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**INTERIM AIR PURITY GUIDELINES FOR DRY DECK SHELTER  
(DDS) OPERATIONS**

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## **TECHNICAL REVIEW AND APPROVAL NMRI 90-109**

The experiments reported herein were conducted according to the principles set forth in the current edition of the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animal Resources, National Research Council.

This technical report has been reviewed by the NMRI scientific and public affairs staff and is approved for publication. It is releasable to the National Technical Information Service where it will be available to the general public, including foreign nations.

**LARRY W. LAUGHLIN  
CAPT, MC, USN  
Commanding Officer  
Naval Medical Research Institute**

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## INTRODUCTION

Historically, different air purity standards have been applied to different operational settings within the U.S. Navy. These operational settings include routine Fleet diving, saturation diving, and nuclear submarines. Because Dry Deck Shelter (DDS) operations represent a hybrid of normal air diving and submarine atmosphere exposure, air purity questions for such missions fall outside the scope of current U.S. Navy documents, such as the U.S. Navy Diving Manual and the Nuclear Powered Submarine Atmosphere Control Manual. Thus, the Naval Medical Research Institute was tasked to develop purity standards for divers' air derived from submarine air banks.

This report provides screening procedures for verifying purity of divers' breathing air during DDS operations. These guidelines have been previously promulgated to the Fleet (COMNAVSEASYS COM ltr 10560 00C3/2101 of 16 July 86) but only now are being formally published to facilitate reference and distribution. This published version is identical in all aspects to that previously distributed to COMNAVSEASYS COM and the Fleet.

INTERIM AIR PURITY GUIDELINES FOR DRY DECK SHELTER (DDS)  
OPERATIONS

|               |                                                                                                                                                                                                                                            |
|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Section I:    | Limits for Gaseous Contaminants in Diver's Air                                                                                                                                                                                             |
| Section II:   | Required Sampling Apparatus                                                                                                                                                                                                                |
| Section III:  | Detector Tube Sampling Technique                                                                                                                                                                                                           |
| Section IV:   | Photoionization Detector (PID) Sampling<br>Technique                                                                                                                                                                                       |
| Section V:    | Stainless Steel Cylinder Sampling Technique                                                                                                                                                                                                |
| Section VI:   | Sampling and Action Schedule                                                                                                                                                                                                               |
| Section VII:  | Individual Gases, Safe Limits, and Detection<br>Methods<br><br>Category 1 Must Analyze - PID insensitive<br>Category 2 Must Analyze - PID sensitive<br>Category 3 Analyze - Engineering Casualty Only<br>Category 4 Not routinely analyzed |
| Section VIII: | Submarine High Pressure Air Management                                                                                                                                                                                                     |

## SECTION I: LIMITS FOR GASEOUS CONTAMINANTS IN DIVER'S AIR

1. The Interim Air Purity Guidelines for DDS Operations define a process by which air is periodically analyzed, thus providing a monitoring function during the conduct of operations. The process must be implemented as written to ensure acceptable diver's air. Exceptions to these procedures should only be in consultation with the Diving Medical Officer.

2. The acceptable limits for gaseous contaminants in submarine compressed air for use as diver's breathing air are derived from the 8-hour Time Weighted Average (TWA) as established by the Occupational Health and Safety Administration (OHSA). Since the operations are assumed to expose the divers to a pressure of about 4 ATA, the partial pressure and presumed toxicity of contaminants are assumed to be 4 times as harmful as the same gas at 1 ATA. All analyses are performed near 1 ATA. The applicable DDS limits are therefore the OHSA limits divided by four. OHSA limits (1978 compilation) are listed in Section IV and longer lists can be found in NAVMEDCOMINST 6270.3 Series or DHEW(NIOSH) Publication 78-210 "Pocket Guide to Chemical Hazards". These limits are periodically updated, and the most current value should be used.

3. Gaseous contaminants found in submarines number in the thousands of compounds. Routine surveillance for that number is impossible. However the larger majority of substances are present in only very low amounts and present no toxic hazard. A

selected number are suitable for DDS monitoring since they can be measured on-site and their probability of occurrence and degree of toxicity merit concern. These selected compounds are listed in Section VII along with the appropriate detection methods. Additional compounds are also listed in Section VII to assist in the understanding of unexpected equipment problems which might be remedied without return to port or access to a full gas analysis laboratory.

4. Should a sample indicate an unacceptably high level of any compound, the following actions should be followed:

- a) Confirm the nature of the contaminant, preferably by sending a sample of the air to a gas analysis laboratory.
- b) Change DDS supply to another air bank or bleed and refill the contaminated bank with fresh surface air, consistent with requirements of the host submarine.
- c) Repeat the tests on the new gas supply.

It is desirable but not required to receive the results from the gas analysis laboratory before resuming operations.



## SECTION II: REQUIRED SAMPLING APPARATUS

1. Diver's air should be sampled from an inboard location and downstream of the DDS lithium hydroxide scrubber.

2. A sample line should be fitted with components to allow gas to be routed to each of four analysis sites: (1) a gas bag for detector tubes, (2) the Central Atmospheric Monitoring System-I (CAMS-I), (3) a photoionization detector (PID), (4) a sample bomb connection for shore based analysis. A functional schematic diagram is presented in Figure 1. All piping and fittings should be of oxygen clean metal, and final "soft" connectors should be short as possible and be made of Teflon or polyethylene rather than a rubber material.

3. Necessary components include:

- a) A valve to isolate the sampling apparatus and if necessary a regulator to step down air bank pressure to 1000 psi maximum. If the sample line is  $\frac{1}{4}$  inch, a Whitney  $\frac{1}{4}$  turn ball valve, P/n SS-42F2 is acceptable.
- b) A microvalve or throttling valve to control flow in the range of 0-10 liters per minute and a flowmeter with this range. A Whitney micro valve P/n SS-21RF2 is acceptable.
- c) A multiway valve to direct gas flow to each of the necessary instruments. A 5-way multiport valve such as the Whitney P/n SS-432F2 is acceptable.

- d) A 5 liter Tedlar bag with airtight fittings for detector tubing sampling.
- e) A needle adapter and septum (or equivalent) to allow detector tube connection. The bag, needle adaptor and replacement septa can be obtained from SKC Co. (334 Valley View Rd., Eighty-four, PA 15330), stock numbers 231-05, 231-9-12, 231-9-04.
- f) An open mouth fitting of 1-1.5 cm dia. and 5-10 cm. length for gas access to the PID. A 5 ml plastic syringe barrel is acceptable.
- g) A clean connection to sample cylinders. Either CGA 580 male or  $\frac{1}{4}$  inch brass or stainless steel pipe thread female is acceptable. This connection should deliver at least 50 psi to the sample cylinders. Do not exceed the maximum pressure stated on the cylinder (nominally 1800 psig).
- h) Detector tube hand pumps. The submarine's Draeger hand pump is acceptable for Draeger and SKC Tubes. A separate pump is needed for other manufacturers.
- i) A collection of detector tubes as specified in Section VII. These should be stored at 30 °C or less for 2 years or less as specified by the manufacturer.
- j) A photoionization trace gas detector (available through NAVSEA Code 56YF1, part number 2S 6665011545338A2 or Model PI 101 from HNU Inc., 160

- Sharlemont St, Newton Highlands, MA 02161) with rechargeable battery pack and 10.2 eV lamp.
- k) A calibration gas of 10-15 ppm isobutylene in hydrocarbon free air and a high purity regulator (0-100 psi delivery) with appropriate adaptor for the fitting in item f). Gas cylinder should preferably be aluminum to avoid contamination of contents. Can be obtained from Scott Specialty Gases, Plumsteadville, PA, as well as other suppliers.
- l) Stainless steel sample bombs for use in a gas analysis laboratory can be obtained from the Hyperbaric Medicine Program Center, Naval Medical Research Institute, Bethesda, MD. The emergency gas sampling kit specified in the Submarine Atmosphere Control Manual is also acceptable.

### SECTION III: DETECTOR TUBE SAMPLING TECHNIQUE

Operating principal: Prepackaged tubes contain a chemically reactive system that is rather specific for a single gas. When the gas is drawn past the chemicals, a color-producing reaction will occur to an extent dependent on the gas concentration and the total volume passed through the tube. Each tube has a package insert that describes possible cross-reactions with other gases that may cloud interpretation. Some tube systems can have increased sensitivity by increasing the volume of gas.

Note: Detector tubes are manufactured by different companies, and no one source has a full range of tubes. Known tube suppliers are:

National Draeger, P.O. Box 120, Pittsburgh, PA 15230. Tel: (412) 787-8383. Federal stock FC-66051. Also available from SKC Co., 395 Valley View Rd., Eighty-four, PA 15330. Tel: (800) 752-8472. Federal Stock FC-55659.

MSA (Mine Safety Appliances), 600 Penn Center Blvd., Pittsburgh, PA 15235. Tel: (800) 672-2222, Federal Stock FC-40912.

MSA, 3880 Meadowbrook Rd., Murrysville, PA 15668. Tel: (412) 325-1313, Federal Stock FC-55799.

Kitigawa Co., available from Matheson Gas Products, 932 Patterson Plank Rd., P.O. Box 85, East Rutherford, NJ 07073. Tel: (201) 933-2400, Federal Stock FC-96355.

Also available from Scientific Gas Products Inc., 2300  
Hamilton Blvd., South Plainfield, NJ 07080. Tel: (201)  
754-7700.

Where Federal Stock Numbers are known, they are included in the  
tables in Section VII.

The following procedure is taken from the Draeger detector  
tube manual. Operation of other pumps and additional equipment  
such as pyrolyzer attachments should follow supplier's  
instructions.

1. Conduct a check of the detector tube pump to ensure  
that there are no leaks as follows:
  - a) Insert an unopened detector tube into the inlet  
orifice.
  - b) Compress the hand pump.
  - c) Observe for 2 minutes to ensure that there is no  
re-expansion of the pump which would indicate a  
leak.
  - d) Remove tube at the end of 2 minutes.

This check should be carried out before the first sample each day  
that gas analysis is to be performed. If a leak is found,  
another pump should be used.

2. Compress and release pump with no detector tube in  
place. Pump should expand immediately to the full length of the  
restricting chain. This check should be carried out before the  
first sample each day to ensure proper function of the pump. If

expansion is not immediate and complete, another pump should be used.

3. Check expiration date on detector tubes and ensure that there are no cracks or discolorations. Discard if expiration date has passed or defects are present.

4. Turn the multiport valve (Figure 1) to the flowmeter position, open the ball valve to DDS bank air and adjust the microvalve until a flow of \*1/min is obtained. Allow gas to flow for \* minutes prior to taking sample to purge the HP piping from the air banks to the sample valve. After the designated time, adjust microvalve to obtain flow of \* 1/min.

\* Flow settings and times are dependent on equipment as installed. Guidance should be sought from an instrumentation engineer before the operation.

5. Turn the multiport valve to the detector tube sample bag. Wait 15 seconds to purge the tube leading to the bag. Begin filling the bag by pushing stainless steel hose connection into bag valve.

6. Fill detector tube sample bag completely (but avoid overfilling and consequently pressurizing and damaging the bag).

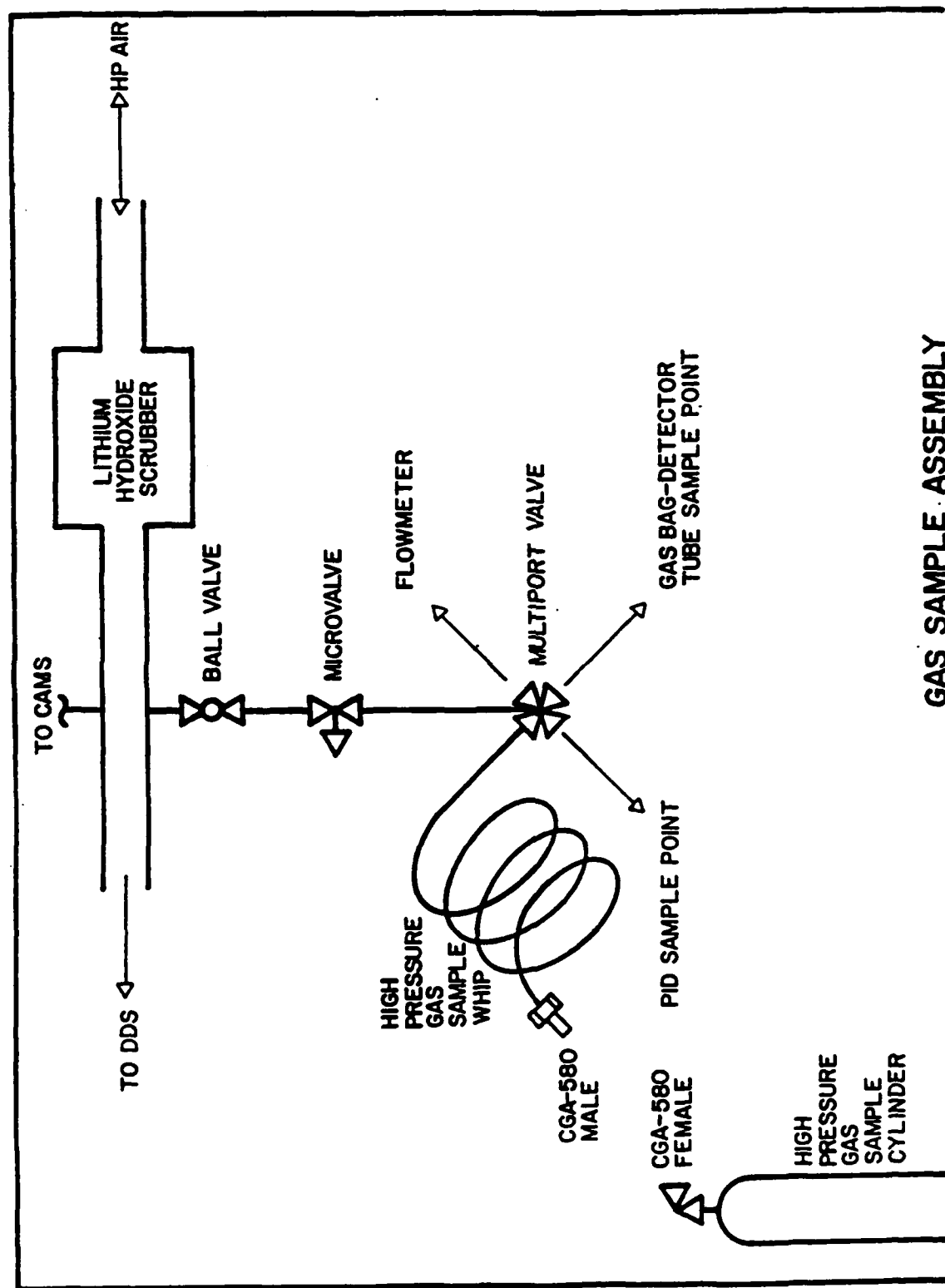
7. Pull stainless steel hose connection out to stop filling and to secure bag.

8. Empty sample bag by removing nut from sample port and manually expelling gas from bag. Replace sample nut.

9. Repeat steps 5-8 a total of 3 times.

10. Refill the sample bag a forth time.

FIGURE 1



GAS SAMPLE ASSEMBLY

11. Pull hose connection out to secure bag. Turn the multiport valve to the flowmeter.
12. Insert the needle adapter into septum of the sample bag.
13. Break both ends off of the appropriate detector tube.
14. Press down on the sample bag briefly to flush the needle adapter sample tubing.
15. Insert the detector tube into the needle adapter.
16. Compress the hand pump.
17. Insert other end of detector tube into hand pump.
18. Release hand pump bellows and ALLOW PUMP TO EXPAND UNTIL RESTRICTING CHAIN IS COMPLETELY TAUT. This should take 20-30 seconds due to the restricted flow through the needle.
19. If required by the detector tube instructions compress hand pump and release to complete additional cycles.
20. Wait 30 seconds (or other intervals if specified by the tube manufacturer).
21. Read the level of the gaseous contaminant from the length of the stain (colored portion) of the detector tube and record. If additional samples are needed, leave needle adapter in place in sample bag and remove detector tube.
22. Repeat steps 13-21 for additional detector tubes.
23. Additional tubes may be tested from the sample bag until bag is empty. When empty, the bag should be refilled; additional flushing of the bag is not necessary.



#### SECTION IV: PHOTOIONIZATION DETECTOR (PID) SAMPLING TECHNIQUE

Operating principle: An internally-sealed light source emits at an energy (10.2 ev) which can ionize some, but not all gases. Ion formation and migration rates depend on properties of the gas (especially first ionization potential, concentration, and flow rate). The total ion current is read on the meter. Small, usually nontoxic gases, ( $O_2$ ,  $CO_2$ , CO, methane, freons) gives little or no response. For example, pure nitrogen, helium and air read about 0.3-0.4 ppm. Many toxic gases such as aromatics and ketones are sensed with high efficiency.

- Notes:
- a) If a plastic syringe barrel is used as a sampling port, replace it and any other plastic connectors daily
  - b) All meter readings are from 0.0 to a maximum of 0.0 divisions
  - c) The isobutylene calibration gas is completely non-toxic, tends to oxidize in hopcalite  $CO/H_2$  burner, and has a long history of safe use in submarines by NRL chemists

1. Attach the high purity regulator to the isobutylene gas cylinder and attach a syringe sampling port to the regulator. Place cylinder of isobutylene calibration gas in a position where both that gas and the DDS sample can be analyzed without moving the instrument between compartments.

2. Disconnect PID from battery charger. Check battery status with range switch. If battery is not OK, instrument can be used with line power via battery charger. Turn meter to "STANDBY" with probe in room air. Wait 5 minutes for instrument to warm up.

3. Open the calibration gas regulator valve and increase flow gradually. Insert PID probe into the open mouth of the syringe barrel. The gas flow out of the syringe barrel should be greater than the gas consumption of the PID probe, i.e., the gas flow should be barely audible from the syringe.

4. With the range in "STANDBY", adjust meter to 0 with "ZERO" knob.

5. Without moving probe, switch range to 0-20 and wait for meter to stabilize (20-30 sec). Use "SPAN" knob to adjust meter reading to a convenient number. For example, with 14 ppm calibration gas, set at 14.0. If the SPAN knob will not keep the meter on scale, use a higher range (i.e. 0-200).

6. Without moving probe, recheck zero on "STANDBY". Repeat directions #4-6 if zero drift occurred.

7. Turn multiport valve (Figure 1) to the flowmeter and set a flow of 5 l/min with the microvalve. Turn multiport valve to PID sample point. Position probe in flowing sample of DDS gas. Check zero in "STANDBY".

8. Without moving probe, switch range to 0-20 and sample DDS gas with probe and record meter reading to nearest 0.1 (ex. 6.7, 6.8, 6.9). The maximum meter reading is 20.0 divisions. If

the meter goes off scale, switch to the next higher range.

Record range reading (0-20, 0-200, 0-2000).

9. Without moving probe, check zero on "STANDBY". If zero shifted, repeat steps 7-9.

10. Record: calibration gas used; meter reading in divisions (0-20.0); range reading (0-20 ppm, 0-200 ppm, 0-2000 ppm), and span knob reading at time of calibration.

Note: Span knob readings are for information only.

Significant changes from day to day with the same calibration gas suggests instrument malfunction.

11. Convert PID meter reading to ppm isobutylene equivalents:

$$\text{ppm} = \frac{(\text{meter reading})(\text{range})(\text{CONV})}{20}$$

where:

$$\text{CONV} = \frac{\text{calibration gas isobutylene concentration (ppm)}}{\text{calibration meter reading}} \cdot \frac{\text{calibration gas range}}{20}$$

## SECTION V: STAINLESS STEEL CYLINDER SAMPLING TECHNIQUE

The stainless steel sample bombs obtained from the Hyperbaric Medicine Program Center, Naval Medical Research Institute are cleaned and evacuated to a very high vacuum (<30 millitorr).

To obtain a sample, the stainless steel sample whip is attached to the multiport valve (Figure 1). The multiport valve is first turned to the flowmeter and 5 l/min of DDS air flow is set using the microvalve. The multiport valve is then turned to the whip to purge it. Flow air for one minute. While gas continues flowing, the CGA 580 male fitting of the whip is loosely threaded into the CGA 580 female fitting of the cylinder. After purging of the fitting is complete, the cylinder connection is made wrench-tight. The sample cylinder valve is then opened slowly and the cylinder allowed to equilibrate (about 2 minutes). Extreme care must be taken not to expose the cylinder to more pressure than its working pressure. When equilibration is complete, the cylinder valve closed, and the cylinder disconnected from the whip, gas flow is once again diverted to the flowmeter. The date, time, and circumstances of sampling are labeled on the cylinder and in accompanying documentation.

Cylinders must be declared as hazardous cargo ("Air, Compressed Non-Flammable Gas") prior to air transport. Analysis of cylinder content can be requested from the Naval Medical Research Institute. Similar sample bombs are available from

other labs and comprehensive gas analysis can be requested of them as geographical circumstances and other factors dictate.

## SECTION VI: SAMPLING AND ACTION SCHEDULE

1. The DDS air bank should be lined up at least 1 hour before sampling. Lines should be flushed with air bank gas for at least 20 times the sampling dead space (total volume of piping, valves, regulators between air bank itself and analysis instruments).

2. Sample for the 7 compounds listed in Section VII as Category 1. Detector tubes are available for these gases, but alternatively a CAMS-I in good operating condition can be used for 4 of them. If any of the 7 readings exceeds the DDS limit, the gas is unusable.

3. Sample the gas with the PID. If the PID reading is over 50 ppm isobutylene equivalents, the gas is unusable.

4. Examine the list of compounds in Category 2 of Section VII. Any compound whose PID/DDS limit [column (e)] is greater than the PID reading from the air bank can be ruled out as a potential contaminant.

**EXAMPLE:** The PID detector shows 7 ppm as isobutylene. From Section VII, Category 2: most of the compounds can be declared as not present in toxic amounts; only n-hexane methyl chloride, methyl chloroform, phenol, and trichloroethane remain in possibly toxic amounts.

5. Use detector tubes to sample for the presence of Category 2 compounds whose PID/DDS limit is below the air bank reading. Any compound found to be above the DDS limit [column (c)] makes the gas unusable.

6. If PID reading is above 5 ppm and detector tube results from step 5 do not provide an explanation, the gas should not be used. PID readings below 1 ppm are not reliable.

7. DDS air levels of carbon dioxide should be monitored as continuously as operationally feasible. This is especially important if the air banks are being changed continuously. In general, at a minimum, carbon dioxide levels should be monitored every 30 minutes during diving operations. If the level rises above 1250 ppm, the lithium hydroxide scrubber should be changed as soon as possible.

8. Use Category 3 detector tubes only if indicated (e.g. following fire, battery spill, etc.). These compounds normally interact with steel walls of piping and tanks and do not persist as inhalation hazards.

9. Category 4 compounds are either not detectable with current on-board equipment, or not expected to present a hazard. Information is provided for reference only.

10. With the exception of CO<sub>2</sub> noted in item 7, gas samples need not be repeated during the course of a single operation. HOWEVER a complete resampling following steps 2-5 is necessary before diving operations if any of the following occur:

- a) the air bank used for DDS divers is changed to one which has not undergone sampling since its last charge.
- b) the air bank is charged after the initial sampling, whether submerged or not.
- c) the air bank dedicated to DDS supply is opened to a nondelicated bank that has not been sampled since its last charge,
- d) a previous test has confirmed unusable gas.

11. If the air bank used for the DDS is being bled and charged continuously, the assurance of safe gas is more difficult. In this case a complete resampling should be conducted whenever 5% of the bank has been exchanged. For example, a bank at 3000 psi bled to 2850 psi and recharged to 3000 psi would call for resampling.

NOTE: Carbon dioxide is the most likely gas to cause contamination problems. If divers report symptoms suggestive of CO<sub>2</sub> buildup despite acceptable levels in the air bank supply, the symptoms may be due to inadequate ventilation of the DDS, gas pocketing in the DDS, excessive exercise, or a combination of these factors.

12. Stainless steel cylinder samples should be obtained for definitive shore-based analysis whenever a new system is being debugged, an unexpected and/or unexplained problem is



encountered, or an exceptionally high contaminant level is indicated by the CAMS-I, the detector tubes, or the photoionization detector. It is very important that the details of the problem and the sampling conditions be transmitted to the gas analysis laboratory. A copy of that information should be sent to the Hyperbaric Medicine Program Center, Naval Medical Research Institute, Bethesda, MD. 20814-5055 to aid in developing long term solutions to the air purity problem.

13. If the PID fails, only items marked with a # in Category 2 of the Section VII must be checked with detector tubes before using gas.

# SECTION VII: INDIVIDUAL GASES, SAFE LIMITS, AND DETECTION METHODS

Category 1: Commonly present and toxic. Must be checked before operation  
using detector tubes or CAMS-I. Not detectable by PID.

| Compound                                                 | TLV limit<br>(ppm) | DDS limit<br>(ppm)              | Detector Tubes<br>or CAMS-I                                                                                      | Tube Range<br>(ppm)                                 |
|----------------------------------------------------------|--------------------|---------------------------------|------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| Ammonia                                                  | 50                 | 12.5                            | M-92115*<br>*FSN6665-00-406-9450<br>D-CH 20501<br>S-800-20501<br>K-8014-105Sc                                    | 10-400<br>5-700<br>5-700<br>10-260, 5-130<br>MULTI  |
| Carbon<br>monoxide                                       | 50                 | 12.5<br>(9.5 mTorr)<br>(0.125%) | M-47134*<br>*FSN6665-00-276-7545<br>D-CH 25601<br>S-800-33051<br>K-8014-106Sb*<br>*FSN6665-01-169-3595<br>CAMS-I | 10-1000<br>5-700<br>2-300<br>5-50                   |
| Carbon<br>dioxide                                        | 5000               | 1250.<br>(0.95 Torr)<br>(1.25%) | M-85976*<br>*FSN6665-00-019-2110<br>D-CH 23501<br>S-800-28521<br>K-8014-126Sb<br>CAMS-I                          | 200-120,000<br>100-60,000<br>100-3000<br>500-10,000 |
| Freon 113<br>(1,1,2-trichloro-<br>1,2,2-trifluoroethane) | 1000               | 250.<br>(192 mTorr)             | M-92030*<br>*FSN6665-00-406-8150                                                                                 | 100-4000                                            |
| Freon 114<br>(dichlorotetra-<br>fluoroethane)            | 1000               | 250.<br>(192 mTorr)             | M-88536*<br>*FSN6665-00-406-8146<br>CAMS-I                                                                       | 200-2000<br>MULTI                                   |
| Freon 12<br>(dichloro-<br>difluoromethane)               | 1000               | 250.<br>(192 mTorr)             | M-88536*<br>*FSN6665-00-406-8146<br>CAMS-I                                                                       | 25-3000<br>MULTI                                    |

SECTION VII: Category 1 (continued)

| Compound          | TLV limit<br>(ppm) | DDS limit<br>(ppm) | Detector Tubes<br>or CAMS-I | Tube Range<br>(ppm) |
|-------------------|--------------------|--------------------|-----------------------------|---------------------|
| Hydrazine         | 1                  | .25                | D-CH 31801                  | 0.25-3              |
|                   |                    |                    | M-460425*                   | 0.5-40              |
|                   |                    |                    | *FSN6665-31-142-9107        |                     |
|                   |                    |                    | S-800-31801                 | 0.25-3              |
| Vinyl<br>chloride | 5                  | 1.3                | M-462534                    | 0-100               |
|                   |                    |                    | D-67 28061                  | 0.25-6              |
|                   |                    |                    | S-800-28031                 | 1-50                |
|                   |                    |                    | K-8014-123Sc                | 0.5-10              |

Notes: (1) The CAMS-I has a carbon dioxide accuracy specification for field use of  $\pm 1.25$  Torr. In practice, it is frequently more accurate. On the first sample of the day, the CAMS should be checked with a detector tube. If the measurements agree, the CAMS alone can be used for subsequent monitoring. EXCEPTION: if the CAMS has had a reading of 4 Torr or higher (e.g., from another compartment), the next DDS carbon dioxide sample should be checked with both CAMS and a detector tube.

(2) Entries under detector tubes provide the manufacturer and product number. D- is from National Draeger, Inc.; M- is from MSA; K- is from Kitigawa; S- is from SKC. "multi" under range means that the tube has multiple response ranges for multiple gases; see manufacturers instructions with tube. \* indicates a federal stock system item and number.

(3) Conversion of units: 1 millitorr = 1.3 pp,  
1 torr = 1316 ppm  
1% = 10,000 ppm

## SECTION VII

Category 2: Possibly present and toxic. Detectable by PID. No hazard if PID reading is less than PID/DDS limit in column (e).

| (a)<br>Compound               | (b)<br>TLV<br>(ppm) | (c)<br>DDS limit<br>(ppm) | (d)<br>PID<br>Sensitivity<br>factor | (e)<br>PID/DDS<br>limit (ppm<br>as isobut-<br>ylene) | (f)<br>Detector<br>tubes                                                      | (g)<br>Tube Range<br>(ppm)                  |
|-------------------------------|---------------------|---------------------------|-------------------------------------|------------------------------------------------------|-------------------------------------------------------------------------------|---------------------------------------------|
| Chloro-<br>benzene            | 75                  | 19.                       | 2.4                                 | 46.                                                  | D-67 28 761<br>S-800-28761<br>M-85834*<br>*FSN6665-00-406-9447<br>K-8014-178S | 5-200<br>5-200<br>10-200<br>5-140           |
| Cumene<br>(Isopropyl benzene) | 50                  | 12.5                      | 2.0                                 | 25.                                                  | M-460422                                                                      | 0-1000                                      |
| Cyclohexane                   | 300                 | 75.                       | .3                                  | 23.                                                  | D-67 25201(H)<br>S-800-25201<br>K-8014-115S(H)                                | 100-1500<br>100-1500<br>100-6000            |
| #Ethyl<br>benzene             | 100                 | 25.                       | 1.8                                 | 45.                                                  | D-67 28381(H)<br>S-800-28381(H)<br>M-463202<br>K-8014-179S                    | 30-600<br>30-600<br>10-500<br>10-500        |
| n-Heptane                     | 500                 | 125.                      | 0.3                                 | 38.                                                  | No tube                                                                       |                                             |
| #n-Hexane                     | 500                 | 25.                       | 0.2                                 | 25.                                                  | M-463838<br>D-67 28391(H)<br>K-8014-113Sb                                     | 25-5000<br>100-3000<br>50-1400<br>and 3-150 |
| Isopropyl<br>alcohol          | 400                 | 100.                      | 0.2                                 | 20.                                                  | K-8014-150S                                                                   | 100-20000                                   |
| Methyl<br>bromide             | 20                  | 5.                        | 4.2                                 | 21.                                                  | D-67 28211<br>M-462135<br>K-8014-157Sb<br>S-800-28211                         | 3-100<br>2.5-90<br>2.5-80<br>3-100          |

## SECTION VII: Category 2 (continued)

| (a)<br>Compound                                  | (b)<br>TLV<br>(ppm) | (c)<br>DDS limit<br>(ppm) | (d)<br>PID<br>Sensitivity<br>factor | (e)<br>PID/DDS<br>limit (ppm<br>as isobut-<br>ylene) | (f)<br>Detector<br>tubes                                                     | (g)<br>Tube Range<br>(ppm)            |
|--------------------------------------------------|---------------------|---------------------------|-------------------------------------|------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------|
| Methyl<br>Chloride (chloromethane)               | 100                 | 25.                       | .12                                 | 3.                                                   | M-92030*<br>*FSN6665-00-406-8150                                             | 25-1000                               |
| #Methyl<br>chloroform (1,1,1-trichloroethane)    | 350                 | 88.                       | 0.04                                | 3.5                                                  | M-88536(H)<br>S-800-21101<br>D-CH 21101<br>K-8014-160S                       | 100-700<br>50-600<br>50-600<br>15-400 |
| Methyl<br>ethyl benzene                          | 200                 | 50.                       | 0.5                                 | 25.0                                                 | No tube                                                                      |                                       |
| Methyl<br>ethyl ketone (2-butanone)              | 200                 | 50.                       | 0.5                                 | 25.0                                                 | K-8014-139Sb(H)                                                              | 100-1400                              |
| Methyl<br>isobutyl ketone (4-methyl 2-pentanone) | 100                 | 25.                       | 0.9                                 | 18.0                                                 | K-8014-155S(H)                                                               | 50-10,000                             |
| Naphthalene                                      | 10                  | 2.5                       | 3.2                                 | 8.0                                                  | No tube                                                                      |                                       |
| n-Nonane                                         | 200                 | 50.                       | 0.4                                 | 20.0                                                 | D-67 30201                                                                   | 200-5000                              |
| n-Octane                                         | 500                 | 125.                      | 0.4                                 | 50.0                                                 | D-67 30201<br>S-800-30201                                                    | 100-2500<br>100-2500                  |
| Phenol                                           | 5                   | 1.25                      | 1.7                                 | 2.                                                   | D-CH 31501(H)<br>S-800-31501(H)<br>K-8014-183U                               | 5<br>5<br>0.5-25                      |
| Styrene                                          | 100                 | 25.                       | 1.6                                 | 40.                                                  | M-461781<br>D-67 23301<br>K-8014-158S<br>S-800-33141                         | 0-500<br>10-200<br>5-300<br>10-250    |
| #Toluene                                         | 200                 | 50.                       | 1.8                                 | 90.                                                  | M-93074*<br>*FSN6665-00-406-8152<br>D-CH 23001<br>S-800-23001<br>K-8014-124S | 10-800<br>5-400<br>5-400<br>10-500    |

## SECTION VII: Category 2 (continued)

| (a)<br>Compound                             | (b)<br>TLV<br>(ppm) | (c)<br>DDS limit<br>(ppm) | (d)<br>PID<br>Sensitivity<br>factor | (e)<br>PID/DDS<br>limit (ppm<br>as isobut-<br>ylene) | (f)<br>Detector<br>tubes                             | (g)<br>Tube Range<br>(ppm)           |
|---------------------------------------------|---------------------|---------------------------|-------------------------------------|------------------------------------------------------|------------------------------------------------------|--------------------------------------|
| Trichloro-<br>ethane (1,1,2-)               | 10                  | 2.5                       | 1.5                                 | 3.8                                                  | M-85834 (H) *<br>*FSN6665-00-406-8152                | 50-700                               |
| Trichloro-<br>ethylene                      | 100                 | 25.                       | 13.8                                | 345.                                                 | M-460328<br>D-67 28541<br>S-800-28541<br>K-8014-134S | 25-600<br>2-200<br>2-200<br>5-300    |
| 1,2,4 Tri-<br>methyl benzene (pseudocumene) | 25                  | 6.25                      | 2.0                                 | 12.5                                                 | No tube                                              |                                      |
| 1,3,5 Tri-<br>methyl benzene (mesitylene)   | 25                  | 6.25                      | 2.0                                 | 12.5                                                 | No tube                                              |                                      |
| Xylenes                                     | 100                 | 25.                       | 1.9                                 | 48.                                                  | M-463201<br>D-67 33161<br>S-800-33161<br>K-8014-143S | 10-800<br>10-400<br>10-400<br>5-1000 |

- NOTES: (1) A PID reading of less than column (e) is sufficient to rule out toxic limits of this compound. Detector tubes are then unnecessary.
- (2) Detector tubes in column (f) are specified by manufacturer and product number. D- is from National Draeger, Inc; M- is from MSA; K- is from Kitigawa. S- is from SKC. \* refers to federal stock item and number.
- (3) An entry of (H) under detector tubes means that the tube normally is used for higher concentrations than the DDS limit in column (c). It may still be used by drawing additional gas through the tube. Consult product sheet with each tube.
- (4) TLV values for 1,2,4 and 1,2,5 trimethyl benzene and n-nonane are not provided by OSHA. Limits given are those of the American Conference of Governmental Industrial Hygienists.

# SECTION VII

Category 3: Toxic but probably not present except after engineering casualty.  
Check only if indicated.

| Compound                                 | TLV<br>(ppm) | DDS limit<br>(ppm) | Detector Tubes                                                                         | Range<br>(ppm)                                    |
|------------------------------------------|--------------|--------------------|----------------------------------------------------------------------------------------|---------------------------------------------------|
| Chlorine                                 | 1 ceil.      | 0.25 ceil.         | M-460225*<br>*FSN6665-01-204-1826<br>D-CH 24301<br>S-800-24301<br>K-8014-109Sb         | 0.1-25<br>0.2-30<br>0.2-30<br>0.3-6               |
| Hydrogen chloride<br>(hydrochloric acid) | 5 ceil.      | 1.25 ceil.         | M-91636*<br>*FSN6665-00-406-8149<br>D-CH 29501<br>S-800-29501<br>K-8014-173S(H)        | 0-300<br>0.5-25<br>0.5-25<br>0.4-4<br>and 2-20    |
| Hydrogen fluoride<br>(hydrofluoric acid) | 3            | 0.75               | D-CH30301(H)<br>M-462019<br>S-800-3030(H)                                              | 1.5-15<br>0-25<br>1.5-15                          |
| Nitrogen dioxide                         | 1            | 0.25               | D-CH 30001(H)<br>S-800-30001(H)<br>M-83099*<br>*FSN6665-00-125-6543<br>K-8014-117Sb(H) | 0.5-25<br>0.5-25<br>0-30<br>1-30                  |
| Ozone                                    | 0.1          | .025               | M-93865*<br>*FSN6665-00-406-9451<br>D-CH 31301(H)<br>S-800-31301(H)<br>K-8014-182U(H)  | 0.05-5.0<br>0.05-14<br>0.05-14<br>0.05-3<br>MULTI |
| Sulfur dioxide                           | 5            | 1.25               | M-9262*<br>*FSN6665-00-406-8151<br>D-67 28491<br>S-800-28491<br>K-8014-103Sd           | 1-400<br>0.5-25<br>0.5-25<br>1-60                 |

- NOTES:
- (1) Entries of "ceil." under limits are concentrations which OHSA states as ceiling values for any exposure, rather than safe for 8 hour workdays.
  - (2) Detector tubes in 4th column are specified by manufacturer and product number. D- is from National Draeger, Inc; M- is from Mine Safety Appliances; K- is from Kitigawa. S- is from SKC. \* refers to federal stock item.
  - (3) An entry of (H) under detector tubes means that the tubes normally is used for higher concentrations than the DDS limit in 3rd column. It may still be used by drawing additional gas through the tube. Consult product sheet with each tube.



## SECTION VII

Category 4: Routine analysis not required. Compounds are either below measurement range of CAMS-I, PID, and detector tubes and/or are not likely to be present in toxic quantities. For reference only.

| Compound                               | TLV<br>(ppm) | DDS limit<br>(ppm) | Detector Tubes                                                                          | Range<br>(ppm)                                  |
|----------------------------------------|--------------|--------------------|-----------------------------------------------------------------------------------------|-------------------------------------------------|
| Acetaldehyde                           | 200          | 50.                | D-67 26665(H)<br>M-93963*<br>*FSN6665-00-406-9453<br>S-800-26665<br>K-8014-133          | 100-1000<br>25-1000<br><br>100-1000<br>40-10000 |
| Acetonitrile                           | 40           | 10.                | M-91624*<br>*FSN6665-00-406-8148                                                        | 0-150                                           |
| Acrolein                               | 0.1          | .025               | K-8014-136                                                                              | 50-18,000                                       |
| Arsine                                 | 0.05         | .0125              | D-CH 25001(H)<br>S-800-25001(H)<br>K-8014-140(H)                                        | 0.05-60<br>0.05-60<br>5-160                     |
| Benzene                                | 1            | .25                | M-467050<br>D-67 28561(H)<br>S-800-28561(H)<br>K-8014-118Sc                             | 0-150<br>0.5-10<br>0.5-10<br>1-100              |
| Bromine                                | 0.1          | .025               | M-82399(H)*<br>*FSN6665-00-406-8103<br>S-800-24301(H)<br>D-CH 24301(H)<br>K-8014-114(H) | 5-175<br><br>0.2-30<br>0.2-30<br>1-20           |
| Butyl<br>cellosolve (2-butoxy ethanol) | 50           | 12.5               | M-95097(H)                                                                              | 30-900                                          |
| Carbon<br>disulfide                    | 1            | 0.25               | M-463527<br>D-67 28351(H)<br>S-800-28351(H)                                             | 0-100<br>2.5-120<br>2.5-120                     |

## SECTION VII: Category 4 (continued)

| Compound                                    | TLV<br>(ppm) | DDS limit<br>(ppm) | Detector Tubes                                                      | Range<br>(ppm)                     |
|---------------------------------------------|--------------|--------------------|---------------------------------------------------------------------|------------------------------------|
| Carbon<br>tetrachloride                     | 2            | 0.5                | M-460548<br>D-81 01 021 (H)<br>K-8014-147S (H)<br>S-800-27401 (H)   | 10-200<br>1-15<br>1-60<br>5-50     |
| Chloroethane<br>(ethyl chloride)            | 1000         | 250.               | No tube                                                             |                                    |
| Chloroform                                  | 50           | 12.5               | M-88536 (H)<br>D-67 28861 (H)<br>S-800-28861 (H)<br>K-8014-152S (H) | 25-400<br>2-10<br>2-10<br>23-100   |
| 1,2 Dichloro-<br>ethylene                   | 200          | 50.                | M-85834*<br>*FSN6665-00-406-9447<br>K-8014-145S                     | 10-400<br><br>5-400                |
| Dimethyl<br>formamide                       | 10           | 2.5                | D-67 18501 (H)<br>M-91624 (H)<br>S-800-18501 (H)                    | 10-40<br>5-150<br>10-40            |
| Dioxane                                     | 100          | 25.                | K-8014-154S (H)                                                     | 500-25,000                         |
| Di-sec-octyl<br>phthalate                   | 0.3          | 0.075              | No tube                                                             |                                    |
| Ethyl<br>acetate                            | 400.         | 100.               | S-800-20201 (H)<br>D-CH 20201 (H)<br>K-8014-111S (H)                | 200-3000<br>200-3000<br>100-50,000 |
| Ethylene<br>dichloride (1,2-dichloroethane) | 5            | 1.3                | M-461863 (H)                                                        | 0-600                              |
| Ethylene<br>glycol                          | 5            | 1.3                | No tube                                                             |                                    |
| Freon 11<br>(Trichloromonofluoroethane)     | 1000         | 250.               | M-92030*<br>*FSN6665-00-406-8150<br>D-CH 27401                      | 250-2000<br>200-2000               |
| Formaldehyde                                | 3            | .75                | M-93963 (H)<br>D-67 33081<br>S-800-33081<br>K-8014-171              | 1-100<br>0.2-5<br>0.2-5<br>1-35    |

SECTION VII: Category 4 (continued)

| Compound                                      | TLV<br>(ppm) | DDS limit<br>(ppm) | Detector Tubes                                                                                             | Range<br>(ppm)                             |
|-----------------------------------------------|--------------|--------------------|------------------------------------------------------------------------------------------------------------|--------------------------------------------|
| Methyl acetate                                | 10           | 2.5                | K-8014-148 (H)                                                                                             | 0.01-3.0                                   |
| Methyl alcohol<br>(Methanol)                  | 200          | 50.                | D-67 28941<br>M-95097 (H) *<br>*FSN6665-00-406-9454<br>S-800-28941<br>K-8014-119U*<br>*FSN6665-01-010-0444 | 50-3000<br>100-10000<br>50-3000<br>20-1000 |
| Methyl cellosolve (2-methoxy ethanol)         | 25           | 6.2                | No tube                                                                                                    |                                            |
| Methylene chloride (dichloromethane)          | 500          | 125.               | D-67 28331<br>M-462516*<br>*FSN6665-01-124-2198<br>S-800-24601                                             | 100-3000<br>0-3000<br>50-2000              |
| PCB polychlorinated biphenyl                  | .0001        |                    | No tube                                                                                                    |                                            |
| Perchloroethylene (tetrachloroethylene)       | 100          | 25.                | M-460467<br>S-800-26699<br>D-67 26699<br>K-8014-135S                                                       | 0-800<br>5-50<br>5-50<br>5-300             |
| Phosgene                                      | 0.1          | 0.025              | M-89890 (H)<br>D-CH 19401 (H)<br>S-800-19401 (H)<br>K-8014-146S                                            | 0.1-10<br>0.04-1.5<br>0.04-1.5<br>0.05-10  |
| Vinylidene chloride<br>(1,1 dichloroethylene) | 10           | 2.5                | M-85834*<br>*FSN6665-00-406-4447                                                                           | 10-300                                     |

NOTES: (1) Detector tubes in 4th column are specified by manufacturer and product number. D- is from National Draeger, Inc; M- is from Mine Safety Appliances; K- is from Kitigawa. S- is from SKC. \* refers to federal stock item.

(2) An entry of (H) under detector tubes means that the tube normally is used for higher concentrations than the DDS limit in the 3rd column. It may still be used by drawing additional gas through the tube. Consult product sheet with each tube.

## SECTION VIII: SUBMARINE HIGH PRESSURE AIR MANAGEMENT

1. The host submarine should identify air banks to be used to provide air to the DDS complex prior to commencing operations. If possible, this should occur before deployment to allow baseline gas samples to be sent to a gas analysis laboratory.

2. After identifying the air banks for DDS divers air, the banks should be bled down to minimum allowable pressure and recharged with fresh surface air before initial gas sampling and operations. If banks are suspected as contaminated this process should be repeated several times. Banks should be allowed to settle for several hours before sampling to allow a representative sample to be drawn.

3. Once purged the banks should be kept at maximum allowable pressure. This action tends to dilute any residual gas contaminants as well as to suppress the maximum fraction of gas that condensed contaminants can achieve even if equilibrium vapor pressure is reached.

4. If more than one bank is available, the bank with the lowest contaminant level is preferable. A single photoionization reading (Section IV) and carbon dioxide determination may be sufficient to make this choice.

5. Once the banks for DDS air are identified and sampled, contact of this gas with any system other than the DDS should be avoided to the maximum extent compatible with submarine operating requirements. Connection to other banks, and charging from the

submarine when underway will necessitate additional full samples from the bank before and/or during DDS operations.