygen toxicity, **consult** the Doctor for guidance during the treatment.

H. DCS in ascending excursions

If DCS symptoms other than mild itching occur during an ascending excursion the diver should return to the habitat at once. If symptoms resolve during descent or immediately on reaching the habitat, the diver should breathe 2 cycles of treatment mix at storage depth; details of the symptoms and this treatment should be logged. This diver is not allowed to make another ascending excursion for 24 hours.

If **any DCS** remains after returning to storage depth, an **EX** treatment chart should be used, depending on the symptoms.

I. DCS at the surface following saturation decompression

Treat DCS occurring **at the surface** after reaching surface pressure at the end of a saturation decompression by using standard surface-oriented procedures, namely **USN Table 6.** Try to get a fresh diver as tender; if a diver just decompressed is tender he should breathe all oxygen called for.

If the divers are still in the habitat awaiting a swim-up, use SAT1 or SAT2.

J. Treatment of a "surfaced" saturated diver in the shore/surface facility

The possibility always exists that a habitat diver may ascend to the **surface.** Depending on the saturation depth and the duration of time the diver is at reduced pressure, this may be of no consequence and may even be

part of an operational plan, but for divers saturated at depths greater than about 60 fsw an **unplanned surfacing** can be a serious emergency. The degree of hazard increases with both saturation depth and time at the surface or at reduced pressure.

Local procedures based on habitat depth, time required to reach the shore/surface chamber, and local considerations should direct whether primary treatment is to be in the habitat or the surface facility. The procedure give here is for **unplanned** surfacing; **planned** ascents may be made to the surface within the allowable ranges of the ascending excursion tables (see Chapter V).

The diver who has surfaced **inadvertently** should be recompressed as soon as possible to 30 fsw deeper than his most recent storage pressure and treated according to the history and any signs or symptoms. The procedures, somewhat arbitrarily, divide treatment intensity according to an estimated degree of decompression stress or risk. An estimate of the risks involved is given in Table VI-1. The flow chart for this is Chart ISD.

Table VI-1. Inadvertent surfacing: Estimate of moderate risk threshold

If a diver who has surfaced inadvertently returns to saturation within the time indicated the risk of unmanageable DCS is small.

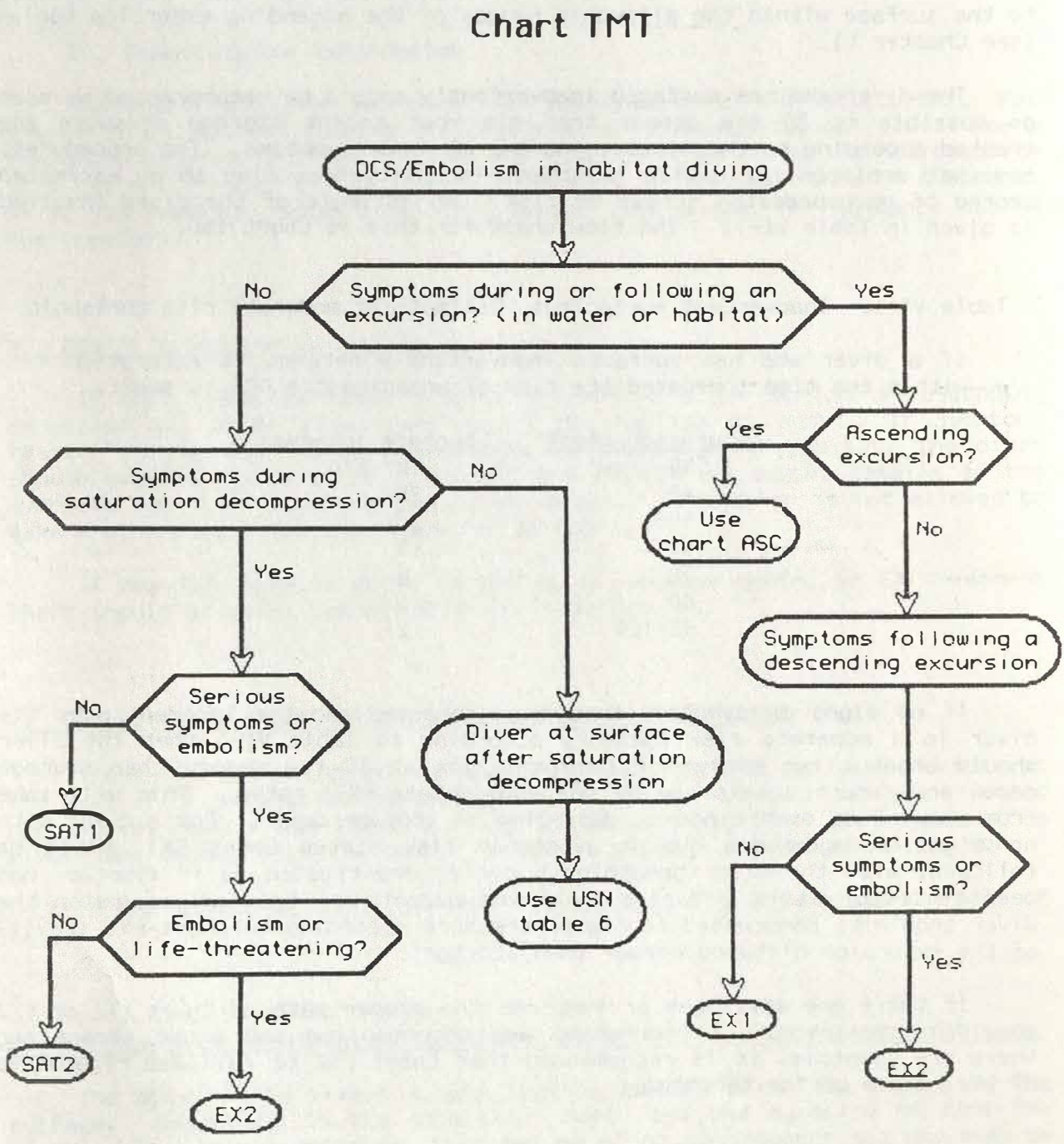
Saturation depth	Surface interval
30 fsw	70 min
40	35
50	20
60	17
70	8
80	5
90-120	2

If **no signs or symptoms** have been observed and the incident puts the diver in a moderate risk category according to Table VI-1 then the diver should breathe two cycles of treatment mix at 30 fsw deeper than storage depth and return to storage by the appropriate RN71 rates. This will take from about 3 to over 8 hours, depending on storage depth. For a diver with no signs or symptoms but in a higher risk status Chart EX1 should be followed, with the diver breathing 6 cycles and treated as if symptoms had been relieved within 2 cycles. If the ascent was from an **excursion** the diver should be compressed to higher pressure according to Chart EX1 (to 1/3 of the excursion distance deeper than storage).

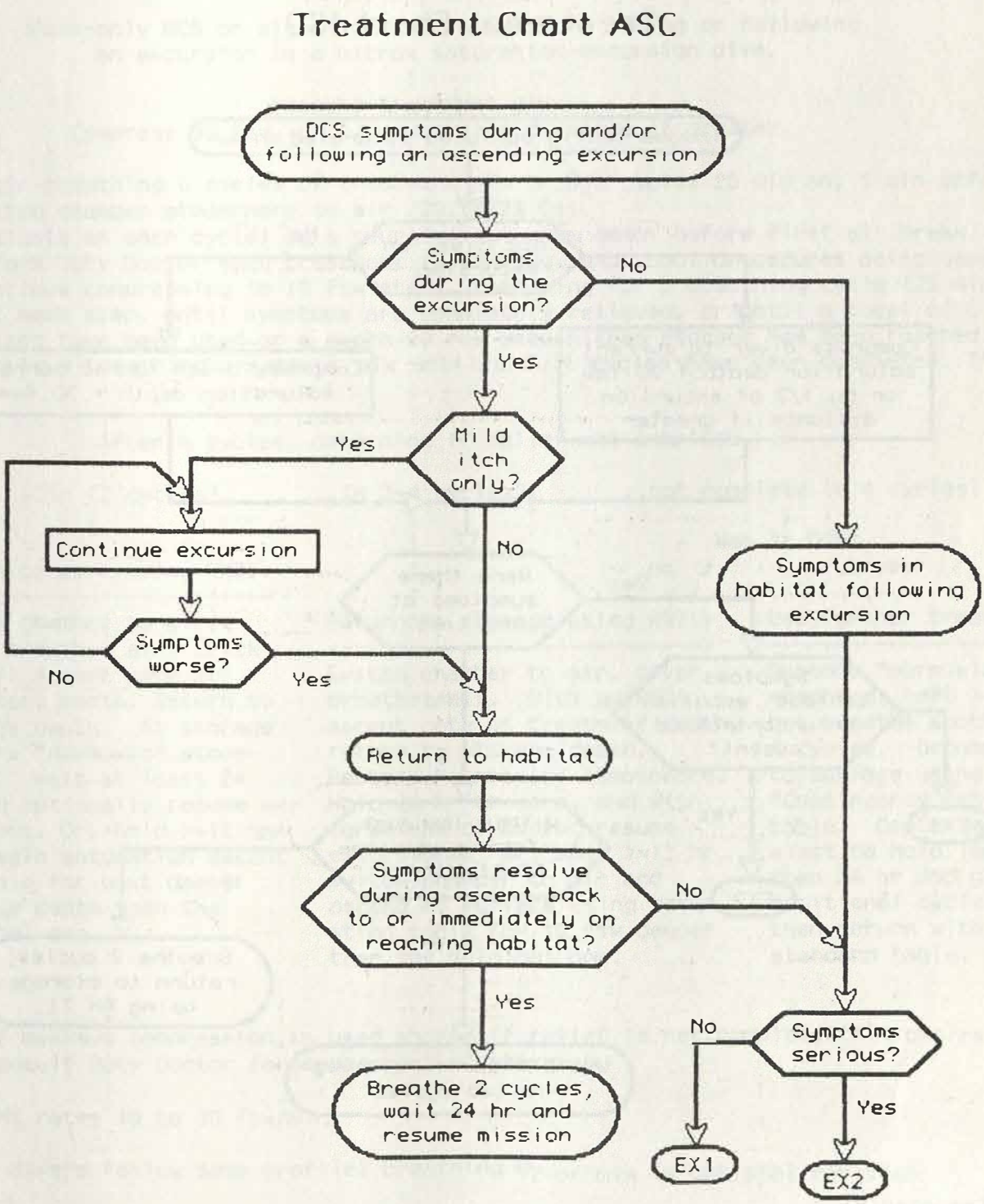
If there are **any** signs or symptoms the **proper path** on Chart EX1 or EX2 should be followed. If surfacing was uncontrolled and under **stress** and there are symptoms, it is recommended that Chart EX2 be followed regardless of the nature of the symptoms.

K. Flow charts

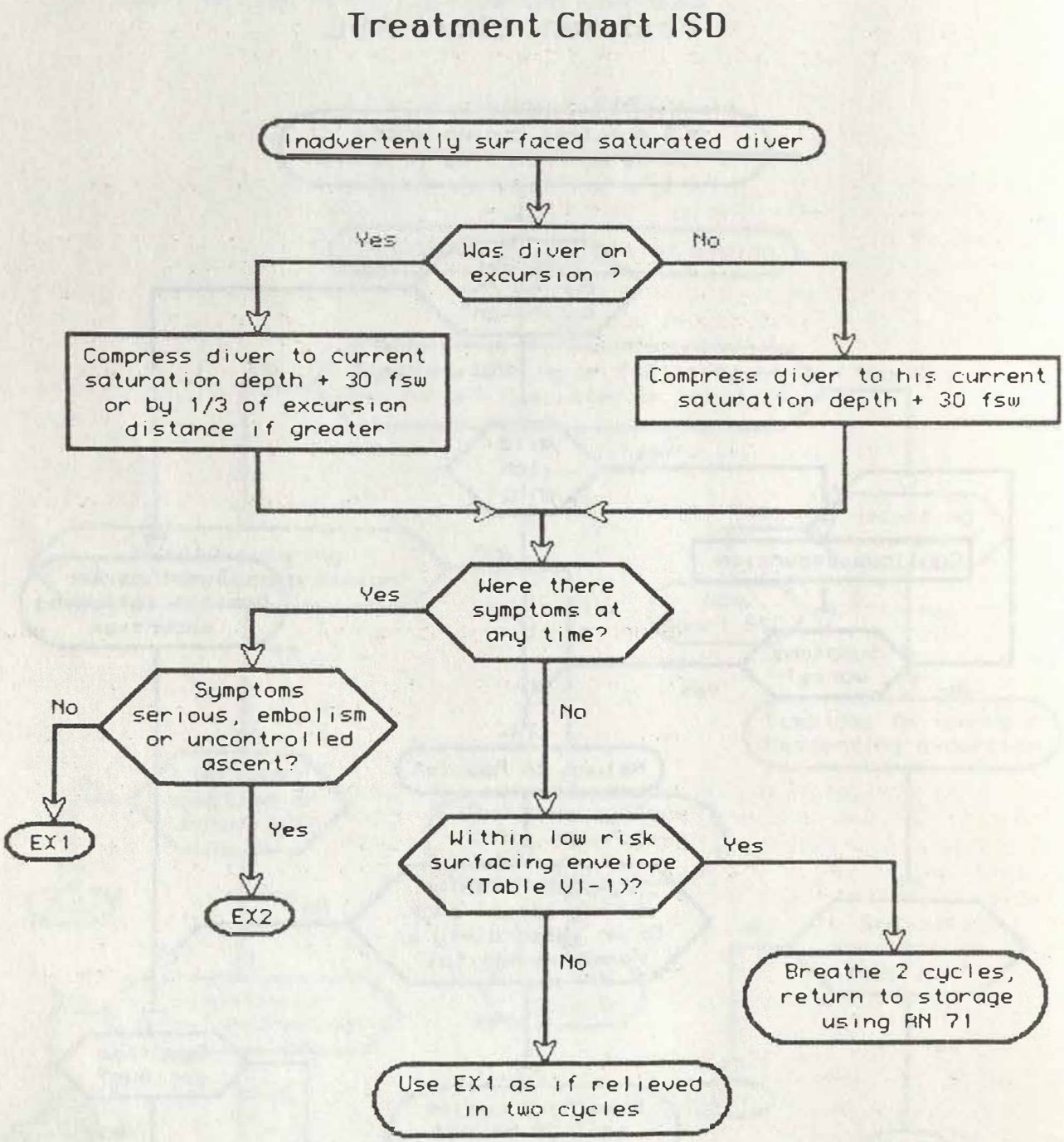
1. Chart TMT for selecting treatment procedure



2. **Treatment Chart ASC for ascending excursions**



3. **Treatment Chart ISD for an inadvertently surfaced diver**



See also VI.J.

L. Treatment charts

1. Treatment chart EX1 for P-O DCS following a habitat excursion

TREATMENT CHART "EX1"

Pain-only DCS or significant skin symptoms during or following an excursion in a nitrox saturation-excursion dive.

Breathe treatment mix.
Compress 30 fsw, or 1/3 excursion distance if greater.

- Begin breathing 6 cycles of treatment mix or O_2; cycles 20 min on, 5 min off.
- Switch chamber atmosphere to air (20.5-22% O_2).
- Evaluate at each cycle; do a neurological exam on or before first air break.
- Inform Duty Doctor that treatment is underway and about procedures being used. **
- Continue compressing in 10 fsw steps, remaining for 1 breathing cycle (25 min) at each step, until symptoms are completely relieved, or until a total of 6 steps have been used or a depth 80 fsw deeper than storage has been reached.
- Continue breathing treatment mix until 6 full cycles have been completed. **

After 6 cycles, determine if relief was complete...

..in <2 cycles?	..in 2-4 cycles?	..not complete in 4 cycles? **
		Was it DCS?
Return to work using RN71:		no / \ yes
Switch chamber to air, diver breathes air. Pick up RN71 ascent rate at treatment depth. Return to storage depth. At storage restore "normoxic" atmosphere. Wait at least 24 hr and optionally resume excursions. Or, hold >=12 hr and begin saturation ascent on table for next deeper storage depth than the original one.	Return to storage using RN71: Switch chamber to air, diver breathes air. Pick up RN71 ascent rate at treatment depth, return to storage depth. Restore "normoxic" atmosphere. Hold 24 hr or more, and with agreement of Doctor resume excursions. Or, hold >=12 hr, switch chamber to air and ascend to surface using saturation table for 10 fsw deeper than the original one.	Use further treatment: Restore "normoxic" atmosphere, hold >=12 hr, breathe another 6 cycles. Decompress to surface using "Contingency Return" table. Doctor may elect to hold longer than 24 hr and give additional cycles, then return with a standard table.

** If maximum compression is used and/or if relief is not complete in 4 cycles consult Duty Doctor for management of the case.

Descent rates 10 to 30 fsw/min.

Other divers follow same profile; breathing O_2 or mix is optional for them.

Chamber should be switched to air for all "return" ascents, back to PO_2 of 0.3-0.5 atm (called "normoxic" here) for holds.

2. Treatment chart EX2 for serious DCS following a habitat excursion

TREATMENT CHART "EX2"

Serious, neurological, or Type II DCS or embolism during or following an excursion in a nitrox saturation-excursion dive, or suspected embolism in a nitrox saturation decompression.

Breathe treatment mix.
Compress 60 fsw or 1/2 excursion distance if greater.

- Begin breathing 6 cycles of treatment mix or O_2; cycles 20 min on, 5 min off.
- Switch chamber atmosphere to air (20.5-22% O_2).
- Consult Duty Doctor for management of the case.
- Evaluate at each cycle; do a neurological exam on or before first air break.
- Compress in 10 fsw steps, remaining for 1 cycle (25 min) at each step.
- Continue compression steps until depth of relief, complete that cycle and compress one additional 10 fsw step. If symptoms are not relieved stop at a total of 6 compression steps.
- Continue breathing treatment mix until 6 full cycles have been completed.

After 6 cycles, determine if relief was complete in first 2 cycles.

yes	no*
Retire diver from mission:	**Give further treatment:**
Return to storage depth using RN71 return. At storage depth restore "normoxic" atmosphere, hold >= 24 hr, switch to air, decompress to surface using "Contingency Return" table. Ascent may be delayed so other divers can continue mission. After 48 hr Doctor may elect to ascend with table for depth 10 fsw deeper than original storage.	Restore "normoxic" atmosphere hold >=12 hr, breathe another 6 cycles. Decompress to surface using "Contingency Return" table. Doctor may elect to hold longer than 24 hr and give additional cycles. After 48 hr and with relief complete, Doctor may elect to ascend on standard table for depth 10 fsw deeper.

Descent rates 10 to 30 fsw/min.

Other divers follow same profile; breathing O_2 or mix is optional for them.

Chamber should be switched to air for all "return" ascents, back to PO_2 of 0.3-0.5 atm (called "normoxic" here) for holds.

After 12 or more hours following an O_2 session of 6 cycles Duty Doctor may call for breathing of 4 to 6 more cycles during ascent back to storage.

* If Doctor decides case was not DCS use center path on Chart EX1.

3. Treatment chart SAT1 for P-O DCS in nitrox saturation decompression

TREATMENT CHART "SAT1"

Pain-only DCS or significant skin symptoms occurring during decompression from a nitrox saturation or saturation-excursion dive.

Breathe O_2 (or treatment mix).
Compress to 10 fsw deeper than onset depth.

- Begin breathing 6 cycles of treatment mix or O_2; cycles 20 min on, 5 min off.
- Switch chamber atmosphere to air (20.5-22% O_2).
- Evaluate at each cycle; do a neurological exam on or before first air break.
- Inform Duty Doctor that treatment is underway and about procedures being used.**
- Continue compressing in 10 fsw steps, remaining for 1 breathing cycle (25 min) at each step, until symptoms are completely relieved, or until a total of 6 steps have been used or a depth 60 fsw deeper than storage has been reached.
- Continue breathing treatment mix until 6 full cycles have been completed. **

After 6 cycles, determine if relief was complete...

..in <2 cycles?	..in 2-4 cycles?	..not complete in 4 cycles? **
		Was it DCS?
		no / yes
Resume decompression:	**Resume decompression:**	**Use further treatment:**
Resume saturation decompression from treatment depth. Use rates for storage depth next deeper than original. Retain air atmosphere or set correct PO_2 according to the table.	Resume saturation decompression from treatment depth. Use rates for storage depth 10 fsw deeper than original storage depth. Retain air atmosphere or set correct PO_2 according to table.	Restore normoxic atmosphere, hold >=12 hr, breathe another 6 cycles. Decompress to surface using "Contingency Return" table. Doctor may choose to hold here longer than 24 hr and/or give additional cycles, and may then return with a standard table.

** If maximum compression is used and/or if relief is not complete in 4 cycles consult Doctor for management of the case.

Descent rates 10 to 30 fsw/min.

Other divers follow same profile; breathing O_2 or mix is optional for them.

Chamber should be switched to air for "return" ascents, back to PO_2 of 0.3-0.5 atm (called "normoxic" here) for holds.

4. Treatment chart SAT2 for serious DCS in nitrox saturation decompression

TREATMENT CHART "SAT2"

Serious, neurological, or Type II DCS occurring during decompression from a nitrox saturation or saturation-excursion dive.

Breathe treatment mix.
Compress to 30 fsw deeper than onset depth

- Begin breathing 6 cycles of treatment mix or O_2; cycles 20 min on, 5 min off.
- Switch chamber atmosphere to air (20.5-22% O_2).
- Consult Duty Doctor for management of the case.
- Evaluate at each cycle; do a neurological exam on or before first air break.
- Continue compression steps until depth of relief, complete that cycle and compress one additional 10 fsw step. If symptoms are not relieved stop at a total of 6 compression steps (+80 fsw).
- Continue breathing treatment mix until 6 full cycles have been completed.

After 6 cycles, determine if relief was complete in first 2 cycles?

yes	no
Resume decompression:	**Give further treatment:**
Resume saturation decompression from treatment depth. Use rates for storage depth 10 fsw deeper than original. Retain air atmosphere or set PO_2 according to table.	Restore "normoxic" atmosphere, hold >=12 hr, breathe another 6 cycles. Decompress to surface using "Contingency Return" table. Doctor may choose to hold here longer than 24 hr and give additional cycles, and may return to surface using a standard table.

Descent rates 10 to 30 fsw/min.

Other divers follow same profile; breathing O_2 or mix is optional for them.

Chamber should be switched to air for all "return" ascents, back to PO_2 of 0.3-0.5 atm (called "normoxic" here) for holds.

After 12 or more hours following an O_2 session of 6 cycles Duty Doctor may call for breathing of 4 to 6 more cycles during ascent back to storage.

M. "Return" tables

The following are the "return" tables called for in the charts.

1. RN71 return

Description: The table here designated "RN71" is derived from the Royal British Navy "Table 71, modified air recompression therapy" (Ministry of Defence, 1976). It provides a relatively efficient means of **returning to storage depth** after a treatment. Companion divers who do not breathe treatment mix but breathe air throughout a treatment profile as specified in the charts can be safely decompressed back to storage depth with RN71.

When to use: For return to storage depth when diver with **normal DCS** symptoms is relieved **promptly** (within the first 2 cycles of breathing treatment mix), or when a diver with serious symptoms and recompressed 60 fsw or more is completely relieved in **4 cycles**. This table as used here is for **returning to storage**, not for ascent to the surface.

Gases: The RN71 return table is designed for **air**. If because of oxygen toxicity or the diver being treated cannot tolerate air breathing, switch chamber atmosphere to "normoxic" (0.3 to 0.5 atm) and hold for at least 12 hours or until the diver is able to proceed.

Procedure: The table gives both stop times and rates to use for the depths to be passed through. The table may be started at any depth between 30 and 230 fsw. Use the **rates** indicated when passing through **each depth range** in the same way as the Repex saturation decompression tables. **Begin** at treatment depth; ascend to the next even 5-fsw stop depth (ascend no more than 5 fsw) in 1 min. If deeper than 205 fsw ascend to 205 at 1 fsw/min. If the **staged** method is used, stay at the first depth for the stop time indicated, then ascend to the next stop in one minute and remain there for the stop time given for that depth, and so on. If using ***linear*** ascent ("continuous bleed") take the first step of up to 5 fsw in one min, then begin ascent at the indicated "rrate" in minutes per foot; using that ascent "rrate" it should take the same time to ascend each 5 fsw stage as the stop time given. The rrates at a stop apply from that stop to the next.

Table VI-2. **RN71 return table** 87Jul07

Stop Depth fsw	Stop time min	RRate min/ fsw	Total time min	Stop Depth fsw	Stop time min	RRate min/ fsw	Total time min	Stop Depth fsw	Stop time min	RRate min/ fsw	Total time min
230-205	--	1	25	150	30	6	280	90	60	12	840
205	15	3	40	145	30	6	310	85	60	12	900
200	15	3	55	140	30	6	340	80	60	12	960
195	15	3	70	135	30	6	370	75	60	12	1020
190	15	3	85	130	50	10	420	70	60	12	1080
185	15	3	100	125	50	10	470	65	100	20	1180
180	15	3	115	120	50	10	520	60	100	20	1280
175	15	3	130	115	50	10	570	55	100	20	1380
170	30	6	160	110	50	10	620	50	100	20	1480
165	30	6	190	105	50	10	670	45	100	20	1580
160	30	6	220	100	50	10	720	40	100	20	1680
155	30	6	250	95	60	12	780	35	200	40	1880

2. **Contingency return**

When to use: For those cases that do **not** result in **complete relief** within 4 cycles and require a 12-hr hold and another session of treatment mix. Or, it can be used for final decompression in difficult cases.

Procedure: These tables are to be used in the **same** manner as the **Repex** saturation tables. Enter the table at current depth, ascend in 1 minute to the next stop depth, remain at that depth for the stop time given, ascend to the next stop, and so on.

Gases: Select the gas **appropriate** to the diver's tolerance; CPTD values are given for each stop (except for 0.5, where all are zero). Air should not be used for this table deeper than 105 fsw. Note that the 0.6 table becomes air at 60 fsw and the 0.5 at 45 fsw. Switch chamber atmosphere before beginning ascent. To use another oxygen level change atmosphere on arriving at a stop and begin using the new times at that stop.

Maximum depth: In the unlikely event that a diver being treated is deeper than 150 fsw and requires the Contingency Return table, use RN71 to ascend to 150 fsw and follow the Contingency Return table thereafter.

Table VI-3. **Contingency return table** k = 2.3100 87Jul07

	AIR				0.6 PO_2				0.5 PO_2		
Depth fsw	Stop Time min	RRate min/ fsw	Time togo min	CPTD at stop	Stop Time min	RRate min/ fsw	Time togo min	CPTD at stop	Stop Time min	RRate min/ fsw	Time togo min
150					220	44	8040	58	265	53	8950
145					220	44	7820	58	265	53	8685
140					220	44	7600	58	265	53	8420
135					220	44	7380	58	265	53	8155
130					220	44	7160	58	265	53	7890
125					220	44	6940	58	265	53	7625
120					220	44	6720	58	265	53	7360
115					220	44	6500	58	265	53	7095
110					220	44	6280	58	265	53	6830
105	150	30	5650	119	220	44	6060	58	265	53	6565
100	155	31	5500	114	220	44	5840	58	265	53	6300
95	160	32	5345	109	220	44	5620	58	265	53	6035
90	170	34	5185	106	220	44	5400	58	265	53	5770
85	175	35	5015	99	220	44	5180	58	265	53	5505
80	185	37	4840	93	220	44	4960	58	265	53	5240
75	190	38	4655	84	220	44	4740	58	265	53	4975
70	200	40	4465	76	220	44	4520	58	265	53	4710
65	210	42	4265	66	220	44	4300	58	265	53	4445
60	220	44	4055	54	220	44	4080	54	265	53	4180
55	235	47	3835	40	235	47	3860	40	265	53	3915
50	250	50	3600	23	250	50	3625	23	265	53	3650
45	265	53	3350	0	265	53	3375	0	265	53	3385
40	280	56	3085	0	285	57	3110	0	285	57	3120
35	300	60	2805	0	305	61	2825	0	305	61	2835
30	325	65	2505	0	325	65	2520	0	330	66	2530
25	355	71	2180	0	355	71	2195	0	355	71	2200
20	385	77	1825	0	390	78	1840	0	390	78	1845
15	425	85	1440	0	430	86	1450	0	430	86	1455
10	475	95	1015	0	480	96	1020	0	480	96	1025
5	540	108	540	0	540	108	540	0	545	109	545

VII.
SUMMARY INSTRUCTIONS AND TABLES

A. Summary instructions

This section covers the **essentials** of using the tables but not all the details, and does not define terms. The user should be familiar with the full instructions and not rely solely on these.

1. **GENERAL**

a. Compress to storage depth at any convenient and comfortable rate.

b. Use the set of table pages for the range that includes the storage depth.

c. Breathing air, divers may operate without restriction between the storage depth and the deeper "oxygen window" depth; except when following within 24 hr of a descending excursion, this may be extended upward (shallower) to the no-limit ascending excursion depth.

d. Dive limits: Not over 12 hr deeper than O_2 window depth for any 24 hr period.
No more than 14 no-stop or 4 one-stop excursions without a 16-hr break (1 one-stop = 3 no-stops).
Daily oxygen exposure limits given in Table VII-4.

e. Unless specified otherwise, for interpolations use the most conservative choice. For excursions this will be the shorter allowable excursion time, and for saturation decompression it will be the longer decompression profile.

2. **ASCENDING EXCURSIONS**

a. Wait 24 hr after a descending excursion before doing an ascending excursion. If <24 hr, use depth of deepest descending excursion as "storage depth" for choosing ascending excursion time limit. Submaximal rules can be used to reduce this wait (IV.F.3), but not below 12 hours.

b. Wait 4 hr after an ascending excursion before doing another ascending excursion.

c. Times are for the entire ascending excursion, from beginning to end. That is, timing is from beginning of ascent until return to storage.

d. Rates 10-30 fsw/min ascent and 30-75 fsw/min descent.

3. **OXYGEN WINDOW EXCURSIONS**

a. The O_2 window depth is given on each table page pair as a differential deeper than storage, in fsw.

b. Unlimited time (except for 12 hr limit) is allowed in the oxygen window. Optionally, no-stop descending excursions can be timed to and from the oxygen window; stop depths for one-stop excursions are based on storage depth only.

4. **NO-STOP DESCENDING EXCURSIONS**

a. Table entries are allowable times for excursions to depths shown at top of each column. Repetitive status selection criteria use the **number** of the dive in a sequence, and the **interval** since the end of the last excursion.

b. A **new** excursion sequence ("1st" excursion) starts after **16 hours** at storage depth or within oxygen window. All excursions after the 2nd are "3+."

c. Intervals are from **end** of preceding excursion. Excursions <1/2 hr after preceding excursion are considered a **continuation** of it, including time spent at storage depth.

d. Descent **rates** are optional; ascent 10-60 fsw/min, 30 preferred.

e. No-stop excursions are **timed** from beginning descent to beginning ascent.

f. Adjustment for a **postsubmaximal excursion**, where the preceding excursion is less than the full allowed time (i.e., is submaximal); the adjustment is a reduction in the **penalty** of the postsubmaximal excursion. Times are from the tables.

adjusted t = t:min + {(t:max - t:min) * (t:allowed - t:used) / t:allowed}

where: t:max = time that would be allowed had submaximal excursion not taken place at all

t:min = time that would be allowed on postsubmaximal excursion had submaximal excursion been full

t:allowed and t:used apply to the submaximal excursion.

5. **ONE-STOP EXCURSIONS**

a. These excursions use a **stop** for a defined time at a point ideally **15 fsw deeper** than the storage depth, with a range of 10-20 fsw acceptable.

b. All "one-stop" excursions also require a **2-minute stop** 10 fsw deeper than the selected stop depth.

c. Use the table for the appropriate **interval** after a preceding dive, 2-16 hr or >16 hr. A one-stop excursion must be at **least 2 hr** after the preceding excursion.

d. Any dive **following** a one-stop becomes a "3+" in the sequence, unless more than 16 hours have elapsed.

e. **Select** the depth next deeper than the desired excursion depth. The stop time is given to the right of the bottom time that is next longer than the time used for the excursion.

f. **Rates** are as for no-stop excursions; descend at a convenient rate, ascend at 10-60 fsw/min (30 fsw/min preferred).

g. **Timing** of bottom time is from beginning of descent to end of primary stop.

h. There is **no "submaximal"** modification for one-stop excursions.

6. **SATURATION DECOMPRESSION**

a. If there have been no excursions **deeper** than the oxygen window during the last 36 hours use the "main" table on the right.

b. **Change** the habitat atmosphere to air (20.5-22.0% O_2) as soon as practical, preferably before decompression commences.

c. For the **main** table, without excursions, **begin** by ascending to the depth of the first stop, ideally in one minute but any moderate rate will do. The first ascent will be 5 fsw or less.

d. If any diver in the group to be decompressed has **excursed** outside the oxygen window in the last **36 hours** use the **precursory** table on the left. Select the **starting depth** from the 2-line chart for the deepest excursion any time during the last 36 hours; that depth (or the next deeper) becomes the first full stop on the precursory table.

e. Divers on the **last excursion** return to the habitat, and the entire team is recompressed to the starting depth. Start compressing at a rate of 10 to 30 fsw/min within 5 minutes. Begin **timing** the first stop when all divers are at **starting depth.** Follow the precursory table until it joins the main table; the times are continuous. If a closed bell is used, the habitat is compressed to the starting depth to meet the divers returning from the last excursion.

f. Begin **timing** other stops at the moment ascent to that stop begins.

g. The breathing gas is **air** for all stops in all tables from 100 fsw and shallower. The 4 deeper tables have a **break** at a PO_2 of 0.5 for 4 stops. Change to 0.5 PO_2 after beginning the break, and back to air before the beginning of the next air stop. No oxygen breathing by mask is used.

h. No sleep stops are used. Divers are advised to **get up and stretch** for 2 minutes every 2 hours during sleep.

i. **Linear** ascent may be used instead of stops. **Begin** by a step ascent to the first stop depth, then begin the indicated linear ascent rate (or "rrate") for that 5-fsw interval. **Continue** ascent using the rate for each step, passing the stop depth at the "time to go" given in the table, and ending at the surface at the time for the end of the last stop.

j. **Deviations:** If during ascent it is noted that ascent is **too slow**, continue at prescribed rate from that point (do not catch up). If it is noted that ascent is **too fast**, recompress to the proper depth for the prevailing time and continue ascent at the proper rate for that depth.

k. Divers are not to travel by aircraft within 48 hours after completing a nitrox saturation decompression; >72 hours is preferable.

7. O_2 EXPOSURE LIMITS

a. Excursion tables to deeper than 200 fsw are limited in order to reduce oxygen toxicity. Maximum times are 29 min at 220 fsw and 16 min at 240 fsw.

b. Chronic oxygen toxicity can be prevented by limiting average daily exposures according to the duration of the mission. See Chart VII-4.

c. The oxygen exposure of the saturation decompression should be included in the overall dive plan. The saturation decompression tables from 100-104 fsw and deeper use a period of 4 stops, about 12 hr, of low oxygen (PO_2=0.5 atm) early in the decompression.

B. Reference materials

The following section contains reference tables giving maximum times allowed using the no-stop and one-stop procedures, oxygen dose information, a listing of the saturation decompression tables with times, and conversion tables between minutes and hours and minutes.

Table VII-1. Allowable no-stop excursions

Table shows the maximum allowable no-stop excursions for each excursion depth from each saturation storage depth range. These are the times for the first dive in a new sequence, after an interval of 16 hr or more in the habitat. Times not shown to the left or below "480" are for a full 480 minutes.

Storage Depth	Excursion Depth, first excursion after 16 hr interval												
	65	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
30-34		480	370	216	163	111	87	73	61	49	42	36	33
35-39			480	439	256	183	132	99	80	69	55	46	40
40-44	. . . . .			480	480	325	208	161	114	90	75	64	51
45-49						480	395	243	179	135	101	83	71
50-54	. . . . .						480	455	296	201	158	116	92
55-59								480	480	364	231	175	138
60-64	. . . . .									480	420	282	199
65-69											480	465	324
70-74	. . . . .											480	480
75-79													480

Storage Depth	Excursion Depth, first excursion after 16 hr interval												
	130	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
30-34	29	27	24	21	19	18	15	12	10	09	08	06	05
35-39	35	32	29	26	24	21	19	15	12	10	09	07	06
40-44	44	38	34	31	28	26	24	19	16	12	10	08	07
45-49	58	48	42	37	33	30	28	23	19	16	13	09	07
50-54	77	67	54	45	40	35	32	27	23	19	16	11	08
55-59	104	85	73	61	50	43	38	31	27	23	19	13	10
60-64	159	119	94	79	69	56	47	37	31	26	23	16	11
65-69	214	167	128	99	83	71	59	43	34	29	25	18	12
70-74	358	231	176	139	105	86	74	51	39	32	27	20	14
75-79	480	386	253	187	151	111	90	66	46	36	30	23	16
80-84		480	420	282	199	159	119	79	56	41	33	24	16
85-89	. . . .	480	462	324	214	167	99	71	49	38	27	16	
90-94			480	480	358	231	139	86	62	44	29	16	
95-99	. . . . .					480	386	187	111	77	54	29	16
100-104							480	282	159	94	69	29	16
105-109	. . . . .						480	463	214	128	83	29	16
110-114								480	358	176	105	29	16
115-120	. . . . .								480	253	151	29	16

Table VII-2. Allowable one-stop excursions

An increase in bottom time is allowed by using a single decompression stop 10 to 20 feet deeper than the habitat. These are designed to be used with a "way station", but can be water stops if operational conditions permit. An additional 2-minute water stop 10 feet below the way station is required for all "one-stop" decompressions. This 2 minutes does not vary, but the main stop time varies as a function of the allowable bottom time. The maximum allowable times using the stop are given in the table. Where no time is shown the only excursions allowed are with no-stop techniques.

Storage Depth	Excursion Depth, first excursion after 16 hr interval												
	65	70	75	80	85	90	95	100	105	110	115	120	125
30-34				240	240	240	210	180	180	150	120	120	120
35-39	. . . . .					240	240	210	180	150	150	120	120
40-44							240	240	240	210	180	180	150
45-49	. . . . .								240	240	210	180	150
50-54										240	240	240	210
55-59	. . . . .											240	240
60-64													240

Storage Depth	Excursion Depth, first excursion after 16 hr interval												
	130	135	140	145	150	155	160	170	180	190	200	220	240
30-34	90	90	60	60	45	45	45	30	30	30	20	20	16
35-39	90	90	60	60	60	60	45	45	30	30	30	20	16
40-44	150	120	120	90	90	60	60	45	45	30	30	29	16
45-49	150	120	120	90	90	90	60	60	45	45	30	29	16
50-54	180	180	150	120	120	90	90	60	45	45	30	20	16
55-59	180	240	150	120	120	90	90	60	60	45	30	29	16
60-64	240	240	210	180	150	150	150	90	60	60	45	29	16
65-69	240	240	240	210	180	180	150	120	90	60	60	29	16
70-74		240	240	240	240	210	180	150	90	60	60	29	16
75-79	. . . . .			240	240	210	210	180	120	90	60	29	16
80-84					240	240	240	210	150	120	90	29	16
85-89	. . . . .					240	240	240	180	150	120	29	16
90-94							240	240	240	180	150	29	16
95-99	. . . . .							240	240	210	150	29	16
100-104									240	210	150	29	16
105-109	. . . . .								240	240	210	29	16
110-114										240	240	29	16
115-120	. . . . .									. .	240	29	16

Table VII-3. Pulmonary toxicity doses breathing air

Shows rate of "dose" accumulation for calculating time to reach recommended daily limits. At depths below dashed line the exposure time limits are set to prevent CNS O_2 toxicity.

Depth, fsw	PO_2 breathing air	CPTU per min	CPTU per hr
45	0.50	0.00	0
50	0.53	0.09	6
55	0.56	0.17	10
60	0.59	0.24	15
65	0.62	0.31	19
70	0.66	0.38	23
75	0.69	0.44	27
80	0.72	0.50	30
85	0.75	0.56	34
90	0.78	0.62	37
95	0.81	0.68	41
100	0.85	0.74	44
105	0.88	0.79	48
110	0.91	0.85	51
115	0.94	0.90	54
120	0.97	0.96	57
125	1.01	1.01	61
130	1.04	1.06	64
135	1.07	1.11	67
140	1.10	1.16	70
145	1.13	1.22	73
150	1.16	1.27	76
155	1.20	1.32	79
160	1.23	1.37	82
170	1.29	1.46	88
180	1.36	1.56	94
190	1.42	1.66	99
200	1.48	1.75	105
220	1.61	1.94	116
240	1.74	2.12	127

Table VII-4. Allowable daily oxygen doses

This table gives guidelines for management of long-duration oxygen exposure. The daily dose predicted to be tolerable is given in the second column for various mission durations; the tolerable daily level or average daily dose is a function of how many days exposure are involved. Here "mission duration" is the number of days of exposure to increased PO_2. The 3rd column gives the total allowable exposure for the full missions defined in the first two columns. The dose covers the entire period of a dive when PO_2 is greater than 0.5 atm.

Exposure (mission) duration, (inc dec)	Avg daily dose	Total this mission
1	850	850
2	700	1400
3	620	1860
4	525	2100
5	460	2300
6	420	2520
7	380	2660
8	350	2800
9	330	2970
10	310	3100
11	300	3300
12	300	3600
13	300	3900
14	300	4200
15-30	300	n/a

Table VII-5. Saturation time summary

The chart shows summary times for the decompressions for the storage depths shown at left; the depths given are for the deepest point in each 5-fsw storage depth range. Precursory times do not progress evenly because they cover slightly different depth ranges; the precursory times shown are for the deepest possible use, and will be shorter in many cases.

	Precursory Table				Main Table				Total			
Depth	Time	Time			Time	Time			Time	Time		
fsw	HH:MM	Days	+Hrs	CPTD	HH:MM	Days	+Hrs	CPTD	HH:MM	Days	+Hrs	CPTD
30-34	16:25	0	16.4	186	19:40	0	19.7	0	36:05	1	12.1	186
35-39	15:15	0	15.3	220	22:05	0	22.1	0	37:20	1	13.3	220
40-44	14:35	0	14.6	258	24:45	1	0.8	0	39:20	1	15.3	258
45-49	13:55	0	13.9	301	27:25	1	3.4	0	41:20	1	17.3	301
50-54	13:15	0	13.3	337	30:00	1	6.0	11	43:15	1	19.3	348
55-59	12:35	0	12.6	369	32:15	1	8.3	32	44:50	1	20.8	401
60-64	11:40	0	11.7	383	34:25	1	10.4	60	46:05	1	22.1	443
65-69	10:45	0	10.8	393	36:15	1	12.3	95	47:00	1	23.0	487
70-74	9:35	0	9.6	399	38:10	1	14.2	135	47:45	1	23.8	534
75-79	10:20	0	10.3	467	41:05	1	17.1	181	51:25	2	3.4	648
80-84	9:20	0	9.3	439	44:25	1	20.4	240	53:45	2	5.8	679
85-89	9:35	0	9.6	492	47:00	1	23.0	303	56:35	2	8.6	795
90-94	8:35	0	8.6	457	50:00	2	2.0	370	58:35	2	10.6	827
95-99	8:10	0	8.2	458	53:35	2	5.6	452	61:45	2	13.8	910
100-104	8:10	0	8.2	492	66:45	2	18.8	358	74:55	3	2.9	850
105-109	7:30	0	7.5	464	76:25	3	4.4	485	83:55	3	11.9	949
110-114	6:50	0	6.8	433	85:45	3	13.8	633	92:35	3	20.6	1066
115-120	6:10	0	6.2	401	94:50	3	22.8	802	101:00	4	5.0	1203

Table VII-6. HR:MIN to MIN Conversion Table (next page)

This 2-page table converts between hours and minutes and just minutes over a 24-hour period. The hour is shown across the top, with the minutes that go with it along the left margin. Table entries are minutes.

Table VII-6. HR:MIN to MIN Conversion Table. Page 1 of 2

	Hours											
MINS:	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00
0 :	0	60	120	180	240	300	360	420	480	540	600	660
1 :	1	61	121	181	241	301	361	421	481	541	601	661
2 :	2	62	122	182	242	302	362	422	482	542	602	662
3 :	3	63	123	183	243	303	363	423	483	543	603	663
4 :	4	64	124	184	244	304	364	424	484	544	604	664
5 :	5	65	125	185	245	305	365	425	485	545	605	665
6 :	6	66	126	186	246	306	366	426	486	546	606	666
7 :	7	67	127	187	247	307	367	427	487	547	607	667
8 :	8	68	128	188	248	308	368	428	488	548	608	668
9 :	9	69	129	189	249	309	369	429	489	549	609	669
10 :	10	70	130	190	250	310	370	430	490	550	610	670
11 :	11	71	131	191	251	311	371	431	491	551	611	671
12 :	12	72	132	192	252	312	372	432	492	552	612	672
13 :	13	73	133	193	253	313	373	433	493	553	613	673
14 :	14	74	134	194	254	314	374	434	494	554	614	674
15 :	15	75	135	195	255	315	375	435	495	555	615	675
16 :	16	76	136	196	256	316	376	436	496	556	616	676
17 :	17	77	137	197	257	317	377	437	497	557	617	677
18 :	18	78	138	198	258	318	378	438	498	558	618	678
19 :	19	79	139	199	259	319	379	439	499	559	619	679
20 :	20	80	140	200	260	320	380	440	500	560	620	680
21 :	21	81	141	201	261	321	381	441	501	561	621	681
22 :	22	82	142	202	262	322	382	442	502	562	622	682
23 :	23	83	143	203	263	323	383	443	503	563	623	683
24 :	24	84	144	204	264	324	384	444	504	564	624	684
25 :	25	85	145	205	265	325	385	445	505	565	625	685
26 :	26	86	146	206	266	326	386	446	506	566	626	686
27 :	27	87	147	207	267	327	387	447	507	567	627	687
28 :	28	88	148	208	268	328	388	448	508	568	628	688
29 :	29	89	149	209	269	329	389	449	509	569	629	689
30 :	30	90	150	210	270	330	390	450	510	570	630	690
31 :	31	91	151	211	271	331	391	451	511	571	631	691
32 :	32	92	152	212	272	332	392	452	512	572	632	692
33 :	33	93	153	213	273	333	393	453	513	573	633	693
34 :	34	94	154	214	274	334	394	454	514	574	634	694
35 :	35	95	155	215	275	335	395	455	515	575	635	695
36 :	36	96	156	216	276	336	396	456	516	576	636	696
37 :	37	97	157	217	277	337	397	457	517	577	637	697
38 :	38	98	158	218	278	338	398	458	518	578	638	698
39 :	39	99	159	219	279	339	399	459	519	579	639	699
40 :	40	100	160	220	280	340	400	460	520	580	640	700
41 :	41	101	161	221	281	341	401	461	521	581	641	701
42 :	42	102	162	222	282	342	402	462	522	582	642	702
43 :	43	103	163	223	283	343	403	463	523	583	643	703
44 :	44	104	164	224	284	344	404	464	524	584	644	704
45 :	45	105	165	225	285	345	405	465	525	585	645	705
46 :	46	106	166	226	286	346	406	466	526	586	646	706
47 :	47	107	167	227	287	347	407	467	527	587	647	707
48 :	48	108	168	228	288	348	408	468	528	588	648	708
49 :	49	109	169	229	289	349	409	469	529	589	649	709
50 :	50	110	170	230	290	350	410	470	530	590	650	710
51 :	51	111	171	231	291	351	411	471	531	591	651	711
52 :	52	112	172	232	292	352	412	472	532	592	652	712
53 :	53	113	173	233	293	353	413	473	533	593	653	713
54 :	54	114	174	234	294	354	414	474	534	594	654	714
55 :	55	115	175	235	295	355	415	475	535	595	655	715
56 :	56	116	176	236	296	356	416	476	536	596	656	716
57 :	57	117	177	237	297	357	417	477	537	597	657	717
58 :	58	118	178	238	298	358	418	478	538	598	658	718
59 :	59	119	179	239	299	359	419	479	539	599	659	719

Table VII-6. HR:MIN to MIN Conversion Table, Page 2 of 2

	Hours											
MINS:	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
0 :	720	780	840	900	960	1020	1080	1140	1200	1260	1320	1380
1 :	721	781	841	901	961	1021	1081	1141	1201	1261	1321	1381
2 :	722	782	842	902	962	1022	1082	1142	1202	1262	1322	1382
3 :	723	783	843	903	963	1023	1083	1143	1203	1263	1323	1383
4 :	724	784	844	904	964	1024	1084	1144	1204	1264	1324	1384
5 :	725	785	845	905	965	1025	1085	1145	1205	1265	1325	1385
6 :	726	786	846	906	966	1026	1086	1146	1206	1266	1326	1386
7 :	727	787	847	907	967	1027	1087	1147	1207	1267	1327	1387
8 :	728	788	848	908	968	1028	1088	1148	1208	1268	1328	1388
9 :	729	789	849	909	969	1029	1089	1149	1209	1269	1329	1389
10 :	730	790	850	910	970	1030	1090	1150	1210	1270	1330	1390
11 :	731	791	851	911	971	1031	1091	1151	1211	1271	1331	1391
12 :	732	792	852	912	972	1032	1092	1152	1212	1272	1332	1392
13 :	733	793	853	913	973	1033	1093	1153	1213	1273	1333	1393
14 :	734	794	854	914	974	1034	1094	1154	1214	1274	1334	1394
15 :	735	795	855	915	975	1035	1095	1155	1215	1275	1335	1395
16 :	736	796	856	916	976	1036	1096	1156	1216	1276	1336	1396
17 :	737	797	857	917	977	1037	1097	1157	1217	1277	1337	1397
18 :	738	798	858	918	978	1038	1098	1158	1218	1278	1338	1398
19 :	739	799	859	919	979	1039	1099	1159	1219	1279	1339	1399
20 :	740	800	860	920	980	1040	1100	1160	1220	1280	1340	1400
21 :	741	801	861	921	981	1041	1101	1161	1221	1281	1341	1401
22 :	742	802	862	922	982	1042	1102	1162	1222	1282	1342	1402
23 :	743	803	863	923	983	1043	1103	1163	1223	1283	1343	1403
24 :	744	804	864	924	984	1044	1104	1164	1224	1284	1344	1404
25 :	745	805	865	925	985	1045	1105	1165	1225	1285	1345	1405
26 :	746	806	866	926	986	1046	1106	1166	1226	1286	1346	1406
27 :	747	807	867	927	987	1047	1107	1167	1227	1287	1347	1407
28 :	748	808	868	928	988	1048	1108	1168	1228	1288	1348	1408
29 :	749	809	869	929	989	1049	1109	1169	1229	1289	1349	1409
30 :	750	810	870	930	990	1050	1110	1170	1230	1290	1350	1410
31 :	751	811	871	931	991	1051	1111	1171	1231	1291	1351	1411
32 :	752	812	872	932	992	1052	1112	1172	1232	1292	1352	1412
33 :	753	813	873	933	993	1053	1113	1173	1233	1293	1353	1413
34 :	754	814	874	934	994	1054	1114	1174	1234	1294	1354	1414
35 :	755	815	875	935	995	1055	1115	1175	1235	1295	1355	1415
36 :	756	816	876	936	996	1056	1116	1176	1236	1296	1356	1416
37 :	757	817	877	937	997	1057	1117	1177	1237	1297	1357	1417
38 :	758	818	878	938	998	1058	1118	1178	1238	1298	1358	1418
39 :	759	819	879	939	999	1059	1119	1179	1239	1299	1359	1419
40 :	760	820	880	940	1000	1060	1120	1180	1240	1300	1360	1420
41 :	761	821	881	941	1001	1061	1121	1181	1241	1301	1361	1421
42 :	762	822	882	942	1002	1062	1122	1182	1242	1302	1362	1422
43 :	763	823	883	943	1003	1063	1123	1183	1243	1303	1363	1423
44 :	764	824	884	944	1004	1064	1124	1184	1244	1304	1364	1424
45 :	765	825	885	945	1005	1065	1125	1185	1245	1305	1365	1425
46 :	766	826	886	946	1006	1066	1126	1186	1246	1306	1366	1426
47 :	767	827	887	947	1007	1067	1127	1187	1247	1307	1367	1427
48 :	768	828	888	948	1008	1068	1128	1188	1248	1308	1368	1428
49 :	769	829	889	949	1009	1069	1129	1189	1249	1309	1369	1429
50 :	770	830	890	950	1010	1070	1130	1190	1250	1310	1370	1430
51 :	771	831	891	951	1011	1071	1131	1191	1251	1311	1371	1431
52 :	772	832	892	952	1012	1072	1132	1192	1252	1312	1372	1432
53 :	773	833	893	953	1013	1073	1133	1193	1253	1313	1373	1433
54 :	774	834	894	954	1014	1074	1134	1194	1254	1314	1374	1434
55 :	775	835	895	955	1015	1075	1135	1195	1255	1315	1375	1435
56 :	776	836	896	956	1016	1076	1136	1196	1256	1316	1376	1436
57 :	777	837	897	957	1017	1077	1137	1197	1257	1317	1377	1437
58 :	778	838	898	958	1018	1078	1138	1198	1258	1318	1378	1438
59 :	779	839	899	959	1019	1079	1139	1199	1259	1319	1379	1439

C. References

Note: References documenting many of the procedures, limits, etc., are given in the companion Repex Report listed in the preface.

NOAA Diving Manual. Second edition, edited by JW Miller. Rockville, MD: NOAA, U.S. Department of Commerce, 1979.

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U.S. Navy Diving Manual. NAVSEA 0994-LP-001-9010. Volume 1. Revision 1. Washington: Navy Department, Jun 1985.

D. The Repex tables

The following 36 pages, separately numbered T-1 through T-36, contain the tables.

APPENDIX A
POST-SUBMAXIMAL CALCULATION WORKSHEET

OXYGEN MANAGEMENT AT 30-34 FSW

Pressure: 30 fsw = 9.21 msw = 92.11 kilopascals = 1.91 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 15.7 to 18.3 percent oxygen at 30 fsw

PO_2 of air at		CPTU/hr at	
30 fsw=	0.40	**30 fsw=**	0
34 fsw=	0.43	**34 fsw=**	0
34 fsw=	0.43	**34 fsw=**	0
38 fsw=	0.45	**38 fsw=**	0

ASCENDING EXCURSIONS FROM 30-34 FSW

Target depth range, **fsw:**	**0-5**	**5-10**	**10-15**	**15-20**	**>=20**
Time allowed:	30	37	48	60	no limit

OXYGEN WINDOW EXCURSION RANGE Breathing air: **Storage depth + 4 fsw**

NO-STOP EXCURSIONS FROM 30-34 FSW

85Aug D55R00.K00; .H01

Allowable time (min) at each excursion depth **(fsw)**

Excn#	Intrvl	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr	480	480	370	216	163	111	87	73	61	49	42	36	33
2nd	8-16	480	480	357	214	162	111	87	73	61	49	42	36	33
2nd	4-8	480	480	305	203	152	110	87	72	61	49	42	36	33
2nd	2-4	480	457	233	175	127	104	81	67	58	49	41	36	32
2nd	1-2	480	367	161	135	94	80	69	56	48	42	38	34	30
2nd	1/2-1	480	289	103	94	62	58	51	41	35	32	29	26	24
3+	8-16	480	480	357	214	162	111	87	73	61	49	42	36	33
3+	4-8	480	480	304	203	152	110	87	72	61	49	42	36	33
3+	2-4	480	306	197	145	120	99	81	67	58	49	41	36	32
3+	1-2	426	171	107	87	67	55	47	40	35	32	29	26	25
3+	1/2-1	241	91	68	47	36	29	29	25	22	19	17	16	14

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	29	27	24	21	19	18	15	12	10	09	08	06	05
2nd	8-16	29	27	24	21	19	18	15	12	10	09	08	06	05
2nd	4-8	29	27	24	21	19	18	15	12	10	09	08	06	05
2nd	2-4	29	27	24	21	19	18	15	12	10	09	08	06	05
2nd	1-2	27	25	23	21	19	17	15	12	10	09	08	06	05
2nd	1/2-1	22	20	18	17	16	15	15	12	10	09	08	06	05
3+	8-16	29	27	24	21	19	18	15	12	10	09	08	06	05
3+	4-8	29	27	24	21	19	18	15	12	10	09	08	06	05
3+	2-4	29	27	24	21	19	18	15	12	10	09	08	06	05
3+	1-2	24	23	21	20	19	17	15	12	10	09	08	06	05
3+	1/2-1	13	12	11	11	10	10	09	08	07	07	06	06	05

ONE-STOP EXCURSIONS FROM 30-34 FSW

85Aug D5840O.K00; .K01

Interval >16 hr

Excursion depths (fsw) with bottom and stop times (min)

80	85	90	95	100	105	110	115	120
216 0	163 0	111 0	87 0	73 0	61 0	49 0	42 0	36 0
240 5	180 7	120 2	90 1	90 7	90 12	60 4	45 2	45 4
	210 15	150 9	120 8	120 17	120 28	90 17	60 8	60 12
	240 21	180 21	150 22	150 34	150 44	120 38	90 23	90 32
		210 29	180 34	180 45	180 58	150 54	120 47	120 56
		240 36	210 42					

125	130	135	140	145	150	155	160	170
33 0	29 0	27 0	24 0	21 0	19 0	18 0	15 0	12 0
45 6	30 1	30 3	30 4	30 6	20 1	20 1	20 2	20 4
60 16	45 8	45 12	45 15	45 18	30 7	30 9	30 10	30 13
90 40	60 20	60 23	60 27	60 30	45 21	45 24	45 27	
120 63	90 47	90 54						

180	190	200	220	240
10 0	9 0	8 0	6 0	5 0
20 7	10 1	10 1	10 2	10 4
30 18	20 9	20 11	20 14	16 20
	30 22			

Interval 2-16 hr

Excursion depths (fsw) with bottom and stop times (min)

80	85	90	95	100	105	110	115	120
145 0	120 0	99 0	81 0	67 0	56 0	49 0	41 0	36 0
150 10	150 20	120 17	90 5	90 21	60 2	60 6	45 2	45 4
180 13	180 58	150 61	120 43		90 35	90 58	60 12	60 24
210 43								
240 61								

125	130	135	140	145	150	155	160	170
32 0	29 0	27 0	24 0	21 0	19 0	18 0	15 0	12 0
45 8	30 1	30 3	30 4	30 6	20 1	20 1	20 2	20 4
60 35	45 12	45 16	45 25	45 35	30 7	30 9	30 12	30 17
	60 44	60 54			45 41	45 49	45 56	

180	190	200	220	240
10 0	9 0	8 0	6 0	5 0
20 7	10 1	10 1	10 2	10 4
30 25	20 9	20 11	20 17	16 26
	30 39			

SATURATION DECOMPRESSION FROM STORAGE AT 30-34 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	45	50	55	60	65	70	75	80	85	90	>90
Starting depth to use	35	40	45	50	55	60	65	70	75	80	80

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
80	2165	60	12	air	0.72	30
75	2105	95	19	air	0.69	42
70	2010	95	19	air	0.66	36
65	1915	95	19	air	0.62	30
60	1820	95	19	air	0.59	23
55	1725	95	19	air	0.56	16
50	1630	95	19	air	0.53	9
45	1535	95	19	air	0.50	0
40	1440	120	24	air	0.46	0
35	1320	140	28	air	0.43	0

Main Table: k = 4.9647

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
30	1180	155	31	air	0.40	0
25	1025	165	33	air	0.37	0
20	860	180	36	air	0.34	0
15	680	200	40	air	0.31	0
10	480	225	45	air	0.27	0
5	255	255	51	air	0.24	0

Precursory		16.3 hr	CPTD	186
Main		19.4 hr	CPTD	0
Total	1 d +	12.1 hr	CPTD	186

OXYGEN MANAGEMENT AT 35-39 FSW

Pressure: 35 fsw = 10.75 msw = 107.47 kilopascals = 2.06 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 14.6 to 16.9 percent oxygen at 35 fsw

PO_2 of air at		CPTU/hr at	
35 fsw=	0.43	**35 fsw=**	0
39 fsw=	0.46	**39 fsw=**	0
41 fsw=	0.47	**41 fsw=**	0
45 fsw=	0.49	**45 fsw=**	0

ASCENDING EXCURSIONS FROM 35-39 FSW

Target depth range, **fsw:**	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**>=25**
Time allowed:	24	31	40	52	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 6 fsw**

NO-STOP EXCURSIONS FROM 35-39 FSW

85Aug D55R00.K02; .K03

Allowable time (min) at each excursion depth **(fsw)**

Excn#	Intrvl	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr	480	480	480	439	256	183	132	99	80	69	55	46	40
2nd	8-16	480	480	480	413	255	181	132	99	80	69	55	46	40
2nd	4-8	480	480	480	356	243	171	132	98	80	68	55	46	40
2nd	2-4	480	480	480	276	200	145	114	92	75	63	55	46	39
2nd	1-2	480	480	480	192	149	109	86	74	63	52	46	41	37
2nd	1/2-1	480	480	480	122	112	73	59	55	46	38	34	31	28
3+	8-16	480	480	480	413	255	181	132	99	80	69	55	46	40
3+	4-8	480	480	480	356	243	171	132	98	80	68	55	46	40
3+	2-4	480	480	356	216	155	121	104	88	75	63	55	46	39
3+	1-2	480	480	201	118	93	72	58	49	42	37	33	30	27
3+	1/2-1	480	414	107	77	52	39	31	26	25	23	20	18	17

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	35	32	29	26	24	21	19	15	12	10	09	07	06
2nd	8-16	35	32	29	26	24	21	19	15	12	10	09	07	06
2nd	4-8	35	32	29	26	24	21	19	15	12	10	09	07	06
2nd	2-4	35	31	28	26	24	21	19	15	12	10	09	07	06
2nd	1-2	32	29	26	24	22	21	19	15	12	10	09	07	06
2nd	1/2-1	26	24	21	20	18	17	16	14	12	10	09	07	06
3+	8-16	35	32	29	26	24	21	19	15	12	10	09	07	06
3+	4-8	35	32	29	26	24	21	19	15	12	10	09	07	06
3+	2-4	35	31	28	26	24	21	19	15	12	10	09	07	06
3+	1-2	25	23	21	20	20	19	18	15	12	10	09	07	06
3+	1/2-1	15	14	13	12	11	10	10	09	08	07	07	07	06

ONE-STOP EXCURSIONS FROM 35-39 FSW

85Aug D58400.K02; .K03

Interval >16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

90	95	100	105	110	115	120	125	130
183 0	132 0	99 0	80 0	69 0	55 0	46 0	40 0	35 0
210 8	150 3	120 5	90 4	90 9	60 1	60 5	45 2	45 4
240 14	180 14	150 15	120 11	120 22	90 14	90 18	60 9	60 13
	210 22	180 26	150 27	150 37	120 31	120 40	90 25	90 33
	240 28	210 34	180 38		150 47		120 49	

135	140	145	150	155	160	170	180	190
32 0	29 0	26 0	24 0	21 0	19 0	15 0	12 0	10 0
45 06	30 1	30 3	30 4	30 6	20 1	20 2	20 4	20 6
60 17	45 9	45 12	45 15	45 18	30 7	30 10	30 13	30 17
90 41	60 20	60 23	60 26	60 29	45 21	45 26		

200	220	240
9 0	7 0	6 0
10 1	10 2	10 3
20 8	20 12	16 16
30 21		

Interval 2-16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

85	90	95	100	105	110	115	120	125
155 0	121 0	104 0	88 0	75 0	63 0	55 0	46 0	39 0
210 30	150 9	120 8	120 32	90 13	90 27	60 3	60 8	45 2
240 46	180 45	150 48				90 48		60 16

130	135	140	145	150	155	160	170	180
35 0	31 0	28 0	26 0	24 0	21 0	19 0	15 0	12 0
45 5	45 9	30 1	30 3	30 5	30 6	20 1	20 2	20 4
60 28	60 37	45 12	45 18	45 28	45 35	30 7	30 12	30 16
		60 45				45 42		

190	200	220	240
10 0	9 0	7 0	6 0
20 7	10 1	10 2	10 3
30 26	20 9	20 13	16 20

SATURATION DECOMPRESSION FROM STORAGE AT 35-39 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	50	55	60	65	70	75	80	85	90	95	>95
Starting depth to use	40	45	50	55	60	65	70	75	80	85	85

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
85	2240	60	12	air	0.75	34
80	2180	60	12	air	0.72	30
75	2120	95	19	air	0.69	42
70	2025	95	19	air	0.66	36
65	1930	95	19	air	0.62	30
60	1835	95	19	air	0.59	23
55	1740	95	19	air	0.56	16
50	1645	95	19	air	0.53	9
45	1550	95	19	air	0.50	0
40	1455	130	26	air	0.46	0

Main Table: k = 4.9646

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
35	1325	145	29	air	0.43	0
30	1180	155	31	air	0.40	0
25	1025	165	33	air	0.37	0
20	860	180	36	air	0.34	0
15	680	200	40	air	0.31	0
10	480	225	45	air	0.27	0
5	255	255	51	air	0.24	0

Precursory	15.3 hr	CPTD	220
Main	22.1 hr	CPTD	0
Total	1 d + 13.3 hr	CPTD	220

OXYGEN MANAGEMENT AT 40-44 FSW

Pressure: 40 fsw = 12.28 msw = 122.82 kilopascals = 2.21 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 13.6 to 15.8 percent oxygen at 40 fsw

PO_2 of air at		CPTU/hr at	
40 fsw=	0.46	**40 fsw=**	0
44 fsw=	0.49	**44 fsw=**	0
47 fsw=	0.51	**47 fsw=**	2
51 fsw=	0.53	**51 fsw=**	6

ASCENDING EXCURSIONS FROM 40-44 FSW

Target depth range, **fsw:**	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**>=30**
Time allowed:	17	24	31	40	52	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 7 fsw**

NO-STOP EXCURSIONS FROM 40-44 FSW

85Aug D55R00.K04; .H05

		Allowable time (min) at each excursion depth **(fsw)**												
Excn#	Intrvl	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr				480	480	325	208	161	114	90	75	64	51
2nd	8-16				480	480	323	207	159	114	90	75	64	51
2nd	4-8				480	436	281	195	149	113	89	74	64	51
2nd	2-4	...All		480...	480	352	215	168	125	104	84	70	60	51
2nd	1-2				480	262	151	129	92	79	69	58	49	40
2nd	1/2-1				480	184	102	89	61	56	51	42	36	30
3+	8-16				480	480	323	207	159	114	90	75	64	51
3+	4-8				480	401	278	195	149	113	89	74	64	51
3+	2-4				425	240	167	128	104	92	79	70	60	51
3+	1-2				244	131	90	78	62	51	44	38	34	31
3+	1/2-1				132	75	57	42	33	27	23	22	22	19

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	44	38	34	31	28	26	24	19	16	12	10	08	07
2nd	8-16	44	38	34	31	28	26	24	19	16	12	10	08	07
2nd	4-8	44	38	34	31	28	26	24	19	16	12	10	08	07
2nd	2-4	43	38	34	30	28	26	24	19	16	12	10	08	07
2nd	1-2	40	45	31	28	26	24	22	19	16	12	10	08	07
2nd	1/2-1	30	37	25	23	21	19	18	16	14	12	10	08	07
3+	8-16	44	38	34	31	28	26	24	19	16	12	10	08	07
3+	4-8	44	38	34	31	28	26	24	19	16	12	10	08	07
3+	2-4	43	38	34	30	28	26	24	19	16	12	10	08	07
3+	1-2	28	25	23	22	20	19	18	17	16	12	10	08	07
3+	1/2-1	17	16	14	13	12	12	11	10	09	08	07	06	05

ONE-STOP EXCURSIONS FROM 40-44 FSW

85Aug D584O0.K04; .K05

Interval >16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

90	95	100	105	110	115	120	125	130
325 0	208 0	161 0	114 0	90 0	75 0	64 0	51 0	44 0
	210 1	180 7	120 2	120 7	90 6	90 10	60 2	45 1
	240 7	210 15	150 9	150 20	120 15	120 25	90 15	60 6
		240 20	180 20	180 31	150 31	150 40	120 34	90 19
			210 27	210 38	180 41	180 53	150 49	120 42
			240 36					150 57

135	140	145	150	155	160	170	180	190
38 0	34 0	31 0	28 0	26 0	24 0	19 0	16 0	12 0
45 3	45 5	45 6	30 2	30 3	30 5	20 1	20 2	20 4
60 10	60 14	60 17	45 9	45 12	45 15	30 7	30 10	30 12
90 27	90 35	90 42	60 20	60 23	60 26	45 21	45 26	
120 50	120 57		90 48					

200	220	240
10 0	8 0	7 0
20 6	10 1	10 2
30 17	20 10	16 14
	29 24	

Interval 2-16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

90	95	100	105	110	115	120	125	130
167 0	128 0	104 0	92 0	79 0	70 0	60 0	51 0	43 0
240 31	180 32	150 36	120 20	90 5	90 20	90 38	60 5	45 1
	210 52	180 63	150 64	120 54			90 62	60 10

135	140	145	150	155	160	170	180	190
38 0	34 0	30 0	28 0	26 0	24 0	19 0	16 0	12 0
45 3	45 6	45 9	30 2	30 3	30 5	20 1	20 2	20 4
60 22	60 30	60 39	45 13	45 21	45 29	30 7	30 12	30 16
			60 53			45 43		

200	220	240
10 0	8 0	7 0
	10 1	10 2
	20 10	16 15

SATURATION DECOMPRESSION FROM STORAGE AT 40-44 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	55	60	65	70	75	80	85	90	95	100	>100
Starting depth to use	45	50	55	60	65	70	75	80	85	90	90

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
90	2360	60	12	air	0.78	37
85	2300	60	12	air	0.75	34
80	2240	60	12	air	0.72	30
75	2180	95	19	air	0.69	42
70	2085	95	19	air	0.66	36
65	1990	95	19	air	0.62	30
60	1895	95	19	air	0.59	23
55	1800	95	19	air	0.56	16
50	1705	95	19	air	0.53	9
45	1610	125	25	air	0.50	0

Main Table: k = 4.8476

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
40	1485	135	27	air	0.46	0
35	1350	145	29	air	0.43	0
30	1205	155	31	air	0.40	0
25	1050	170	34	air	0.37	0
20	880	185	37	air	0.34	0
15	695	205	41	air	0.31	0
10	490	230	46	air	0.27	0
5	260	260	52	air	0.24	0

Precursory	14.6 hr	CPTD	257
Main	1 d + 0.8 hr	CPTD	0
Total	1 d + 15.3 hr	CPTD	257

OXYGEN MANAGEMENT AT 45-49 FSW

Pressure: 45 fsw = 13.82 msw = 138.17 kilopascals = 2.36 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 12.7 to 14.8 percent oxygen at 45 fsw

PO_2 of air at		CPTU/hr at	
45 fsw=	0.50	**45 fsw=**	0
49 fsw=	0.52	**49 fsw=**	4
53 fsw=	0.55	**53 fsw=**	9
57 fsw=	0.57	**57 fsw=**	12

ASCENDING EXCURSIONS FROM 45-49 FSW

Target depth range, **fsw:**	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**>=30**
Time allowed:	12	18	25	32	42	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 8 fsw**

NO-STOP EXCURSIONS FROM 45-49 FSW

85Aug D55R00.K06; .H07

		Allowable time (min) at each excursion depth **(fsw)**												
Excn#	Intrvl	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr					480	480	395	243	179	135	101	83	71
2nd	8-16					480	480	373	241	177	135	101	83	71
2nd	4-8					480	480	318	229	167	134	100	82	70
2nd	2-4	...All 480...				480	438	243	187	141	112	95	77	65
2nd	1-2					480	370	166	139	106	83	73	64	54
2nd	1/2-1					480	326	103	104	71	57	53	48	39
3+	8-16					480	480	373	241	177	135	101	83	71
3+	4-8					480	454	309	229	167	134	100	82	70
3+	2-4					480	269	181	136	110	92	83	72	64
3+	1-2					310	149	98	81	66	54	46	40	35
3+	1/2-1					170	79	64	45	35	29	24	21	19

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	58	48	42	37	33	30	28	23	19	16	13	09	07
2nd	8-16	58	48	42	37	33	30	28	23	19	16	13	09	07
2nd	4-8	58	48	42	37	33	30	28	23	19	16	13	09	07
2nd	2-4	57	48	41	36	33	30	27	23	19	16	13	09	07
2nd	1-2	47	42	38	34	30	28	25	22	19	16	13	09	07
2nd	1/2-1	35	32	29	27	25	23	20	17	15	14	12	09	07
3+	8-16	58	48	42	37	33	30	28	23	19	16	13	09	07
3+	4-8	58	48	42	37	33	30	28	23	19	16	13	09	07
3+	2-4	57	48	41	36	33	30	27	23	19	16	13	09	07
3+	1-2	32	29	26	24	22	21	19	17	16	16	13	09	07
3+	1/2-1	20	18	17	15	14	13	12	11	10	09	08	07	06

ONE-STOP EXCURSIONS FROM 45-49 FSW

85Aug D58400.K06; .K07

Interval >16 hr

Excursion depths (fsw) with bottom and stop times (min)

105	110	115	120	125	130	135	140	145
179 0	135 0	101 0	83 0	71 0	58 0	48 0	42 0	37 0
180 1	150 3	120 4	90 3	90 7	60 1	60 3	45 2	45 3
210 8	180 13	150 14	120 10	120 19	90 12	90 16	60 7	60 11
240 14	210 21	180 25	150 24	150 34	120 28	120 36	90 22	90 29
	240 26	210 32	180 35		150 43		120 44	

150	155	160	170	180	190	200	220	240
33 0	30 0	28 0	23 0	19 0	16 0	13 0	9 0	7 0
45 5	45 7	30 2	30 5	20 1	20 2	20 4	10 1	10 2
60 14	60 17	45 10	45 15	30 7	30 10	30 12	20 8	16 12
90 36	90 42	60 20	60 26	45 20	45 25		29 20	

Interval 2-16 hr

Excursion depths (fsw) with bottom and stop times (min)

95	100	105	110	115	120	125	130	135
181 0	136 0	110 0	92 0	83 0	72 0	64 0	57 0	48 0
240 19		150 25	120 13	120 42	90 13	90 30	60 2	60 6
		180 51	150 54	150 77	120 66		90 53	90 73
		210 72						

140	145	150	155	160	170	180	190	200
41 0	36 0	33 0	30 0	27 0	23 0	19 0	16 0	13 0
45 2	45 3	45 7	45 10	30 2	30 5	20 1	20 2	20 4
60 15	60 24	60 33	60 46	45 15	45 31	30 7	30 11	30 16
						45 43		

220	240
9 0	7 0
10 1	10 2
20 8	16 12
29 37	

SATURATION DECOMPRESSION FROM STORAGE AT 45-49 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	60	65	70	75	80	85	90	95	100	105	>105
Starting depth to use	50	55	60	65	70	75	80	85	90	95	95

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
95	2480	60	12	air	0.81	41
90	2420	60	12	air	0.78	37
85	2360	60	12	air	0.75	34
80	2300	60	12	air	0.72	30
75	2240	95	19	air	0.69	42
70	2145	95	19	air	0.66	36
65	2050	95	19	air	0.62	30
60	1955	95	19	air	0.59	23
55	1860	95	19	air	0.56	16
50	1765	120	24	air	0.53	11

Main Table: k = 4.7935

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
45	1645	130	26	air	0.50	0
40	1515	140	28	air	0.46	0
35	1375	150	30	air	0.43	0
30	1225	160	32	air	0.40	0
25	1065	175	35	air	0.37	0
20	890	190	38	air	0.34	0
15	700	210	42	air	0.31	0
10	490	230	46	air	0.27	0
5	260	260	52	air	0.24	0

Precursory	13.9 hr	CPTD	300
Main	1 d + 3.4 hr	CPTD	0
Total	1 d + 17.3 hr	CPTD	300

OXYGEN MANAGEMENT AT 50-54 FSW

Pressure: 50 fsw = 15.35 msw = 153.52 kilopascals = 2.52 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 11.9 to 13.9 percent oxygen at 50 fsw

PO_2 of air at		CPTU/hr at	
50 fsw=	0.53	**50 fsw=**	6
54 fsw=	0.55	**54 fsw=**	9
60 fsw=	0.59	**60 fsw=**	14
64 fsw=	0.61	**64 fsw=**	18

ASCENDING EXCURSIONS FROM 50-54 FSW

Target depth range, **fsw:**	**0-5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**>=35**
Time allowed:	7	13	18	25	32	42	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 10 fsw**

NO-STOP EXCURSIONS FROM 50-54 FSW

85Aug D55R00.K08; .K09

		Allowable time (min) at each excursion depth **(fsw)**												
Excn#	Intrvl	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr						480	480	455	296	201	158	116	92
2nd	8-16						480	480	431	294	200	157	116	92
2nd	4-8						480	480	374	262	189	147	116	91
2nd	2-4			...All 480...			480	480	292	200	162	123	103	86
2nd	1-2						480	462	205	142	124	91	77	68
2nd	1/2-1						480	419	131	98	85	59	50	50
3+	8-16						480	480	431	294	200	157	116	92
3+	4-8						480	480	340	253	189	147	116	91
3+	2-4						480	307	197	145	115	95	83	75
3+	1-2						427	171	107	78	70	57	48	42
3+	1/2-1						241	91	72	49	38	30	25	22

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	77	67	54	45	40	35	32	27	23	19	16	11	08
2nd	8-16	77	67	54	45	40	35	32	27	23	19	16	11	08
2nd	4-8	77	66	54	45	40	35	32	27	23	19	16	11	08
2nd	2-4	72	62	53	45	39	35	32	27	23	19	16	11	08
2nd	1-2	60	51	45	41	37	33	30	25	21	19	16	11	08
2nd	1/2-1	44	37	34	31	28	26	24	20	17	15	14	11	08
3+	8-16	77	67	54	45	40	35	32	27	23	19	16	11	08
3+	4-8	77	66	54	45	40	35	32	27	23	19	16	11	08
3+	2-4	67	60	53	45	39	35	32	27	23	19	16	11	08
3+	1-2	37	33	30	27	25	23	21	19	17	15	14	11	08
3+	1/2-1	19	19	18	17	16	15	14	12	10	09	08	07	06

ONE-STOP EXCURSIONS FROM 50-54 FSW

85Aug D5840O.K08; .K09

Interval >16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

105	110	115	120	125	130	135	140	145
296 0	201 0	158 0	116 0	92 0	77 0	67 0	54 0	45 0
	210 2	180 7	120 1	120 6	90 5	90 9	60 2	60 5
	240 8	210 15	150 8	150 19	120 14	120 22	90 13	90 17
		240 20	180 19	180 29	150 28	150 37	120 31	120 38
			210 26	210 37	180 38	180 50	150 45	
			240 36					

150	155	160	170	180	190	200	220	240
40 0	35 0	32 0	27 0	23 0	19 0	16 0	11 0	8 0
45 2	45 4	45 5	30 2	30 5	20 1	20 2	20 6	10 1
60 8	60 12	60 15	45 10	45 15	30 7	30 10		16 10
90 24	90 31	90 37	60 21		45 20			
120 45								

Interval 2-16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

100	105	110	115	120	125	130	135	140
197 0	145 0	115 0	95 0	83 0	75 0	67 0	60 0	53 0
240 4	210 29	180 41	150 44	120 33	90 7	90 22	90 46	60 3
	240 44	210 60	180 68	150 67	120 57			90 66

145	150	155	160	170	180	190	200	220
45 0	39 0	35 0	32 0	27 0	23 0	19 0	16 0	11 0
60 9	45 2	45 4	45 7	30 2	30 5	20 1	20 2	20 6
	60 19	60 27	60 40	45 18	45 32	30 8	30 11	
				60 71		45 48		

240
8 0
10 1
16 10

SATURATION DECOMPRESSION FROM STORAGE AT 50-54 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	70	75	80	85	90	95	100	105	110	115	>115
Starting depth to use	55	60	65	70	75	80	85	90	95	100	100

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
100	2595	60	12	air	0.85	44
95	2535	60	12	air	0.81	41
90	2475	60	12	air	0.78	37
85	2415	60	12	air	0.75	34
80	2355	60	12	air	0.72	30
75	2295	95	19	air	0.69	42
70	2200	95	19	air	0.66	36
65	2105	95	19	air	0.62	30
60	2010	95	19	air	0.59	23
55	1915	115	23	air	0.56	20

Main Table: k = 4.6889

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
50	1800	125	25	air	0.53	11
45	1675	130	26	air	0.50	0
40	1545	140	28	air	0.46	0
35	1405	150	30	air	0.43	0
30	1255	165	33	air	0.40	0
25	1090	175	35	air	0.37	0
20	915	195	39	air	0.34	0
15	720	215	43	air	0.31	0
10	505	235	47	air	0.27	0
5	270	270	54	air	0.24	0

Precursory		13.3 hr	CPTD	337
Main	1 d +	6.0 hr	CPTD	11
Total	1 d +	19.3 hr	CPTD	348

OXYGEN MANAGEMENT AT 55-59 FSW

Pressure: 55 fsw = 16.89 msw = 168.88 kilopascals = 2.67 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 11.3 to 13.1 percent oxygen at 55 fsw

PO_2 of air at		CPTU/hr at	
55 fsw=	0.56	**55 fsw=**	10
59 fsw=	0.59	**59 fsw=**	14
66 fsw=	0.63	**66 fsw=**	20
70 fsw=	0.65	**70 fsw=**	23

ASCENDING EXCURSIONS FROM 55-59 FSW

Target depth range, **fsw:**	**<5**	**5-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**	**>=40**
Time allowed:	0	7	13	18	25	32	42	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 11 fsw**

NO-STOP EXCURSIONS FROM 55-59 FSW

85Aug D55R00.K10; .K11

		Allowable time (min) at each excursion depth **(fsw)**												
Excn#	Intrvl	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr							480	480	480	364	231	175	138
2nd	8-16							480	480	480	343	230	174	138
2nd	4-8							480	480	429	290	218	163	133
2nd	2-4		...All 480...					480	480	335	219	176	138	111
2nd	1-2							480	480	266	147	131	103	82
2nd	1/2-1							480	480	208	99	98	69	54
3+	8-16							480	480	480	343	230	174	138
3+	4-8							480	480	372	273	214	163	133
3+	2-4							480	356	217	156	122	100	85
3+	1-2							480	201	118	84	71	61	51
3+	1/2-1							415	108	62	54	40	32	27

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	104	85	73	61	50	43	38	31	27	23	19	13	10
2nd	8-16	104	85	73	61	50	43	38	31	27	23	19	13	10
2nd	4-8	103	84	72	61	50	43	38	31	27	23	19	13	10
2nd	2-4	95	79	67	59	50	43	38	31	26	23	19	13	10
2nd	1-2	72	64	56	49	44	40	35	29	24	21	19	13	10
2nd	1/2-1	52	47	41	36	33	30	28	24	20	17	15	13	10
3+	8-16	104	85	73	61	50	43	38	31	27	23	19	13	10
3+	4-8	103	84	72	61	50	43	38	31	27	23	19	13	10
3+	2-4	75	69	62	56	50	43	38	31	26	23	19	13	10
3+	1-2	43	38	34	30	28	25	24	20	18	16	15	13	10
3+	1/2-1	23	20	18	16	16	17	15	13	11	10	09	08	07

ONE-STOP EXCURSIONS FROM 55-59 FSW

85Aug D58400.K10; .K11

Interval >16 hr

Excursion depths (fsw) with bottom and stop times (min)

115	120	125	130	135	140	145	150	155
231 0	175 0	138 0	104 0	85 0	73 0	61 0	50 0	43 0
	210 6	180 10	120 2	120 7	90 5	90 9	60 2	60 4
	240 11	210 17	150 10	150 19	120 14	120 22	90 13	90 16
		240 22	180 20	180 29	150 28		120 30	
				210 27				
				240 41				

160	170	180	190	200	220	240
38 0	31 0	27 0	23 0	19 0	13 0	10 0
45 2	45 5	30 2	30 4	30 7	20 3	16 7
60 8	60 14	45 9	45 14		29 11	
90 23		60 19				

Interval 2-16 hr

Excursion depths (fsw) with bottom and stop times (min)

105	110	115	120	125	130	135	140	145
217 0	156 0	122 0	100 0	85 0	75 0	69 0	62 0	56 0
	210 20	150 3	150 37	120 31	120 50	90 21	90 44	90 59
	240 33	180 33	180 59	150 59		120 68		
		210 50						

150	155	160	170	180	190	200	220	240
50 0	43 0	38 0	31 0	26 0	23 0	19 0	13 0	10 0
60 3	45 1	45 2	45 6	30 2	30 5	30 7	20 4	16 7
	60 10	60 22		45 18			29 14	

SATURATION DECOMPRESSION FROM STORAGE AT 55-59 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	75	80	85	90	95	100	105	110	115	120	>120
Starting depth to use	60	65	70	75	80	85	90	95	100	105	105

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
105	2690	60	12	air	0.88	48
100	2630	60	12	air	0.85	44
95	2570	60	12	air	0.81	41
90	2510	60	12	air	0.78	37
85	2450	60	12	air	0.75	34
80	2390	60	12	air	0.72	30
75	2330	95	19	air	0.69	42
70	2235	95	19	air	0.66	36
65	2140	95	19	air	0.62	30
60	2045	110	22	air	0.59	27

Main Table: k = 4.6565

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
55	1935	120	24	air	0.56	21
50	1815	125	25	air	0.53	11
45	1690	135	27	air	0.50	0
40	1555	140	28	air	0.46	0
35	1415	150	30	air	0.43	0
30	1265	165	33	air	0.40	0
25	1100	180	36	air	0.37	0
20	920	195	39	air	0.34	0
15	725	215	43	air	0.31	0
10	510	240	48	air	0.27	0
5	270	270.	54	air	0.24	0

Precursory	12.6 hr	CPTD	369
Main	1 d + 8.3 hr	CPTD	32
Total	1 d + 20.8 hr	CPTD	401

OXYGEN MANAGEMENT AT 60-64 FSW

Pressure: 60 fsw = 18.42 msw = 184.23 kilopascals = 2.82 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 10.6 to 12.4 percent oxygen at 60 fsw

PO_2 of air at	**60 fsw=**	0.59	CPTU/hr at	**60 fsw=**	15
	64 fsw=	0.62		**64 fsw=**	18
	72 fsw=	0.67		**72 fsw=**	24
	76 fsw=	0.69		**76 fsw=**	27

ASCENDING EXCURSIONS FROM 60-64 FSW

Target depth range, **fsw:**	**<10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**	**40-45**	**>=45**
Time allowed:	0	8	14	20	27	34	44	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 12 fsw**

NO-STOP EXCURSIONS FROM 60-64 FSW

85Aug D55R00.K12; .K13

		Allowable time (min) at each excursion depth **(fsw)**												
Excn#	Intrvl	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr									480	480	420	282	199
2nd	8-16									480	480	397	281	198
2nd	4-8									480	477	327	250	186
2nd	2-4				...All 480...					480	382	244	191	159
2nd	1-2									480	314	182	135	121
2nd	1/2-1									480	271	114	93	83
3+	8-16									480	480	397	281	198
3+	4-8									480	409	290	224	183
3+	2-4									426	240	167	129	104
3+	1-2									244	132	90	72	63
3+	1/2-1									132	69	59	43	34

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	159	119	94	79	69	56	47	37	31	26	23	16	11
2nd	8-16	157	119	94	79	69	56	47	37	31	26	23	16	11
2nd	4-8	147	118	94	79	68	56	47	37	31	26	23	16	11
2nd	2-4	123	103	88	74	64	56	47	37	30	26	23	16	11
2nd	1-2	91	78	69	61	53	47	42	34	28	24	21	16	11
2nd	1/2-1	60	54	50	45	38	35	32	27	23	19	17	14	11
3+	8-16	157	119	94	79	69	56	47	37	31	26	23	16	11
3+	4-8	147	118	94	79	68	56	47	37	31	26	23	16	11
3+	2-4	88	77	71	63	57	52	47	37	30	26	23	16	11
3+	1-2	52	45	39	35	31	28	26	22	19	17	15	13	11
3+	1/2-1	28	24	21	18	16	15	14	12	13	11	10	08	07

ONE-STOP EXCURSIONS FROM 60-64 FSW

85Aug D58400.K12; .K13

Interval >16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

120	125	130	135	140	145	150	155	160
282 0	199 0	159 0	119 0	94 0	79 0	69 0	56 0	47 0
	210 3	180 7	120 1	120 5	90 4	90 8	60 1	60 3
	240 8	210 14	150 8	150 17	120 12	120 20	90 11	90 15
		240 19	180 17	180 26	150 25	150 33	120 27	120 34
			210 24	210 35	180 35		150 41	150 48
			240 35					

170	180	190	200	220	240
37 0	31 0	26 0	23 0	16 0	11 0
45 3	45 6	30 3	30 5	20 2	16 6
60 10	60 16	45 11	45 15	29 10	
90 27		60 21			

Interval 2-16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

115	120	125	130	135	140	145	150	155
167 0	129 0	104 0	88 0	77 0	71 0	63 0	57 0	52 0
210 9	180 14	150 17	120 23	120 43	90 15	90 37	90 53	60 2
240 24	210 41	180 50	150 51	150 72	120 61			90 66

160	170	180	190	200	220	240
47 0	37 0	30 0	11 0	23 0	16 0	11 0
60 7	45 3	45 8	30 3	30 5	20 2	16 6
	60 34		45 22		29 11	

SATURATION DECOMPRESSION FROM STORAGE AT 60-64 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	80	85	90	95	100	105	110	115	120	125	>125
Starting depth to use	65	70	75	80	85	90	95	100	105	110	110

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
110	2765	45	9	air	0.91	38
105	2720	60	12	air	0.88	48
100	2660	60	12	air	0.85	44
95	2600	60	12	air	0.81	41
90	2540	60	12	air	0.78	37
85	2480	60	12	air	0.75	34
80	2420	60	12	air	0.72	30
75	2360	95	19	air	0.69	42
70	2265	95	19	air	0.66	36
65	2170	105	21	air	0.62	33

Main Table: k = 4.6066

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
60	2065	115	23	air	0.59	28
55	1950	120	24	air	0.56	21
50	1830	125	25	air	0.53	11
45	1705	135	27	air	0.50	0
40	1570	145	29	air	0.46	0
35	1425	155	31	air	0.43	0
30	1270	165	33	air	0.40	0
25	1105	180	36	air	0.37	0
20	925	195	39	air	0.34	0
15	730	215	43	air	0.31	0
10	515	240	48	air	0.27	0
5	275	275	55	air	0.24	0

Precursory	11.7 hr	CPTD	383
Main	1 d + 10.4 hr	CPTD	60
Total	1 d + 22.1 hr	CPTD	443

OXYGEN MANAGEMENT AT 65-69 FSW

Pressure: 65 fsw = 19.96 msw = 199.58 kilopascals = 2.97 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 10.1 to 11.8 percent oxygen at 65 fsw

$P\bullet_2$ of air at		CPTU/hr at	
65 fsw=	0.62	**65 fsw=**	19
69 fsw=	0.65	**69 fsw=**	22
79 fsw=	0.71	**79 fsw=**	29
83 fsw=	0.74	**83 fsw=**	32

ASCENDING EXCURSIONS FROM 65-69 FSW

Target depth range, **fsw:**	**<15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**	**40-45**	**45-50**	**>=50**
Time allowed:	0	8	14	20	27	34	44	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 14 fsw**

NO-STOP EXCURSIONS FROM 65-69 FSW

85Aug D55R00.K14; .K15

		Allowable time (min) at each excursion depth **(fsw)**												
Excn#	Intrvl	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr										480	480	465	324
2nd	8-16										480	480	439	314
2nd	4-8										480	480	345	265
2nd	2-4				...All 480...						480	448	253	199
2nd	1-2										480	379	187	136
2nd	1/2-1										480	337	135	86
3+	8-16										480	480	431	313
3+	4-8										480	455	313	238
3+	2-4										480	269	181	137
3+	1-2										310	149	98	73
3+	1/2-1										171	79	65	46

Excn#	Intrvl	130	135	140	145	150	155	160	170	180	190	200	220	240
1st	>16 hr	214	167	128	99	83	71	59	43	34	29	25	18	12
2nd	8-16	212	165	128	99	83	71	59	43	34	29	25	18	12
2nd	4-8	201	155	127	99	82	71	59	43	34	29	25	18	12
2nd	2-4	167	130	107	93	77	66	58	42	34	28	25	18	12
2nd	1-2	125	97	80	71	63	55	48	40	32	26	23	18	12
2nd	1/2-1	92	64	55	51	47	40	35	30	26	21	18	14	12
3+	8-16	212	165	128	99	83	71	59	43	34	29	25	18	12
3+	4-8	192	155	127	99	82	71	59	43	34	29	25	18	12
3+	2-4	110	92	79	73	65	58	53	42	34	28	25	18	12
3+	1-2	67	55	46	40	36	32	29	24	21	18	16	14	12
3+	1/2-1	36	29	25	21	19	17	15	13	12	12	11	09	07

ONE-STOP EXCURSIONS FROM 65-69 FSW

85Aug D58400.K14; .K15

Interval >16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

125	130	135	140	145	150	155	160	170
324 0	214 0	167 0	128 0	99 0	83 0	71 0	59 0	43 0
	240 5	180 4	150 5	120 4	90 3	90 7	60 1	45 1
		210 11	180 14	150 14	120 9	120 17	90 10	60 6
		240 16	210 21	180 23	150 23	150 31	120 25	90 18
			240 29	210 30	180 32	180 40	150 38	120 38

180	**190**	**200**	**220**	**240**
34 0	29 0	25 0	18 0	12 0
45 4	30 1	30 4	20 1	16 5
60 12	45 7	45 12	29 8	
90 30	60 17	60 22		

Interval 2-16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

120	125	130	135	140	145	150	155	160
181 0	137 0	110 0	92 0	79 0	73 0	65 0	58 0	53 0
240 15	180 18	150 23	150 44	120 37	90 7	90 29	60 1	60 1
	210 32	180 42	180 65	150 64	120 54	120 70	90 48	90 61
	240 46	210 59						

170	**180**	**190**	**200**	**220**	**240**
42 0	34 0	28 0	25 0	18 0	12 0
45 1'	45 5	30 1	30 4	20 1	16 5
60 14	60 44	45 12	45 26	29 8	

SATURATION DECOMPRESSION FROM STORAGE AT 65-69 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	85	90	95	100	105	110	115	120	125	130	>130
Starting depth to use	70	75	80	85	90	95	100	105	110	115	115

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
115	2820	45	9	air	0.94	41
110	2775	45	9	air	0.91	38
105	2730	60	12	air	0.88	48
100	2670	60	12	air	0.85	44
95	2610	60	12	air	0.81	41
90	2550	60	12	air	0.78	37
85	2490	60	12	air	0.75	34
80	2430	60	12	air	0.72	30
75	2370	95	19	air	0.69	42
70	2275	100	20	air	0.66	38

Main Table: k = 4.5887

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
65	2175	110	22	air	0.62	34
60	2065	115	23	air	0.59	28
55	1950	120	24	air	0.56	21
50	1830	125	25	air	0.53	11
45	1705	135	27	air	0.50	0
40	1570	145	29	air	0.46	0
35	1425	155	31	air	0.43	0
30	1270	165	33	air	0.40	0
25	1105	180	36	air	0.37	0
20	925	195	39	air	0.34	0
15	730	215	43	air	0.31	0
10	515	240	48	air	0.27	0
5	275	275	55	air	0.24	0

Precursory	10.8 hr	CPTD	393
Main	1 d + 12.3 hr	CPTD	94
Total	1 d + 23.0 hr	CPTD	487

OXYGEN MANAGEMENT AT 70-74 FSW

Pressure: 70 fsw = 21.49 msw = 214.93 kilopascals = 3.12 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 9.6 to 11.2 percent oxygen at 70 fsw

PO_2 of air at	**70 fsw=**	0.66	CPTU/hr at	**70 fsw=**	23
	74 fsw=	0.68		**74 fsw=**	26
	85 fsw=	0.75		**85 fsw=**	34
	89 fsw=	0.78		**89 fsw=**	37

ASCENDING EXCURSIONS FROM 70-74 FSW

Target depth range, **fsw:**	**<20**	**20-25**	**25-30**	**30-35**	**35-40**	**40-45**	**45-50**	**50-55**	**>=55**
Time allowed:	0	9	15	21	28	36	47	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 15 fsw**

NO-STOP EXCURSIONS FROM 70-74 FSW

85Aug D55R00.K16; .K17

		Allowable time (min) at each excursion depth **(fsw)**												
Excn#	Intrvl	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr											480	480	480
2nd	8-16											480	480	480
2nd	4-8											480	480	378
2nd	2-4					...All 480...						480	480	284
2nd	1-2											480	462	215
2nd	1/2-1											480	420	172
3+	8-16											480	480	465
3+	4-8											480	480	340
3+	2-4											480	307	197
3+	1-2											427	171	107
3+	1/2-1											242	91	72

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	358	231	176	139	105	86	74	51	39	32	27	20	14
2nd	8-16	336	230	175	139	105	86	74	51	39	32	27	20	14
2nd	4-8	285	218	164	134	104	85	73	51	39	32	27	20	14
2nd	2-4	214	174	139	112	96	80	68	51	39	32	27	20	14
2nd	1-2	143	129	104	82	73	65	57	45	36	29	25	19	14
2nd	1/2-1	87	96	69	55	52	48	41	33	28	24	20	15	13
3+	8-16	336	230	175	139	105	86	74	51	39	32	27	20	14
3+	4-8	253	202	164	134	104	85	73	51	39	32	27	20	14
3+	2-4	146	115	96	82	75	67	60	49	39	32	27	20	14
3+	1-2	78	70	57	48	42	37	33	27	23	20	18	14	14
3+	1/2-1	49	38	30	26	22	19	17	14	12	12	12	09	08

ONE-STOP EXCURSIONS FROM 70-74 FSW

85Aug D58400.K17

Interval >16 hr

Excursion depths (fsw) with bottom and stop times (min)

135	140	145	150	155	160	170	180	190
231 0	176 0	139 0	105 0	86 0	74 0	51 0	39 0	32 0
240 2	180 2	150 2	120 3	90 2	90 5	60 2	45 2	45 5
	210 8	180 11	150 12	120 7	120 15	90 13	60 8	60 14
	240 13	210 18	180 21	150 20	150 28	120 29	90 22	
		240 23	210 27	180 29	180 37	150 42		
			240 41	210 41				

200	220	240
27 0	20 0	14 0
30 2	29 7	16 4
45 9		
60 19		

Interval 2-16 hr

Excursion depths (fsw) with bottom and stop times (min)

135	140	145	150	155	160	170	180	190
115 0	96 0	82 0	75 0	67 0	60 0	49 0	39 0	32 0
		120 32	120 48	90 23	90 43	60 4	45 2	45 7
		150 57		120 64		90 67	60 23	

200	220	240
27 0	20 0	14 0
30 2	29 7	16 4
45 17		

SATURATION DECOMPRESSION FROM STORAGE AT 70-74 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	95	100	105	110	115	120	125	130	135	140	145	>145
Starting depth to use	75	80	85	90	95	100	105	110	115	120	125	125

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
125	2865	45	9	air	1.01	45
120	2820	45	9	air	0.97	43
115	2775	45	9	air	0.94	41
110	2730	45	9	air	0.91	38
105	2685	60	12	air	0.88	48
100	2685	60	12	air	0.85	44
95	2625	60	12	air	0.81	41
90	2565	60	12	air	0.78	37
85	2505	60	12	air	0.75	34
80	2445	60	12	air	0.72	30
75	2385	95	19	air	0.69	42

Precursory	9.6 hr	CPTD	443
Main	1 d + 14.2 hr	CPTD	134
Total	1 d + 23.8 hr	CPTD	577

Main Table: k = 4.5798

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
70	2290	105	21	air	0.66	40
65	2185	110	22	air	0.62	34
60	2075	115	23	air	0.59	28
55	1960	120	24	air	0.56	21
50	1840	125	25	air	0.53	11
45	1715	135	27	air	0.50	0
40	1580	145	29	air	0.46	0
35	1435	155	31	air	0.43	0
30	1280	165	33	air	0.40	0
25	1115	180	36	air	0.37	0
20	935	195	39	air	0.34	0
15	740	220	44	air	0.31	0
10	520	245	49	air	0.27	0
5	275	275	55	air	0.24	0

OXYGEN MANAGEMENT AT 75-79 FSW

Pressure: 75 fsw = 23.03 msw = 230.29 kilopascals = 3.27 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 9.2 to 10.7 percent oxygen at 75 fsw

PO_2 of air at		CPTU/hr at	
75 fsw=	0.69	**75 fsw=**	27
79 fsw=	0.71	**79 fsw=**	30
91 fsw=	0.79	**91 fsw=**	38
95 fsw=	0.82	**95 fsw=**	41

ASCENDING EXCURSIONS FROM 75-79 FSW

Target depth range, **fsw:**	**<25**	**25-30**	**30-35**	**35-40**	**40-45**	**45-50**	**50-55**	**55-60**	**>=60**
Time allowed:	0	9	15	21	28	36	47	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 16 fsw**

NO-STOP EXCURSIONS FROM 75-79 FSW

85Aug D55R00.H18

Excn#	Intrvl	Allowable time (min) at each excursion depth **(fsw)** **65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr												480	480
2nd	8-16												480	480
2nd	4-8												480	480
2nd	2-4					...All 480...							480	480
2nd	1-2												480	480
2nd	1/2-1												480	480
3+	8-16												480	480
3+	4-8												480	480
3+	2-4												480	357
3+	1-2												480	201
3+	1/2-1												415	108

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	480	386	253	187	151	111	90	66	46	36	30	23	16
2nd	8-16	480	364	252	185	150	111	90	66	46	36	30	23	16
2nd	4-8	423	310	237	175	140	110	89	66	46	36	30	23	16
2nd	2-4	329	234	182	148	117	100	84	62	45	36	30	22	16
2nd	1-2	260	160	132	112	85	75	67	51	41	33	27	21	16
2nd	1/2-1	217	99	96	76	56	53	49	37	31	27	22	16	14
3+	8-16	480	364	252	185	150	111	90	66	46	36	30	23	16
3+	4-8	372	270	212	175	140	110	89	66	46	36	30	23	16
3+	2-4	217	156	122	100	85	76	69	55	45	36	30	22	16
3+	1-2	118	84	74	60	50	43	38	30	25	22	19	15	13
3+	1/2-1	66	54	40	32	27	23	20	16	13	12	13	10	08

ONE-STOP EXCURSIONS FROM 75-79 FSW

85Aug D58400.K19

Interval >16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

145	150	155	160	170	180	190	200	220
187 0	151 0	111 0	90 0	66 0	46 0	36 0	30 0	23 0
210 5	180 9	120 2	120 6	90 8	60 4	45 3	45 6	29 5
240 10	210 15	150 9	150 17	120 20	90 15	60 10	60 15	
	240 20	180 18	180 26	150 33	120 33	90 26		
		210 24	210 36	180 45				
240								
16 0								

Interval 2-16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

145	150	155	160	170	180	190	200	220
100 0	85 0	76 0	69 0	55 0	45 0	36 0	30 0	22 0
150 31	120 27	120 42	90 17	90 50	60 9	45 3	45 8	29 5
180 50	150 50		120 58			60 32		
240								
16 0								

SATURATION DECOMPRESSION FROM STORAGE AT 75-79 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	100	105	110	115	120	125	130	135	140	145	150	>150
Starting depth to use	80	85	90	95	100	105	110	115	120	125	130	130

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
130	3085	45	9	air	1.04	48
125	3040	45	9	air	1.01	45
120	2995	45	9	air	0.97	43
115	2950	45	9	air	0.94	41
110	2905	45	9	air	0.91	38
105	2860	60	12	air	0.88	48
100	2800	60	12	air	0.85	44
95	2740	60	12	air	0.81	41
90	2680	60	12	air	0.78	37
85	2620	60	12	air	0.75	34
80	2560	95	19	air	0.72	48

Main Table: k = 4.4131

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
75	2465	100	20	air	0.69	44
70	2365	105	21	air	0.66	40
65	2260	110	22	air	0.62	34
60	2150	120	24	air	0.59	29
55	2030	125	25	air	0.56	22
50	1905	130	26	air	0.53	12
45	1775	140	28	air	0.50	0
40	1635	150	30	air	0.46	0
35	1485	160	32	air	0.43	0
30	1325	175	35	air	0.40	0
25	1150	185	37	air	0.37	0
20	965	205	41	air	0.34	0
15	760	225	45	air	0.31	0
10	535	250	50	air	0.27	0
5	285	285	57	air	0.24	0

Precursory	10.3 hr	CPTD	467
Main	1 d + 17.1 hr	CPTD	181
Total	2 d + 3.4 hr	CPTD	648

OXYGEN MANAGEMENT AT 80-84 FSW

Pressure: 80 fsw = 24.56 msw = 245.64 kilopascals = 3.42 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 8.8 to 10.2 percent oxygen at 80 fsw

PO_2 of air at		CPTU/hr at	
80 fsw=	0.72	**80 fsw=**	30
84 fsw=	0.74	**84 fsw=**	33
98 fsw=	0.83	**98 fsw=**	43
102 fsw=	0.86	**102 fsw=**	45

ASCENDING EXCURSIONS FROM 80-84 FSW

Target depth range, **fsw:**	**<25**	**25-30**	**30-35**	**35-40**	**40-45**	**45-50**	**50-55**	**55-60**	**60-65**	**>=65**
Time allowed:	0	5	10	16	23	30	37	48	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 18 fsw**

NO-STOP EXCURSIONS FROM 80-84 FSW

85Aug D55R00.K19

Excn#	Intrvl	Allowable time (min) at each excursion depth **(fsw)** **65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr													
2nd	8-16													
2nd	4-8													
2nd	2-4					...All 480...								
2nd	1-2													
2nd	1/2-1													
3+	8-16													
3+	4-8													
3+	2-4													
3+	1-2													
3+	1/2-1													

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	480	480	420	282	199	159	119	79	56	41	33	24	16
2nd	8-16	480	480	397	281	198	157	119	79	56	41	33	24	16
2nd	4-8	480	477	327	250	187	147	118	79	56	41	33	24	16
2nd	2-4	480	382	244	191	159	123	103	74	56	41	33	24	16
2nd	1-2	480	314	182	135	121	91	78	61	47	39	31	22	16
2nd	1/2-1	480	271	114	93	83	60	54	46	35	29	25	18	14
3+	8-16	480	480	397	281	198	157	119	79	56	41	33	24	16
3+	4-8	480	410	290	224	183	147	118	79	56	41	33	24	16
3+	2-4	426	240	168	129	105	88	78	63	52	41	33	24	16
3+	1-2	244	132	90	72	63	52	45	35	28	24	21	16	13
3+	1/2-1	132	69	59	43	34	28	24	18	15	12	12	11	09

ONE-STOP EXCURSIONS FROM 80-84 FSW

85Aug D58400.K20

Interval >16 hr

Excursion depths (fsw) with bottom and stop times (min)

150	155	160	170	180	190	200	220	240
199 0	159 0	119 0	79 0	56 0	41 0	33 0	24 0	16 0
210 2	180 6	120 1	90 3	60 1	45 1	45 4	29 4	
240 7	210 12	150 7	120 11	90 10	60 6	60 12	29 12	
	240 17	180 15	150 23	120 24	90 18	90 29	29 22	
		210 21	180 31	150 37	120 37			
		240 30	210 46					

Interval 2-16 hr

Excursion depths (fsw) with bottom and stop times (min)

140	145	150	155	160	170	180	190	200
168 0	129 0	105 0	88 0	78 0	63 0	52 0	41 0	33 0
210 8	180 21	150 25	120 19	120 37	90 30	60 2	45 2	45 5
240 20	210 35	180 43	150 44	150 61	120 66	90 57	60 14	60 39
	240 47		180 63					

220	240
24 0	16 0
29 4	

SATURATION DECOMPRESSION FROM STORAGE AT 80-84 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	105	110	115	120	125	130	135	140	145	150	>150
Starting depth to use	85	90	95	100	105	110	115	120	125	130	130

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
130	3225	45	9	air	1.04	48
125	3180	45	9	air	1.01	45
120	3135	45	9	air	0.97	43
115	3090	45	9	air	0.94	41
110	3045	45	9	air	0.91	38
105	3000	60	12	air	0.88	48
100	2940	60	12	air	0.85	44
95	2880	60	12	air	0.81	41
90	2820	60	12	air	0.78	37
85	2760	95	19	air	0.75	54

Precursory	9.3 hr	CPTD	439
Main	1 d + 20.4 hr	CPTD	239
Total	2 d + 5.8 hr	CPTD	678

Main Table: k = 4.2351

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
80	2665	100	20	air	0.72	50
75	2565	105	21	air	0.69	46
70	2460	110	22	air	0.66	42
65	2350	115	23	air	0.62	36
60	2235	125	25	air	0.59	31
55	2110	130	26	air	0.56	22
50	1980	135	27	air	0.53	12
45	1845	145	29	air	0.50	0
40	1700	155	31	air	0.46	0
35	1545	165	33	air	0.43	0
30	1380	180	36	air	0.40	0
25	1200	195	39	air	0.37	0
20	1005	215	43	air	0.34	0
15	790	235	47	air	0.31	0
10	555	260	52	air	0.27	0
5	295	295	59	air	0.24	0

OXYGEN MANAGEMENT AT 85-89 FSW

Pressure: 85 fsw = 26.10 msw = 260.99 kilopascals = 3.58 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 8.4 to 9.8 percent oxygen at 85 fsw

PO_2 of air at		CPTU/hr at	
85 fsw=	0.75	**85 fsw=**	34
89 fsw=	0.78	**89 fsw=**	37
104 fsw=	0.87	**104 fsw=**	47
108 fsw=	0.90	**108 fsw=**	49

ASCENDING EXCURSIONS FROM 85-89 FSW

Target depth range, **fsw:**	**<30**	**30-35**	**35-40**	**40-45**	**45-50**	**50-55**	**55-60**	**60-65**	**65-70**	**>=70**
Time allowed:	0	5	10	16	23	30	37	48	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 19 fsw**

NO-STOP EXCURSIONS FROM 85-89 FSW

85Aug D55R00.K20

Excn#	Intrvl	Allowable time (min) at each excursion depth **(fsw)** **65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr													
2nd	8-16													
2nd	4-8													
2nd	2-4					...All 480...								
2nd	1-2													
2nd	1/2-1													
3+	8-16													
3+	4-8													
3+	2-4													
3+	1-2													
3+	1/2-1													

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr	480	480	462	324	214	167	99	71	49	38	27	16	
2nd	8-16	480	480	439	314	212	165	99	71	49	38	27	16	
2nd	4-8	480	480	345	265	201	155	99	71	49	38	27	16	
2nd	2-4	480	448	253	200	167	130	93	66	49	38	26	16	
2nd	1-2	480	380	187	136	125	97	71	55	43	35	24	16	
2nd	1/2-1	480	337	135	86	92	64	51	40	32	28	20	15	
3+	8-16	480	480	431	314	212	165	99	71	49	38	27	16	
3+	4-8	480	455	313	238	192	155	99	71	49	38	27	16	
3+	2-4	480	270	181	137	110	92	73	58	49	38	26	16	
3+	1-2	311	149	98	73	67	55	40	32	26	23	17	14	
3+	1/2-1	171	79	65	46	36	29	21	17	14	12	11	09	

ONE-STOP EXCURSIONS FROM 85-89 FSW

85Aug D58400.K22

Interval >16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

150	155	160	170	180	190	200	220	240
324 0	214 0	167 0	99 0	71 0	49 0	38 0	27 0	16 0
	240 4	180 4	120 4	90 6	60 2	45 3	29 2	
		210 10	150 13	120 16	90 13	60 8		
		240 14	180 21	150 28	120 29	90 22		
			210 27	180 36	150 41	120 40		
			240 41					

Interval 2-16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

145	150	155	160	170	180	190	200	220
181 0	137 0	110 0	92 0	73 0	58 0	49 0	38 0	26 0
240 13	180 15	150 20	120 11	90 6	90 41	60 4	45 3	29 2
	210 28	180 36	150 38	120 47		90 63	60 23	
	240 39	210 51	180 56					

240
16 0

SATURATION DECOMPRESSION FROM STORAGE AT 85-89 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	115	120	125	130	135	140	145	150	155	160	>160
Starting depth to use	90	95	100	105	110	120	125	130	135	140	140

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
140	3395	30	6	air	1.10	35
135	3365	45	9	air	1.07	50
130	3320	45	9	air	1.04	48
125	3275	45	9	air	1.01	45
120	3230	45	9	air	0.97	43
115	3185	45	9	air	0.94	41
110	3140	45	9	air	0.91	38
105	3095	60	12	air	0.88	48
100	3035	60	12	air	0.85	44
95	2975	60	12	air	0.81	41
90	2915	95	19	air	0.78	59

Main Table: k = 4.1716

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
85	2820	100	20	air	0.75	56
80	2720	105	21	air	0.72	53
75	2615	105	21	air	0.69	46
70	2510	115	23	air	0.66	44
65	2395	120	24	air	0.62	38
60	2275	125	25	air	0.59	31
55	2150	130	26	air	0.56	22
50	2020	140	28	air	0.53	13
45	1880	150	30	air	0.50	0
40	1730	160	32	air	0.46	0
35	1570	170	34	air	0.43	0
30	1400	180	36	air	0.40	0
25	1220	200	40	air	0.37	0
20	1020	215	43	air	0.34	0
15	805	240	48	air	0.31	0
10	565	265	53	air	0.27	0
5	300	300	60	air	0.24	0

Precursory	9.6 hr	CPTD	492
Main	1 d + 23.0 hr	CPTD	303
Total	2 d + 8.6 hr	CPTD	795

OXYGEN MANAGEMENT AT 90-94 FSW

Pressure: 90 fsw = 27.63 msw = 276.34 kilopascals = 3.73 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 8.0 to 9.4 percent oxygen at 90 fsw

PO_2 of air at		CPTU/hr at	
90 fsw=	0.78	90 fsw=	37
94 fsw=	0.81	94 fsw=	40
110 fsw=	0.91	110 fsw=	51
114 fsw=	0.94	114 fsw=	54

ASCENDING EXCURSIONS FROM 90-94 FSW

Target depth range, fsw:	<35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	>=75
Time allowed:	0	6	12	18	24	31	40	52	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: Storage depth + 20 fsw

NO-STOP EXCURSIONS FROM 90-94 FSW

85Aug D55R00.H21

Allowable time (min) at each excursion depth (fsw)

Excn#	Intrvl	70	75	80	85	90	95	100	105	110	115	120	125
1st	>16 hr												
2nd	8-16												
2nd	4-8												
2nd	2-4					...All 480...							
2nd	1-2												
2nd	1/2-1												
3+	8-16												
3+	4-8												
3+	2-4												
3+	1-2												
3+	1/2-1												

Excn#	Intrvl	130	135	140	145	150	155	160	170	180	190	200	220	240
1st	>16 hr	480	480	480	480	480	358	231	139	86	62	44	29	16
2nd	8-16	480	480	480	480	337	230	139	86	62	44	29	16	
2nd	4-8	480	480	480	378	285	218	134	85	62	44	29	16	
2nd	2-4	480	480	480	284	214	174	112	80	60	44	29	16	
2nd	1-2	480	480	453	215	144	129	82	65	50	40	27	16	
2nd	1/2-1	480	480	420	173	87	96	55	48	36	30	22	16	
3+	8-16	480	480	480	465	337	230	139	86	62	44	29	16	
3+	4-8	480	480	480	340	253	202	134	85	62	44	29	16	
3+	2-4	480	480	307	198	146	115	82	67	54	44	29	16	
3+	1-2	480	428	171	107	78	70	48	37	30	25	19	16	
3+	1/2-1	242	91	72	50	38	26	19	16	13	12	10		

ONE-STOP EXCURSIONS FROM 90-94 FSW

85Aug D58400.K23

Interval >16 hr

Excursion depths (fsw) with bottom and stop times (min)															
155		**160**		**170**		**180**		**190**		**200**		**220**		**240**	
358	0	231	0	139	0	86	0	62	0	44	0	29	0	16	0
		240	2	150	2	90	1	90	8	45	1				
				180	10	120	7	120	20	60	4				
				210	16	150	18	150	32	90	15				
				240	21	180	26	180	44	120	32				
						210	36			150	45				
						240	51								

Interval 2-16 hr

Excursion depths (fsw) with bottom and stop times (min)															
150		**155**		**160**		**170**		**180**		**190**		**200**		**220**		**240**	
198	0	146	0	115	0	82	0	67	0	54	0	44	0	29	0	16	0
240	3	180	4	150	12	120	27	90	20	60	1	45	1				
		210	21	180	30	150	49	120	55	90	48	60	10				
		240	32	210	44	180	68										
				240	56												

SATURATION DECOMPRESSION FROM STORAGE AT 90-94 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	120	125	130	135	140	145	150	155	160	170	>170
Starting depth to use	95	100	105	110	115	120	125	130	135	140	140

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
140	3515	30	6	air	1.10	35
135	3485	45	9	air	1.07	50
130	3440	45	9	air	1.04	48
125	3395	45	9	air	1.01	45
120	3350	45	9	air	0.97	43
115	3305	45	9	air	0.94	41
110	3260	45	9	air	0.91	38
105	3215	60	12	air	0.88	48
100	3155	60	12	air	0.85	44
95	3095	95	19	air	0.81	65

Precursory		8.6 hr	CPTD 457
Main	2 d +	2.0 hr	CPTD 370
Total	2 d +	10.6 hr	CPTD 827

Main Table: k = 4.0488

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
90	3000	100	20	air	0.78	62
85	2900	100	20	air	0.75	56
80	2800	105	21	air	0.72	53
75	2695	110	22	air	0.69	49
70	2585	115	23	air	0.66	44
65	2470	120	24	air	0.62	38
60	2350	130	26	air	0.59	32
55	2220	135	27	air	0.56	23
50	2085	145	29	air	0.53	13
45	1940	150	30	air	0.50	0
40	1790	165	33	air	0.46	0
35	1625	175	35	air	0.43	0
30	1450	190	38	air	0.40	0
25	1260	205	41	air	0.37	0
20	1055	225	45	air	0.34	0
15	830	245	49	air	0.31	0
10	585	275	55	air	0.27	0
5	310	310	62	air	0.24	0

OXYGEN MANAGEMENT AT 95-99 FSW

Pressure: 95 fsw = 29.17 msw = 291.69 kilopascals = 3.88 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 7.7 to 9.0 percent oxygen at 95 fsw

PO_2 of air at		CPTU/hr at	
95 fsw=	0.81	**95 fsw=**	41
99 fsw=	0.84	**99 fsw=**	44
116 fsw=	0.95	**116 fsw=**	55
120 fsw=	0.98	**120 fsw=**	58

ASCENDING EXCURSIONS FROM 95-99 FSW

Target depth range, fsw:	<40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	>=80
Time allowed:	0	6	12	18	24	31	40	52	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 21 fsw**

NO-STOP EXCURSIONS FROM 95-99 FSW

85Aug D55R00.H22

Excn#	Intrvl	Allowable time (min) at each excursion depth (fsw) 75	80	85	90	95	100	105	110	115	120	125
1st	>16 hr											
2nd	8-16											
2nd	4-8											
2nd	2-4					...All 480...						
2nd	1-2											
2nd	1/2-1											
3+	8-16											
3+	4-8											
3+	2-4											
3+	1-2											
3+	1/2-1											

Excn#	Intrvl	130	135	140	145	150	155	160	170	180	190	200	220	240
1st	>16 hr				480	480	480	386	187	111	77	54	29	16
2nd	8-16				480	480	480	364	185	111	77	54	29	16
2nd	4-8				480	480	423	310	175	111	76	54	29	16
2nd	2-4	...All 480...			480	480	329	235	148	100	71	53	29	16
2nd	1-2				480	480	260	160	112	75	59	46	29	16
2nd	1/2-1				480	480	218	99	76	53	43	34	25	16
3+	8-16				480	480	480	364	185	111	77	54	29	16
3+	4-8				480	480	373	270	175	111	76	54	29	16
3+	2-4				480	357	217	156	100	76	61	51	29	16
3+	1-2				480	201	118	84	60	43	34	28	20	16
3+	1/2-1				415	108	66	54	32	23	18	14	12	11

ONE-STOP EXCURSIONS FROM 95-99 FSW

85Aug D58400.K24

Interval >16 hr

Excursion depths (fsw) with bottom and stop times (min)

160	170	180	190	200	220	240
386 0	187 0	111 0	77 0	54 0	29 0	16 0
	210 5	120 2	90 4	60 1		
	240 9	150 8	120 12	90 11		
		180 16	150 23	120 24		
		210 22	180 31	150 36		
		240 32	210 45			

Interval 2-16 hr

Excursion depths (fsw) with bottom and stop times (min)

160	170	180	190	200	220	240
156 0	100 0	76 0	61 0	51 0	29 0	16 0
210 15	150 27	120 37	90 31	60 3		
240 24	180 43	150 59	120 63	90 54		
	210 58					

SATURATION DECOMPRESSION FROM STORAGE AT 95-99 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	125	130	135	140	145	150	155	160	170	>170
Starting depth to use	100	105	110	115	120	125	130	135	145	145

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
145	3705	30	6	air	1.13	36
140	3675	30	6	air	1.10	35
135	3645	45	9	air	1.07	50
130	3600	45	9	air	1.04	48
125	3555	45	9	air	1.01	45
120	3510	45	9	air	0.97	43
115	3465	45	9	air	0.94	41
110	3420	45	9	air	0.91	38
105	3375	60	12	air	0.88	48
100	3315	100	20	air	0.85	74

Main Table: k = 3.8804

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
95	3215	100	20	air	0.81	68
90	3115	100	20	air	0.78	62
85	3015	105	21	air	0.75	59
80	2910	110	22	air	0.72	55
75	2800	115	23	air	0.69	51
70	2685	120	24	air	0.66	46
65	2565	125	25	air	0.62	39
60	2440	135	27	air	0.59	33
55	2305	140	28	air	0.56	24
50	2165	150	30	air	0.53	14
45	2015	160	32	air	0.50	0
40	1855	170	34	air	0.46	0
35	1685	180	36	air	0.43	0
30	1505	195	39	air	0.40	0
25	1310	215	43	air	0.37	0
20	1095	230	46	air	0.34	0
15	865	255	51	air	0.31	0
10	610	285	57	air	0.27	0
5	325	325	65	air	0.24	0

Precursory	8.2 hr	CPTD	458
Main	2 d + 5.6 hr	CPTD	451
Total	2 d + 13.8 hr	CPTD	909

OXYGEN MANAGEMENT AT 100-104 FSW

Pressure: 100 fsw = 30.70 msw = 307.05 kilopascals = 4.03 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 7.4 to 8.7 percent oxygen at 100 fsw

PO_2 of air at	**100 fsw=**	0.85	CPTU/hr at **100 fsw=**	44
	104 fsw=	0.87	**104 fsw=**	47
	123 fsw=	0.99	**123 fsw=**	59
	127 fsw=	1.02	**127 fsw=**	62

ASCENDING EXCURSIONS FROM 100-104 FSW

Target depth range, **fsw:**	**<45**	**45-50**	**50-55**	**55-60**	**60-65**	**65-70**	**70-75**	**75-80**	**>=80**
Time allowed:	0	7	13	18	25	32	42	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 23 fsw**

NO-STOP EXCURSIONS FROM 100-104 FSW

85Aug D55R00.H23

Excn#	Intrvl	Allowable time (min) at each excursion depth **(fsw)** **80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr										
2nd	8-16										
2nd	4-8										
2nd	2-4				...All 480...						
2nd	1-2										
2nd	1/2-1										
3+	8-16										
3+	4-8										
3+	2-4										
3+	1-2										
3+	1/2-1										

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr					480	480	480	282	159	94	69	29	16
2nd	8-16					480	480	480	281	157	94	69	29	16
2nd	4-8					480	480	477	250	147	94	68	29	16
2nd	2-4	... All 480...				480	480	383	191	123	88	64	29	16
2nd	1-2					480	480	314	135	91	69	53	29	16
2nd	1/2-1					480	480	271	93	60	50	38	27	16
3+	8-16					480	480	480	281	157	94	69	29	16
3+	4-8					480	480	410	224	147	94	68	29	16
3+	2-4					480	426	240	129	88	71	57	29	16
3+	1-2					480	244	132	72	52	39	31	22	16
3+	1/2-1					480	132	69	43	28	21	16	12	11

ONE-STOP EXCURSIONS FROM 100-104 FSW

85Aug D58400.K25

Interval >16 hr

Excursion depths (fsw) with bottom and stop times (min)												
170		**180**		**190**		**200**		**220**		**240**		
282	0	159	0	94	0	69	0	29	0	16	0	
		180	6	120	5	90	7					
		210	11	150	14	120	16					
		240	15	180	22	150	28					
				210	27							

Interval 2-16 hr

Excursion depths (fsw) with bottom and stop times (min)												
170		**180**		**190**		**200**		**220**		**240**		
129	0	88	0	71	0	57	0	29	0	16	0	
180	18	120	17	90	10	90	40					
210	30	150	38	120	45	120	70					
240	41	180	55	150	69							
		210	71									

SATURATION DECOMPRESSION FROM STORAGE AT 100-104 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	130	135	140	145	150	155	160	170	180	>180
Starting depth to use	105	110	115	120	125	130	135	145	155	155

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
155	4495	30	6	air	1.20	39
150	4465	30	6	air	1.16	38
145	4435	30	6	air	1.13	36
140	4405	30	6	air	1.10	35
135	4375	45	9	air	1.07	50
130	4330	45	9	air	1.04	48
125	4285	45	9	air	1.01	45
120	4240	45	9	air	0.97	43
115	4195	45	9	air	0.94	41
110	4150	45	9	air	0.91	38
105	4105	100	20	air	0.88	79

Precursory	8.2 hr	CPTD	492
Main	2 d + 18.8 hr	CPTD	358
Total	3 d + 2.9 hr	CPTD	850

Main Table: k = 3.5166

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
100	4005	105	21	air	0.85	77
95	3900	105	21	air	0.81	71
90	3795	175	35	0.5	0.50	0
85	3620	175	35	0.5	0.50	0
80	3445	175	35	0.5	0.50	0
75	3270	175	35	0.5	0.50	0
70	3095	175	35	air	0.66	66
65	2920	175	35	air	0.62	55
60	2745	175	35	air	0.59	43
55	2570	175	35	air	0.56	30
50	2395	175	35	air	0.53	16
45	2220	175	35	air	0.50	0
40	2045	185	37	air	0.46	0
35	1860	200	40	air	0.43	0
30	1660	215	43	air	0.40	0
25	1445	235	47	air	0.37	0
20	1210	255	51	air	0.34	0
15	955	285	57	air	0.31	0
10	670	315	63	air	0.27	0
5	355	355	71	air	0.24	0

OXYGEN MANAGEMENT AT 105-109 FSW

Pressure: 105 fsw = 32.24 msw = 322.40 kilopascals = 4.18 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 7.2 to 8.4 percent oxygen at 105 fsw

PO_2 of air at	**105 fsw=**	0.88	CPTU/hr at **105 fsw=**	48
	109 fsw=	0.90	**109 fsw=**	50
	129 fsw=	1.03	**129 fsw=**	63
	133 fsw=	1.06	**133 fsw=**	66

ASCENDING EXCURSIONS FROM 105-109 FSW

Target depth range, **fsw:**	**<50**	**50-55**	**55-60**	**60-65**	**65-70**	**70-75**	**75-80**	**80-85**	**>=85**
Time allowed:	0	7	13	18	25	32	42	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 24 fsw**

NO-STOP EXCURSIONS FROM 105-109 FSW

85Aug D55R00.H24

Allowable time (min) at each excursion depth **(fsw)**

Excn#	Intrvl	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr										
2nd	8-16										
2nd	4-8										
2nd	2-4			...All 480...							
2nd	1-2										
2nd	1/2-1										
3+	8-16										
3+	4-8										
3+	2-4										
3+	1-2										
3+	1/2-1										

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr						480	480	463	214	128	83	29	16
2nd	8-16						480	480	439	212	128	83	29	16
2nd	4-8						480	480	345	201	127	82	29	16
2nd	2-4			...All 480...			480	480	253	167	107	77	29	16
2nd	1-2						480	480	187	125	80	63	29	16
2nd	1/2-1						480	480	135	92	55	47	29	16
3+	8-16						480	480	432	212	128	83	29	16
3+	4-8						480	480	313	192	127	82	29	16
3+	2-4						480	480	181	110	79	65	29	16
3+	1-2						480	311	98	67	46	36	24	16
3+	1/2-1						480	171	65	36	25	19	13	12

ONE-STOP EXCURSIONS FROM 105-109 FSW

85Aug D58400.K26

Interval >16 hr

Excursion depths (fsw) with bottom and stop times (min)												
170		180		190		200		220		240		
463	0	214	0	128	0	83	0	29	0	16	0	
		240	4	150	4	90	2					
				180	12	120	8					
				210	17	150	19					
				240	23	180	26					
						210	37					

Interval 2-16 hr

Excursion depths (fsw) with bottom and stop times (min)												
170		180		190		200		220		240		
181	0	110	0	79	0	65	0	29	0	16	0	
240	11	150	17	120	28	90	20					
		180	32	150	48	120	53					
		210	44	180	66							
		240	56									

SATURATION DECOMPRESSION FROM STORAGE AT 105-109 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	140	145	150	155	160	170	180	>180
Starting depth to use	110	115	120	125	135	145	155	155

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
155	5035	30	6	air	1.20	39
150	5005	30	6	air	1.16	38
145	4975	30	6	air	1.13	36
140	4945	30	6	air	1.10	35
135	4915	45	9	air	1.07	50
130	4870	45	9	air	1.04	48
125	4825	45	9	air	1.01	45
120	4780	45	9	air	0.97	43
115	4735	45	9	air	0.94	41
110	4690	105	21	air	0.91	89
Precursory		7.5 hr			CPTD	464
Main	3 d +	4.4 hr			CPTD	485
Total	3 d +	11.9 hr			CPTD	949

Main Table: k = 3.1779

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
105	4585	110	22	air	0.88	87
100	4475	115	23	air	0.85	85
95	4360	190	38	air	0.50	0
90	4170	190	38	0.5	0.50	0
85	3980	190	38	0.5	0.50	0
80	3790	190	38	0.5	0.50	0
75	3600	190	38	0.5	0.69	84
70	3410	190	38	air	0.66	72
65	3220	190	38	air	0.62	60
60	3030	190	38	air	0.59	47
55	2840	190	38	air	0.56	33
50	2650	190	38	air	0.53	17
45	2460	195	39	air	0.50	0
40	2265	205	41	air	0.46	0
35	2060	220	44	air	0.43	0
30	1840	240	48	air	0.40	0
25	1600	260	52	air	0.37	0
20	1340	285	57	air	0.34	0
15	1055	310	62	air	0.31	0
10	745	350	70	air	0.27	0
5	395	395	79	air	0.24	0

OXYGEN MANAGEMENT AT 110-114 FSW

Pressure: 110 fsw = 33.78 msw = 337.75 kilopascals = 4.33 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 6.9 to 8.1 percent oxygen at 110 fsw

PO_2 of air at	**110 fsw=**	0.91	CPTU/hr at **110 fsw=**	51
	114 fsw=	0.94	**114 fsw=**	53
	135 fsw=	1.07	**135 fsw=**	67
	139 fsw=	1.10	**139 fsw=**	70

ASCENDING EXCURSIONS FROM 110-114 FSW

Target depth range, **fsw:**	**<55**	**55-60**	**60-65**	**65-70**	**70-75**	**75-80**	**80-85**	**85-90**	**>=90**
Time allowed:	0	7	13	18	25	32	42	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: **Storage depth + 25 fsw**

NO-STOP EXCURSIONS FROM 110-114 FSW

85Aug D55R00.H25

Allowable time (min) at each excursion depth **(fsw)**

Excn#	Intrvl	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**
1st	>16 hr									
2nd	8-16									
2nd	4-8									
2nd	2-4				...All 480...					
2nd	1-2									
2nd	1/2-1									
3+	8-16									
3+	4-8									
3+	2-4									
3+	1-2									
3+	1/2-1									

Excn#	Intrvl	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**170**	**180**	**190**	**200**	**220**	**240**
1st	>16 hr							480	480	358	176	105	29	16
2nd	8-16							480	480	337	175	105	29	16
2nd	4-8							480	480	285	164	104	29	16
2nd	2-4		...All 480...					480	480	214	139	93	29	16
2nd	1-2							480	463	144	104	73	29	16
2nd	1/2-1							480	420	87	69	52	29	16
3+	8-16							480	480	337	175	105	29	16
3+	4-8							480	480	253	164	104	29	16
3+	2-4							480	307	146	102	75	29	16
3+	1-2							480	171	78	57	42	27	16
3+	1/2-1							480	91	50	30	22	14	12

ONE-STOP EXCURSIONS FROM 110-114 FSW

85Aug D58400.K27

Interval >16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

180		190		200		220		240	
358	0	176	0	105	0	29	0	16	0
		180	1	120	3				
		210	7	150	10				
		240	10	180	17				
				210	23				
				240	33				

Interval 2-16 hr

Excursion depths **(fsw)** with bottom and stop times (min)

170		180		190		200		220		240	
307	0	146	0	102	0	75	0	29	0	16	0
		180	3	120	2	120	37				
		210	18	150	28	150	58				
		240	28	180	44						

SATURATION DECOMPRESSION FROM STORAGE AT 110-114 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	145	150	155	160	170	180	>180
Starting depth to use	115	120	125	135	145	155	155

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
155	5555	30	6	air	1.20	39
150	5525	30	6	air	1.16	38
145	5495	30	6	air	1.13	36
140	5465	30	6	air	1.10	35
135	5435	45	9	air	1.07	50
130	5390	45	9	air	1.04	48
125	5345	45	9	air	1.01	45
120	5300	45	9	air	0.97	43
115	5255	110	22	air	0.94	99

Precursory	6.8 hr	CPTD	433
Main	3 d + 13.8 hr	CPTD	633
Total	3 d + 20.6 hr	CPTD	1066

Main Table: k = 2.9420

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
110	5145	115	23	air	0.91	98
105	5030	120	24	air	0.88	95
100	4910	205	41	0.5	0.50	0
95	4705	205	41	0.5	0.50	0
90	4500	205	41	0.5	0.50	0
85	4295	205	41	0.5	0.50	0
80	4090	205	41	air	0.72	103
75	3885	205	41	air	0.69	91
70	3680	205	41	air	0.66	78
65	3475	205	41	air	0.62	64
60	3270	205	41	air	0.59	50
55	3065	205	41	air	0.56	35
50	2860	205	41	air	0.53	19
45	2655	210	42	air	0.50	0
40	2445	225	45	air	0.46	0
35	2220	240	48	air	0.43	0
30	1980	260	52	air	0.40	0
25	1720	280	56	air	0.37	0
20	1440	305	61	air	0.34	0
15	1135	335	67	air	0.31	0
10	800	375	75	air	0.27	0
5	425	425	85	air	0.24	0

OXYGEN MANAGEMENT AT 115-120 FSW

Pressure: 115 fsw = 35.31 msw = 353.11 kilopascals = 4.49 atm abs

Habitat gas = 0.3 to 0.35 atm oxygen partial pressure
= 6.7 to 7.8 percent oxygen at 115 fsw

PO_2 of air at 115 fsw= 0.94
120 fsw= 0.97
142 fsw= 1.11
147 fsw= 1.14

CPTU/hr at 115 fsw= 54
120 fsw= 57
142 fsw= 71
147 fsw= 74

ASCENDING EXCURSIONS FROM 115-120 FSW

Target depth range, fsw:	<60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	>=95
Time allowed:	0	7	13	18	25	32	42	60	no limit

OXYGEN WINDOW EXCURSION RANGE

Breathing air: [illegible]

NO-STOP EXCURSIONS FROM 115-120 FSW

85Aug D55R00.H26

Allowable time (min) at each excursion depth (fsw)

Excn#	Intrvl	90	95	100	105	110	115	120	125
1st	>16 hr								
2nd	8-16								
2nd	4-8								
2nd	2-4				...All 480...				
2nd	1-2								
2nd	1/2-1								
3+	8-16								
3+	4-8								
3+	2-4								
3+	1-2								
3+	1/2-1								

Excn#	Intrvl	130	135	140	145	150	155	160	170	180	190	200	220	240
1st	>16 hr							480	480	480	253	151	29	16
2nd	8-16							480	480	480	252	150	29	16
2nd	4-8							480	480	424	237	140	29	16
2nd	2-4		...All 480...					480	480	329	182	117	29	16
2nd	1-2							480	480	260	133	86	29	16
2nd	1/2-1							480	480	218	96	56	29	16
3+	8-16							480	480	480	252	150	29	16
3+	4-8							480	480	373	213	140	29	16
3+	2-4							480	480	217	122	85	29	16
3+	1-2							480	480	118	74	50	29	16
3+	1/2-1							480	416	66	40	27	16	12

ONE-STOP EXCURSIONS FROM 115-120 FSW

85Aug D58400.K28

Interval >16 hr

Excursion depths (fsw) with bottom and stop times (min)

190		200		220		240	
253	0	151	0	29	0	16	0
		180	7				
		210	13				
		240	16				

Interval 2-16 hr

Excursion depths (fsw) with bottom and stop times (min)

180		190		200		220		240	
217	0	122	0	85	0	29	0	16	0
		150	2	120	20				
		180	21	150	38				
		210	32	180	55				
		240	43						

SATURATION DECOMPRESSION FROM STORAGE AT 115-120 FSW

86Dec

Selecting precursory starting depth:

Max excn last 36 hr	150	155	160	170	180	>180
Starting depth to use	120	125	135	145	155	155

Precursory table:

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
155	6060	30	6	air	1.20	39
150	6030	30	6	air	1.16	38
145	6000	30	6	air	1.13	36
140	5970	30	6	air	1.10	35
135	5940	45	9	air	1.07	50
130	5895	45	9	air	1.04	48
125	5850	45	9	air	1.01	45
120	5805	115	23	air	0.97	110

Precursory	6.2 hr	CPTD	401
Main	3 d + 22.8 hr	CPTD	802
Total	4 d + 5.0 hr	CPTD	1203

Main Table: k = 2.7737

Depth fsw	Time togo	Stop time	RRat mn/f	Gas mix	PO2, atm	CPTD stop
115	5690	115	23	air	0.94	104
110	5575	120	24	air	0.91	102
105	5455	220	44	0.5	0.50	0
100	5235	220	44	0.5	0.50	0
95	5015	220	44	0.5	0.50	0
90	4795	220	44	0.5	0.50	0
85	4575	220	44	air	0.75	124
80	4355	220	44	air	0.72	111
75	4135	220	44	air	0.69	97
70	3915	220	44	air	0.66	83
65	3695	220	44	air	0.62	69
60	3475	220	44	air	0.59	54
55	3255	220	44	air	0.56	38
50	3035	220	44	air	0.53	20
45	2815	220	44	air	0.50	0
40	2595	235	47	air	0.46	0
35	2360	255	51	air	0.43	0
30	2105	275	55	air	0.40	0
25	1830	295	59	air	0.37	0
20	1535	325	65	air	0.34	0
15	1210	360	72	air	0.31	0
10	850	400	80	air	0.27	0
5	450	450	90	air	0.24	0

POST-SUBMAXIMAL WORKSHEET Date _____ Time _____ Initials _____

For calculating the extra allowed time for a no-stop excursion following one that did not use its full allowable time.

A. Finding t:used Excn depth _____ **t:used** _____

t:used is the **actual** time that was used for the submaximal excursion, as taken from the dive log. It has to be **less** than the full table time allowed (see B, next).

B. Finding t:allowed (same depth as A) **t:allowed** _____

t:allowed is the maximum time that could have been used on the submaximal excursion had it not been submaximal, i.e. time of a normal full length excursion. 1. First determine the interval before the submaximal excursion:

a. Submax start time: _____ b. Preceding excn end time: _____

c. Difference between (1) and (2), hr. Time interval: _____

2. Excursion sequence number for the submaximal excursion: _____
3. Read t:allowed from the table for the proper sequence and interval.

C. F:unused, the portion of time unused = (t:allowed - t:used)/t:allowed

F:unused = (_____ - _____)/_____ = _____

D. Finding t:min Excn depth _____ **t:min** _____

t:min is the full time that would have been allowed for the post-submaximal excursion had the submaximal excursion been a full length excursion ending at the same time. 1. First determine the interval for the post-submaximal excursion.

a. Post-submax start time: _____. b. Submax excn end time: _____

c. Difference between (a) and (b), in hours. Time interval: _____

2. Excursion sequence number for post-submaximal excursion: _____
3. Read t:min from the table.

E. Finding t:max (same depth as D) **t:max** _____

t:max is the time that would be allowed for the post-submaximal excursion if the submaximal excursion had not occurred at all. Determined from the tables. 1. First determine the interval.

a. Post-submax start time: _____. b. Excn before submax end time: _____

c. Difference between (a) and (b), in hours. Time interval: _____

2. Excursion sequence number for the post-submaximal excursion. Excn sequence number: _____
3. Read t:max from the table.

F. Calculating the adjusted post-submaximal excursion time:

max:penalty = t:max - t:min = _____ - _____ = _____

t:adj = t:min + (max:penalty * F:unused)

t:adj = _____ + (_____ * _____) = _____

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