AD-A133 150

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

SUBMARINE BASE, GROTON, CONN.

SPECIAL REPORT 83-1

Proceedings of the

THIRD TRIPARTITE CONFERENCE

on

SUBMARINE MEDICINE

France United Kingdom United States

May 9 and 10, 1983

Released by:

W. C. Milroy, CAPT, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory

1 June 1983

PROCEEDINGS

of

The Third Tripartite Conference

on

SUBMARINE MEDICINE

(France, The United Kingdom, The United States of America)

9-10 May 1983

Compiled and edited from papers and recorded transcripts of the proceedings

by

Captain Douglas R. Knight, MC, USN

and

Commander Kenneth R. Bondi, MSC, USN

Naval Submarine Medical Research Laboratory
Naval Submarine Base, New London
Groton, Connecticut
USA

COMPONENT PART NOTICE

THIS PAPER IS A COMPONENT PART OF THE FOLLOWING COMPILATION REPORT:

(TITLE): Proceedings of the Tripartite Conference on Submarine Medicine (3rd), [redacted] France, United Kingdom, and United States, [redacted] 9-10 May 1983.

(SOURCE): Naval Submarine Medical Research Lab., Groton, CT.

TO ORDER THE COMPLETE COMPILATION REPORT USE AD-A133 150 .

THE COMPONENT PART IS PROVIDED HERE TO ALLOW USERS ACCESS TO INDIVIDUALLY AUTHORED SECTIONS OF PROCEEDINGS, ANNALS, SYMPOSIA, ETC. HOWEVER, THE COMPONENT SHOULD BE CONSIDERED WITHIN THE CONTEXT OF THE OVERALL COMPILATION REPORT AND NOT AS A STAND-ALONE TECHNICAL REPORT.

THE FOLLOWING COMPONENT PART NUMBERS COMPRISE THE COMPILATION REPORT:

AD#:	TITLE:
P001 877	MPC for Routine Operations in Diesel Submarines.
P001 878	Maximum Permissible Concentrations of Atmosphere Contaminants under Operational Conditions Aboard Conventional Submarines.
P001 879	Maximum Concentrations of Toxic Substances in Conventional Submarines under Normal Operating Conditions - Stanag 1206.
P001 880	Critical Toxic Concentrations.
P001 881	United Kingdom Approach to Emergency Exposure Levels (Stanag 1184).
P001 882	Limits of Respiratory Gases and Carbon Monoxide at Which Conventional Submarines Must Ventilate.
P001 883	Materials Toxicity Clearance in RN Submarines.
P001 884	Cadmium Levels in Submarine Atmospheres and Methods for Its Detection and Monitoring.
P001 885	Bone and Body Mineral Composition Studies in Active Duty and Retired Submariners.
P001 886	Nitrogen Dioxide Levels Aboard Nuclear Submarines.
P001 887	Experimental Studies of Chronic Toxicity of Some Atmosphere Contaminants. Determination of Maximum Allowable Concentrations.
P001 888	Rescue from Pressurized Submarines.
P001 889	Escape and/or Rescue?
P001 890	United Kingdom Escape and Rescue Policy Review Committee Report 1982.
P001 891	AMTE(PL) Proposed Research Programme.
P001 892	Some Considerations on the Treatment of Decompression Illnesses Arising from Submarine Escape or Rescue.
P001 893	Anomalies of Ocular Refraction in Relation to Stay in Confined Space.
P001 894	Current Studies in Submariners.
P001 895	A Preliminary Study of Cardiovascular Risks in Retired Submariners.
P001 896	Carbohydrate Metabolism in Submariner Personnel.

COMPONENT PART NOTICE (CON'T)

AD#:	TITLE:
P001 897	Present Thoughts on Exercise, Weight, and Performance Aboard Nuclear Submarines.
P001 898	The Analysis of French Submarine Atmosphere Contaminants.

Table of Contents

Table of Contents—continued

Participants

Bennett, Brad, L., LT, MSC, USNR, Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Bondi, Kenneth R., CDR, MSC, USN, (delegate), Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Bowman, Jeffrey S., LCDR, MSC, USN, (delegate), Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Burgess, David, Ph. D., (delegate), AMTE, Gosport, Hants. United Kingdom.

Catron, Phillip, CDR, MC, USN, Naval Medical Research Institute, Bethesda, MD. United States.

Christen, Cathleen A., Design Engineer, General Dynamics Corporation-Electric Boat Division, Groton, CT. United States.

Eckenhoff, Roderic G., LCDR, MC, USNR, (delegate), Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Foulger, Brian, Ph.D., (delegate), AMTE, Holton Heath, Poole, Dorset. United Kingdom.

Giacomoni, Louis A., Medecin en Chef, (delegate), CERTSM, Toulon. France.

Harrison, John R., Surgeon Commander, RN, (Chief delegate), Institute of Naval Medicine, Alverstoke, Gosport, Hants. United Kingdom.

Hée, Jean G., Ingenieur Des Constructions Navales, (delegate), CERTSM, Toulon. France.

Heyder, Elly, M.S., (delegate), Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Holt, David C. B., Surgeon Lieutenant Commander, RN, (delegate), Institute of Naval Medicine, Alverstoke, Gosport, Hants. United Kingdom.

Kent, Donald G., M.D., General Dynamics Corporation-Electric Boat Division, Groton, CT. United States.

Knight, Douglas R., CAPT, MC, USN, (delegate), Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Participants--continued

Kobus, David A., LTJG, MSC, USN, Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Luria, S. M., Ph.D., Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Marblé, Georges L., Pharmacien Chimiste, (Chief delegate), CERTSM, Toulon. France.

Marlor, Russel L., CAPT, MC, USN, (Chief delegate), Naval Medical Command, Department of the Navy, Washington, DC. United States.

Messier, Arthur A., M.S., (delegate), Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Milroy, William C., CAPT, MC, USN, Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Moeller, George O., Ph.D., Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Osborne, Steven F., LT, MC, USN, (delegate), Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Pearson, Ramsay R., Surgeon Captain, RN, (delegate), HMS Dolphin, Gosport, Hants. United Kingdom.

Radziszewski, Eugene V., Ingenieur des Constructions Navales, (delegate), CERTSM, Toulon. France.

Rossier, Robert, Environmental System Engineer, General Dynamics Corporation-Electric Boat Division, Groton, CT. United States.

St. Andre, Kenneth, LCDR, MC, USN, COMSUBRON TEN, Naval Submarine Base New London, Groton, CT. United States.

Shea, Michael L., Ph.D., (delegate), Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Smith, Douglas J., Ph.D., (delegate), Institute of Naval Medicine, Alverstoke, Gosport, Hants. United Kingdom.

Sphar, Raymond L., CAPT, MC, USN, Naval Medical Research Institute, Bethesda, MD. United States.

Tappan, Donald V., Ph.D., (delegate), Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Thomson, Gordon, Design Engineer, General Dynamics Corporation-Electric Boat Division, Groton, CT. United States.

Tobias, Jerry V., Ph.D., Naval Submarine Medical Research Laboratory, Naval Submarine Base New London, Groton, CT. United States.

Venezky, David L., Ph.D., (delegate), Naval Research Laboratory, Washington, DC. United States.

Wyatt, Jeffrey R., Ph.D., (delegate), Naval Research Laboratory, Washington, DC. United States.

MPC FOR ROUTINE OPERATIONS IN DIESEL SUBMARINES

BY

MICHAEL SHEA
NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
NAVAL SUBMARINE BASE NEW LONDON
GROTON, CONNECTICUT 06349

In 1976, the NATO Naval Medical Working Party drafted an agreement (STANAG 1206) concerning design criteria for atmospheric control in conventional diesel powered submarines. The agreement was intended to establish maximum allowable limits for shipboard atmospheric substances which could pose a health threat to the crew. A list of 22 substances and their proposed limits for a two-day continuous exposure at a normal operating pressure of 1 BAR were attached to the STANAG in Annex A. The bottom line of the agreement was that participating nations would agree to maintain those limits and also agree to design submarines that would not exceed the limits.

We reviewed the substance on the list using the American Conference of Governmental Industiral Hygenists publication "Documentation of the Threshold Limit Values - Fourth edition, 1980" as a criteria standard. The following briefly describes each substance in relation to its health effects and proposed design limits:

The three substances on the list that have limits based solely on their explosive limits, acetylene, hydrogen, and methane will not be discussed.

Ammonia

Ammonia has a sharp intensely irritating odor detectable by humans between 1 and 50 ppm with the average complaint level at about 25 ppm. It takes a 100 ppm concentration to elicit irritation of the respiratory tract in most humans. Currently there is a disagreement between the national agencies NIOSH and ACGIH as to what the level should be to protect against eye and respiratory irritation but both agree that its less than that the proposed criteria limit of 50 PPM for a two-day exposure aboard a diesel submarine. We feel the level should be lowered to 25 PPM.

Arsine

The extreme acute toxicity of arsine is well known, 250 PPM for 30 minutes is fatal and 3 to 10 PPM can cause poisoning in a few hours. Animal experiments have shown that exposures from 0.5 to 2 PPM for three hours/day can elicit blood changes in a few weeks. Typical are hemoglobinuria, jaundice and hemolytic anemia. Since arsenic has been found in urine of workers exposed to as little as 0.25 PPM the national standard has now been set at 0.05 PPM which is similar to the proposed diesel sub design criteria.

Carbon dioxide

The effects of carbon dioxide are well known. A 5% concentration stimulates the respiratory center and submarine personnel exposed continuously to 3% have been shown to be only slightly affected provided the O_2 content of the air is maintained at normal concentrations. However, when the O_2 is reduced to 15% to 17%, results include a reduced acuity of hearing as well as increasing blood pressure and pulse, evidence of stress, decrement in psychomotor performance, headaches, and a slight acidosis. Exposure for 2 days to 3% CO_2 at normoxic conditions can be considered safe.

Carbon Monoxide

Although the effects of carbon monoxide are thought to be well known since its a simple chemical asphixiant producing hypoxia by binding with hemoglobin, a great deal of confusion has resulted over the years from the summation of thousands of publications on the effects of CO on man because of serious difficulty in the determination of low levels of the compound in air and blood. It now seems reasonably certain that a man exposed to 50 PPM CO for 8 hours will have a HbCO value of 5 to 6% under normal working conditions. With this condition, no symptoms or health impairments are expected. However submariners exposed to 50 PPM CO for many days have complained of headaches but 60 day exposure at 40 PPM have shown no effects. The primary effects of exposures to low CO concentration results from the hypoxic stress occurring due to the reduction in the oxygen carry capacity of blood. This is compensated for by increasing cardiac output and flow to critical organs. In order to protect workers with advanced cardiovascular disease NIOSH recommends 35 PPM as a TWA but the ACGIH feels that while 50 PPM may be too high under conditions of heavy labor and high temperatures, it will not result in either mild temporary distress or permanent impairment of health for the majority of workers under a wide range of working conditions.

REFRIGERANT F-12

Refrigerant F-12 has a very low active toxicity as demonstrated by numerous animal studies with a wide range of concentrations. (100's to 800,000 PPM for 2 hours in cats, rats, and guinea pigs). Human volunteers who inhaled F-12 at 10,000 PPM for 2.5 hours showed only a 7% reduction in a standardized psychomotor test score and no other adverse effects. Chronic studies by oral and other routes reveal few biologic effects. Rats fed 380 mg/kg 5 day/week for 18 weeks showed no clinical, nutritional, histologic or enzyme changes. Dogs fed 3000 PPM daily for 2 years showed no evidence of toxicity and 3 generation reproductive studies in rats fed 3000 PPM for 2 years also showed no adverse effects. Based on the absence of observed significant effects in animals exposed to high concentration of F-12 a TLV of 1,000 PPM has been established so the 500 ppm for diesel subs should be well within safe limits.

Hydrogen Chloride

Hydrogen chloride is a strong irritant with exposures of 50-100 ppm being barely tolerable for 1 hour, 35 ppm causing throat irritation for short periods and 10 ppm allowable for prolonged exposure. Although 5 ppm is the TLV for HCL, even this level can be somewhat disagreeable and bordereline irritating, but it is low enough to prevent toxic injury. The proposed 2.5 PPM TLV for diesel submarines for a 2 day exposure probably will not produce any noticable irritation.

Hydrogen Fluoride

Hydrogen fluoride is a product of freon degradation in the H_2 burner. Many animal and human studies have concluded that insignificant pathologic changes result from repeated exposures up to 17 ppm. Human exposures for 6 hours per day for 10 to 50 days at concentrations up to 4.7 PPM have been tolerated without severe effect. Skin redness and nose and eye irritation were the major problems. A public health survey study showed no pulmonary dysfunction for workers breathing 1 PPM HF. Although 1.5 PPM TLV could cause minor eye irritation in some diesel submariners, no major symptoms would occur.

Mercury

Elemental mercury vapor poisoning is very well documented, however, studies involving the relation between air concentrations and chronic Hg poisoning suggest that in some cases 0.1 mg/m^3 is an adequate TLV whereas others find occasional cases at lesser values. A 1970 survey of the chlorine industry concluded that 0.1 mg/m^3 produced no significant incidence of poisoning but that the 0.1 mg/m^3 TLV also contained little or no safety margin. The TLV for Hg vapor is currently set at 0.05 mg/m^3 which is identical to the value proposed for the diesel submarine atmosphere and is probably safe.

Chlorine

Chlorine is produced chiefly from the mixture of sea water with storage battery acid and 5 PPM can cause respiratory complaints, corrosion of the teeth, and inflammation of the mucous membranes. A 0.05 PPM TLV has been recommended on the basis that concentrations too low to affect the lower respiratory passages may still irritate the eyes, nose, and throat of humans, however, a 1 ppm TLV is what is currently used. The 0.5 TLV for diesel submarines would certainly minimize chronic changes in the lungs as well as accelerated aging and erosion of the teeth.

Methanol

Methanol is slowly eliminaited from the body so repeated exposures can result in an increasing concentration in both blood and tissues. Death or blindness has occurred from occupational poisoning due to working in confined space such as varnishing the interior of beer vats and as little as 8 grams can affect the eyes. That dose would result from inhalation of 800 to 1,000 PPM for 8 hours. Headaches have been reported among office workers exposed to 300 PPM when operating duplicating machines and wood industry workers exposed from 160 to 780 PPM have not shown a definite evidence of injury. Animal studies have been the most conclusive with dogs being exposed 379 consecutive days to 450 to 500 PPM without any symptoms or pathology. The 200 PPM TLV currently used is thought to incorporated a fairly large margin of safety against serious toxic effects and a two day exposure to 100 ppm on a diesel submarine would be well within safe limits.

Nitrogen Dioxide

Nitrogen dioxide is a principle component of diesel exhaust and also results from fires, smoking, and even cooking. Over the years the TLV for NO_2 has been lowered a number of times mainly because the incidence of chronic effects from long exposures at low concentrations is not well defined. Back in the 1950's the TLV was 25 PPM but this was revised down to 5 PPM based on numerous animal studies. A 1970 study with monkeys exposed to 10 PPM for 1 month or 5 PPM for 2 months showed a marked decrease in resistance to infections. Based on animal studies a TLV of 5 PPM was adopted. Since then a number of papers involving the effects of relatively short exposures on individuals with chronic lung disease as well as papers dealing with changes in resistance to infections of animals exposed to low concentrations of NO_2 have appeared and as a result the TLV has been lowered to 3 PPM with a STEL of 5 PPM. Since the design criteria for diesel submarines is 2.5 PPM, it is probably a safe limit at least by current opinion.

Ozone

Ozone is a highly injurious and lethal gas at relatively low concentration and short exposures. The primary site of acute injury is the lung which is characterized by pulmonary congestion, edema, and hemorrhage. The suseptibility of man to O_3 appears to be at least equal to that of the most susceptible animal species (mouse and rat). For example, humans exposed to 1.5 PPM O_3 for 2 hours showed a 20% reduction in timed vital lung capacity. Numerous reports also seem to indicate that O_3 when inhaled at concentrations not acutely injurious per se may initiate, accelerate, or exacerbate respiratory tract disease of bacterial or viral origin. The present consensus of opinion is that there doesn't seem to be a definite threshold for effects caused by O_3 so although a TLV which is currently set at 0.1 PPM represents a limit which may result in no ostensible injury, it can still possibly cause premature aging if the exposure is sufficiently prolonged. We feel that the lower the MPC for O_3 on submarines the better in light of the fact that it can cause injury so rapidly.

Phosgene

The proposed level of 0.5 PPM phosgene for a 2 day exposure as stated in the STANAG 1206 agreement may be in error. Evidence from all animal studies show conclusively that concentrations as low as 0.5 PPM for 2 hours can cause depressed ciliary function as well as definite pathological changes in the lungs such as pulmonary edema and lung lesions. On the other hand, its been shown that breathing phosgene at concentrations from 0.5 to 1 PPM for 6 hours can induce tolerance against the acute effects of itself as well as other edemagenic agents such as O_3 and NO_2. This development of tolerance is a common property of these types of agents, however, the tolerance is believed to be the triggering mechanisms of chronic irreversible pulmonary changes of emphysema and fibrosis from prolonged daily exposure at concentrations that produce no ostensible acute response. Concentrations slightly above 0.1 PPM are thought to develop a tolerance. We strongly feel that the maximum concentration would be no more than 0.1 PPM.

Stibine

Stibine like arsine is a hemolytic agent which injures the kidney and liver and is also a lung irritant. Studies in a battery room have shown the presence of stibine during overcharging but generally in concentrations below 1 PPM. Being less toxic than arsine its been given a TLV of 0.1 PPM so the proposed design criteria of 0.05 PPM leaves a large margin of safety especially in light of the fact that it would be found mainly in the well ventilated battery spaces.

Sulphur Dioxide

Since SO_2 is a principle component of diesel smoke, you might expect to see increased levels onboard a conventional submarine due to minor leaks in the exhaust manifold and associated plumbing as well as induction of exhaust through the snorkel intake when the wind is blowing in the right direction. Basically SO_2 causes irritation of the mucous membranes which results from the action of sulfurous acid formed when the highly soluble gas dissolves. Short term exposure causes brochoconstriction measured as an increase in flow resistance, the magnitude of the response being dose related. A high incidence of respiratory disease has been associated with workers exposed from 2 to 10 PPM SO_2 in paper mills and many studies have concluded that at or below 2 PPM can contribute to pulmonary disease and accelerate the loss of pulmonary function. The national standard for an 8 hour exposure has been reduced to 2 PPM from 5 PPM based on this evidence and the proposed limit on diesel submarines is only 0.5 PPM higher. The concensus of opinion is that effects reported below 2 PPM are not sufficiently serious to justify a lower limit so the value of 2.5 PPM is probably safe.

TRI-ORTHO-CRESYL PHOSPHATE [Triaryl Phosphate]

Triaryl phosphate is a toxic component of the hydraulic fluid cellulube. Short term low-level exposures to triaryl phosphate can cause paralysis, nausea, vomiting, diarrhea, and abdominal pain. Since the use of cellulube has been prohibited in U.S. Navy submarines because of its toxicity, we recommend that NATO forces consider the use of other hydraulic fluids. The current standard for triaryl phosphate is 0.1 mg/m_3 for 8 hours exposure, therefore, 0.1 mg/m_3 for 48 which is the proposed design criteria for diesel submarines would leave little or no safety factor.

Methyl Chloroform

Methyl chloroform is mostly used as a cleaning solvent having a very low systemic toxicity but acting as an anesthetic can cause death at concentrations in excess of 15,000 PPM. Pathologic changes have not been seen in animals except those exposed for 3 months to methyl chloroform at concentrations from 1,000 to 10,000 PPM. Methyl chloroform being poorly metabolized is excreted unchanged in the expired air of human test subjects, and in some, anesthetic effects occur at about 500 PPM but 350 PPM has produced no untoward effects. For this reason 350 PPM has been chosen as a national TLV and the 250 PPM design criteria for diesel submarines could be considered safe.

MAXIMUM PERMISSIBLE CONCENTRATIONS OF ATMOSPHERE CONTAMINANTS UNDER OPERATIONAL CONDITIONS ABOARD CONVENTIONAL SUBMARINES. CERTSM'S-POINT-OF VIEW.

E. Radziszewski

CERTSM - TOULON

1. -

1.1 - To form a true estimate of the submariners' level of exposure to the various contaminants which are present in the submarine atmosphere, and also to define submarine design criteria, it is most advisable to know, in addition to the nature of the contaminants, both the frequency and the duration of the exposures.

In this connection, the definition given in the draft STANAG 1206 is still lacking in precision. As a matter of fact, although the 48 - hour exposure provided for in the STANAG is rather typical of the mean submergence time of a conventional submarine (and even this value should probably be doubled for the most recent submarines), it is not specified anywhere whether it relates to a unique and accidental exposure or to repeated exposures to the suggested concentrations.

1.2 - In conventional submarines, exposure periods are interrupted by snorkel navigation periods during which contaminant concentrations are reduced almost to zero. The submariners are thus subjected to a discontinuous chronic exposure which is, in some respects, not unlike industrial exposure conditions.

Even though the sequences cannot be superimposed exactly, the total exposure time over one year is similar in both cases. Consequently, we believe that the 48 - hour maximum permissible concentrations provided for in the draft STANAG 1206 should be set with reference to industrial TLVs whenever possible. However, it will be possible to investigate separately such particular cases as those involving carbon monoxide and dioxide, the physiological mechanisms of which are rather well known.

1.3 - As regards the <u>nature of the contaminants</u> taken into account by the STANAG 1206 we think it is important to differentiate between <u>permanent</u> contaminants which may be assigned a safety factor, if required, with respect to industrial standards, and <u>accidental</u> contaminants whose concentration limits may sometimes be exceeded.

Moreover, with regard to submarine construction requirements, only the permanent polluants are to be taken into consideration. Under these circumstances, one may wonder why some compounds (such as sulfur dioxide) that are not to be found aboard have been listed.

Now, as far as contamination level monitoring aboard submarines is concerned, the STANAG does not give any detail about either the measures to be taken or the monitoring frequency. Anyhow, it seems out of the question to take aboard all equipment required to analyze all the listed products. At best it will be possible to carry out pinpoint checks during trial submergences for instance.

1.4 - As a conclusion to these few remarks I would say that further details must be added to the draft STANAG 1206 in order to avoid misinterpreting by the signers.

2. -

2. - On the basis of the above-mentioned considerations, the CERTSM has carefully examined the list of MACs suggested by STANAG 1206. Our main proposals are summarized in the tables I and II.

2.1 - Contaminants about which the CERTSM has no remark to make <u>either</u> because the MACs suggested by STANAG are comparable with industrial TLVs, which corresponds to what has just been mentioned, <u>or</u> because the listed contaminants are generally not present on board French submarines (table I).

2.2 - Contaminants for which it is suggested to revise the MACs.
Reasons for this revision are given in table II.

2.3 - Particular cases involving carbon monoxide and dioxide :

- CO_2

In the draft STANAG, it is suggested to set the CO_2 MAC at 3 %. We can't agree that this value should be regarded as a permissible limit for repeated exposures under normal operational conditions with $FiCO_2$ passing through zero as it occurs in conventional submarines. During our trials in a climatic chamber, it has been shown that exposure of men to $FiCO_2$ 3 % induces an alveolar and arterial blood gases PCO_2 overload of 6 torr, an increase of ventilation by about 70 %, a drop of arterial blood pH by 0,035 u, and finally, a worse adaptation to exercise.
At last, as noted by SCHAEFER et all. (1979), acclimatization does not occur during intermittent exposure to 3 % CO_2.

Taking into account these data, we suggest to set CO_2 MAC at 1 % under usual operational conditions ; 3 % may be regarded as a permissible concentration, tolerated for 48 hours provided it remains exceptional.

- Carbon monoxide and oxygen

As far as CO is concerned, the STANAG 48-hour MAC which is set at 50 ppm is apparently in keeping with ACGIH TLV - TWA. However, the conditions of exposure are quite different : in the industrial work environment, oxygen is assumed to be maintained constant at PiO_2 21 kPa, whereas in draft STANAG PiO_2 is allowed to drop by 3 kPa.
According to the simple reversible equation $HbCO + O_2 \rightleftharpoons HbO_2 + CO$ it should be remembered that for a fixed concentration of CO in air, each PiO_2 variation induces a fluctuation of COHb concentration.

The relationship between HbCO and PiO_2 may be predicted from the HALDANE static equilibrium equation :

$$\frac{HbCO}{HbO_2} = M \frac{PCO}{Pa_{O_2}} \qquad (M \sim 250)$$

example 1 : with FiCO = 50 ppm → Pi_{CO} = 50 ppm x 713 and Pi_{O_2} = 21 kPa → Pa_{O_2} = 13,3 kPa } HbCO = 8 %

example 2 : with Pi_{CO} = 50 ppm x 713 and Pi_{O_2} = 18 kPa → Pa_{O_2} ∿ 10,6 kPa } HbCO ∿ 10 %

This combined effect of hypoxia and carbon monoxide is summed up on the figure 1 : the actual values of CO concentrations in air are plotted on the abscissa, and the equivalent estimated physiological concentrations on the ordinate.
For example, if a subject is exposed to FiCO 50 ppm and Pi_{O_2} 21 kPa (point A) HbCO at equilibrium will reach about 8 % ;
when Pi_{O_2} decreases from 21 to 18 kPa (point B) HbCO reaches 10 %, concentration equivalent to the effect of about 62 ppm of CO at Pi_{O_2} 21 kPa (point C).

This graph clearly indicates that when oxygen is set at 18 % as mentioned in the draft STANAG 1206, carbon monoxide MAC should be dropped to 40 ppm (D) to be in keeping with the concentration of 50 ppm in air as adopted by ACGIH (E).

Furthermore, it should be remembered that smoking, as allowed aboard U.S and British submarines, induces an additional increase of HbCO level in smokers. As an example, during a trial carried out in our climatic chamber, it has been found by GUILLERM et al. (1963) that after 48 hours of exposure to a concentration of 50 ppm, HbCO of non-smokers reaches 8 % compared to 15 % in smokers (15 - 20 cigarettes/day).
It must also be noted that night vision was impaired only in smokers.

Finally, taking into account the kinetic of CO output the delay between repeated exposure must be specified to avoid chronic toxicity.

2.4 - The last point concerns oxygen. We suggest to set MAC at 17 % instead of 18 %. From a physiological point of view, the difference between 18 and 17 % is barely detectable, when from operational point of view, 17 % allows a noticeable increase of the submarines autonomy.

3. - The author believes

In conclusion, we believe that the 48 - hour MAC provided for in the draft STANAG 1206 should be set with reference to industrial TLV's whenever possible. For each polluant it should be necessary to arrive to the best compromise between technical/military necessity and personnel tolerance, what is not always easy to do.

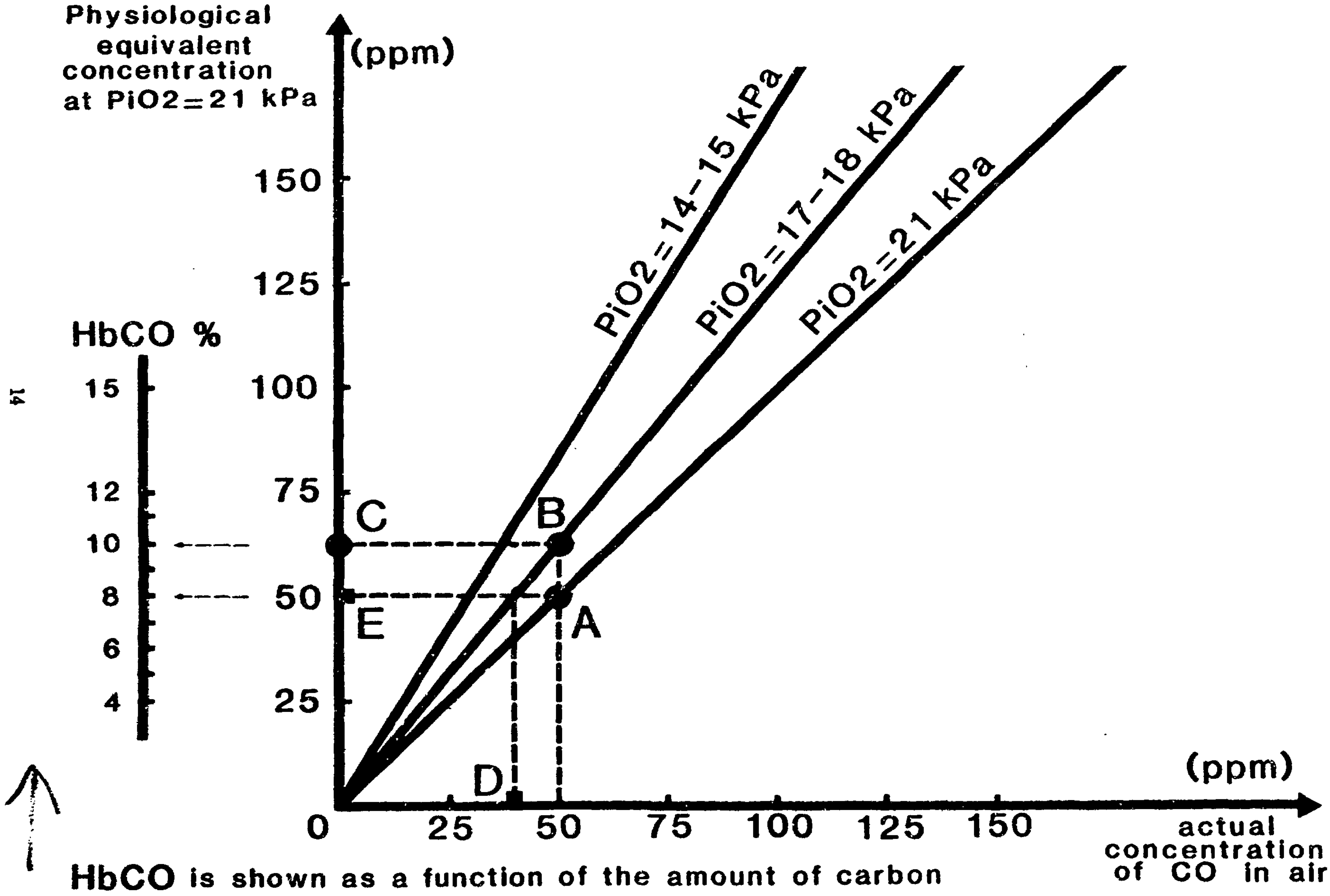
GUILLERM et al. (1963) : Biometeorology II, Proceedings of the third Intern, Biometeorol. Congress, PAU, 306-313.

SCHAEFER K.E. (1979) : Undersea Biomed. Res. Sub. Suppl. S.115-S.134.

POLLUTANTS		STANAG 1206 MAC	ACGIH TLV–TWA	CERTSM COMMENTS and PROPOSALS
Ammonia	ppm	50	25	Not aboard f.s/m
Arsine	ppm	0.05	0.05	agreement
Mercury	mg/m3	0.05	0.05	" " " "
Methyl Alcohol	ppm	100	300	Agreement inspite of TLV-Permanent
Nitrogen Dioxide	ppm	2.5	3	Not aboard f.s/m
Stibine	ppm	0.05	0.1	Agreement
Sulfur Dioxide	ppm	2.5	2	accidental ?
Triorthocresyl Phosphate	ppm	0.12	–	Agreement
Methyl Chloroform	ppm	250	350	Agreement

Table 1

POLLUTANTS		STANAG 1206 MAC	ACGIH TLV-TWA	CERTSM COMMENTS
ACETYLENE	%	2.5	–	Explosivity * 2%
DICHLORODIFLUOROMETHANE HALON 12	ppm	500	1000	*500 ppm for total halons
TOTAL HYDROCARBONS (Methane excepted)		–	–	* 300 mg/m3 (in C)
HYDROGEN CHLORIDE	ppm	2.5	5	Accidentally aboard * 5 ppm
HYDROGEN BROMIDE	ppm	1.5	3	" " " * 3 ppm
CHLORINE	ppm	0.5	1	" " " * 1 ppm
HYDROGEN	%	2	–	* 3 %
METHANE	%	5.3	–	? Explosivity * < 5%
OZONE	ppm	0.05	0.1	Not aboard f.s/m * 0.1 ppm
PHOSGENE	ppm	0.5	0.1	* 0.1 ppm



HbCO is shown as a function of the amount of carbon monoxide in the air and the inspired pressure partial of oxygen

MAXIMUM CONCENTRATIONS OF TOXIC SUBSTANCES IN CONVENTIONAL SUBMARINES UNDER NORMAL OPERATING CONDITIONS - STANAG 1206

Surgeon Lieutenant Commander D C B HOLT, Royal Navy
Institute of Naval Medicine, Alverstoke, Hampshire, UK.

UK ratified Stanag 1206 on 22 April 1977 and later proposed amendments in respect of CO and hydrocarbons.[1] It is apparent now, however, that many of the MPCs proposed in the first draft (Figure 1) can and probably should be revised downward.

The purposes of submarine atmosphere control are fourfold (Figure 2) and concern health, performance, material preservation and integrity and explosive and flammable hazards. Accordingly the utility of the stanag should be to provide guidance on standards which not only meet these purposes but are compatible with design, maintenance, operation and where relevant control. This Stanag seeks to determine such levels for continuous exposure for two days. Unfortunately submarine atmospheres are not static and many constituents will rise gradually over a period. Few will achieve equilibrium levels in two days and some standards must therefore represent maximum levels or time weighted averages.

The MPCs proposed in the first draft of Stanag 1206 are compared with ACGIH TLVs, the MPCs currently set for UK conventional and nuclear submarines and those proposed by the UK SSK Atmosphere Control Working Party (of the Submarine Air Purification Committee) which has been re-examining the subject (Figure 3). It will be noted that the existing values for UK SSKs are principally limited to the critical gases and vapours considered to be of prime importance, it being intended that other important but less critical substances be minimised by adequate design and material control.

While nuclear submarine MPCs are not infrequently based on a "200 hour week" and may be set at one fifth (or less) of the TLV the proposals in the current draft Stanag vary little if at all from the TLVs. Yet after the two days for which this Stanag is applicable, continuous exposure will have exceeded that catered for by the TLV by a factor of three. Furthermore with repeated intermittent exposures, each of two days, a crew may only rarely experience truly clean air. Nor can the working weeks be separated by weekends. Accordingly there may be a case for moving toward conformity with the nuclear MPCs, thereby minimising the dual standards. Only in the case of CO_2 is it proposed to raise the MPC. Recent work at INM[2,3], has indicated that it should be quite acceptable to allow a time weighted average over up to 30 days of 1.5% for intermittent exposure provided 2% is not exceeded. Implementation of this proposal will alleviate the practical and logistic difficulties of maintaining CO_2 below 1% during prolonged dives.

The draft Stanag contains many contaminants which can only practicably be considered as design criteria. If that principle is confirmed then benzene, toluene and xylenes should be added to the list for that reason, as should phosphine consistent with its prime source, acetylene (Figure 4). Though not included as a generic group, aerosols should, perhaps, also be added and a standard derived.

The author proposes

In conclusion, it is proposed that Stanag 1206 be redrafted to reflect the higher standards believed to be necessary in nuclear submarines. Such standards should be readily achievable in new build submarines and many current classes, but levels should in any case be always as low as reasonably attainable.

REFERENCES

1. INM's letter 120/5/121/78 EMU dated 14 April 1978. Institute of Naval Medicine.

2. DUGGAN A, D J SMITH, J R HARRISON and C S M SEARING. Respiratory consequences of 30 days of exposure to 1.5% CO_2 in man. Institute of Naval Medicine Report 51/82. 1982.

3. SEARING C S M, D J SMITH, J R HARRISON and A DUGGAN. Acid-base response to a 30 day exposure to 1.5% CO_2. Institute of Naval Medicine Report 2/83. 1983.

TABLE OF MAXIMUM EXPOSURE CONCENTRATION OF TOXIC SUBSTANCES

Recommended maximum permissible concentrations for continuous 2 days exposure

		Maximum Permissible Concentration	
		Vol/Vol	Wt/Vol
		% of ppm	mg/m^3
1	Acetylene	2.5%	-
2	Ammonia	25ppm	18.0
3	Arsine	0.05ppm	0.15
4	Carbon Dioxide	3%	-
5	Carbon Monoxide	25ppm	27.5
6	Dichlorodifluoromethane Refrigerant 12	500ppm	2500
7	Hydrocarbons (Total)	10ppm	4.0
8	Hydrogen Chloride	2.5ppm	4.0
9	Hydrogen Fluoride	1.5ppm	1.35
10	Hydrogen	2.0%	-
11	Mercury	-	0.05
12	Chlorine	0.5ppm	1.5
13	Methane	5.3%	-
14	Methyl Alcohol	100ppm	-
15	Nitrogen Dioxide	2.5ppm	5.0
16	Oxygen	18% Min	-
17	Ozone	0.05ppm	0.1
18	Phosgene	0.1ppm	0.4
19	Stibine	0.05ppm	-
20	Sulphur Dioxide	2.5ppm	4.05
21	Triaryl Phosphate	0.12ppm	2.0
22	Methyl Chloroform	250ppm	1425.0

Figure 1

ATMOSPHERE CONTROL

NECESSARY TO:

1. ENSURE CREW HEALTH
   - SHORT TERM
   - LONG TERM

2. ENSURE CREW PERFORMANCE
   - S/M SAFETY
   - OPERATIONAL EFFICIENCY

3. PREVENT MATERIAL EFFECTS
   - PERFORMANCE
   - ENDURANCE

4. PREVENT FLAMMABLE AND EXPLOSIVE CONCENTRATIONS

Figure 2

COMPARISON OF DRAFT STANAG 1206 WITH CURRENT AND PROPOSED RN PRACTISE

	SUBSTANCE	ACGIH TLV	STANAG 1206	BR3944	BR1326	PROPOSED SSK(AWCP)	PROPOSED STANAG 1206
1	C_2H_2	E	2.5% (LEL)		0.5%		<0.5%
2	NH_3	25vpm	25vpm		10vpm		<5vpm
3	A_rH_3	0.05vpm	0.05vpm				<0.05vpm
4	CO_2	0.5%	3%	1%	1%	1.5%	1.5%
5	CO	50vpm	25vpm	25vpm	15vpm	< 15vpm	<15vpm
6	CCl_2F_2	1000vpm	500vpm	500vpm	500vpm	< 500vpm	<500vpm
7	HC(total)		10vpm		10vpm	TBD	<10vpm
8	HCl	5vpm	2.5vpm	1vpm	1vpm	1vpm	<1vpm
9	HF	3vpm	1.5vpm		0.1vpm		<0.1vpm
10	H_2	E	2%(LEL:4%)	2%	2%	2%	<2%
11	Hg	$0.05mgm^{-3}$	$0.05mgm^{-3}$		$0.01mgm^{-3}$		$<0.01mgm^{-3}$

FIGURE 3

12	Cl_2	1vpm	0.5vpm	0.1vpm	0.1vpm	<0.1vpm	<0.1vpm
13	CH_4	E	5.3%		1%		<1%
14	CH_3OH	200vpm(skin)	100vpm		10vpm		<10vpm
15	NO_2	3vpm	2.5vpm		0.5vpm		<0.5vpm
16	O_2	135mmHg(min)	18%	18–22% (at760mmHg)	137mmHg	137–167mmHg – 22%	137–167mmHg
17	O_3	0.1vpm	0.05vpm		0.02vpm		<0.02vpm
18	$COCl_2$	0.1vpm	0.1vpm		0.05vpm		<0.05vpm
19	SbH_3	0.1vpm	0.05vpm				<0.05vpm
20	SO_2	2vpm	2.5vpm	2vpm	1vpm		<1vpm
21	$(Aryl)_3PO_{(4)}$	0.01/0.02 vpm*	0.12vpm		0.06vpm		0.01mgm^{-3}**
22	CH_3CCl_3	350vpm	250vpm		2.5vpm		2.5vpm

* = approx for TOCP and TPP

** = as aerosol

TOCP = Triorthocresylphosphate
TPP = Triphenyl phosphate

ADDITIONAL SUBSTANCES FOR CONSIDERATION

23	C_6H_6	10vpm	-	-	0.5vpm	-	<0.5vpm
24	$C_6H_4(CH_3)_2$	100vpm(skin)	-	-	4vpm	-	<4vpm
25	$C_6H_5CH_3$	100vpm(skin)	-	-	4vpm	-	<4vpm
26	PH_3	0.3vpm	-	-	0.1vpm	-	<0.1vpm

FIGURE 4

DISCUSSION

TOBIAS: We will take questions and comments please.

KNIGHT: One frustration that our delegation had in preparing for the first two sessions was the lack of data on concentration of contaminants aboard diesel submarines at sea. Do you have such data?

MALASPINA: We have similar problems aboard our submarines during long duration dives which are 4-5 days.

HOLT: For the same reason, perhaps, Captain Knight, we can say that having the information is rather difficult in our Navy as in yours. A little over a year ago, we started a working party, the SSK atmosphere control working party, and we've been trying to address the problem of how we can, perhaps, make better recommendations and be better advised on atmosphere control in SSKs. At the moment, we do have a doctor at sea on an SSK for about 2 months. He is trying to gather as much information as he can. At least it's a start. Additionally, we think possibly as with the SSNs and SSBNs that after refit, we may have to introduce a simplified form of air purification (plan) when we (analyze) these substances (from the present run) so perhaps in the future we will have some data.

BONDI: Dr. Holt, just a clarification on your slides. Is the furthest column to our right a proposed standard?

HOLT: Yes.

BONDI: You have "less-than" signs on most of those. What do you exactly mean by that? Do you want them all to be "less" or, are you proposing that. That is sort of a qualitative statement isn't it?

HOLT: I think if I (stand on) my last statement.....In such values, what are they? Are they going to maximum values or are they going to be time-rated averages? One problem with that statement is that we don't have static atmospheres in submarines. You start off at a low level and you end off with a high level.

RADZISZEWSKI: One question about the proposals concerning carbon dioxide. Why at this high level of carbon dioxide in the draft STANAG, is it concentrations which correspond to special operational conditions in your submarines? On what basis have you fixed this STANAG? In all the literature concerning the carbon dioxide effect we agree with 1.5% for conventional submarines. When we compare 1.5% with 3% CO_2, there are fantastic differences (which can be measured with precision).

SHEA: You're basing your 1.5% on repeated, 2-day exposures. We're basing ours on just 1- to 2-day exposures. I would agree with you that if you base it on repeated exposures, the lower level would be better.

HOLT: I think that our understanding is that this is for normal operational conditions. Were it under unusual emergency conditions, I think it's the next STANAG we're coming up to (that addresses this).

HARRISON: I'd like to make a general observation, which I think you'll have noticed concerning the STANAGs, having been on the NATO Naval Medical Working Party for the last five years. Since it might be worth my while just spending a minute or so describing what the objectives of the STANAGs really are and reinforcing the purpose of this particular STANAG, what I might consider to be one of the great difficulties is presented to us this morning. First of all, the STANAG does not have to be purchased equipment and logistics. There is a misconception within people who are not involved with the NATO idea that STANAGs should be agreements between nations and procedures as well. And procedures should lead ultimately to better operational conditions for submarines, then that is a desirable objective. So that the fact that most STANAGs are concerned with equipment and logistics, and this one isn't, it doesn't matter. And as far as NATO is concerned, it is extremely valuable. On the historical side of NATO, when this STANAG was first put up, I think it was around 1976. I think the Americans are unfortunate; you picked it up as a sort of study because you don't have any conventional submarines. Nevertheless, you do have a large scientific organization throughout your country to investigate some of these problems and probably more research associates, so I think it is appropriate. I think the real problem for all of us is to decide about how long the exposures should be. The STANAG as it is written covers 48 hours. What is magical about 48 hours? Our new design SSK will probably remain down for 5 days. And I think it was generally considered among the NATO nations that most of the conventional type submarines which are used are capable of diving for periods up to 48 hours before they really have to come up and ventilate and recharge their batteries, so that's the reason for 48 hours. And then, the smaller nations in NATO have absolutely no research facilities and so between us we have more submarines, we have some research facilities, it's beholden to us to come up with an agreed list for the NATO nations. So the smaller nations really do get some value out of these STANAGs. This STANAG is different, so what? But, as far as Mission is concerned, it really is extremely well put, and what the NATO Medical Working Party is hoping is that it will be possible for this conference, or meeting, to come up with some proposals as a draft STANAG which, if we agreed, everybody else would agree with us. And I think that essentially, if we were able to come up with an agreement today, or if not all of those substances, then some of them, then we would be taking that step forward which would help the NATO nations, particularly the small ones to have some idea of what they should be looking for.

MALASPINA: I would like to give the interview on our list. I think it all seems to satisfy you on this matter to be allowed to measure the different contaminants that are listed in this STANAG. Apart from the substances aboard the SSKs there are no such contaminants in operational conditions. I think there is a problem with a long list of contaminants.

HARRISON: I think that what France has suggested is right. I think this list is ridiculously long. And I think that chances of most of the contaminants actually being present routinely in the submarine environment are remote in the extreme. And I think it would be better if we were able to agree to a shorter list of more obvious, important substances, and then to set limits which we think are ideal, which ideally should not be exceeded. That might be a way ahead - to go down the list and cross them off as we go along as being almost irrelevant. And so that then we have a agreed operational list, normal operational list, which is short, and either with portable instruments, or with professional instruments, and at the same time is a guide to the design. And I'm sure that most of the designers would be wondering where on earth the sulfur dioxide is going to be coming from, and I can't think where, routinely, sulfur dioxide is going to be coming from under normal operating conditions. An occasional fire or something. But this is under routine conditions. It's inconceivable that these things would actually arise. So I think that we've got an extraordinary list ...

Not routinely, that's an emergency. If you actually inhale or ingest or induce exhaust, that is not a routine operational condition. That is an emergency condition. I don't see that as being normal.

MILROY: Would it be appropriate to suggest that we run down the list and cross out the things we don't need. For everybody else, a copy of the list is before you and we will start at the top.

HARRISON: The objective is to decide whether they should be on the list or not?

MILROY: Right.

HOLT: The point I was making, sir, is that conditions are not necessarily more severe, but the period of exposure is longer. In other words, at sea for 2 days, you're exposed, if you are shut down, for 48 hours. If you were working ashore, you would be working two 8-hour days. So you are being exposed 48 hours instead of 16 hours.

GIACOMONI: For some pollutants like ammonia, you recommend a number of 5 ppm for SSBN's and 10 ppm for conventional submarines.

HOLT: I think that you must try to set the level as low as you reasonably can. Now, there are some sources of ammonia in a nuclear submarine. Those sources do not exist in conventional submarines. So, yes, we could say 10 ppm if it is possible to achieve the lower levels........

I do think that since the STANAG starts with the words "design criteria", we should set the limits as low as we can reasonably achieve, so that people who have responsibility for making submarines and designing submarines know that they can maintain high standards.

MILROY: Are we ready to proceed down the list? The decision is only whether or not to retain them on the list, not what level. The first on the list is .....

RADZISZEWSKI: One question. According to the definition - what are the definitions?

MILROY: Normal operational conditions.

RADZISZEWSKI: What are these normal operational conditions. For instance, are these values which may be discussed but, after the selection, will this value be selected.

MILROY: I think the first thing to do is to decide whether or not we need a limit set for all these items or not. Acetylene. Nobody feels strongly that we need a normal limit for acetylene. Very good. Acetylene is out. Ammonia. Nobody feels strongly that we need ammonia under normal conditions. Ammonia is out.

WYATT: One think we have to remember, that both arsine and stibine come to mind as materials that can be used in battery construction. For instance, there is a big concern on nuclear boats for improved batteries. One of the ways to improve the batteries is to use more antimony in them. But the worry is, because on a nuclear boat, you're not on the surface when you're charging your batteries or you're not snorkeling when you're charging your batteries. You may introduce, this is more of a problem and right now they don't allow the use of it in construction and in keeping arsine and stibine here, if you would tell the designer you must be careful about the kind of batteries you design, or verify during battery charging, none of the vapors or all of the vapors go overboard. On a diesel boat, that's what is done now. If someone in the future said, "We can give you an improved battery by using more arsenic", then he would have to prove that it would not affect this particular level.

MILROY: I think that we're probably in agreement then on arsine and stibine. It should be retained to maintain battery quality.

HOLT: I have some difficulty in deciding whether we wanted a long list, of all things, to represent a quality control, or whether we really wanted to reduce it to the bare essentials that could, perhaps, be readily monitored.

MILROY: Your point is well taken. Maybe these two are the exceptions to just the important things for the specific reasons stated. Are we ready to proceed? I don't think anyone will disagree that the next two are obviously staying on. Then there was a question regarding the refrigerants. We were to change that to a lump of all the halons and freons, or continue to maintain a separate one just for freon-12.

HARRISON: We routinely use freon-12 in all of our submarines, so I think it's standard practice in most submarine services. I believe it is freon-12.

MILROY: OK, I bring it up because the question was.....

MALASPINA: With regard to the relatively high levels of toxicity, what is the reason why freons will be kept on this list?

GIACOMONI: I think that because of the similarity of toxicity of these different things, I think it is possible to keep a general term below which the atmosphere is quite sufficient, because the limits are quite the same for common (.....). Is it necessary to keep precise data?

HARRISON: Actually, there is a little problem, because we smoke in our submarines and the chemical properties of each halon are different and the breakdown products are different. And they breakdown in different proportions with the same temperature, and so we would like to keep it as Halon 1220 or freon-12.

FOULGER: You mentioned that the main reason for keeping an idea on the concentrations of freon is mainly by virtue of it decomposing into toxic products and mainly phosgene and hydrogen chloride would be more appropriate to delete freon-12 and just monitor the decomposition product?

WYATT: The problem is that the decomposition products are mainly going to be due to smoking. So you will filter them out. For smoking, you have very large concentrations of HCl or HF, if there's a large concentration of freon. In fact, you might need a--operationally, you'd have one level of freon, which presuming you could measure, you wouldn't allow smoking. If there is a leak of refrigerant, then the submarine--the smoking lamp would be turned out until they cleared it up by going up to the surface, so there is kind of a dual level that you might want to--I don't necessarily think it would be here. You'd have an asterisk or something.

MILROY: Well, can we get up to an agreement as to whether it is freon-12 or all freons. Our problem is that we allow smoking, so that concentration is in the individual. It's not measurable. So, we're proposing keeping it low. May I suggest, then, that in the interests of moving forward, we keep it as freon-12 and we take it and get on with the list at this time. Total hydrocarbons, as everyone will agree, belong on the list. Hydrogen chloride, under normal conditions, shouldn't be there. Hydrogen? Yes. Mercury? Yes. Chlorine? No. OK, methane?

HARRISON: I think that this is where the crux comes. Methane is a hydrocarbon. And this is where your real problem comes before this STANAG. Is to decide what is a hydrocarbon. Because methane is a real hydrocarbon.

MILROY: Normal limits for normal conditions. We just pool with the rest of hydrocarbons. Yes. Good. You see, methane goes in with the Total Hydrocarbons.

PEARSON: I would support that, having spent years trying to argue about what divers should breathe. That's the way we've gone in diving breathing gases.

MILROY: OK

MALASPINA: I think it is better to, not to include methane with Total Hydrocarbons because it is not the same problem. It is not a problem of toxicity.

HARRISON: Yes.

MILROY: So we specify the normal limit as "less methane" because we don't have it specified separately on this list.

HARRISON: Yes, yes.

MILROY: OK. Methyl alcohol?

(Group): No.

MILROY: Stibine we already agreed on.

(Group): Sulfur Dioxide?

MILROY: Sulfur Dioxide? Triaryl Phosphate? Methyl Chloroform? I think that's a nice piece of work.

MARLOR: In honor of La Belle France, ethyl alcohol?

MILROY: I think the recommendations we need to use there is to increase the level on US submarines. Well, we've done very nicely. We've cut all this by more than half.

TOBIAS: Would you review the list?

MILROY: Alright, the list as we have currently agreed on consists of: arsine, carbon dioxide, carbon monoxide, dichlorodifluoromethane, refrigerant-12, freon/halon, total hydrocarbons less methane, hydrogen, mercury, oxygen, and stibine. Is there anyone who feels strongly that we have left something off that really must be on? Now we have to proceed with levels to set for those that we've agreed to keep.

TOBIAS: I am happy to have this body sit to set such levels, but the scheduled time for our first morning break is upon us. What is your preference?

MILROY: Let's take a break.

WYATT: There is one hydrocarbon that is particularly more toxic than any of the others, and that's benzene. I don't know whether we (can) bring it on board, but do we want to have a lower level that someone, sometime might want to monitor. You might want to restrict the benezene level in diesel fuel for some reason. I don't know. If that's the only hydrocarbon that's significantly more toxic than any of the others, and you don't work to have a level that would allow maybe too much. That's the only thing that I would think of that you might want to put in.

HARRISON: We are concerned about all the aromatics, really, I think this question whether to subdivide into aliphatics and aromatics, you start going down a long path of ..... then the whole series of extra substances would be very difficult to set agreement on. I think we'd have to have a new substance in for benzene. You're almost suggesting that actually we should have a new substance listed as benzene, so that the total hydrocarbons would be less methane and less benzene, and then set a level of benzene.

WYATT: Not less benzene, because the benzene level would be much lower than the total hydrocarbon level. But, only that, of all the hydrocarbons, to my knowledge, other than very unusual things, of the common hydrocarbons, benzene is much more toxic. This is a known carcinogen. I don't think that there's ever been a problem with it. In general, we find it, of all the aromatics we look at, benzene is one of the lowest. Certainly on nuclear boats.

MILROY: Would a single statement to cover all these possibilities added to this be appropriate to the effect that, "lack of mention on the list does not imply permissivity, but rather that it should not normally be present under normal operating conditions. That covers all of the possible individual items that we could come up with. And then are we sticking ourselves with any problem if we say that.

HARRISON: I would support that statement. Very good suggestion.

MILROY: We have the vast majority of potential contaminants all covered, and now, we have only nine to decide on the right levels.

TOBIAS: Thank you very much.

Editors' comments: Please turn to p. 199 for a presentation of the recommended levels.

AD P001880

CRITICAL TOXIC CONCENTRATIONS

G. MARBLÉ — CERTSM - 83800 TOULON/NAVAL - FRANCE

INTRODUCTION - CONCEPT OF THE MAXIMUM PERMISSIBLE CONCENTRATION

Estimating the toxicologic risk due to the presence of metabolic gases or of some contaminants depends on the chemical constitution of such gases or contaminants as well as on their concentrations in the submarine atmosphere. That is the reason why we have been led to set Maximum Permissible Concentrations (MPC_S) for various chemicals and for some exposure durations. In submarines we have selected the 90 day MPC which applies to 90 days of a long term patrol, the MPC_{24} which applies only to 24 hours and indeed even to 48 hours, and the MPC_1 which relates to 1 hour of exposure.

I think it may be necessary to give again the definition of a maximum permissible concentration :

«MPC is the maximum permissible concentration of a chemical compound which causes no detrimental biological effects as measured with currently available investigation methods».

It is generally a time weighted average value.

PURPOSE OF THE STANDARDIZATION AGREEMENT (STANAG 1184)

The purpose of the STANAG 1184 is to set toxic substance concentration limits above which ventilation would be required aboard conventional submarines.

Toxic chemical compounds have been listed and maximum permissible concentration values for one hour of exposure have been given as reference values.

REMARKS ON THE CHOICE OF 1 HOUR MPC_S

We don't believe that selecting 1 hour MPC_S as operational criteria is the right answer to the question under consideration.

As a matter of fact these MPC_S are permissible concentrations which are therefore atmosphere monitoring values and so within the «physiological limits». Thus, they are normal values relating to the health and the medical survey of the crew under normal submarine operational conditions. Such MPC_S are not operational criteria to be taken into account in the event of accidents of a toxicological nature requiring ventilation of the submarine atmosphere.

CONCEPT OF CRITICAL TOXIC CONCENTRATION

Apart from normal situations there may be emergencies (such as a serious accident or a fire, for instance) in which the Commanding Officer may have to answer the following question that can be vital for the crew and of paramount importance for the submarine mission fulfillment. This question is : **what is the limit that must not be exceeded and above which the submarine crew will run the risk of being no longer able to execute the orders received unless ventilation measures are taken immediately ?** In practice such measures involve either the wearing of respiratory masks or the submarine surfacing to ventilate through the «Snort». Such a limit is the «critical toxic concentration» (CTC) which we define as follows :

> **«The critical toxic concentration of a chemical compound in a submarine atmosphere is the concentration of this coumpound that can cause, either immediately or within a short time period, reversible pathological effects without behavior troubles in the crew members breathing such a product for 15 minutes».**

This is not a permissible concentration and CTC is not a medical standard. It is an indicative value given by toxicologists to the Commanding Officer to enable him to better appreciate the situation aboard the submarine. It may thus appear as an essential assistance in the Commanding Officer's decision.

PROPOSALS FOR A REVISION OF STANAG 1184

We don't think that the choice of MPC_S is satisfactory to initiate operational processes. We believe it would be better to use the critical toxic concentrations which have just been defined. In our opinion these concentrations are more suitable for meeting the Commanding Officer's requirements.

That is why we are suggesting to substitute the CTC_S for the MPC_S as toxicological criteria to be possibly used by the Submarine Command. CTC_S are in perfect keeping with both the spirit and the object of STANAG 1184.

COMPARISON OF NUMERICAL VALUES

The numerical values for 1 hour MPC_S and for CTC_S together with the values referred to by the «National Institute for Occupational Safety and Health» as «Immediately Dangerous to Life and Health» (IDLH) are all listed in a table to be found in Appendix 1.

You can see the CTC values are distinctly greater than the 1 hour MPC_S and generally lower than IDLH values. The criteria proposed under the CTC definition therefore appear to be less penalizing than the 1 hour MPC_S. This is not obvious since exposure periods are different. However, it is an exposure criterion that may result in beginning of an acute intoxication and it is therefore better to refer to a relatively short period of time.

NATURE OF THE CHEMICAL COMPOUNDS TO BE CHECKED

On board French diesel electric submarines we do not measure ozone, nitrogen oxides and acrolein because there are no sources of such products (O_3 and NO_x) or the production there of can be reduced.

A colorimeter tube for acrolein measurement is currently under development. It could possibly be put into operation.

On the other hand, a quantitative determination of hydrochloric acide might also be added to the existing list.

SUMMATION OF THE EFFECTS OF VARIOUS CHEMICAL COMPOUNDS

In the numerical value table to be found in Appendix 1 we don't take into account the summation of the effects of various chemicals. In particular, the decrease in oxygen content or the increase in carbon monoxide concentration are assumed to take place separately. More over, we don't either take into consideration the hyperventilation caused by an increase in carbon dioxide concentration. This hyperventilation will result in an increase in the quantity of inspired contaminants and more particularly of inhaled carbon monoxide.

By determining the carboxyhemoglobin level produced by carbon monoxide either alone or in association with oxygen and carbon dioxide we have obtained the table to be found in Appendix 2. In this table you can see that we get a factor of roughly 2 either for the 1 hour MPCs or for the CTCs, taking into account the effects of O_2 and CO_2 or CO inhalation.

Such an observation shows the advantages of the CTCs, these CTCs are generally more severe than IDLH values since the reciprocal effects of gaseous contaminants cannot be determined before the measurements. It is thus difficult to establish rules that should be strictly applicable to operational environments.

CONCLUSIONS

In an emergency on board a conventional submarine the Maximum Permissible Concentrations cannot be the toxic substance and metabolic gas concentration limits to be taken into account in order to assist the Commanding Officer in his decision whether to ventilate or not.

It is suggested to replace in STANAG 1184 the MPCs by the CTCs which are more suitable criteria of acute intoxication.

More over, ozone and nitrogen oxides as well as acrolein are not routinely measured aboard French submarines.

It seems most desirable to monitor the acrolein concentration together with the hydrochloric acid concentrations.

O_2, CO_2 and HbCO Concentrations

	CO ppm	O_2 %	CO_2 %	HbCO % calculated with CO concentration only	HbCO % calculated with CO_2 and O_2 concentrations
STANAG 1184 CMA (1h)	200	18	3	4.7	7.2
CTC (1/4h)	1000	14	5	6.2	14.5

LIMITS OF CONCENTRATIONS

CHEMICALS	STANAG	FRENCH NAVY		NIOSH
	1184 (1h)	CMA (1h)	CTC(1/4h)	IDLH(1/2h)
Oxygen	18-22%	17-22%	14%	
Carbon Dioxide	3%	4%	5%	5%
Carbon Monoxide	200 ppm	600 ppm	1000 ppm	1500 ppm
Ozone	0.5 ppm	0.5 ppm	1 ppm	10 ppm
Nitrogen Oxides	10 ppm	10 ppm	30 ppm	50 ppm
Chloride	5 ppm	5 ppm	10 ppm	25 ppm
Acrolein	2 ppm	2 ppm	5 ppm	5 ppm
Mercury Vapours	1 mg/m3	2 mg/m3	5 mg/m3	28 mg/m3
Hydrogen Chloride		10 ppm	50 ppm	100 ppm

AD P001881

UNITED KINGDOM APPROACH TO EMERGENCY EXPOSURE LEVELS (STANAG 1184)

By

Surgeon Commander J R Harrison RN

Institute of Naval Medicine
Alverstoke, Hants, UK

Stanag 1184 was the first attempt by the NATO nations to agree on emergency limits for atmosphere contaminants in NATO submarines (Appendix 1). Almost immediately it became apparent that difficulty existed on the term 'emergency'. There are two possible interpretations:

a. emergency levels which are temporary e.g. up to 24 hours arising from the minor breakdown or maintenance of air purification machinery and where it may not be necessary or prudent to ventilate.

and b. real emergency levels when ventilation is essential. This is when levels might cause an unacceptable decrement in performance or cause irreversible medical effects on the crew.

In the former, it is reasonable to put forward acceptable levels for periods up to several days while in the latter short exposures of up to 1 hour only would be acceptable.

A further complication arises when the submarine only has limited emergency breathing equipment. Some conventional and nuclear submarines have emergency breathing systems capable of supporting all the ships company for over 1 day, while other smaller submarines may have considerably less available air. The significance of the emergency levels here will depend on the efficiency of the snort ventilation system and the internal ventilation arrangements.

In order to set levels, which will be acceptable for all the NATO nations, it would be necessary to know what the maximum exposure to any particular level might have to be. For example the exposure may be necessary for long periods because of operational constraints on snort ventilating.

At the 9th meeting the Nations were required to send national levels to the UK custodian. The US does not currently have conventional submarines, and therefore have no immediate suggestions. Portugal and France use identical levels, Canada and Denmark have none and Germany apparently do not accept any level above the normal. The United Kingdom has two sets of EEL's which are known as Maximum Permissible Concentrations. They are for 24 hours and 1 hour ($MPC_{24\ hours}$ and $MPC_{1\ hour}$).

First what are the important levels? We believe that only the really important substances are worth using in the STANAG. (Table 1).

TABLE 1. UK MPCs

Substance	MPC 24 hours	MPC 1 hour
Hydrogen	2%	2%
Oxygen (min)	18%	17%
Carbon Dioxide	2%	3%
Carbon Monoxide	100 ppm	200 ppm

Other substances e.g. NO_2, Otto Fuel only apply when particular types of weapon systems are deployed. Hydrogen is not a medical problem and it must be left to Naval engineers to decide on the safe limit. The remaining substances, Oxygen, Carbon Monoxide and Carbon Dioxide apply to all submarines. However some of these levels are at present being revised and for CO_2 the following are recommended (Table 2).

TABLE 2. MPCs FOR CO_2

Time	Level
30 days	1.5%
8 days	2%
4 days	3%
6 hours	4%
Ventilate	> 5%

This latter approach would appear to be more acceptable and more helpful for the submarine commands, but in order to produce a worthwhile list for all the substances a very considerable amount of research would be necessary. It, therefore becomes more reasonable to limit the STANAG table to the 3 important substances. This feature is very much in sympathy with comments of HOLT[1], HEE[2] and MARBLE[3]. The UK proposes, therefore, that STANAG 1184 should be disbanded in its existing form and changed to cover Carbon Dioxide, Carbon Monoxide and Oxygen only, with the list in Table 2 forming the basis for the new STANAG. If this is acceptable then UK would be prepared to produce such a new draft STANAG and then to study the other substances in the light of comments by other NATO Nations. It is for consideration that the NIOSH levels would be the best for the ventilating level, the other levels would require more study. Engineering criteria will effect many of the other substances. For example in measuring or giving levels for Freon, much will depend on the many other factors than that of pure toxicology, in particular the effect on other items of air purification machinery such as Freon breakdown in molecular sieves or burners.

It will be apparent that many of the points which have been made do not relate specifically to conventional submarines. The premise adopted is that any real emergency level must apply to any submarine. The ultimate objective in producing a new level must be to prevent unacceptable medical or performance effects in all our submariners.

Accordingly, the UK proposal goes one step further, namely to delete the phrase "conventional" from the title so that all submarines are covered by this important STANAG.

REFERENCES

1. HOLT, D C B (1981). UK viewpoint on MPCs for short and medium periods. In Proceedings of Tripartite Conference, Toulon, June 1981. p 93.

2. HÉE, J (1981). CO_2 CMA for short and medium periods of exposure. In Proceedings of Tripartite Conference, Toulon, June 1981. p 94-96.

3. MARBLÉ, G (1981). Emergency Exposure Limit Concept. "CO_2 Critical Toxic Concentrations (CTC)". In Proceedings of Tripartite Conference, Toulon, June 1981. p 97-99.

STANAG 1184

TABLE OF MAXIMUM EXPOSURE CONCENTRATIONS

Substance	Emergency (1 hour)
Acrolein	2 ppm
Chlorine	5 ppm
Carbon Dioxide	3%
Carbon Monoxide	200 ppm
Ozone	0.5 ppm
Oxygen (range)	18-22%
Mercury (metallic)	1 mg/m^3
Nitrogen Dioxide	10 ppm

LIMITS OF RESPIRATORY GASES AND CARBON MONOXIDE AT WHICH CONVENTIONAL SUBMARINES MUST VENTILATE

DOUGLAS KNIGHT AND MICHAEL SHEA

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
NAVAL SUBMARINE BASE NEW LONDON
GROTON, CONNECTICUT 06349

The Annex to STANAG 1184 requires that commanders of conventional submarines ventilate the ship with sea-level air when oxygen (O_2) content falls below 18%, carbon dioxide (CO_2) content exceeds 3%, or carbon monoxide (CO) content exceeds 200 ppm. We accept these limits as realistic figures for requiring ventilation of conventional submarines. Our justification is based on a review of investigations conducted by scientists at the Naval Submarine Medical Research Laboratory, New London (NSMRL). Two important questions should be asked of the results from those investigations:

The first question is, "Why not use lower concentrations of oxygen which translate to the partial pressure of oxygen at 10,000 feet altitude (P_{O_2} = 109 torr)?" The experience of World War II was that crew members developed headaches, vomiting, labored breathing, sluggish activity, and heat stress toward the end of 16 hour submergences in non-nuclear submarines (1). These responses were reproduced in field studies after the War without the added factor of heat stress. Confinement in the submarine progressively raised the concentration of CO_2 in a linear relationship to time. The ratio of % increment CO_2 to % decrement O_2 approximated the respiratory exchange ratio for man as long as gas composition in the atmosphere was not artificially modified (2). There was a high incidence of headaches at the higher concentration of CO_2 (table 1). Decrements of performance tended to occur at the high levels of CO_2 which could not be entirely explained by distractions resulting from submergence sickness. For example, some of the performance test scores showed a learning effect. However, shortness of breath interfered with effective communications over the ship's internal communications system. There were also decrements of night vision, mental recall, and efficiency of physical exercise. The crews tended to feel ill during mild reductions of O_2 (P_{O_2} 129-133 torr) and euphoric during lower levels of O_2 (P_{O_2} 115-130 torr) in combination with lesser elevations of CO_2 (P_{CO_2} 14-16 torr)(2, 3, 4,). The euphoric response to partial removal of CO_2 from the atmosphere, without addition of O_2, raises concern for safety because the submariner may be deprived of physiological warnings of hypoxia.

The coexistence of hypercapnia with hypoxia seems to confer a protective effect against decrement of perfomance. There is a body of experimental evidence to suggest that hypercapnia maintains brain tissue O_2 and supports human performance until CO_2 reaches 6%, at which time protection from hypoxia is lost (5, 6, 7, 8). Data at NSMRL showed that 1.5% CO_2 degrades sensitivity to night vision and green color vision (9). It therefore seems best to ventilate the ship when subtle changes of crew performance begin to occur. NSMRL field studies indicated that the atmosphere imposes these changes at P_{O_2} 130 torr and P_{CO_2} 23 torr.

The second question is, "How much carbon monoxide can safely be tolerated by submariners?" Although concentrations of CO are less than 10 ppm during either snorkelling or 12 hours of submergence (18, 19), dives longer than 36 hours will allow CO levels to rise above 100 ppm if there is no equipment for detoxifying the atmosphere. No symptoms of poisoning were reported from the controlled exposures to 100 ppm CO (10, 11). One submarine crew was poisoned by CO at sea. Only one measurement of CO, 100 ppm (12), was lower than levels usually associated with poisoning (13).

Since carbon monoxide can be maintained below 100 ppm in conventional submarines without scrubbers, then detection of 100 ppm indicates an unusual level which will not diminish until the ship is ventilated. Vigilance may not be impaired by 100 ppm CO in the presence of low levels of O_2 (14, 15). The data from NSMRL indicate that man can safely tolerate 200 ppm carbon monoxide for 3 hours without symptoms of poisoning and with only mild impairment of vision (16). The U.S. military adopted a one-hour exposure limit of 200 ppm CO for maintenance of mental acuity (17). Based on the review of data compiled at NSMRL, it is ~~therefore~~ recommended that the ship ventilate with sea-level air when levels of CO reach 200 ppm.

Finally, guidelines for ventilating conventional submarines must seem reasonable to the operational forces as well as to the scientists who issue the standards. This requires that there be a common understanding based on measurements performed in the field as well as the laboratory. Standardization of techniques for measuring the atmosphere aboard conventional submarines in NATO forces, therefore, seems to be a practical necessity.

REFERENCES

1. An undated interview (Ca. 1955) with LCDR CNG Hendrick, USN. Submarine Habitability.

2. Dykhuizen, Robert F. 1953. Some medical aspects of controlled submarine atmospheric conditions including a method of determining the metabolic requirements of submarine personnel. Medical Research Laboratory Report No. 220.

3. Karlin, J. E. and J. F. Curtis. 1945. Observations of efficiency of submarine personnel during prolonged submergence when the atmospheric oxygen is maintained at 17% and the carbon dioxide at 3%. Bureau of Medicine and Surgery Research Division - Project X-516 (Sub No. 105) (Paragraph 6).

4. Kinsey, Jack L. 1953. Some aspects of the habitability of the attack class submarines in cold and warm waters. Medical Research Laboratory Report No. 218.

5. Gellhorn, E. 1936. The effectiveness of carbon dioxide in combating the changes in visual intensity discrimination produced by oxygen deficiency. American J. of Physiology 117: 75-78.

6. Karl, A. A., G. R. McMillan, S. L. Ward, A. T. Kissen, and M. E. Sauder. 1978. Effects of increased ambient CO_2 on brain tissue oxygenation and performance in the hypoxic rhesus. Aviation Space Environmental Medicine 49(8): 984-989.

7. Schaefer, K. E., C. R. Carey, and J. H. Dougherty, Jr. 1970. The effect of intermittent exposure to 3% CO_2 on respiration. Naval Submarine Medical Center Report No. 618.

8. Schaefer, K. E., C. C. Morgan, A. A. Messier, and M. J. Jacey. 1970. The effect of intermittent exposure to 3% CO_2 on acid-base balance and electrolyte excretion. Naval Submarine Medical Center Report No. 635.

9. Weitzmanan, Donald J., Jo Ann S. Kinney, and S. M. Luria. 1970. Effect on vision of repeated exposure to carbon dioxide. Naval Submarine Medical Center Report No. 566.

10. Nichols, George Jr. and Jack L. Kinsey. 1953. Carbon monoxide as a habitatility factor in prolonged submarine submergence. U.S. Naval Medical Research Laboratory Report No. 223.

11. Ebersole, John N. 1960. The new dimensions of submarine medicine. New England Journal of Medicine 262: 602-603.

12. Alvis, H. J. and C. W. Tanner. 1952. Carbon monoxide toxicity in submarine operations. A case report. Naval Submarine Medical Center Report 208.

13. Steward, Richard, Jack E. Peterson, Edward P. Baretta, Romeo T. Bachand, Michale J. Hasko, and Anthony A. Hermann. 1970. Experimental human exposure to carbon monoxide. Archives Environmental Health. 21: 154-164.

14. 1970. Air quality criteria for carbon monoxide. U.S. Department of Health, Education and Welfare. National Air Pollution Control Administration Publication No. AP-62.

15. Christensen, Carol L., Jeffrey A. Gilner, Steven M. Horvath, and Jeames A. Wagner. 1977. Effects of three kinds of hypoxias on vigilance performance. Aviation Space and Environmental Medicine 48: 491-496.

16. Luria, S. M. and Christine L. McKay. 1972. Effect of low levels of carbon monoxide on visual processes: A preliminary study. Naval Submarine Medical Research Laboratory Report No. 727.

17. DuBois, Arthur B. 1970. Establishment of "threshold" CO exposure levels. Annals New York Academy Sciences. 174: 425-428.

18. Hayter, Robert. 1947. Medical report on snorkel operations of USS Amberjack (SS-522). Medical Research Laboratory Report No. 117.

19. Kinsey, Jack L. 1952. Observations on the habitability of submarines in northern waters. Medical Research Laboratory Report No. 197.

TABLE 1

EFFECT OF ATMOSPHERIC CARBON DIOXIDE AND OXYGEN ON THE INCIDENCE OF HEADACHES IN SUBMARINE CREWS

HIGH INCIDENCE*		LOW INCIDENCE	
P_{CO_2}	P_{O_2}	P_{CO_2}	P_{O_2}
30	129	27	144-152
23	129	20-23	152-167
23	133	17	137-152
		16	144
		16	122
		16	116
		14	130

*"high incidence" means that more than 10% of the crew suffered headaches

DISCUSSION

RADZISZEWSKI: If you combine 18% oxygen, 3% carbon dioxide, that is to say to take into account all the parameters which interfere with the intoxication by carbon monoxide, we obtain 7.2% HbCO for one hour. This is not a very dangerous level: we don't need to fix a carbon dioxide level.

HARRISON: I think you may have misunderstood a little of what I said. I only made suggestions for the carbon dioxide. I would be very happy to look at your suggestions for carbon monoxide which I happen to agree with, but I have not put up a graded level for carbon monoxide. I'm trying to suggest that there is an alternative approach to producing the specifications for one hour which really doesn't mean very much. Is it one hour gradually going up, or is it one hour time weighted average, or is it one hour critical level when you must do something or actually have men dying or unable to do their job. I would like that sort of approach for all those critical substances and to ignore all the others, because really if you get a fire you're going to hit dangerous levels of carbon monoxide either before or at the same time as all those other substances and it will probably be carbon monoxide that will cause the toxicities rather than all the other substances, although they are of very great significance.

DISCUSSION

HARRISON: I want to ask you a question about the combined effect of high oxygen and low CO_2. Do I take it that you are suggesting a ventilation level at 15% when you have a high level of CO_2 as well? That is an aspect that needs to be addressed on the definition in our STANAG. Are we dealing with substances singularly or together? Because it's quite a different situation. One the one hand you're saying 14% is acceptable alone and 17% if you have a high level of CO_2 and so on. You're beginning to build up a matrix.

KNIGHT: But when they reach 17% oxygen they should ventilate. I can't cover every situation encountered by a submarine. I think the usual situation is that the carbon dioxide and the oxygen will change together and at about the same time they will reach 3% and 17%. That's when I would like to tell the ship's commander, "When you reach that point you should ventilate or you'll begin to see decrements in performance. You won't lose your ship but you'll begin to see that." I only see manipulations of the atmosphere as prolonging, temporarily, those decisions and I am a little concerned about carbon monoxide. Until we know more about it I still have to say that if you reach the 3 percent carbon dioxide or 17% oxygen or 200 PPM carbon monoxide, you must ventilate.

RADZISZEWSKI: As I understand it you are using as your criterion, headaches taken from your records of the second World War. There are some discrepancies between the results given in your reports from the second World War and the experiments we carried out in our climatic chamber. We never had a problem of crew restlessness or other problems reported in your reports; so one question: "Is it sufficient for an emergency condition to take into account only headaches? Do perceptual aspects concern your last position? It is usually accepted in the literature that decrements of performance occur when a subject is exposed to hypoxia peaking at 13% except for vision for which decrements appear at 17 or 18%. Maybe we ought to define the conditions because 3% carbon dioxide or 17% oxygen or 200 PPM carbon monoxide are not detrimental for the points taken with different compounds.

KNIGHT: Maybe headaches are not the best criterion but it is the best criterion I had to organize and discuss. I found that when there was a high incidence of headaches there was also a problem with changes in performance. The other assumption that I made was that there was no equipment aboard the submarine to manufacture oxygen or scrub carbon dioxide. I don't know whether that is still true today. The point was that in a field study during submergence, the time course was one of gradual change of both carbon dioxide and carbon monoxide to this point. It is clear that when you have 200 PPM you have an unusual source of carbon monoxide aboard ship, and since there is no way of controlling the carbon monoxide it is going to be there and it may rise. I think you have to ventilate the ship sometime and so I am proposing the commander consider doing that before he reaches a point at which he can no longer respond.

DISCUSSION

MILROY: I think with these emergency limits we reach a real problem that is not correct to resolve, that is the operating setting. If the submarine is operating close to home and there are no surface contacts above and it is a safe place either to snorkel or to surface, than we have to be very conservative in our emergency limits and we can allow no adverse effects. On the other hand, with submarines operating in places where snorkelling or surfacing is absolutely out of the question, then obviously the commander has a very tough decision to make and he may want to operate with atmospheric conditions that we would be absolutely horrified to hear about, but are the lesser of two evils. I think that being the case we ought to set conservative limits assuming that they are to be employed in the easy situation and that in the hard situation it doesn't matter what limits we recommend. They are going to be the least consideration in a trying situation.

HOLT: I couldn't agree more with what Captain Milroy has just said. I think it is perhaps worth noting that there is the possibility of using a two-tiered system (that is two sets of standards) to deal with precisely the scenarios you set forth.

HARRISON: Once again I completely agree with Captain Milroy but I still think that we have a requirement to set levels which we think are really dangerous, when they really should ventilate.

KNIGHT: How much time are you going to allow them to ventilate after they reach that point?

GIACOMONI: I agree. I know from discussions with friends of mine that they don't have any idea what levels are dangerous. They won't know when to take action.

HOLT: Perhaps I should have gone on to mention that apart from the theoretical discussion of the two-tiered system, the UK is at present operating one in that we have our 24-hour and one-hour MPCs which would equate to under normal operating circumstances when things go wrong, but additionally, we have at the commander's disposal a guide which is prepared to try to explain to him what the penalties may be if he is up against the wall and he can't ventilate and he has just got to make the best of it. We do try to give him some guide as to what to expect, what will happen to his crew, and how performance will fall off. Technically they are already operating under a two-tiered system.

MESSIER: I have the feeling that you have also alluded to synergistic effects. Is there work being done in either France or the United Kingdom on the interaction of the effects between CO_2, oxygen and carbon monoxide? Is there any animal work being done?

SEVERAL PEOPLE ANSWER: No

GIACOMONI: I think this is a good idea for research. I think also we need information about the activity of the men during World War II. We don't know if they were working or resting.

KNIGHT: A variety of levels of activities were imposed on the crew ranging from routine watch standing to performance under general quarters. The mean oxygen uptake for an entire submergence period was .35 to .4 liters per man.

HARRISON: Mr. Chairman, with your permission, as the custodian of this STANAG would it be appropriate if I could ask whether the French delegation and the United States agree to my proposal to reduce the STANAG to three important essential gases?

MARLOR: Yes John, I think that would be an excellent idea.

GIACOMONI: We agree with you.

HARRISON: Could I then come to the next point please? Do we want a two-tiered system in the STANAG? In other words, do we want normal conditions when the submarine captain should ventilate and then one for real emergencies and not a whole series six hours, one hour, and so on?

WYATT: One thing that occurs to me: on a submarine there is provision for some sort of emergency, carbon dioxide removal from the system or whatever and also some oxygen candles or other oxygen source; and the engineers need some guidance as to how you want to arrange it so that you reach a critical point both when your oxygen is low and carbon dioxide is high. There is no point in having one that causes the ship to have to surface. You might as well provision the ship the most efficiently and so you need some guidance as they work their way down until they run out of both candles and CO_2 at the same time. You don't want to overprovision them either one of them. You need some guidance system as to how long you can go before you have permanent damage on the boat. Obviously this can be some sort of synergistic effect as well.

THOMPSON: It would appear to me that you may wish to provide provisioning for one instance and not the other as a limit. By that I mean, for example, if one were to provide an excess of CO_2 removal capability he may allow the oxygen to go down from say 17% to 14% but not exceed the maximum level of CO_2. This might be something worth consideration. Or conceivably on the other end you may wish to extend the CO_2 concentration given normal oxygen levels.

DISCUSSION

MARLOR: As I understand, we are supposed to tell them when to do something and not necessarily what to do about it. Is that correct?

HARRISON: Yes. We agreed that we should have real emergency limits for three substances and only that in the STANAG. Or should we produce graded guidelines while we're producing them?

MARLOR: I didn't want you to misunderstand. I think we should make the document as useful as we can. So I think that the more information we can get into it the better off we are. But on the other hand, we are not in a position to tell them what to do, what action to take in a given situation. It would be nice if we could do that, but since we cannot, then I think we should put in as much information as we have available that will be useful to them in making decisions.

GIACOMONI: I think we agree about these measures, but perhaps there are others which are not of great use to the commanding officer and which we have to measure--outpourings from batteries, for example. And if we don't measure, we have no idea of this.

HARRISON: The reason I've selected these three was because they're all odorless, colorless gases and you have no idea that you may have a problem that you need to monitor. The systems still exist in each submarine for these primary substances. I would suggest that if you have a dangerous level of chlorine, you would know and the same for nitrogen dioxide and other dangerous substances.

GIACOMONI: You would know because there is an active toxic substance.

HARRISON: Yes. As it is conceivable that you would have low levels of oxygen or high levels of carbon dioxide and the carbon monoxide in the submarine coming from various materials, this could be of some danger to the ship's company.

MATERIALS TOXICITY CLEARANCE IN RN SUBMARINES

Surgeon Lieutenant Commander D C B HOLT, Royal Navy

INSTITUTE OF NAVAL MEDICINE, ALVERSTOKE, HAMPSHIRE, UK

In 1982, more than 150 items were presented to the Submarine Medicine Section at the Institute of Naval Medicine (INM) for materials toxicity clearance and subsequently entered in the Materials Toxicity Guide (MTG) which is held on computer file and reissued six monthly as an Annex to BR1326, Air Purification in Nuclear Submarines. The increasing demand for clearance coupled with the need to retrospectively examine many common place and traditional items already in service has resulted in the evolution of a formalised procedure. This consists of a series of progressive stages, not all of which are necessary in the majority of cases. The full procedure is described.

A request for clearance is submitted by design, maintenance and operational authorities to the Secretary of the Submarine Air Purification Committee of the Directorate General, Ships (DG Ships) who sponsors BR1326. While other aspects - material and fire - are referred to Admiralty Marine Technology Establishment (AMTE), the submission is forwarded to INM for toxicological assessment, with such information as is available, usually only manufacturers' data sheets. Additionally, information about the intended purpose of the material, usage (in build, refit, maintenance or at sea), frequency and duration of use, quantities required, available alternatives and an assessment of the penalties, if the material cannot be used, is provided on a proforma (A) from the source authority.

On receipt in INM, it is usually necessary to first write to the manufacturer requesting the product formulation which will be protected, Commerical-in-Confi and other relevant data which may be available or is specifically deemed necessary. Simultaneously an internal working form (B) is raised and completed as details are obtained.

Once the chemical composition of a product is known then each component is sought in a source reference such as Aldrich[1] from which initial information - molecular formula and some physical properties - is obtained; there may also be references to NIOSH 'RTECS'[2] and Sax[3]. Additional information may be sought in other texts such as Patty[4]. Furthermore some inference of toxicity may be dra by analogy from the chemical formula and molecular structure.

If these sources provide insufficient information or there is particular concern about safety, evidence of mutagenicity or suspected carcinogenicity or there is marked potential for exposure then a literature search is requested. The Defence Research Information Centre select a suitable agency to search appropriate files and subfiles; Toxline, Chemline, Cancerline and Medline usually suffice. HEEP or Health Effects of Environmental Pollutants is an example of a subfile of Toxline.

Other sources of advice may be requested to assist. If information on formulation is inadequate or lacking then AMTE will perform material analysis. The Toxicology Division of the Chemical Defence Establishment may conduct in vitro mutagenicity and animal studies. Information may be sought from the USN under IEP B52 auspices or the French Navy through the Anglo-French Information Exchange. The Ministry of Agriculture, Fishery and Food, the Health and Safety Executive (HSE) and large industrial concerns, particularly producers of chemicals and petroleum products, may also be able to provide specialised information.

With the data accumulated it should, at this stage, be possible to make a valued judgement about the acceptability of use in submarines. Where appropriate Maximum Permissible Concentrations (MPC) are set and will be established in respect of the most toxic components and principal products likely to be evolved. This may entail study of the chemical and physical properties to determine break down products, potential for evaporation and subsequent behaviour. In relation to vapour pressure and likely ambient temperature, maximal atmospheric concentrations can be predicted as can the minimum quantities which would need to be released to achieve such levels. Flash points, flammable limits in air and lower explosive limits must also be considered and may in some cases represent the limiting factors.

The MPC may be based on existing TLVs obtained from ACGIH[5] or HSE[6] and be modified by a factor of five to extrapolate to a "200 hour week" (the additional 32 hours compensating for loss of intervening periods of non-exposure between working days and weeks). Where TLVs have not been set or are considered inappropriate for submarine application the determination of MPCs might be based upon information derived from the literature and other sources or research; desired MPCs may also have to be realistically adjusted to take account of the degree of control practicably achievable provided that compatibility with health and performance is maintained. Carbon dioxide, carbon monoxide and Halon are particular examples.

When an MPC is set it must be decided whether that should solely represent a design criterion in terms of performance of air purification equipment, engineering containment or restriction on use or whether compliance should be monitored either retrospectively or in real time. If the latter is required and no suitable monitoring means is available then the necessary procurement is recommended. Currently no routine biological monitoring of RN submariners is conducted.

Guidance on safety and hygiene is necessary in some cases and may be derived from standard sources,[3,4,7,8] manufacturers' safety data sheets or compiled de novo from data gathered during investigation. In particular, handling precautions, physical and respiratory protection required and the management of spills, leakage or other excursions and personal contamination must be specified.

Finally whatever the outcome of the investigation, the material must be entered into the MTG. This requires assigning a material to a suitable category for which there are currently fourteen tables (Figure 1). Within that table it is given a serial number according to alphabetical positioning, named as an item, which may be starred* if considered especially hazardous, listed by Naval Store number or NP if non-patternised and, most importantly, is designated by class of item from one to five (Figure 2) which specifies its usage within the submarine. Class is normally determined by the potential contribution to the submarine atmospheric content (of pollutant) during prolonged shut down periods but may also take into account the fire characteristics if significant quantities of the material will be used or carried. The next column specifies the quantities which may be carried at sea unless the extremes of NC (not carried) or AS REQD (as required) are stated. Between these extremes, latitude may be granted by 'MINIMUM' or 'AS FITTED BY BUILDER'. The final, remarks, column contains brief notes on usage, conditions of ventilation required, particular hazards and precautions; more detailed guidance is provided through formal Service channels. A representative page is exampled as Figure 3.

The recommended decision about a material is forwarded to DG SHIPS on a form (C) detailed in the format in which it will appear in the MTG when the recommendation is confirmed. This form is then returned to INM as authorisation to amend the MTG.

Currently the MTG applies only to nuclear submarines. However, the new design SSK, the '2400', will be designed and built to current MTG standards and proposed new materials for use in build will undergo the same scrutiny as if for nuclear submarines. To what extent stores carried by SSKs should be governed by the MTG in its present form is under discussion. The restrictions imposed on nuclear submarines may be excessive for conventional operating conditions; accordingly it may be decided that a revised guide, incorporating sub columns (for nuclear and conventional) under both 'class' and 'quantity carried' columns, will be appropriate. The addition of a further column coding the pyrolysis product hazard in an analogous manner to toxicity class is also under consideration.

In conclusion, a comprehensive but flexible screening procedure exists to scrutinise each material proposed for use in nuclear submarines. The full procedure is required for only a minority of substances. The provision of the (MTG) and the screening procedure are being applied to the new design SSK and the MTG may be modified to accommodate conventional submarine requirements. The MTG may further be modified to include fire hazard assessment.

REFERENCES

1. ALDRICH. Catalogue Handbook of Fine Chemicals. Aldrich Chemical Company Limited. 1983.

2. NIOSH. Registry of Toxic Effects of Chemical Substances. Ed. LEWIS R J and R L TATKEN. US Government Printing Office, Washington. 1980.

3. SAX, N I. Dangerous Properties of Industrial Materials. 5th Edition Van Nostrand Reinhold Company, New York. 1979.

4. PATTY, F A. Industrial Hygiene and Toxicology, Volume IIA Ed. CLAYTON G D and F E CLAYTON 3rd Edition. Wiley-Interscience, New York. 1981.

5. ACGIH. Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment with Intended Changes for 1982. ACGIH, Cincinnati. 1982.

6. HSE, TLV 1982 Guidance Note EH15/82 from the Health and Safety Executive. HMSO, London. 1982.

7. NIOSH/OSHA. Occupational Health Guidelines for Chemical Hazards. US Government Printing Office. 1981.

8. HSE. Guidance Notes in the Medical, Environmental Health, Chemical and General Series from the Health and Safety Executive, HMSO, London.

CATEGORIES IN THE MATERIALS TOXICITY GUIDE (BR1326A)

TABLE	CATEGORY
1	ADHESIVES
2	JOINTING COMPOUNDS & SEALANTS
3	CLEANING AGENTS & DISINFECTANTS
4	DETERGENTS
5	INSULANTS
6	RUBBERS, PLASTICS & SYNTHETICS
7	OILS & GREASES
8	MEDICAL MATERIALS
9	PAINTS & VARNISHES
10	PESTICIDES & FUNGICIDES
11	PHOTOGRAPHIC MATERIALS
12	CHEMICALS
13	DOMESTIC MATERIALS
14	MISCELLANEOUS

Figure 1

MATERIAL CLASSIFICATION

CLASS	INTERPRETATION
1	PROHIBITED
2	CONSTRUCTION AND REFIT ONLY
3	MAINTENANCE AND DED (DOCKING AND ESSENTIAL DEFECTS)
4	RESTRICTED - USE AT SEA UNDER SPECIAL CIRCUMSTANCES
5	PERMITTED - CARRIED IN APPROVED QUANTITIES

Figure 2

Figure 3

TABLE 6 RUBBERS PLASTICS SYNTHETICS

S/N	ITEM	NS CAT NO	CLASS	QUANTITY CARRIED	REMARKS
1	ABS PLASTIC (CYCOLAC T)	NP	5	AS REQD	FITTINGS ON BATTERY AGITATION SYSTEM
2	ADC MK2 POLYURETHANE PARTS	NP	4	AS REQD	
3	ARNO TAPE (ADHESIVE BACKED NEOPRENE RUBBER)	NP	5		MADE BY ARNO ADHESIVES TAPES LTD. APPROVED FOR USE IN SMALL QUANTITY. NOT MORE THAN 1 cu ft TOTAL
4	BORON NITRIDE THYRISTORS	NP	5	AS REQD	USED IN SPE DEVELOPMENT
5	CARPET UNDERLAY. RUBBER OR FOAM	NP	2	NC	FURNISHING
6	CAST NYLON 6	NP	5	AS REQD	TEMPORARY COVERS FOR FURNITURE AND EQUIPMENT
7	CLOTH SILICON RUBBER COATED GLASS	0330/139-0530	5	AS REQD	TYGLAS
8	DECLON	NP	5	AS REQD	VENT EXHAUST FILTERS
9	DELRIN	NP	5	AS REQD	AS REQD FOR 24 POSITION ROTARY WAFER SWITCHES ONLY
10	DINGHY REPAIR OUTFIT (*)	0472/2405	4	1 KIT	RESTRICTED USE ONLY WHEN IN OPENED UP CONDITION
11	ELF PLASTIC CAPS	CLASS GROUP 0269	5	AS REQD	
12	EPOXIDE RESIN UW45 LV	NP	4	Minimum	HAZARDOUS. FOR EMERGENCY USE ONLY. TO BE HELD BY ECO. PROTECTIVE CLOTHING AND RESPIRATORY PROTECTION REQUIRED.
13	EXPANDED POLYSTYRENE	NP	1	NC	USED FOR PACKING STORES
14	EXPANDED SYNTHETIC RUBBER	NP	3	NC	USED ON SSK MAIN GENERATOR RESILIANT BED
15	FABLON SELF ADHESIVE VINYL	NP	5	AS REQD	IN SHOWER SPACES TO IMPROVE WATERTIGHTINESS
16	FABULUX SUPERTREAD AND ARMOURTREAD	NP	2	AS REQD	VINYL FLOOR COVERING
17	FURMANITE FCE	NP	5	AS REQD	-
18	GILFLEX NORYL PLASTIC CONDUIT	NP	2	AS REQD	ONLY NORYL-POLYPHENYLENE OXIDE IS TO BE USED
19	LATEX FOAM MATTRESSES	NP	5	AS FITTED BY SHIPBUILDER	APPROVED FOR USE WHEN ENCASED IN RUBBERISED ASBESTOS COVER. OTHERWISE USE POLYETHER FOAM MATTRESSES
20	LEXAN 2000	NP	5	AS REQD	USED ON CENTRALISED CONTROL CONSOLE FACIA PANELS
21	LIMESTONE REINFORCED POLYPROPYLENE (LPPN 2969)	NP	5	AS REQD	USED ON TEMPERATURE MONITORING HEAD AMPLIFIER CASES
22	LINATEX	NP	4	APPROVED SPARES	FLEXIBLE RUBBER CONNECTIONS FOR VENTILATION TRUNKING

AD P001884

CADMIUM LEVELS IN SUBMARINE ATMOSPHERES AND METHODS FOR ITS DETECTION AND MONITORING

J. S. BOWMAN, LCDR, MSC, USN AND K. R. BONDI, CDR, MSC, USN
NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY, GROTON, CONNECTICUT

Few places in the world can legtimately claim to be as isolated, physically and psychologically as a nuclear submarine on patrol. This is particularly true for Fleet Ballistic Missile submarines, whose very existence depends on this isolation. Apart from very infrequent snorkeling evolutions, the atmosphere aboard the submarine is totally machine-made and subject to only those contaminants and pollutants found aboard. While this atmosphere is supposed to be as good as, if not better than, that found outside the boat, the closed nature of the environment could increase the harmful effects of any possible toxic contaminants.

One potential contaminant which could have severe long-term effects on the health and performance of crewmembers, is cadmium. Before specifically addressing its possible sources and impact on submarines and their crewmembers, as well as methods of monitoring its presence, both within the submarine and the crew, I will present a synopsis of general information regarding cadmium, its uses, and its effects. Cadmium was discussed in 1818 by the German mettallurigist F. Strohmeyer (Budgen, 1924). It is almost always found in concert with zinc and is recovered in its pure form as a by-product of zinc roasting, smelting, and processing. Cadmium is also found with copper and lead ores and is recovered in some quantities from the processing of these ores also. Some common uses for cadmium include: Use in low melting-point alloys, low-friction, high-fatigue strength bearings, electroplating of pot, pans and cans, as a component in solder, in NiCad and regular storage batteries, as a phosphor material for cathode ray tubes and screens. Cadmium is also used in paint pigments, rubber and plastic products, as a component in fertilizers and as a barrier in atomic fission processes. The toxic effects of cadmium have been known and studied for years and many articles and reviews have been published concerning its health effects (Lee and White, 1980; Iwao, Tsuchiya, and Sakurai, 1980; Bonner, King, and Park, 1979; Fullmer, Oku, and Wasserman, 1979; Naqawa, Ishizaki and Kabayashi, 1978; Eakin, Schroeder, Whanger, and Weswing, 1980, Friberg, 1959). The effects of the element can be acute or chronic. Chronic exposure leads to as accumulation of the element in the kidneys, liver, cardiac muscle, and ultimately renal failure due to the tubular dysfunction.

Unfortunately, there are many potential sources of cadmium aboard submarines. For a partial list see Table I. With all of these possible sources of cadmium available on a submarine, and having an essentially closed environment, the logic of the situation would dictate that there must be a problem with cadmium contamination. Is this in fact true, and can levels of cadmium be accurately monitored to find out?

Several years ago, samples of scalp hair were collected by an NSMRL investigator at the beginning and end of a Fleet Ballistic Missile submarine patrol. When the hair samples were analyzed, cadmium levels were found, which were determined to be many times reference population levels (Biersner and Gilman, 1982). These findings were in conflict with those of an earlier study done by the Royal Dutch Navy (Oeseburg, 1976). This laboratory was asked to initiate a study to determine whether a cadmium contamination problem existed aboard U.S. Navy submarines.

Such a program has been underway at this laboratory for approximately nine months to determine (1)if there is a problem with cadmium contamination aboard subarines and (2)to determine ways of monitoring cadmium levels, both physically and biologically, if a problem exists. One factor which gave credence to the possibility of a cadmium contamination problem was the discovery that considerable zinc mining and smelting activity takes places in the vicinity of Grennock, Scotland, which is located very near the U.S. Navy submarine facilities at Holy Loch. These activities increased the possibility of either inhalation or tactile contamination within the immedicate area of the naval installation. A number of Fleet Ballistic Missile submarines, operating from Holy Loch, as well as geographical sites (Holy Loch, Groton, CT) have been sampled, with additional submarines and land sites due to be sampled in the future. Table II gives a breakdown of sampling sites and populations.

Physically, the atmospheres aboard the submarines were sampled by placing air pumps with sampling cassettes randomly around the ships, daily, and sampling from the given compartment (s) for 6-8 hours per day. In this way, every compartment was sampled a number of times during the patrols, assuring a sample size large enough to be a valid measure. The same format was used to sample the geographical control sites, the pumps having been placed either on the submarines decks or atop the sail. Biological monitoring was carried out through the collection of scalp hair, serum, and urine samples (Eads and Lambdin, 1973; Hammer, Finklea, Hendricks, and Shy and Horton, 1971; Klevay, 1973; Maugh, 1978; Stankovic, Milic, Djuric, and Stankovic, 1977; Strain, Pories, Flynn, and Hill, 1973; Forssen and Erametsa, 1974; Chattopadhyay and Jervis, 1974; Hopps, 1974; Corridan, 1974, Ellis, Yasumura and Cohn, 1981, Iwao, Tsuchiya, and Sakurai, 1980). The samples were collected at given intervals prior, during, and after the patrol. The control populations were sampled on dates roughly corresponding to the beginning and end of the patrol.

All the air samples collected have been analyzed for several toxic contaminants, which should indicate whether or not atmospheric contamination is present in any areas of the submarines, as well as at any of the control sites sampled. Table III gives a synopsis of the cadmium results from the air samples. These results, when combined with the much more extensive results being obtained from analyses of the biological samples, will allow the investigators to determine: (1) Whether or not contamination problems actually exist aboard the submarines or at the control sites tested, (2) If problems exist, whether they are functions of inhalation of airborne particles or of tactile or ingested routes of body entry, (3) the most efficient and effective (from the crewmembers' point of view) method(s) of monitoring both the submarines and the crewmembers, and (4) what steps should be taken by both the engineering/design personnel and the health care personnel to alleviate the problems, if they exist.

As was seen from Table III, there appear to be no problems, atmospherically, aboard the submarines or at the control sites. The biological specimens are currently undergoing analysis, and the results are expected in the very near future. A potentially beneficial off-shoot of the sampling methods used in the study is that a wide range of other trace elements are being included in the analyses of blood, urine, and hair, thereby providing a tremendous data bank of information concerning real or potential hazards in submarine atmospheres, in the event future questions arise concerning toxic contaminants.

BIBLIOGRAPHY

Biersner, R. J. and S. C. Gilman. 1982. Elevated levels of cadmium and lead among U.S. Navy personnel. Submitted for publication.

Bonner, F. W., L. J. King, and D. V. Parke. 1980. Cadmium-induced reduction of bone alkaline phosphatase and its prevention by zinc. Chemical and Biological Interactions 29: 369-372.

Budgen, N. F. 1924. Cadmium: Its metallurgy, properties, and uses. J. B. Lippincott Company, Philadelphia.

Chattopadhyay, A. and R. E. Jervis. 1974. Hair as an indication of multielement exposure of population groups. In: TRACE SUBSTANCES IN ENVIRONMENTAL HEALTH - VIII. D. D. Hemphill, Editor, University of Missouri Press, Columbia. pp. 31-38.

Corridan, J. P. 1974. Head hair samples as indicators of environmental pollution. Environ. Res. 8: 12-16.

Eads, E. A. and C. E. Lambdin. 1973. A survey of trace metals in human hair. Environ. Res. 6: 247-252.

Eakin, D. J. J., L. A. Schroeder, P. D. Whanger, and P. H. Weswing. 1980. Cadmium and nickel influence of blood pressure, plasma renin, and tissue mineral concentration. Am. J. Physiol. 228 (Endocrinol. Metab. I): E53-E61.

Ellis, K. J., S. Yasumura, and S. H. Cohn. 1981. Hair cadmium content: Is it a biological indicator of the body burden of cadmium for the occupationally exposed worker? Am. J. Industrial Med. 2: 323-330.

Forssen, A. and O. Erametsa. 1974. Inorganic Elements in the human body: Ba, Br, Ca, Cd, Cu, K, Ni, Pb, S_n, Sr, Ti, Y, and Zn in hair. Annales Academia Scinetorium Fennica Aiv Medica, 162: 1-5.

Friberg, L. 1959. Chronic cadmium poisoning. AMA Archives of Industrial Health 20: 401-407.

Fullmer, C. S., T. Oku, and R. H. Wasserman. 1980. Effect of cadmium adminstration on intestinal calcium absorption and vitamin D-dependent calcium-binding protein. Environmental Research 22: 386-399.

Hammer, D. I., J. F. Finklea, R. H. Hendriks, C. M. Shy, and R.J.M. Horton. 1971. Hair trace metal levels and environmental exposure. Am. J. Epidemiology, 93: 84-92.

Hopps, H. C. 1974. The biological bases of using hair and nail for analyses of trace elements. IN: TRACE SUBSTANCES IN ENVIRONMENTAL HEALTH - VIII. D. D. Hemphill, Editor, University of Missouri Press, Columbia. pp. 59-73.

Iwao, S., K. Tsuchiya, and H. Sakurai. 1980. Serum and urinary β-2-microglobulins among cadmium -exposed workers. J. Occupational Med. 22(6): 399-402.

Klevay, L. M. 973. Hair as a biopsy material. III. Assessment of environmental lead exposure. Archives of Environmental Health, 26: 169.

Lee, J. S. and K. L. White. 1980. A review of the health effects of cadmium. Am. J. Industrial Med., 1: 307-317.

Maugh, T. H. 1973. Hair: A diagnostic tool to complement blood, serum, and urine. Science 202: 1271-1273.

Nogawa, K., A. Ishizaki, and E. Kobayashi. 1979. A comparison between health effects of cadmium and cadmium concentration in urine among inhabitants of the itai-itai disease endemic district. Environmental Research 18: 397-409.

Oeseburg, F. 1976. Determination of the concentration of cadmium aerosol and of some other contaminants present in the atmosphere of a submarine of the Royal Dutch Navy. Cadmium pollution, November 1977-October 1980 (Citations from the NTIS Data Base), Abstract No. 79104.

Stankovic, M., S. Milic, D. Djuric, and B. Stankovic. 1977. Cadmium, lead, and mercury content of human scalp hair in relation to exposure. In: CLINICAL CHEMISTRY AND CHEMICAL TOXICOLOGY OF METALS". S. S. Brown, Editor. Holland: Elsevier. p. 327.

Strain, W. H., W. J. Pories, A. Flynn, and O. A. Hill. 1973. Trace element nutriture and metabolism through head hair analysis. In: TRACE SUBSTANCES IN ENVIRONMENTAL HEALTH-VIII. D. D. Hemphill, Editor. University of Missouri Press, Columbia, pp. 383-397.

TABLE 1

SOURCES OF CADMIUM ABOARD SUBMARINES

BOLTS	BRAZING RODS
WELDING RODS	EPOXIES
PIPING	SOLVENTS
PLATING MATERIAL	GALLEY EQUIPMENT AND UTENSILS
ELECTRONIC EQUIPMENT	FOOD (MEATS, VEGETABLES, FISH)
TOBACCO	

TABLE II

SAMPLING POPULATIONS AND SITES

SITES		Control	Experimental
S I T	HOLY LOCH	Crewmembers assigned to the drydock at the site (non-submariners)	Crewmembers assigned to submarines (FBM's) operating from Holy Loch
	NSMRL, Groton	NSMRL Laboratory personnel (non-submariners)	
E S		PROJECTED	
	Naval Station Charleston, S.C.	Personnel assigned to shore duty at Charleston (non-submariners)	Crewmembers assigned to FBM operating from Charleston, S.C.

TABLE III

RESULTS OF ATMOSPHERE SAMPLING

SOURCE	Cd level (mg/m^3)*
Submarine 1	<0.34 $\mu g/m^3$
Submarine 2	<0.20 $\mu g/m^3$
Holy Loch	<0.34 $\mu g/m^3$
NSMRL, Groton	<0.34 $\mu g/m^3$

* Normal level = 0.001-0.350 g/m (HEW, 1966)

BONE AND BODY MINERAL COMPOSITION STUDIES IN ACTIVE DUTY AND RETIRED SUBMARINERS

A. A. MESSIER[1], S. H. COHN[2], R. M. NEER[3], A. VASWANI[2], D. V. TAPPAN[1], AND K. R. BONDI[1]

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY, NAVAL SUBMARINE BASE NLON, GROTON, CONNECTICUT[1], BROOKHAVEN NATIONAL LABORATORY, UPTON, NEW YORK[2] AND MASSACHUSETTS GENERAL HOSPITAL, BOSTON, MASSACHUSETTS[3]

INTRODUCTION

There has been considerable interest in identifying, isolating, and studying the factors inherent in closed space environments that may affect calcium metabolism; whether it be a submarine or a space capsule. Laboratory controlled studies of variables present in the submarine environment have considered 1) the role of carbon dioxide, 2) lack of sunlight leading to decreased levels of vitamin D, 3) diminished physical activity, and 4) alteration in diet with an intake of distilled water lacking in trace minerals as factors which may influence calcium metabolism and could be reflected, over a period of time after repeated exposures, by changes in bone mineral content and body elemental composition.

Table 1 presents evidence of changes associated with the four individual factors and what is known from submarine field studies. Note should be made concerning the multifactorial nature of the submarine environment and the question of addition or interaction of effects.

The implication of these findings is that prolonged and repeated exposure to the submarine environment may have an effect on calcium metabolism and could be indirectly monitored by measurement of body composition and bone mineral content of submariners. Although surveys of epidemiological studies of submariners have not identified the skeletal system as a source of potential health problems; we felt that because of substantial circumstantial evidence, it would be judicious as a preventive measure, to obtain measurement of bone and body mineral content to insure early detection of changes that might be occurring.

OBJECTIVE

The objective of this study was to establish whether any detectable change in bone and body elemental composition has occurred in a selected group of active duty and retired submariners who have been exposed for a significant period of time to the submarine environment.

RESEARCH DESIGN AND METHODS

<u>RETIRED SUBMARINERS</u>. In the first section of the study, ten retired submariners between the ages of 40-45 were selected and asked to volunteer for a single experimental testing period. A non-invasive method was used to determine total body elemental composition. These measurements were made by the total body neutron activation analysis (TBNAA) method and were made at

TABLE 1

EFFECT OF ENVIRONMENTAL FACTORS UPON BLOOD, URINE, FECAL, AND BONE CALCIUM CONCENTRATION

	FACTOR	BLOOD C_a	URINE C_a	FECAL C_a	BONE C_a	POSSIBLE CLINICAL MANIFESTATION
DATA FROM LABORA TORY AND CLIN ICAL STUDIES	INCREASED INSPIRED CO_2	↑ / ↓ /NC	↓	↑	↓	SOFT TISSUE CALCIFICATION; SECONDARY HYPERPARATHYROIDISM
	ABSENCE OF SUNLIGHT	↑ /NC	↓	↑	↓	RICKETS; OSTEOPOROSIS
	DECREASED EXERCISE	↑	↑	↑	↑	DISUSE-OSTEOPOROSIS; FRACTURES
	ALTERED DIET	↑/↓ /NC	↑ /↓ /NC	↑ /↓ / NC	↑ /↓ /NC	INCREASED CDV RISK; RICKETS; ELECTROLYTE CHANGES
DATA FROM SUBMARINE PATROL FIELD STUDIES	TOTAL SUB MARINE ENVIRONMENT INCLUDING KNOWN AND UNKNOWN FACTORS	↓ /NC	↓	?	?	NC/?

↑ = Increase; ↓ = Decrease; NC - no change; ? effect unknonw or has not been measured the Medical Department of the Brookhaven National Laboratory (BNL), Upton, New York. A brief physical exam, two venous blood samples, a twenty-four hour urine sample, and the filling out of a diet questionnaire were also required for a complete evaluation of the data.

ACTIVE DUTY SUBMARINERS. In the second section of the study, thirty-nine experienced (3 or more FBM patrols) active duty submariners had their bone mineral content estimated by a portable non-invasive bone mineral analyzer. The bone analyzer consists of a scanner module containing a radioactive source (^{125}I) which transports a highly collimated beam of monoenergetic gamma rays across the left radius. A computer module calculates the bone mineral content for unit length and width of the bone. Each scan takes approximately 25 seconds, and the average radiation dosage is less than 25 millirems per man with the dose confined entirely to the scanned site. The age, weight, and height of the subjects was also taken. The data were used to calculate bone mineral content and were matched to empirically derived "normal population" values.

RESULTS

The data presented in Table 2 and Figure 1 present the results of the retired submariners study. Note the comparison with a normal age-matched contrast population. The data for the normal contrast population is from Ellis and Cohn, J. Appl. Physiol. 1975, and is used for illustrative purposes only. Note that the mean age, weight, and height are similar as well as mean values for total body potassium (TBK), and total body calcium (TBC_a). Make note however of the range of individual values for the TBK and TBC_a data. The data, however, can be normalized so that each individual can be compared with a predicted value corrected for that person's age, weight, height, and sex.

For example, in order to calculate the relative deficit or increase in total skeletal C_a in an individual from an absolute measurement of C_a, it is necessary to normalize the data for each person with a correction based on sex, age, and skeletal size. The variation in C_a content of an individual is so large, because of variation both in size and degree of mineralization among individuals, that an average reading does not provide a suitable reference value against which an individual measurement can be assessed (Cohn, et al, 1974).

The group at the Medical Research Center of the Brookhaven National Laboratory have empirically derived a relationship to calculate the "normal" predicted skeletal C_a or K in a subject, on the basis of sex, age, weight, and height. Table 3 presents the predictive equations that are used to normalize the data, and in Figure 2 it can be seen that the measured total-body C_a may be expressed in terms of the predicted normal C_a and is referred to as the calcium ratio. The relative deficit in C_a for an individual may then be denoted as the difference between 1.00 and the measured values of the ratio. An increase in the ratio would denote a relative increase in body C_a while a decrease in the ratio would denote a corresponding loss of total-body calcium.

The same type of calculations can be made for the bone mineral content (BMC) and a BMC ratio may also be calculated. In Figure 3 the normalized

TABLE 2

TOTAL BODY ELEMENTAL COMPOSITION OF RETIRED SUBMARINERS AND A REPRESENTATIVE NORMAL CONTRAST POPULATION

Subject		Age, Yr	Wt, Kg	Ht, m	TBK, g	TBC_a, g	TBK/TBC_a	TBK/Kp*	TBC_a/Cap*
Normal Contrast Population									
1		43	100.0	1.830	161.3	1348	0.1196	0.979	1.053
2		36	90.0	1.855	180.6	1366	0.1322	1.103	1.056
3		35	86.4	1.690	148.2	1081	0.1371	1.110	1.016
4		33	83.2	1.778	140.7	1169	0.1204	1.017	0.999
5		51	76.4	1.793	142.0	1161	0.1223	1.052	1.022
6		39	72.3	1.598	118.0	1036	0.1148	1.101	1.144
7		49	70.5	1.750	119.8	1042	0.1144	0.964	0.980
8		37	64.1	1.730	115.5	907	0.1273	0.964	0.879
9		30	61.8	1.640	100.4	876	0.1146	0.931	0.944
MEAN ±SD		39.2	78.3	1.740	136.4	1110	0.1225	1.019	1.010
		7.1	12.6	0.085	25.2	171.5	0.0081	0.072	0.074
Subject	**Total Time Submerged, Months**	**Age, Yr**	**Wt, kg**	**HT, m**	**TBK, g**	**TBC_a, g**	**TBK/TBC_a**	**TBK/Kp***	**TBC_a/Cap***
Retired Submariners									
1	20	42	100.5	1.752	168.5	1158	0.1455	1.110	0.933
2	25	44	89.0	1.840	150.9	1371	0.1101	0.963	1.112
3	26	43	82.7	1.736	140.9	1086	0.1297	1.045	0.966
4	18	40	75.0	1.776	128.1	1155	0.1109	0.945	1.054
5	13	42	93.2	1.806	150.1	1219	0.1231	0.966	1.011
6	38	41	67.2	1.723	146.9	1145	0.1283	1.220	1.005
7	28	40	80.8	1.838	122.1	1018	0.1199	0.810	0.919
8	6	45	75.9	1.718	150.2	1222	0.1229	1.194	1.064
9	14	42	62.3	1.810	119.9	1155	0.1038	0.939	1.069
10	12	43	87.7	1.814	145.6	1369	0.1064	0.960	1.147
MEAN ± SD	20.0	42.2	81.4	1.781	142.3	1189	0.1201	1.015	1.028
	9.4	1.6	11.7	0.047	15.0	111.8	0.0127	0.127	0.075

*Kp = αW $^{1/2}H^2$; Cap = $W^{1/4}H^2$; where = 5.52–0.014 (age); = 54.5 $^{1/2}$; W, weight (Kg); H, height (m). Normal contrast population data (Ellis and Cohn, J. Appl. Physiol, 1975).

Total-Body Calcium and Potassium Values in a Normal Contrast Population and in Retired Submariners

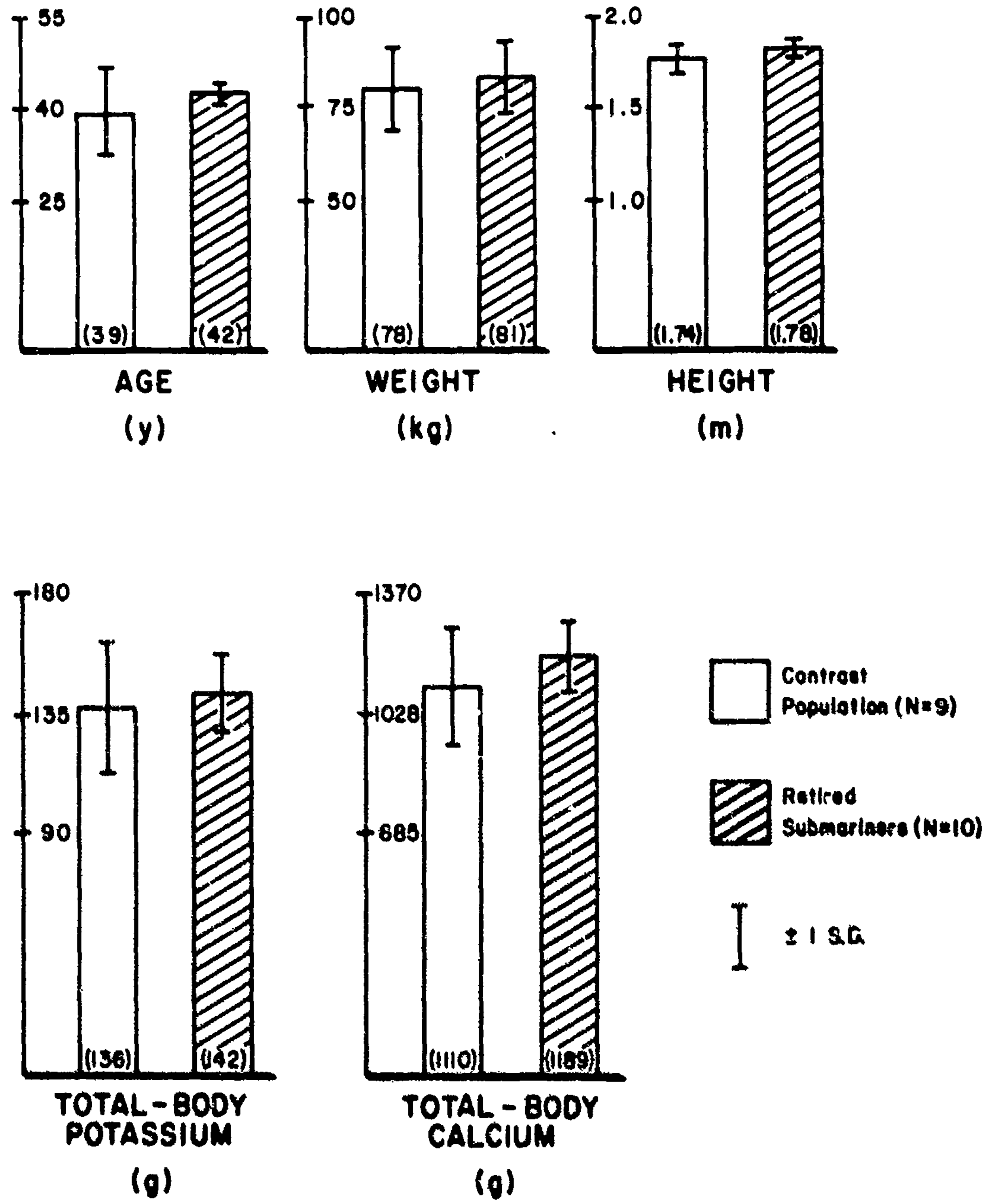


Figure 1

TABLE 3

PREDICTIVE EQUATIONS USED TO CALCULATE NORMALIZED TOTAL BODY POTASSIUM AND TOTAL BODY CALCIUM

<u>TOTAL BODY POTASSIUM</u>

$$Kp = W^{1/2}H^2$$

where:

- Kp = Predicated normal total body potassium, g
- W = weight, Kg
- H = height, m
- A = age, y
- α = 5.52-0.014A, for males

TOTAL BODY CALCIUM

$$Cap = \beta W^{1/2}H^2$$

where:

- Cap = predicted normal total body Ca, g
- W = weight, Kg
- H = height, m
- β = $54.5\,\alpha^{1/2}$

Normalized Total-Body Calcium Corrected For Sex, Age, Weight, And Height

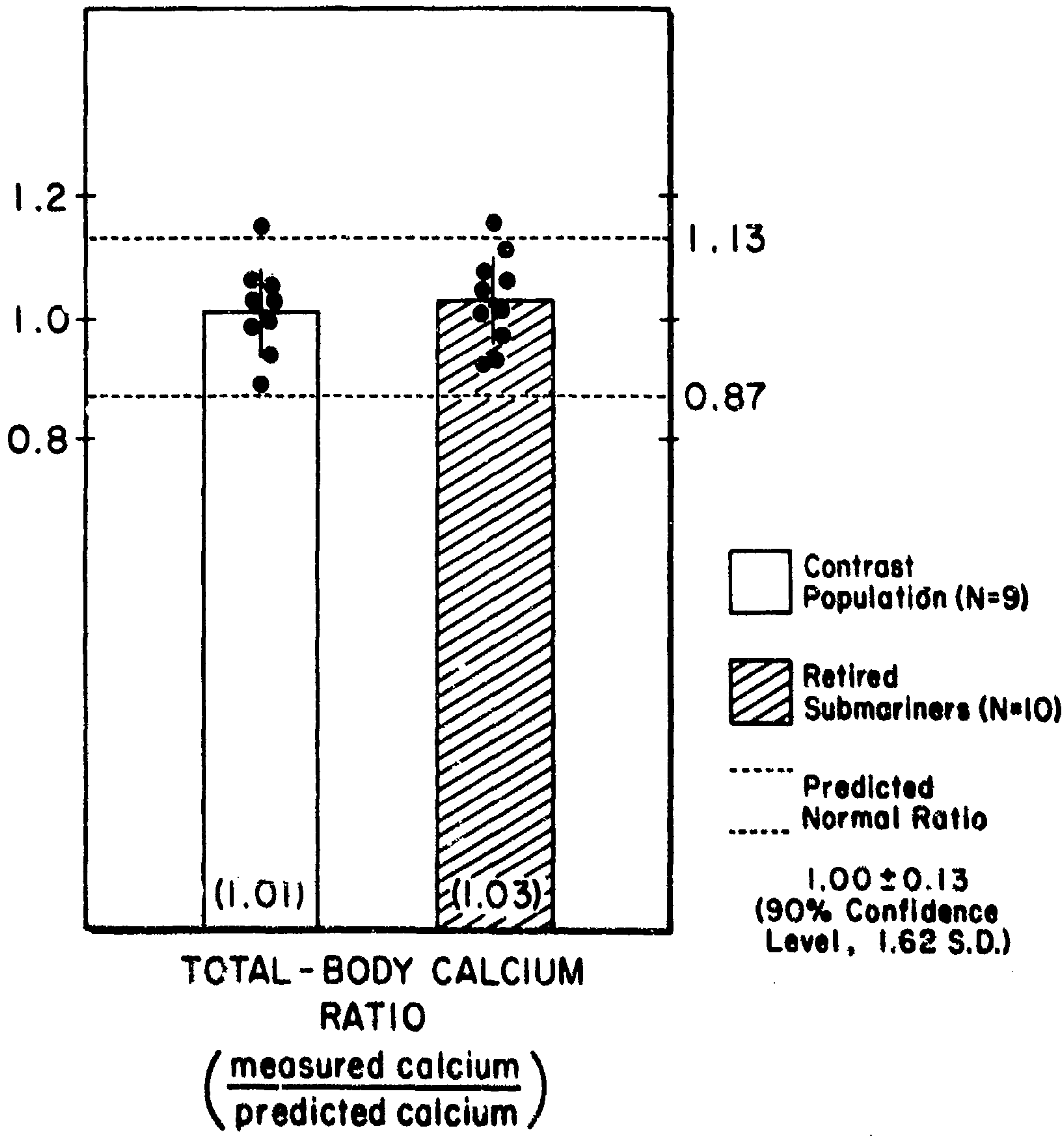


Figure 2

Normalized Bone Mineral Content in Submariners

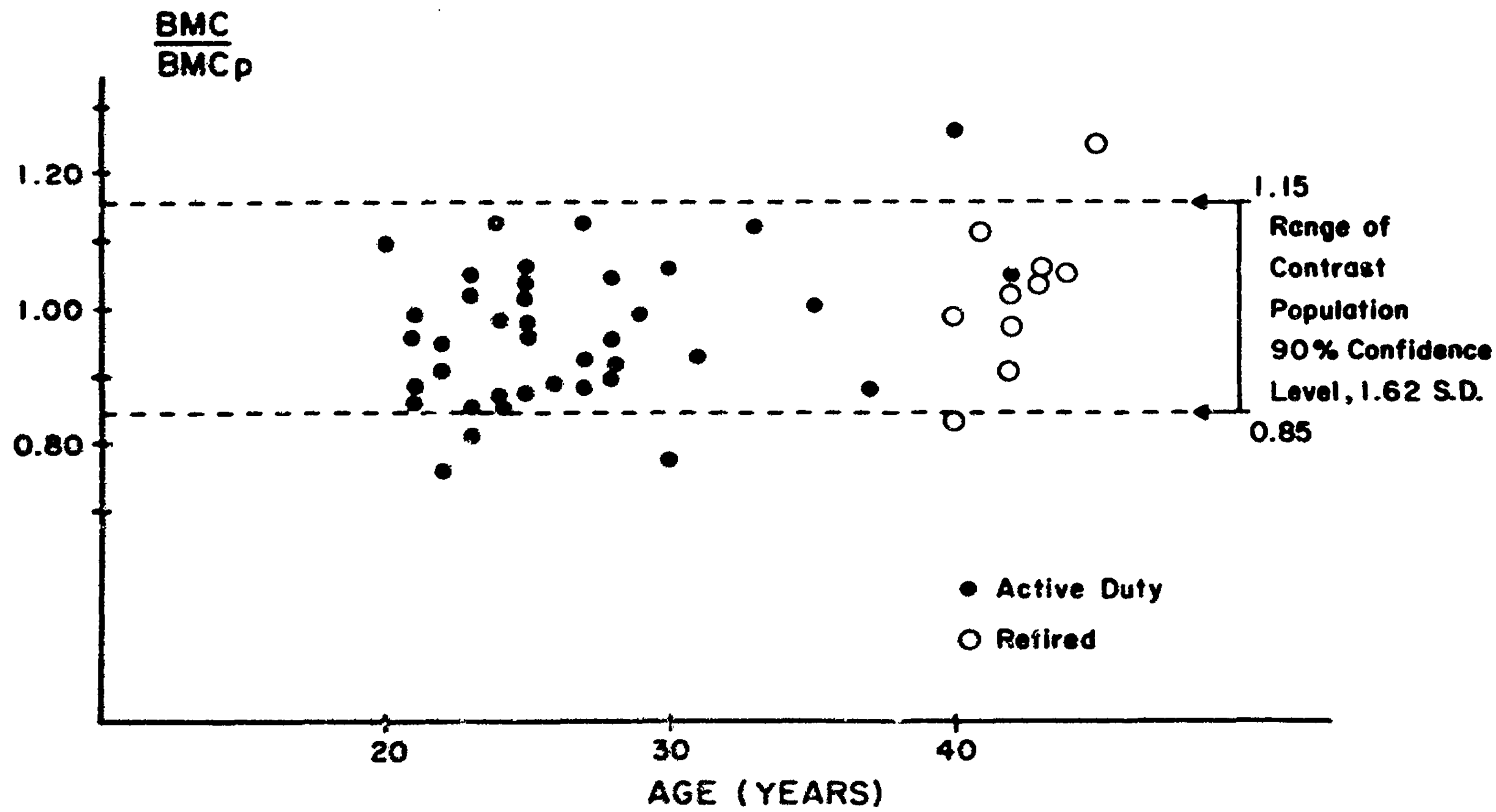


Figure 3

Normalized Bone Mineral Content in Submariners

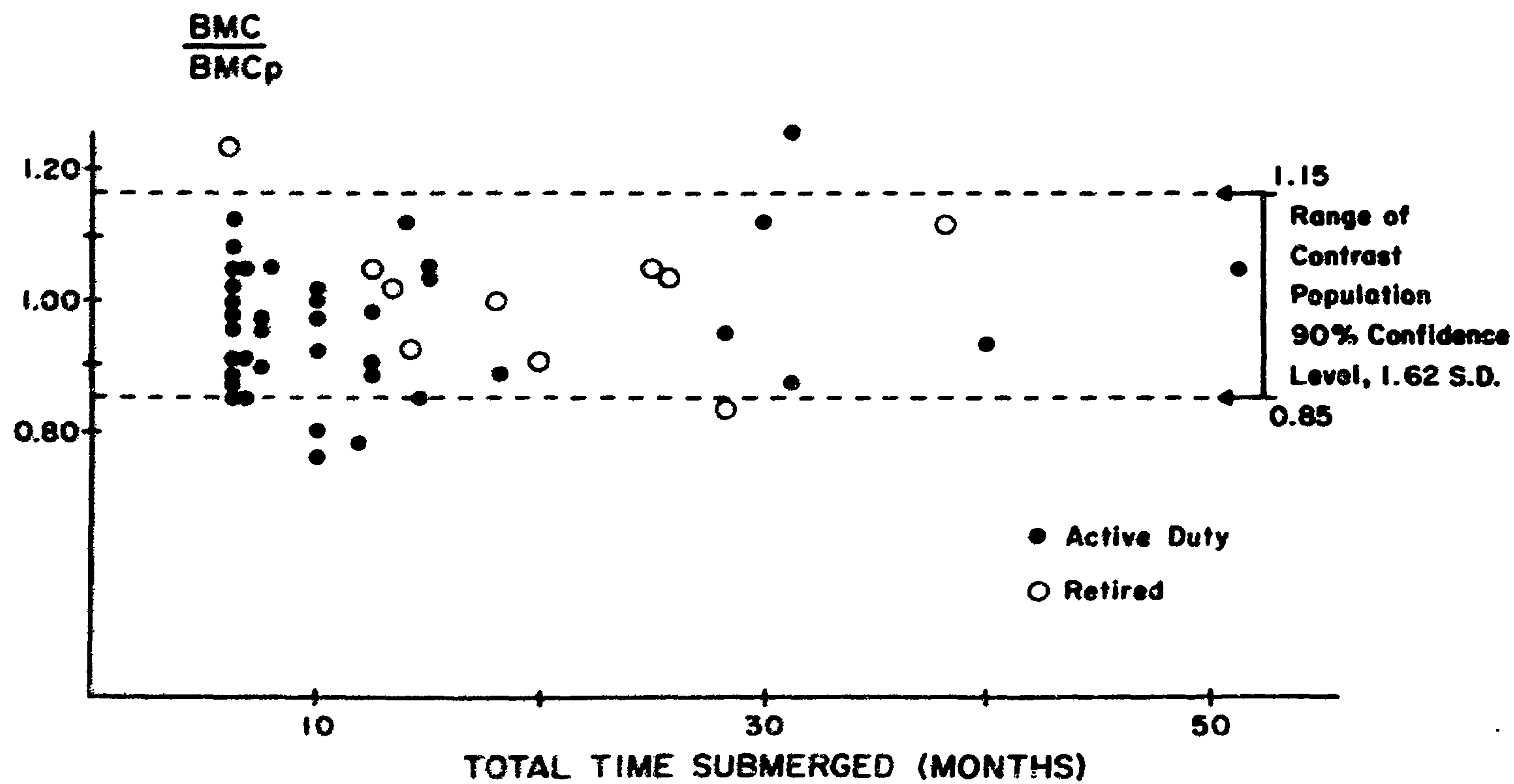


Figure 4

BMC plotted as a function of chronological age for both retired and active duty submariners is presented. There is no evidence of a substantial decrease in the BMC ratio as a function of age over this range.

In Figure 4 the BMC ratio is plotted as a function of total career submerged time. Again there is no substantial alteration in BMC ratio over total time submerged.

CONCLUSION

The total body calcium measurement, indicative of total bone mass, is normal in retired submariners and the bone mineral content, indicative of regional bone mass, is normal in both active duty and retired submariners. Therefore, it is concluded that repeated and prolonged exposure to the submarine environment produces no cumulative changes in skeletal mass.

ACKNOWLEDGMENT

This investigation was conducted in collaboration with Dr. Stanton Cohn and his group at the Brookhaven National Laboratory. Dr. Cohn has been instrumental in the development of the total body neutron activation method. Dr. Ashock Vaswani of the Medical Department at Brookhaven National Laboratory was the responsible physician in this study. Dr. Robert M. Neer, Director of the Endocrine Unit at Massachusetts General Hospital collaborated in the bone densitometry studies. Dr. Neer is a recognized expert of vitamin D metabolism and bone research.

REFERENCES

ELLIS, K. J. and S. H. Cohn. Correlation between skeletal calcium mass and muscle mass in man. J. Appl. Physiol. 38: 455-560, 1975.

COHN, S. H., K. J. Ellis, S. Wallach, I. Zanzi, H. L. Atkins, and J. F. Aloia. Absolute and relative deficit in total skeletal calcium and radial bone mineral in osteoporosis. J. Nucl. Med. 15: 428-435, 1974.

AD P001886

NITROGEN DIOXIDE LEVELS ABOARD NUCLEAR SUBMARINES

by

Kenneth R. Bondi, Ph.D.
Michael L. Shea, Ph.D.
and
Robert M. DeBell, Ph.D.

Biomedical Sciences Department
Naval Submarine Medical Research Laboratory
Box 900, Naval Submarine Base NLON

Groton, Connecticut 06349

INTRODUCTION

Nitrogen dioxide is generated in the closed atmosphere of the submarine primarily by cigarette smoking and diesel exhaust. Certain wind conditions allow diesel exhaust to be sucked into the submarine through the snorkel air supply when running the diesel engine on the surface. While these contaminants are generally significantly reduced by on-board atmosphere control equipment, residual concentrations exist. It is these low-level concentrations and the somewhat higher concentrations which certain crew members are exposed to and the elimination of these contaminants that are of medical concern. Two of these contaminants, CO_2 and CO, have been studied extensively (1-4). This study focuses on nitrogen dioxide (NO_2), another potentially health compromising contaminant.

The NO_2 levels permitted aboard submarines are 0.5 ppm for 90 days, 1 ppm for 24 hours and 10 ppm for 1-hour. The 90 day limit "represents an average value for continuous exposure which may be temporarily exceeded so long as there are corresponding periods of low concentrations". The 24-hour limit "represents an emergency level and is not to be repeated until all affected personnel have completely recovered." The 1-hour limits are "not to be exceeded" and are "not for extrapolation to other exposure times".(5)

A systematic study of NO_2 levels aboard submarines has never been done. The purpose of this study was to obtain information on both ambient and personal levels of NO_2 during the course of a long submerged period. An effort is then made to access these measured levels with regard to their possible short and long-term health effects on submariners.

METHODS AND RESULTS

Personal Sampler Monitoring

Personal samplers for NO_2 were fabricated and supplied by the

Institute of Environmental Medicine, New York University Medical Center. The passive device consists of an acrylic tube (1 cm I.D. x 7 cm long) capped at both ends, commonly called Palmes devices. At the beginning of a collection period, the collector is vertically affixed on a person or object, the time noted, and the bottom cap removed. At the end of the collection period, the bottom cap is replaced and samplers returned to the laboratory for analysis.

Samplers were distributed on two fleet ballistic missile nuclear submarines (A and B). Submarine A was deployed for a total of 40 days, spending 90% of that time submerged. Samplers were exposed on the 30th, 34th, and 36th day of the patrol and all were capped on the 38th day, for mean exposure times of 7.8, 4.8 and 2.5 days. One sampler was exposed on the 37th day for 24 hours. Samplers were distributed to the galley, mess, engine room, machinery room, control room, lounge/library, and crew's berthing spaces. Samplers were also distributed to 10 personnel: 7 of the samplers being worn for the 7.8 day period, 2 for the 4.8-day period, and 2 for the 24-hour period. Only one sampler was distributed per area for a total of 7 area samplers and only one was distributed to each subject for a total of 10 personal samplers. One sampler on board was never uncapped.

Submarine B was deployed for 67 days, with approximately 95% of its time spent submerged. Samplers were exposed on the 1st and 33rd day of the patrol and capped on the last day for a mean exposure time of 66.6 and 33.3 days, respectively. Samplers were placed in the galley, mess, engine room, missile compartment, control, lounge/library, crew's berthing spaces, and the torpedo room (for a total of 8 area samplers). Samplers were distributed to 5 personnel: 5 were worn by them for the total patrol and 5 additional ones were worn by them for the last half of the patrol, for mean exposure times of 66.6 and 33.3 days (for a total of 10 personal samplers).

The time-weighted NO_2 concentrations at various sites aboard the submarines are given in Table I. Both the individual and the ships' average values are higher for submarine A. In all cases, the longer the exposure on submarine A, the less was the time-weighted average, except for the one questionable galley value. The high galley value may be explained by a galley fire that occurred during the 37th day of the patrol. A significant amount of NO_2 was generated on that day, as measured by the only sampler that was coincidentally exposed for one day in the galley, and this one day's high concentration will have a greater influence on the time-weighted average of the shorter exposure samplers. To determine a more realistic long-term average for the ship, the 2.5 day values reported by the Institute were subtracted from the 4.8-and 7.8-day values and the weighted means computed. This factoring procedure produced averages for the 4.8 and 7.8 day exposures of 0.040 and 0.041 ppm, respectively. These average values are not unlike those obtained for submarine B, 0.069 and 0.065 ppm for 33.3-and 66.6 day exposures, respectively. The areas where smoking is likely to be prevalent and where cooking takes place (crew's mess, lounge/library, galley/wardroom) had relatively higher concentrations of NO2.

TABLE 1

AREA TIME WEIGHTED NO_2 CONCENTRATIONS (ppm)*

SUBMARINE A					SUBMARINE B		
	DAYS EXPOSED					DAYS EXPOSED	
AREA	7.8	4.8	2.5	1.0	AREA	66.6	33.3
GALLEY	.213**	.120	.209	.379	WARDROOM	.067	.071
CREW'S MESS	.112	.137	.229		CREW'S MESS	.081	.099
ENGINE ROOM	.050	.069	.124		ENGINE ROOM	.038	.094
MACHINERY ROOM	.071	.092	.163		MISSILE COMPARTMENT	.054	.040
CONTROL	.094	.123	.195		CONTROL	.057	.062
LOUNGE/LIBRARY	.109	.153	.211		LOUNGE/LIBRARY	.077	.057
BERTHING	.093	.131	.204		BERTHING	.068	.063
					TORPEDO ROOM	.078	.068
MEAN (±SD)	.088(.021)	.117(.026)	.191(.035)			.065(.014)	.069(.018)

* Each value was obtained from one sampler only.
** Value questionable - sampler fell in water; not included in average

Personal samplers worn by subjects generally reflected the time-weighted averages of both submarines (Table 2). There was no consistent correlation, however, within an area sampled and a subject who worked in that area. The small sample size precludes a meaningful statistical analysis, and we suspect that the lack of correlation results from the short period of time (33%) one spends at his work station.

Ambient NO_2 concentrations were continuously measured and recorded using a dual channel, chemiluminescent instrument (Model 8440, Monitor Laboratories) with a calibrator (Model 8500, Monitor Laboratories) modified for NO dilution and a two-channel ink pen recorder (Model 222, Gould Instruments). These measurements were made during the 67-day patrol of submarine B only. The machine was located in the lower level missile compartment, chosen because of the availability of space, and sampled ambient air from this area. Calibrations were performed at the beginning and middle of the patrol by diluting a National Bureau of Standards bottle of NO (100 ppm) with NO_2 free gas.

A typical 12-day period showed a mean NO_2 concentration of 0.035 ppm. Once during this period NO_2 increased to a high level of 0.17 ppm during a snorkel operation. During the 67-day patrol, 23 evolutions (including snorkeling, ventilating, and rapid ventilating) produced NO_2 concentrations equaling or exceeding 0.05 ppm. These values rapidly (10 to 30 min) rose to a peak and then exponentially declined over a period of about 5 hours. Peak values recorded were 0.06, 0.05, 0.08, 0.09, 0.18, 0.05, 0.20, 0.10, 0.05, 0.17, and 0.18 ppm.

COMMENTS: In general, the present Navy standards seem reasonable, especially in light of the qualifications put on each limit (in Introduction). While these limits are higher than civilian limits, the population is young and healthy, different from the most "susceptible" people the civilian limits are designed to protect. Fortunately, if the values for the two submarines can be extrapolated to all submarines - and there is no reason why they shouldn't -- there should be little morbidity expected from NO_2 exposure aboard submarines. For the submariners, it would be important to know and understand the dynamics of NO_2 exposure and dark adaptation, and it may be necessary to conduct further research along these lines.

This research was conducted as part of the Naval Medical Research and Development Command Research Work Unit ZF51.524.006-1006 "(U) Carboxyhemoglobin (COHb) in smokers and non-smokers and ambient levels of nitrogen dioxide (NO_2) as a result of smoking during long patrols". The opinions and assertions contained herein are the private ones of the writers and are not to be construed as reflecting the views of the Navy Department, Naval Submarine Medical Research Laboratory, or the naval service at large.

Our gratitude is given to the officers and crews of the Fleet Ballistic Missile submarines USS Simon Bolivar (SSBN 641) and the USS Kamehameha (SSBN 642).

TABLE 2

PERSONNEL TIME WEIGHTED NO_2 CONCENTRATION (ppm)*

SUBMARINE A

RATE	DAYS EXPOSED 7.8	4.8	1.0
COOK	-	-	.364
GALLERY	-	-	.379
ENGINEMAN	-	-	-
ENGINE ROOM	-	-	-
QUARTERMASTER(1)	.111	-	-
" (2)	.092	-	-
CONTROL ROOM	.123	-	-
TORPEDOMAN	.107	-	-
MISSILEMAN	.128	-	-
RADIOMAN	.129	-	-
SUPPLY MAN	.110	-	-
SONARMAN	.125	-	-
CORPSMAN	-	.087	-
SCIENTIST	-	.091	-
PERSONNEL MEAN(± SD)	.114(.012)	.089(.002)	.364

SUBMARINE B

RATE	DAYS EXPOSED 56.6	33.3
COOK	.043	.056
CREW'S MESS	.081	.099
ENGINEMAN	.046	.045
ENGINE ROOM	.038	.094
QUARTERMASTER	.040	.038
CONTROL ROOM	.057	.062
TORPEDOMAN	.082	.031
TORPEDO ROOM	.078	.068
MISSILEMAN	.012	.021
MISSILE COMPARTMENT	.054	.040
PERSONNEL MEAN(± SD)	.045(.025)	.038(.013)

*Each value was obtained from one sampler only

TABLE 3

CONTROL AND BLANK SAMPLERS

SAMPLER #	EXPOSURE HISTORY	CALCULATED VALUE (ppm h)	MEASURED VALUE (ppm h)
624	0.168 ppm for 24th	4.03	3.79
516	0.50 ppm for 77th	3.60	4.77
650	0.155 ppm for 24th	3.72	4.14
511	0.155 ppm for 48th	7.44	6.64
601	0.155 ppm for 92th	14.26	11.92
	MEAN SD*	6.61 4.08	6.25 3.00
653	Never exposed	0	0
574	Never exposed	0	0
351	Never exposed	0	0

* Statistically insignificant ($p > .05$)

REFERENCES

1. Schaefer, K.E.: Physiological Stresses Related to Hypercapnia During Patrols on Submarines. Undersea Biomed. Res. Sub. Suppl. 6: S15-S47 (1979).

2. Wilson, A.J. and K.E. Schaefer: Effect of Prolonged Exposure to Elevated Carbon Monoxide and Carbon Dioxide Levels on Red Blood Cell Parameters During Submarine Patrols. Undersea Biomed. Res. Sub. Suppl. 6:S49-S56 (1979).

3. Bondi, K.R., K.R. Very, and K.E. Schaefer: Carboxyhemoglobin Levels During a Submarine Patrol. Aviat. Space Environ. Med. 49(7): 851-854 (1978).

4. Davies, D.M. and J.E.W. Morris: Carbon Dioxide and Vitamin D Effects on Calcium Metabolism in Nuclear Submariners: A Review. Undersea Biomed. Res. Sub. Suppl. 6:S71-S80 (1979).

5. United States Navy - Nuclear Powered Submarine Atmosphere Control Manual (Unclassified).

6. Palmes, E.D., A. F. Grinnison, J. DiMattio, and C. Tomczyk: Personal Sampler for Nitrogen Dioxide. Am. In. Hyg. Assoc. J. 37: 570-577 (1976).

EXPERIMENTAL STUDIES OF CHRONIC TOXICITY OF SOME ATMOSPHERE CONTAMINANTS. DETERMINATION OF MAXIMUM ALLOWABLE CONCENTRATIONS

J. Hée

CERTSM DCAN 83800 TOULON-NAVAL FRANCE

1. WHY MACs ?

Unlike the industry workers who generally are exposed to their occupational environment only during 8 hours per day, the submariners are exposed 24 hours a day to the shipboard atmosphere, for periods of time liable to reach 3 months on the SNLEs.

Everybody knows that, under such conditions, the exposure limits of the industry, such as the "Threshold limit values" of the American Conference of Governmental Industrial Hygienists, are no longer appropriate : it is therefore necessary to lay down maximum allowable concentrations for 90-day continuous exposures (MAC 90).

The MAC 90 definition responds to a treble purpose :

- it is an evident biological necessity for the medical officer entrusted with crew's health ;

- for the submarine builder, it is a reference basis enabling him to design the atmosphere purification and regeneration systems according to the foreseeable sources of pollution such as the machinery, the cooking and also smoking, alcohol, etc. Those sources also govern the selection of the air contaminant analyzers ;

- for the headquarters, it is an element of decision not only in case of accident during a patrol, but also before embarkation for limiting the introduction of toxic products and prohibiting certain operations liable to entail subsequent air pollution, for example : painting the submarine spaces just before a patrol departure.

2. WHAT MACs ?

The MAC 90 of a pollutant of the air is defined as the average concentration which does not produce any undesirable biological effect, detectable with the present systems, during a 90-day continuous exposure. It is not a limiting value which must not be exceeded, but an average time-weighed value which authorizes some trespassments whose amplitude will be examined under the conditions of use of the MACs.

The number of identified compounds increases unceasingly as new analysis means of the submarine atmosphere are being introduced. We are now capable of detecting more than 200 compounds in the atmosphere of our nuclear submarines. It is neither possible nor necessary, for the time being, to propose allowable limits for all those products. A choice, then, is to be made. Priorities are delineated with respect to :

- physiological requirements : metabolic gases (O_2, CO_2) are evidently to be taken into account in first priority ;

- known pollution sources : the introduction on board of any new product must be contingent on the knowledge of its toxicity (e.g. utilization of a new freon) ;

- clinical or epidemiological observations made during the patrols. A few years ago, the observation of eye and nose inflammations aboard the SNLEs led us not only to investigate the possible sources of irritating compounds but also to precise the chronic toxicity of those compounds ;

- pollutants analyses which will be dealt with by Mr. MALASPINA later on. From the analytical results, it is possible to evaluate the relative importance of each compound by consideration of the ratio of the measured concentrations to the allowable limit, fixed provisionally from the data reported in the literature. This ratio constitutes the so-called toxicity index : the higher this index, the more attention is to be given to the corresponding compound, that is, we will try to establish its allowable limit more accurately.

3. HOW TO DETERMINE MACs ?

The maximum allowable concentrations of atmospheric pollutants can be established in two manners :

- The literature is compiled to acquire data dealing either with epidemiological investigations, or with experimental studies. Unfortunately, epidemiology often lacks precision regarding the concentrations of various pollutants, and experimental toxicologic studies reported are, most of the time, conducted under the exposure conditions of the industrial workers, i.e. 8 hours per day and 5 days per week. From such imperfect bases, then, an extrapolation is generally required to re-establish the conditions particular to a submarine.

- When literature data are too much incomplete or conflicting, or even do not exist, we are obliged to undertake experimental studies of our own in order to determine the toxic threshold of some air contaminants. Those studies require material means ensuring long-duration exposures, and also biological criteria which are to be searched to account for exposure-related disturbances.

Regarding our means, we have intoxication chambers for animals.

As for the biological criteria, they are selected according to the mode of action of the compound ; then they are used in our laboratories of physiology and toxicology.

The action threshold being determined, the maximum allowable concentration is calculated with the introduction of a safety factor of 3 to 5 to pass from animals to human beings and to take into account interactions between the various compounds.

As an example, we will mention the most recent two studies conducted by CERTSM. The first one concerns acrolein , an aldehyde originating mainly from cooking on board our submarines.
The study was started because of the scarcity of information we had about the chronic toxicity of that product, and also because of non negligible concentrations found on board.

After three 3-month experiments on various animal models (see Table 1), the action threshold could be determined at 0.25 ppm. Consequently, with a safety factor of 5, the MAC was fixed at 0.05 ppm.

Our last study concerned ozone, about which literature data are often conflicting due to the possibilities of human adaptation. According to our results (see Table 2) the action threshold amounts to 0.1 ppm. The MAC was fixed at 0.04 ppm. (see tables 2 and 3)

For a 90-day continuous exposure, Table 4 gives the allowable limits of the major pollutants identified aboard the SNLEs. Those values are proposed either from extrapolations or from experimental results : therefore, they are revisable taking into account new data and comparisons between participating countries in this domain.

4. HOW TO USE MACs ?

. As specified in the definition, MACs are not top limits but mean values to be complied with. The permitted margins of fluctuation are formed by the 24-hour MACs and 1-hour MACs defined in our first two papers.

. Most of the MACs correspond to compounds that are not dosed permanently in the atmosphere. The accuracy of determination of the mean value, then, depends upon the frequency of the spot analyses being performed. This frequency must be fixed taking into account the probability of presence of a contaminant (known sources) and its toxicity : a spot analysis of course may be decided as soon as an abnormality or accident occurs.

. The comparison of the MACs and of the analyses results enabled us principally to check the performance of the purification and regeneration plants, to detect abnormal pollution sources, and to propose improvements or precautions to be taken to limit those sources.

REFERENCES

- 242/CERTSM/73

Etude des effets chroniques de l'acroléine (1 et 2 ppm) chez le Rat.

- 114/CERTSM/74

Etude complémentaire des effets chroniques (5 semaines) de l'acroléine (1 et 2 ppm). Comparaison de la sensibilité des rats "conventionnels" et des rats I.O.P.S.

- 310/CERTSM/75

Etude comparative de la sensibilité de diverses espèces animales (rats, souris, cabayes, chats) à l'acroléine. Exposition de 5 semaines à 1 et 2 ppm

- 311/CERTSM/75

Etude des effets chroniques de l'acroléine (0,25 et 0,5 ppm) chez le Rat et la Souris. Etablissement de la concentration maximale admissible

- 189/CERTSM/76

Etude expérimentale de la concentration maximale admissible en chronique de l'acroléine.

- 85/CERTSM/81

Effets d'une exposition continue de 90 jours à 0,20 et 0,45 ppm d'ozone Etude chez le Rat et le Lapin.

- 176/CERTSM/82

Etude expérimentale chez le Rat de la toxicité chronique de l'ozone (exposition continue de 3 mois à 0,1 et 0,2 ppm d'ozone.

- 182/CERTSM/83

Recherche du seuil d'action chronique de l'ozone. Exposition continue de rats pendant 3 mois à 0,05 et 0,10 ppm d'ozone.

TABLE I

Experimental assessment of 90-day M.A.C. of acrolein

(3-month continued exposure of rats, mice, guinea pigs, cats, to 2 - 1 - 0,5 - 0.25 - 0.2 - 0.1 ppm of acrolein)

Biological criteria		Threshold
- Weight increasing		0,25 ppm
- Haematology		>2 ppm
- Airway resistance		1 ppm
- Lung Surfactant		0,5 ppm
- Liver triglycerides		1 ppm
- Histology	- Nose	
	- Trachea	1 ppm
	- Bronchus	
	- Lung	

Chronic M.A.C. : 0,05 ppm

TABLE 2

Experimental assessment of 90 day M of ozone 3 month continued exposure rats and rabbits to 0.45 - 0.20 - 0.10 - 0.05 ppm of ozone

BIOLOGICAL CRITERIA I	THRESHOLD
- Weight increasing	0.20 ppm
- Food consumption	0.45 ppm
- Eyes irritation	> 0.45 ppm
- organs relative weight	
Lung	0.10 ppm
Heart	0.45 ppm
Liver	0,45 ppm
Spleen	< 0.45 ppm
Kidneys	0.45 ppm
- histology	
Nose	> 0.45 ppm
Trachea	> 0.45 ppm
Lung	0,20 ppm
Liver	> 0.45 ppm
Adrenals	> 0.45 ppm
Cornea	> 0.45 ppm
- hematology	
Hematocrit	0.45 ppm

TABLE 3

Experimental assessment of 90 day MAC of ozone 3 month continued exposure of rats to 0.45 - 0.20 - 0.10 - 0.05 ppm of ozone

BIOLOGICAL CRITERIA II	THRESHOLD
- Airways resistance	> 0.45 ppm
- Tracheal mucociliary flow	> 0.45 ppm
- Lung total thiols	0.10 ppm
- Lung phospholipids	0.10 ppm
- Alveolar total proteins	0.20 ppm
- Alveolar macrophages	
- number	0.20 ppm
- morphology	0.20 ppm
- viability	> 0.10 ppm
- adherence to glass	> 0.10 ppm
- phagocytic activity	(0.10 ppm ?)
- acid phosphatase activity	> 0.10 ppm

MAC 90: 0.04 ppm

some MAC 90 for french submarines (ppm)

GASES OR VAPOURS	MAC 90	TLV (8h/d)
Acetaldehyde	7	100
Acetone	100	750
Acrolein	0,05	0,1
Ammonia	10	25
Arsine	0,01	0,05
Benzene	1	10
Carbon dioxide	7000	5000
Carbon monoxide	25	50
Chlorine	0,1	1
Chloroform	5	10
Dichlorodifluoromethane (F 12)	500	1000
Dichloromonofluoromethane (F 21)	500	-
Ethyl alcohol	100	1000
Formaldehyde	0,2	20
Hydrogen chloride	1	5 (c)
Hydrogen fluoride	0,1	3
Hydrogen cyanide	0,1	10
Mercury	0,01 mg/m^3	0,05 mg/m^3
Nitrogen dioxide	0,5	3
Ozone	0,04	0,1
Phosgene	0,05	0,1

ETUDES EXPERIMENTALES DE LA TOXICITE CHRONIQUE DE QUELQUES CONTAMINANTS DE L'ATMOSPHERE

DETERMINATION DES CONCENTRATIONS MAXIMALES ADMISSIBLES (CMA)

J. Hée

CERTSM / DCAN - 83800 TOULON NAVAL - FRANCE

---

1. - POURQUOI DES M.A.C. ?

Contrairement aux employés de l'industrie qui ne sont habituellement exposés aux ambiances professionnelles que pendant 8 heures par jour, les sous-mariniers sont exposés 24 heures sur 24 à l'atmosphère du bord, pour des durées pouvant aller jusqu'à 3 mois sur les sous-marins nucléaires lanceurs d'engins. Chacun sait que, pour de telles conditions, les limites d'exposition industrielles, comme les "Threshold limit values" of the American Conference of Governmental Industrial Hygienists, ne conviennent pas : il est donc nécessaire d'établir des concentrations maximales admissibles pour des expositions continues de 90 jours (M.A.C. 90).

La définition des M.A.C. 90 répond à un triple objectif :

- c'est une nécessité biologique évidente pour le médecin responsable de la santé de l'équipage.

- Pour le constructeur du sous-marin, c'est une base de référence qui lui permet de calculer les systèmes de régénération et d'épuration de l'atmosphère en fonction des sources prévisibles de pollution, comme les machines, la cuisine, le tabagisme, l'alcool etc... Ces sources conditionnent également le choix des analyseurs des contaminants de l'air.

- Pour le commandement c'est un élément de décision, non seulement en cas d'incident en cours de patrouille, mais également avant l'embarquement pour limiter l'introduction de produits toxiques, pour interdire certaines opérations pouvant entraîner une pollution ultérieure de l'air, par exemple la mise en peinture des locaux, juste avant le départ en patrouille.

2. - QUELLES M.A.C. ?

La M.A.C. 90 d'un polluant de l'air est définie comme la concentration moyenne qui, au cours d'une exposition continue de 90 jours ne produit pas d'effet biologique défavorable, décelable avec les moyens actuels. Il s'agit non d'une valeur plafond à ne pas dépasser mais d'une valeur moyenne pondérée dans le temps, ce qui autorise des dépassements dont l'amplitude sera examinée dans les conditions d'utilisation des M.A.C.

Avec l'accroissement des moyens d'analyse de l'air du bord, le nombre de composés identifiés augmente sans cesse : actuellement nous sommes capables de détecter plus de 200 composés dans l'atmosphère de nos sous-marins nucléaires. Il n'est ni possible, ni nécessaire de proposer, pour le moment, des limites admissibles pour tous ces produits. Il faut donc faire un choix.

Les priorités sont établies en fonction :

- des exigences physiologiques : les gaz métaboliques (O_2, CO_2) sont évidemment à prendre en compte avant toute chose.

- Des sources connues de pollution : l'introduction de tout produit nouveau à bord doit être soumise à la connaissance de sa toxicité (exemple : utilisation d'un nouveau fréon).

- Des observations chimiques ou épidémiologiques effectuées au cours des patrouilles. Il y a quelques années l'observation d'irritations oculaires et nasales sur les SNLE nous a amenés non seulement à rechercher les sources possibles de composés irritants mais également à préciser la toxicité chronique de ceux-ci.

- Des analyses des polluants qui seront exposées ultérieurement par M. MALASPINA. A partir des résultats analytiques, il est possible d'évaluer l'importance relative de chaque composé en rapportant les concentrations mesurées à la limite admissible provisoirement fixée à partir des données de la littérature. Ce rapport constitue ce que l'on appelle l'indice de toxicité : plus cet indice est élevé, plus il y a lieu de se préoccuper du composé en question et donc chercher à établir de façon plus précise sa limite admissible.

3. - COMMENT DETERMINER LES M.A.C.

Les concentrations maximales admissibles des polluants atmosphériques peuvent être établies de deux façons :

- en compilant les données de la littérature qui portent soit sur des enquêtes épidémiologiques soit sur des études expérimentales. Malheureusement, l'épidémiologie manque souvent de précision quant aux concentrations des différents polluants, et les études toxicologiques expérimentales en chronique sont la plupart du temps effectuées dans les conditions d'exposition des travailleurs de l'industrie, c'est-à-dire 8 heures par jour et 5 jours par semaine. A partir de ces bases imparfaites, on doit donc le plus souvent extrapoler, pour se replacer dans les conditions propres au sous-marin.

- Lorsque les données de la littérature sont vraiment trop imcomplètes ou contradictoires, voire inexistantes, nous sommes amenés à entreprendre nous-mêmes des études expérimentales en vue de déterminer le seuil toxique de certains contaminants de l'air.

Ces études nécessitent, d'une part, des moyens matériels pour assurer une exposition de longue durée, et, d'autre part, la recherche de critères biologiques pouvant rendre compte des perturbations liées à l'exposition. En ce qui concerne les moyens, nous disposons de caissons d'intoxication pour animaux.

Les critères biologiques sont choisis en fonction du mode d'action du composé et mis en oeuvre dans nos laboratoires de physiologie et de toxicologie. Le seuil d'action étant déterminé, la concentration maximale admissible est établie en prenant un coefficient de sécurité de l'ordre de 3 à 5, pour passer de l'animal à l'homme et tenir compte des interactions entre les différents composés.

A titre d'exemple, nous citerons les deux dernières études effectuées par le CERTSM. La première concerne l'acroléine aldéhyde dont la source principale sur nos sous-marins est la cuisine. Cette étude a été entreprise en raison d'une part du peu de renseignements que nous avions sur sa toxicité chronique, et, d'autre part, à cause des concentrations non négligeables trouvées à bord. A la suite de 3 expériences de 3 mois sur divers modèles d'animaux (cf. tableau 1) le seuil d'action a été trouvé à 0,25 ppm : avec un coefficient de sécurité de 5, la M.A.C. a dont été fixée à 0,05 ppm.

Notre dernière étude a porté sur l'ozone, pour lequel la littérature est souvent contradictoire en raison des possibilités d'adaptation. D'après nos résultats (cf. tableaux 2 et 3) le seuil d'action se situe à 0,1 ppm : la M.A.C. a été fixée à 0,04 ppm.

Le tableau 4 donne pour 90 jours d'exposition continue, les limites admissibles des polluants majeurs identifiés à bord des SNLE. Ces valeurs sont proposées à partir d'extrapolations ou de résultats expérimentaux : elles sont donc révisables en fonction des nouvelles données et des confrontations entre pays coopérant en ce domaine.

4. - COMMENT UTILISER LES M.A.C. ?

Ainsi qu'il est précisé dans la définition, les M.A.C. ne sont pas des valeurs plafonds mais des moyennes à respecter. Les marges de fluctuations autorisées sont constituées par les M.A.C. 24 heures et les M.A.C. 1 heure dont il a été question dans les deux premières conférences.

La plupart des M.A.C. correspondent à des composés qui ne sont pas dosés en permanence dans l'atmosphère. La précision avec laquelle est connue la moyenne dépend donc de la fréquence des analyses ponctuelles qui sont effectuées. Cette fréquence est à fixer à priori en fonction de la probabilité de la présence du contaminant (sources connues) et de sa toxicité : une analyse ponctuelle pouvant être évidemment décidée dès la survenue d'un incident ou d'un accident.

La comparaison des M.A.C. et des résultats des analyses nous a surtout permis de contrôler le bon fonctionnement des installations d'épuration et de régénération, de détecter des sources de pollution anormales et de proposer des améliorations ou des précautions à prendre pour limiter ces sources.

REFERENCES

- 242/CERTSM/73
Etude des effets chroniques de l'acroléine (1 et 2 ppm) chez le Rat.

- 114/CERTSM/74
Etude complémentaire des effets chroniques (5 semaines) de l'acroléine (1 et 2 ppm). Comparaison de la sensibilité des rats "conventionnels" et des rats I.O.P.S.

- 310/CERTSM/75
Etude comparative de la sensibilité de diverses espèces animales (rats, souris, cabayes, chats) à l'acroléine. Exposition de 5 semaines à 1 et 2 ppm

- 311/CERTSM/75
Etude des effets chroniques de l'acroléine (0,25 et 0,5 ppm) chez le Rat et la Souris. Etablissement de la concentration maximale admissible

- 189/CERTSM/76
Etude expérimentale de la concentration maximale admissible en chronique de l'acroléine.

- 85/CERTSM/81
Effets d'une exposition continue de 90 jours à 0,20 et 0,45 ppm d'ozone
Etude chez le Rat et le Lapin.

- 176/CERTSM/82
Etude expérimentale chez le Rat de la toxicité chronique de l'ozone (exposition continue de 3 mois à 0,1 et 0,2 ppm d'ozone.

- 182/CERTSM/83
Recherche du seuil d'action chronique de l'ozone.
Exposition continue de rats pendant 3 mois à 0,05 et 0,10 ppm d'ozone.

TABLE 1

Experimental assessment of 90-day M.A.C. of acrolein

(3-month continued exposure of rats, mice, guinea pigs, cats, to 2 - 1 - 0,5 - 0.25 - 0.2 - 0.1 ppm of acrolein)

Biological criteria		Threshold
- Weight increasing		0,25 ppm
- Haematology		>2 ppm
- Airway resistance		1 ppm
- Lung Surfactant		0,5 ppm
- Liver triglycerides		1 ppm
- Histology	- Nose	
	- Trachea	1 ppm
	- Bronchus	
	- Lung	

Chronic M.A.C. : 0,05 ppm

TABLE 2

Experimental assessment of 90 day MAC of ozone 3 month continued exposure of rats and rabbits to 0.45 – 0.20 – 0.10 – 0.05 ppm of ozone

BIOLOGICAL CRITERIA I	THRESHOLD
– Weight increasing	0.20 ppm
– Food consumption	0.45 ppm
– Eyes irritation	> 0.45 ppm
– organs relative weight	
Lung	0.10 ppm
Heart	0.45 ppm
Liver	0.45 ppm
Spleen	< 0.45 ppm
Kidneys	0.45 ppm
– histology	
Nose	> 0.45 ppm
Trachea	> 0.45 ppm
Lung	0.20 ppm
Liver	> 0.45 ppm
Adrenals	> 0.45 ppm
Cornea	> 0.45 ppm
– hematology	
Hematocrit	0.45 ppm

TABLE 3

Experimental assessment of 90 day MAC of ozone 3 month continued exposure of rats to 0.45 - 0.20 - 0.10 - 0.05 ppm of ozone

BIOLOGICAL CRITERIA II	THRESHOLD
- Airways resistance	> 0.45 ppm
- Tracheal mucociliary flow	> 0.45 ppm
- Lung total thiols	0.10 ppm
- Lung phospholipids	0.10 ppm
- Alveolar total proteins	0.20 ppm
- Alveolar macrophages	
- number	0.20 ppm
- morphology	0.20 ppm
- viability	> 0.10 ppm
- adherence to glass	> 0.10 ppm
- phagocytic activity	(0.10 ppm ?)
- acid phosphatase activity	> 0.10 ppm

MAC 90: 0.04 ppm

some MAC 90 for french submarines (ppm)

GASES OR VAPOURS	MAC 90	TLV (8h/d)
Acetaldehyde	7	100
Acetone	100	750
Acrolein	0,05	0,1
Ammonia	10	25
Arsine	0,01	0,05
Benzene	1	10
Carbon dioxide	7000	5000
Carbon monoxide	25	50
Chlorine	0,1	1
Chloroform	5	10
Dichlorodifluoromethane (F 12)	500	1000
Dichloromonofluoromethane (F 21)	500	–
Ethyl alcohol	100	1000
Formaldehyde	0,2	20
Hydrogen chloride	1	5 (c)
Hydrogen fluoride	0,1	3
Hydrogen cyanide	0,1	10
Mercury	0,01 mg/m^3	0,05 mg/m^3
Nitrogen dioxide	0,5	3
Ozone	0,04	0,1
Phosgene	0,05	0,1

DISCUSSION

HARRISON: Could I ask you, did you ever establish what the reason was for the high levels of cadmium found in submariners?

BOWMAN: No sir, we didn't. We have really no idea as to what caused the levels of cadmium found in the previous study. I don't know right now what our biological samples are going to find. We may find something also. It could have been something to do with the shampoo the people were using. I don't know whether or not that was taken into consideration when the original sampling was done. The samples that I took, I asked every crew member what type of shampoo they used by brand - that was put on the data sheets that went into the laboratory doing the analyses so they would compensate for whatever was in the shampoos. As far as the prior study I really don't know, sir.

HARRISON: Could I ask one more question, please sir? What other elements do you think will be included in the analyses?

BOWMAN: I have a partial listing of the alloys; it's back at my seat. You are more than welcome to look it over if you like, sir. Mostly its the trace metals, basically. Normally found trace metals as well as some more exotic trace metals. And also give a large list of what we consider to be important ratios between elements, mainly for diagnostic purposes. There are possibly 31 minerals and another 11 or 12 ratios that we are getting. The program may have started solely to look at cadmium levels but with the amount of information we are going to be getting, it would certainly behoove us to take advantage of everything we can get. Frankly, the price is the same whether you ask for one element or the whole gamut.

HARRISON: Are you looking for beryllium?

BOWMAN: Beryllium is included, yes sir.

FOULGER: Could you tell me if there is a correlation between the cadmium levels in the scalp and also in the urine samples? You mention there might have been a possible contamination from zinc contained in shampoos that prevent dandruff, etc.

BOWMAN: Well, the only correlation possible ould be between samples taken at the same times. The urine samples are basically collected at a given point in time, and so all you are going to get there is what happens to be there at the specific time that the samples were collected. The hair gives you a longitudinal picture of what was in the body over a long period of time because of the growth rate of the hair, what you may be looking at is what the body burden was twenty or thirty days prior to sample; so as far as the direct correlation, I don't believe you are going to find one because the time period covered by the sampling is too long.

DISCUSSION

WYATT: Ken, did you happen to measure any levels coming out of the machinery room at all?

BONDI: No, we didn't do any of that.

WYATT: Because I believe that if you have nitrogen-containing compounds they will produce NO_2 when they go through the machinery.

BONDI: So you mean in the machinery room we may expect higher levels?

WYATT: You'd have to look at the ventilation diagrams. Sometimes at the burner goes in may be vented to the fan room or something; it depends upon the particular submarine but that's always another possible cause of NO_2.

BOWMAN: You commented earlier that the machine was set up in the missle room and during snorkeling you were also running it. What did your profiles look like before there was snorkeling going on?

BONDI: I'm glad you mentioned that, Jeff. We always had a peak in NO_2 during the snorkeling operation. In general that peak would go up to about .2 parts per million - I'm sorry, that's the highest peak we recorded during snorkeling. In general we rose to about .15 during the evolution and in a matter of a couple of hours returned back to the normal level. But during every instance of snorkeling we did get a significant rise.

MILROY: Do you attribute that to running the diesel?

BONDI: Yes

DISCUSSION

RADZISZEWSKI: How do you consider your results about the total calcium in the body and your results about the effect of submarine environment, especially of carbon dioxide, on urinary calcium and usually interpreted as an increase output of calcium and sometimes considered detrimental for submariners for a long time --- are these two results conflicting?

MESSIER: In the opening remarks, as I said, there were four factors and one of the factors that we refer to is the effect of CO_2 in the isolated laboratory studies. Depending on the studies and the methodologies used, there are changes in our interpretation of what is going on. What was so difficult in interpreting field studies -- that's why we wanted to look and see if there were any cumulative changes that we could see -- not connected with the difficulty of running the field studies but were they cumulative and subtle changes, and that we don't see, and now that we have the latest results from your studies, the British studies, and some of our animal studies -- with the methodologies and such as we discussed earlier, it may not be that there is a great flushing out of calcium in the urine so that we may have to reinterpret the results.

RADZISZEWSKI: I would have been very surprised if you observed that effect on your retired group because this would mean that the effects are not reversible after four or five years. The retired results are expected.

MESSIER: Yes, however, since we had no information at all, and if there have been some changes, then with the NASA results also, if there is so much of a change in the calcaneal calcium content -- if there is 15% change, you could not recover this loss and that could be a subtle change that you were not aware of -- of not recovering and that change could have been picked up in this manner

RADZISZEWSKI: However, even suppose if they cease the carbon dioxide of submarine environment effects on the body calcification and the calcium ratio. The interference of the age on your retired group may be more important. Do you have sufficient evidence to make the distinction between the effect of age which is certainly important and the effect of submarine environment which I suppose is reversible after five years, and you compared the two effects. I think that the age effect is more important and so is decreased.

MESSIER: Again, we have to refer to the problem that there are no "old" retired submariners, and we would see, and we do expect to see a decrease in the bone mineral content in age. We would see that. But again, you can predict even what the normal loss would be and if it was exacerbated on top of that, even that would show up. But again we are wallowing -- we do not have an "old" population to look at.

RADZISZEWSKI: We are very satisfied with the results. Thank you very much.

HARRISON: Thank you very much for a very interesting presentation. Is this work actually published in the open literature at this stage?

MESSIER: Not at this stage; it is being prepared and it will be coming out.

RESCUE FROM PRESSURIZED SUBMARINES

R.G. Eckenhoff, LCDR, MC, USNR
Naval Submarine Medical Research Laboratory
Groton, CT 06349

The techniques for the salvage of humans from a distressed, sunken submarine can be conveniently divided into two broad categories: escape and rescue. Both are fraught with problems which limit their usefulness. For example, submarine escape is limited to depths of between 800 and 1000 feet sea water because of compression gas toxicity and the inherent decompression obligation. On the other hand, submarine rescue is limited largely by time delays and support requirements. The logistic support required for a Deep Submergence Rescue Vehicle (DSRV) mission is nothing short of immense. And the response time for this system is claimed to be about 48 hours, although this figure is probably optimistic. This delay is of great importance, as the crew of a distressed submarine (DISSUB) would probably be exposed to a hazardous environment - containing a potentially toxic atmosphere as well as thermal extremes. Furthermore, there is a high likelihood of atmosphere compression in the DISSUB, and a 48 hour delay would allow the crew to become "saturated" with inert gas (nitrogen) at increased ambient pressure. This factor would significantly complicate both escape and rescue procedures as well as the potential survival in a DISSUB incident. The remaining discussion will be limited to the pressure component of the DISSUB environment, and its effect on submarine rescue.

The source of atmosphere compression could be: flooding, salvage air pressurization, high pressure gas leaks and exhaust from the open circuit emergency breathing systems - probably in that order of importance. The degree of pressurization is unpredicable, as there have been no precedents. However, it is important to understand that DISSUB atmosphere compression need not proceed to equalization with the ambient water pressure - even if flooding occurs, as early compartment isolation may prevent this. Certainly if salvage air pressurization is the source of pressure, the maximum pressure attainable is about 4-6 atmospheres absolute (ATA). Although escape is theoretically possible at almost any DISSUB internal pressure, increasing problems with the decompression obligation would be encountered. On the other hand, rescue with current U.S. systems is physically impossible at DISSUB internal pressures greater than 5 ATA. This reflects previous belief that greater degrees of pressure in the DISSUB would result in the crew's demise prior to the arrival of the rescue vehicles. Thus, it is important to understand how pressure affects the rescue process, so that procedures can be tailored to obtain maximum survival rates. The following discussion will address this goal.

The difficulties caused by DISSUB internal pressurization simplify to two: imposing a decompression obligation, and potential toxicity of the respired gases.

Decompression obligation

The problems in this category can be divided into a) a lack of satisfactory decompression schedules, and b) complicated transfer procedures.

a) Schedules.

There are no standard air saturation decompression schedules in either the U.S. Navy or commercial diving industry, although many candidate schedules have been formulated over the past 10 or 15 years. Research at this laboratory has addressed this problem, and promising schedules for air saturation have emerged. In the past 7 years, over 70 subjects have decompressed from air saturation at depths of from 60-132 fswg, using four different schedules (see table #1), none of which involve oxygen breathing. As would be expected, the slowest schedules yield the lowest incidence of decompression sickness symptoms, but the ascent rates near the surface appear to be more important than the overall ascent rate (see table #2). Schedules based on the linear relationship between ascent rate and the inspired partial pressure of oxygen, of the formula 6 times PiO_2(ATA) (schedule #2) in fsw/hour appear to be well tolerated for saturation depths less than 100 fswg, whereas the formula 5 times PiO_2 (schedule #4) may be required for depths in excess of 100 fswg. This slowing of ascent rate for the greater depths is based more upon the presence of pulmonary oxygen toxicity in the survivors (see below), which is believed to decrease tolerance of decompression, than upon any change in inert gas kinetics. In the practical use of these formulas, the rate is changed every 10 fsw if the breathing medium is air, and the PiO_2 used in the formula is the smallest for the interval.

TABLE #1

SCHEDULES

1		2		3		4	
DEPTHS*	RATE**	DEPTHS	RATE	DEPTHS	RATE	DEPTHS	RATE
60-45	10	65-60	17	132-100	12	132-50	24***
45-20	15	60-50	19	100- 50	15	50-40	26
20- 5	33	50-40	22	50- 0	20	40-30	30
5- 0	36	40-30	25			30-20	36
		30-20	30			20-10	44
		20-10	37			10- 0	58
		10- 0	48				
TOTAL TIME 20:00		32:06		51:42		65:08	

Notes:

* In feet sea water gauge (fswg).

** In minutes per fsw.

*** Constant PiO2 of 0.50 ATA for this interval.

TABLE #2

DECOMPRESSION SCHEDULE COMPARISON

SCHEDULE	MEAN ASCENT RATE FSW/HR	DELTA-P (T1/2=480) MEAN	SURFACING	No. SUBJECTS	DCS SYMPTOMS
1(AIRSAT 1&2)	3.00	0.70	0.38	23	2 (8.7%)
2(SUREX)	2.02	0.34	0.23	18	1 (5.5%)
3(AIRSAT 3)	2.56	0.32	0.84	12	3 (25%)
4(AIRSAT 4)	2.03	0.29	0.16	9	0 (0%)

A complicating factor arises as a result of the length of these schedules, as they are longer than the turnaround time of the DSRV. However, by alternating chambers on the ASR, these logistical problems can probably be solved. If a MOSUB is used, a preferable schedule might include a large initial upward step, followed by at least a 24 hour wait, and then the continuous ascent rates as described above. This has the advantage of storing' the survivors at a pressure more easily attained by the MOSUB's compressed air supply, as well as providing a somewhat less toxic atmosphere for recovery (see below). The final decompression could, therefore, wait until all survivors are aboard the MOSUB. The magnitude of the step will be addressed in a future series of experiments at this laboratory (AIRSAT 5 & MINISAT).

b) Transfer procedures.

Three types of transfers would be involved in pressurized submarine rescue. The first is from the DISSUB to the DSRV, and is easily accomplished by sealing over the escape trunk hatch in the usual manner, sensing the DISSUB pressure through the use of the stud gun, and then equalizing the pressure across the hatch by pressurizing the DSRV (mid and aft spheres only). This is not possible however, with DISSUB internal pressures greater than 5 ATA. Next, the DSRV must transfer its occupants to either a surface craft (ASR), or another submarine (MOSUB). In the latter, a pressurized transfer to the forward compartment of the MOSUB is possible - but to my knowledge, has never been tested. In the former instance, however, a pressurized transfer to the Deck Decompression Chambers (DDC) is not possible due to mating surface incompatibilities. Therefore, a surface decompression-like or "decanting" procedure must be used for transfer. Although this is a well recognized and safe procedure in sub-saturation diving, its use in saturation exposures has not been established until recently. The SUREX experiments at this laboratory have demonstrated the safety and feasibility of this technique when used for shallow air saturation exposures. Briefly, unpressurized transfers appear to be safe for pressures up to about 29 psig (65 fswg equivalent), where about 13 minutes would be allowed for the transfer. However, if the transfer is to be from pressures greater than this, insufficient time would be allowed for transfer of all 24 DSRV occupants (projected to require 15 minutes), some of whom may be sick or injured. If performed anyway, an increasing morbidity and mortality from decompression sickness can be expected. A possible, although unlikely solution would be to reduce the number of DSRV occupants to provide faster transfer times, thus allowing unpressurized transfer from greater pressures (5 to 7 minutes may be allowed from 100 fswg). It should be remembered that treatment of survivors with decompression sickness would be complicated by the presence of pulmonary oxygen toxicity, as well as the limited number of oxygen breathing systems.

Toxicity of inspired gases

The inspired gases in a DISSUB environment would be oxygen, carbon dioxide, nitrogen and a variety of contaminates. Nitrogen, under pressure, may in fact have a favorable influence on the crew's morale due to the euphoric effect, but may cause a slight decrement in work performance. Carbon dioxide can be scrubbed from the atmosphere by manual methods with varying degrees of efficiency, and thus should not reach dangerous levels - although moderate increases may aggravate the effects of oxygen. The presence of significant quantities of contaminates, will in all probability cause the death of the survivors long before rescue can be attempted. Therefore, the problem narrows down to oxygen. A 48 hour exposure to 5 ATA air (a PiO_2 of 1.05 ATA) is expected to cause pulmonary oxygen toxicity, but the progression and recovery of this disorder in hyperbaric air is not well understood. The AIRSAT experiments at NSMRL have been attempting to clarify this area.

The AIRSAT 4 experiments were designed to characterize the development of pulmonary oxygen toxicity in humans exposed to 5 ATA air for 48 hours. Nine subjects have completed the experiment, and an additional six will be studied this fall. Much of the data from these first subjects is still being analyzed, but some preliminary conclusions are possible. a) significant symptoms of pulmonary oxygen toxicity occurred in all of the subjects, to the point of incapacitation in some. b) significant decrements in pulmonary function occurred (see figure #1), c) a significant trend for an early gas exchange defect was noted (Dl_{co} down, alveolar-arterial gradients unchanged), d) recovery from these effects can begin at a PiO_2 of 0.50 ATA, e) the character and timing of pulmonary oxygen toxicity is not significantly different in 5 ATA air than in normobaric 100% oxygen.

The implications of the AIRSAT 4 findings for submarine rescue can be summarized as follows: In the worst rescueable degree of DISSUB pressurization, survivability will not be limited by the presence of pulmonary oxygen toxicity at 48 hours. Nevertheless, a portion of the crew will be sufficiently symptomatic as to require assistance and special consideration. Depending on the submarine, size of compartment, and number of survivors, the oxygen level may have been reduced to a safe level by metabolism after 48 hours. This is less likely, however, in later classes of submarines due to the large compartment size, and relatively constant crew size. The progression of signs and symptoms appears to accelerate between 36 and 48 hours of exposure in the AIRSAT 4 experiments - therefore, a rapid deterioration can be predicted after 48 hours of exposure. Speculation would predict that a degree of mortality would be reached in the 72-96 hour interval.

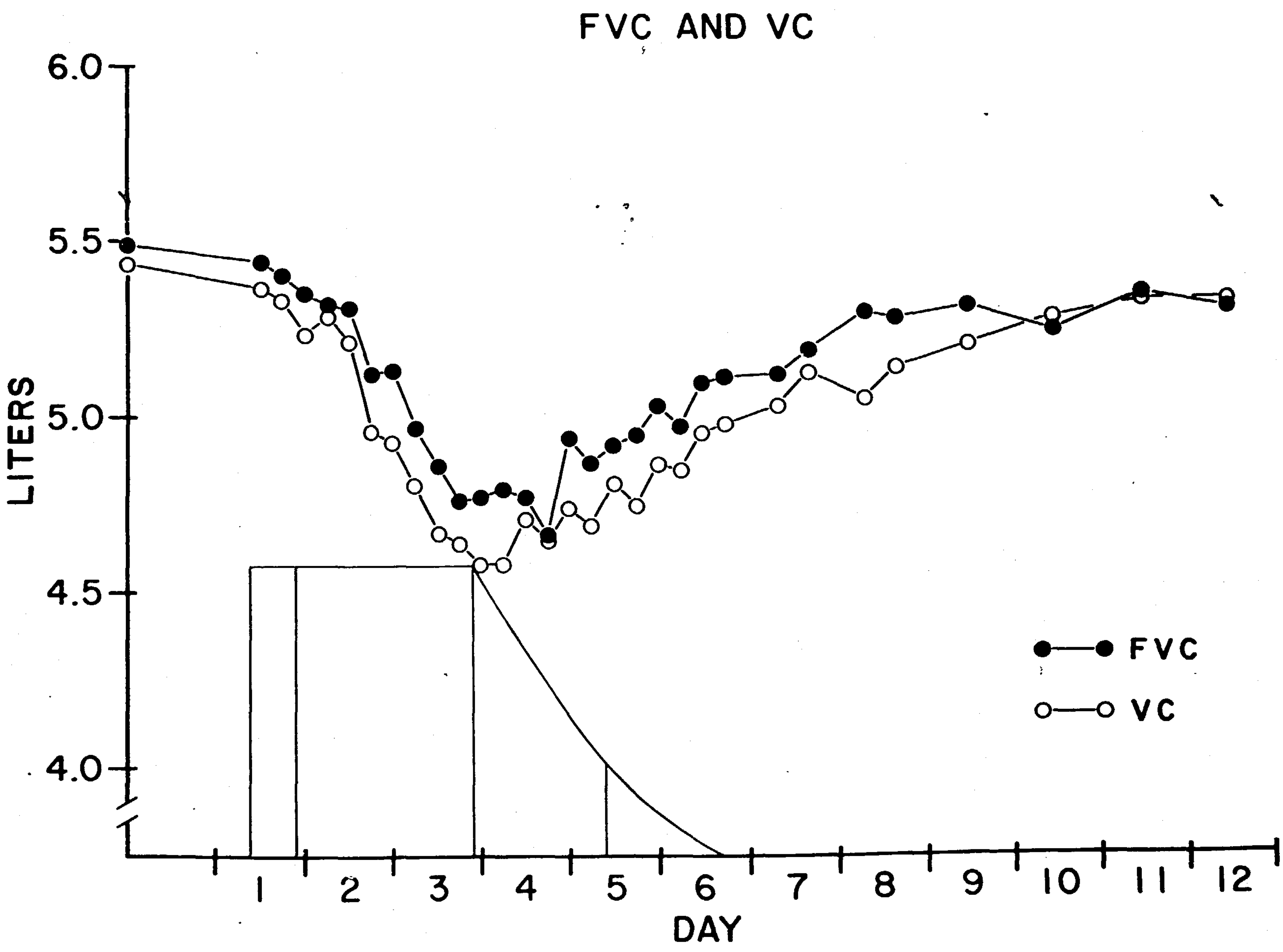


Figure 1

Recovery appears to begin and progress satisfactorily in a 0.50 ATA oxygen atmosphere. This is important, as neither the MOSUB nor the DDC is capable of producing a reduced PiO_2 nitrogen-oxygen atmosphere. Therefore, if the step decompression in the MOSUB can approach a pressure where the PiO_2 is around 0.50-0.60 (46-62 fswg), recovery, or at least stabilization should occur while awaiting the remainder of the crew, and the subsequent decompression. In the DDC, a full load of survivors (25-30) should be able to breathe down the PiO_2 to less than 0.50 ATA in about 6 hours, which could then be maintained by the DDC oxygen make-up system. Additionally, the ability to recover at a PiO_2 of 0.50 is advantageous from a decompression standpoint - probably allowing the use of the faster schedules.

SUMMARY

Pressurization of a ~~DISSUB~~ (distressed submarine) significantly complicates the rescue process. As a result, decompression sickness and oxygen toxicity are potential maladies which could reduce the likelihood of a successful rescue mission. Although several problems which require further investigation remain, sufficient medical information now exists to allow authorization of pressurized rescue, so that appropriate training exercises can occur. This has the potential of further identifying procedural and hardware problems which, when corrected, would improve the capability of current submarine rescue systems to perform their primary mission under a variety of circumstances.

REFERENCES

Eckenhoff RG, Parker JW. Excursions to the surface as a component of emergency decompression from air or nitrox saturation exposures. Naval Submarine Medical Research Laboratory Report No. 992, 1982.

Eckenhoff RG (ed). Workshop on the detection and measurement of pulmonary oxygen toxicity. Naval Submarine Medical Research Laboratory Report No. 980. 1983.

Eckenhoff RG. Submarine escape and rescue in 1980. Naval Undersea Medical Institute Thesis. 1980.

Eckenhoff RG, Vann RD. Air saturation decompression; a report of 4 schedules and 74 subjects. (Manuscript in review)

Gell CF, Parker JW. International workshop on escape and survival from submersibles. Naval Submarine Medical Research Laboratory Report No. 794, 197[illegible].

Greene KM. Theoretical considerations on the decompression of rescued submarine personnel. University of Pennsylvania Institute for Environmental Medicine Report. 1974.

Vorosmarti J. (Chairman) Report of the conference on medical problems of submarine survivors. Submarine Development Group One, San Diego, CA, 1978.

ESCAPE AND/OR RESCUE ?

MEDECIN EN CHEF GIACOMONI - CERTSM - DCAN - TOULON (FRANCE).

Escape or Rescue ? This question may be considered from two different points of view. It concerns the choice of a life saving policy when either escape or rescue survival route is to be selected. It also relates to the decision to be made by the men entrapped in a distressed submarine as to whether to escape or to await rescue.

As far as the French Navy is concerned, although its current submarines are equipped with locks and they can be fitted with the D.S.R.V., the choice of a global life-saving policy is still at issue.

Without prejudging such a choice nor any official statement which might be made within the framework of NATO standardization agreements, if any, the following remarks only express the author's personal thoughts on both above-mentioned points of view.

The first remark deals with the effectiveness limitations of both life-saving methods :

- The rescue system-mainly represented by the D.S.R.V.-
  - depends entirely on the reliability of the alerting and locating system being used,
  - seems to be inoperative at shallow depths,
  - raises the problem of a prolonged stay in a disabled submarine where several hazardous situations may develop (such as release of toxic gases for instance),
  - also raises the critical problem of the therapeutic decompression of a group of survivors rescued from a pressurized submarine.

- As regards the escape policy
  - it is not likely to succeed unless the survivors are rapidly located and assisted on the surface,
  - at the moment it is ineffective beyond 200 m.,
  - it involves a risk of its own which is aggravated when the man trapped in the submarine are exposed to pressure,
  - it requires a training that can be hazardeus and demands a medical selection of the personnel.

Since 1970 the French Navy and particularly the CERTSM have done important work with a view to extend such limits.

As for the escape solution :

Laboratory experiments on minipigs have shown that it is possible to enlarge free escape possibilities down to 300 meters without increasing the risks. This would extend the advantage of such a solution to the whole continental shelf which is the actual area of interest with regard to submarine rescue and escape.

A new training technique has been developed which makes it possible to carry out an escape under realistic environmental conditions together with an ascent from shallow depth at a low rate (about 10 cm/sec.) for an appropriate duration (about 1 min.). This technique eliminates both the risks inherent in training and the selection it involves.

With regard to rescue we have developed a system for ventilating the bottomed submarine. Such a ventilating system could possibly be adapted for the gradual decompression of a submarine compartment, thereby simplifying rescue conditions.

Even though it seems possible to enlarge the field of action of either method, our personal opinion is that both escape and rescue are complementary.

In the 1322/SER study—chaired by Surgeon Commander Harrison—it is assumed that this complementarity leads to the simultaneous availability of both means and it is suggested that an escape manual should be prepared to enable the men possibly trapped in a disabled submarine to decide themselves the choice of whether to escape or to await rescue after analysing their own situation. The substance of this study has been dealt with in an official French Navy statement which cannot be questionned again in any way by the objections that will be raised now and can be summarized in three points as follows :

1) There's some risks in issuing a manual which might be considered as imperative and become a psychological barrier to an actual analysis of the situation. One must therefore take the greatest care in presenting such a manual.

2) The study ≠ 1322 admits, in most cases, that rescue or escape conditions alwaysimply such time intervals that the men are saturated with inert gas at the pressure under consideration. A research work on minipigs carried by the CERTSM has clearly demonstrated, in our opinion, the advantages of early evacuation (before saturation) from a disabled submarine pressurized to 1.9 ATA.

3) The behaviours suggested by the 1322/SER study are based on a knowledge of the risks which would be worth investigating through a series of appropriate experiments. GUILLERM and MASUREL have shown the interest of the minipig as an animal model chronically implanted with a Doppler detector for decompression monitoring by the detection of circulating bubbles.

Conclusion

To the question of whether to choose an escape or rescue policy we personally think that the best answer should be escape and rescue.

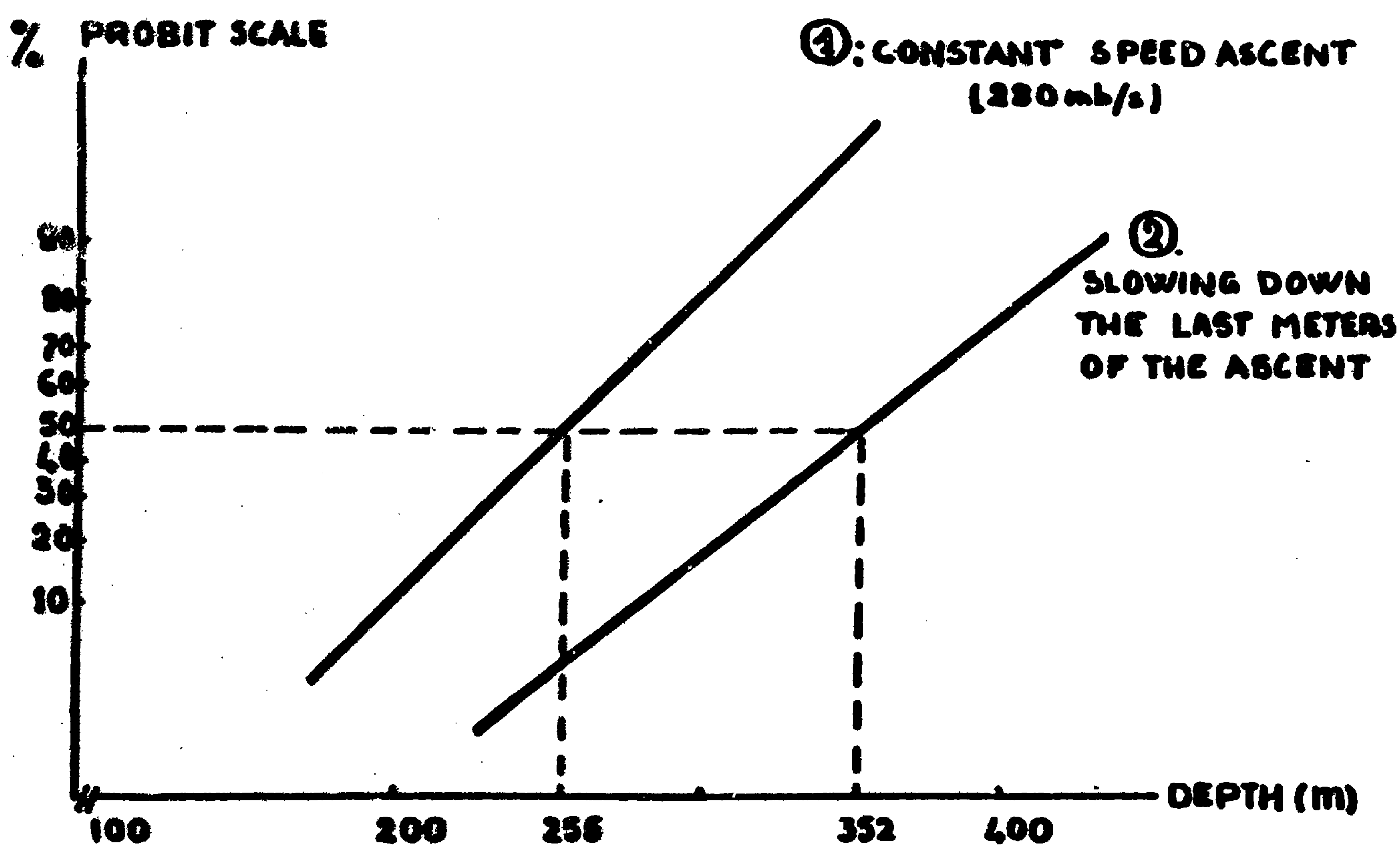
As regards the decision to be made by the men trapped in a distressed submarine when both escape and rescue are available one should dwell on the great advantages of the manual proposed by the 1322/SER study whose data should however be further specified.

RESCUE

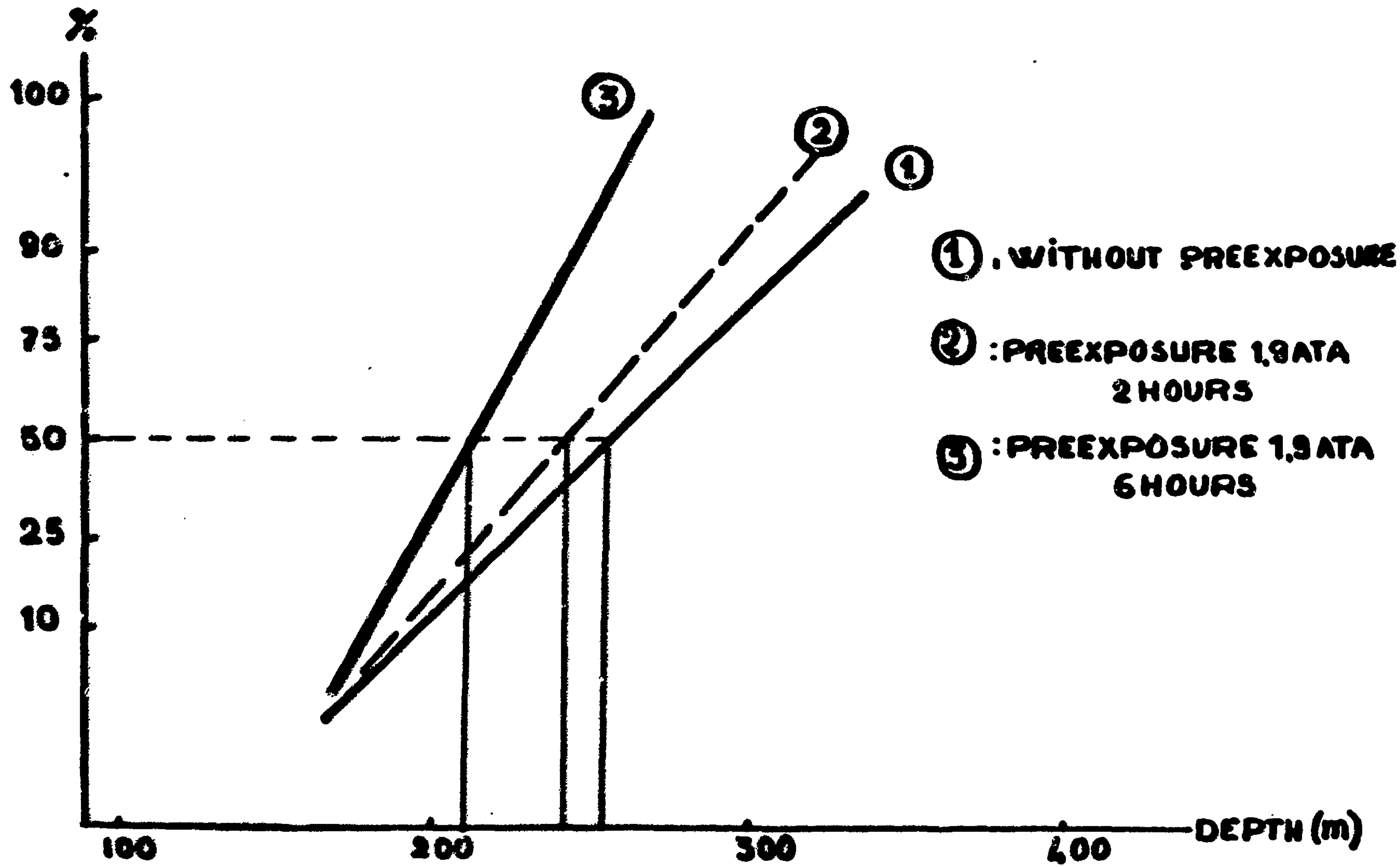
- DEPENDS ON THE RELIABILITY OF ALERTING AND LOCATING SYSTEMS
- SEEMS TO BE INOPERATIVE AT SHALLOW DEPTH (<45m)
- RAISES THE PROBLEM OF A LONG STAY IN HASARDOUS ENVIRONMENTS
- RAISES THE PROBLEM OF DECOMPRESSION OF A GROUP OF SURVIVORS RESCUED FROM A PRESSURIZED DISSUB

ESCAPE

- NOT LIKELY TO SUCCEED UNLESS THE SURVIVORS ARE RAPIDLY ASSISTED ON THE SURFACE
- INEFFECTIVE BEYOND 200m
- INVOLVES A RISK OF IT OWN WHICH IS AGGRAVATED WHEN THE DISSUB IS PRESSURIZED
- REQUIRES A TRAINING WHICH MAY BE HAZARDOUS OF IT OWN
- REQUIRES (FOR TRANING) A MEDICAL SELECTION OF THE PERSONNEL



% OF MINIPIGS WHICH CAUGHT A BEND VERSUS DEPTH
(STATISTICAL REPARTITION)



- % OF MINIPIGS WHICH CAUGHT A BEND -

ESCAPE OR RESCUE OR ESCAPE AND RESCUE

Médecin en Chef GIACOMONI - CERTSM - DCAN TOULON

Escape ou Rescue ? Cette question peut être posée à deux niveaux. Celui du choix d'une politique de sauvetage s'il s'agit tout d'abord d'opter pour l'un ou l'autre de ces moyens. Celui de l'attitude à adopter par les survivants enfermés dans une épave et susceptibles de recourir à l'une ou l'autre technique.

En ce qui concerne la Marine Française, et bien que les bâtiments modernes en service soient équipés de sas et susceptibles de recevoir le DSRV, le choix d'une politique globale de sauvetage est toujours en discussion.

Sans préjuger de ce choix ni même des réponses officielles qui pourraient être faites dans le cadre d'éventuels accords de standardisation OTAN, les réflexions qui suivent expriment seulement l'opinion personnelle de leur auteur à propos des deux questions évoquées en premier.

La première de ces réflexions porte sur la considération des limites d'efficacité de deux systèmes de sauvetage.

La Rescue représentée surtout par le DSRV

- est complètement dépendante de la fiabilité du système d'alerte et de localisation mis en oeuvre,

- paraît inopérante aux faibles profondeurs,

- pose le problème d'une survie de longue durée dans une épave ou peuvent se développer diverses situations dangereuses (dégagement de gaz toxiques par exemple),

- pose aussi dans le cas d'une épave pressurisée, un difficile problème de décompression thérapeutique du groupe de rescapés.

Quant à l'Escape

- son succès ne devient probable que si les survivants sont rapidement découverts et secourus en surface,

- elle est inefficace pour le moment au-delà de 200 mètres,

- elle comporte un risque propre aggravé si les naufragés dans l'épave sont soumis à la pression,

- elle implique un entraînement non dépourvu de risques et qui oblige à une sélection médicale du personnel.

Depuis 1970, la Marine Française et en particulier le CERTSM ont travaillé pour tenter de repousser ces diverses limites.

Dans le cas de l'Escape :

- En démontrant au laboratoire sur le miniporc la possibilité de porter l'efficacité du sassage jusqu'à 300 mètres sans accroître le risque. Ceci étendrait l'intérêt de cette méthode à l'ensemble du plateau continental qui constitue la zone d'intérêt réel du sauvetage des sous-marins.

- En réalisant un nouveau procédé d'entraînement permettant un sassage en condition réaliste et une remontée de faible hauteur à basse vitesse (≃ 10 cm/s) de durée convenable (≃ 1 minute). Cette technique supprime le risque dû à l'entraînement et la sélection qu'il impose.

En ce qui concerne le Rescue, nous avons développé un système de ventilation de l'épave posée sur le fond qui pourrait éventuellement être adapté à la décompression progressive d'un compartiment simplifiant ainsi les conditions du sauvetage.

Même s'il paraît ainsi possible d'élargir le domaine d'action de l'une ou l'autre méthode, notre opinion personnelle est que Escape et Rescue sont complémentaires.

L'étude 1322/SER pilotée par le surgeon commander Harisson suppose que cette complémentarité conduit à disposer simultanément des deux moyens et propose de préparer un guide de conduite permettant au naufragés eux-mêmes après analyse de leur situation de recourir à l'un ou l'autre. Cette étude a, sur le fond, fait l'objet d'une réponse officielle de la France qui n'est en aucun cas remise en cause par les objections que nous allons développer et qui tiennent en trois points :

1) Il existe un certain risque à fournir un guide qui pourrait prendre un caractère impératif et constituer un obstacle psychologique à l'analyse de la situation réelle pour des rescapés plus ou moins frappés de panique. La prudence s'impose donc dans la présentation de ce guide.

2) L'Etude 1322 admet dans la plupart des cas que les conditions de sauvetage impliquent toujours des délais tels que les sujets sont saturés en gaz inerte à la pression considérée. Un travail du CERTSM sur le miniporc montre à notre avis, l'intérêt d'une évacuation précoce (avant saturation) dans le cas d'une épave pressurisée à 1,9 ATA.

3) Les attitudes proposées par l'étude 1322/SER reposent sur une connaissance du risque qui mériterait à notre avis d'être précisée par une série d'expérimentations adaptées. Guillerm et Masurel ont à ce sujet démontré l'intérêt du modèle que constitue le miniporc chroniquement implanté d'une sonde doppler permettant la surveillance par détection de bulles circulantes de la décompression.

En conclusion

A la question de politique Escape ou Rescue, notre opinion personnelle est que la meilleure réponse doit être Escape et Rescue.

A propos du choix à faire par les naufragés eux-mêmes disposant de ces deux moyens, il faut souligner le grand intérêt du guide de conduite proposé par l'étude 1322/SER dont les données pourraient cependant être encore précisées.

AD P001890

UNITED KINGDOM ESCAPE AND RESCUE POLICY REVIEW COMMITTEE REPORT 1982

by

Surgeon Commander J R Harrison, Royal Navy
Institute of Naval Medicine, Alverstoke, Hants UK

Introduction

1. United Kingdom submarine escape and rescue policy was last reviewed in 1971. Since then there have been significant changes to the situation envisaged. In particular, our physiological knowledge has increased, and general European and UK underwater expertise has improved. Not least, UK submarine operating patterns are markedly different from those foreseen in 1971. The United States (Navy) has proved its rescue capability and its escape and rescue philosophy is now firmly directed towards rescue. The UK has negotiated a Memorandum of Understanding with the US which allows us to use the USN Deep Submerged Rescue Vehicle (DSRV). In the light of these changes, the Standing Committee on Submarine Escape and Rescue (SCOSER) was directed to undertake a review of submarine escape and rescue policy in 1981.

The terms of reference of the review committee were:-

a. To examine and report on the various factors, including salvage, affecting Submarine escape and rescue.

b. To review the existing techniques and equipment in use in the Royal and allied Navies and any impending improvements.

c. To recommend methods of escape and other methods of saving life that should be adopted for submarines of the Royal Navy.

d. To report on the material, financial and manpower implications of any changes that may be proposed.

Background

2. Saving life from a sunken submarine (DISSUB) must be kept in perspective. There can be no doubt that the best safeguard is a well constructed submarine manned by a well trained crew. Nevertheless, since 1919 there have been 65 submarines sunk by accident; of these, 2 have sunk within the last 11 years. The individual submariner may perhaps take a somewhat fatalistic view of his possible involvement in an accident

but there can be no doubt that in the event of such an accident, his family, the Service, and the public will all expect that there should be reasonable means for personnel in the DISSUB to survive. There can be no assurance of 100% survival in a submarine accident. There are however sensible limits of insurance: the objective, whenever survival is possible, must be to provide good insurance for the more likely accident situations and some, at least, for the less likely situations.

Aim

3. The aim of the review was to recommend a policy which will provide the most effective means of saving life in the event of a submarine accident. The policy recommended should be compatible with the military and operational characteristics of submarines and within the limitations of a realistic financial premium.

Areas of Study

4. Operations and Administration In this area the present national and international Search and Rescue organisations applicable to submarine accidents were reviewed. Areas identified were the points of contact with other authorities and their communications; the availability of both British and foreign commercial submersibles and of the USN DSRV; the availability of mother ships; delays in alerting shore authorities; and the need for, and facilities carried by, surface escorts for submarines particularly at risk. The current submarine operating patterns both by locality and by depth of water were also examined. The worst case reaction time for a DSRV mother ship to arrive at the DISSUB was also studied.

5. Material This area reviewed the submarine design limitations on escape and rescue, foreseen escape and rescue developments and their cost, means of alerting and of locating a DISSUB, use of commercial equipment for on-scene surveillance, re-supply of life-support stores, the technical problems of escape and rescue, rescue by salvage, and the likely environmental conditions within and without a DISSUB.

6. Bio-medical In this area the problems of survival within the DISSUB, and after escape were reviewed; the combined problems of hypothermia, pressure and control of the atmosphere within the DISSUB and their complicated interactions with escape or rescue. Methods of depressurising the DISSUB were also considered.

7. In addition to consideration of the above areas, the main committee examined in detail the need for facilities for rush compartment escape and the advantages and disadvantages of escape versus rescue. The combination and permutations of the many factors which could affect survival are too numerous to select either a worst case or a single most probable case. Instead the main factors likely to pertain in a typical DISSUB situation have been considered and are contained in the following summary.

Summary of the Review

THE DISSUB

8. Location Analysis of present day submarine operating patterns, which vary significantly from those foreseen in 1971, showed a main peak of activity in the Clyde areas with a subsidiary peak in the English Channel both close to the main submarine bases. Further analysis by depth of water indicates 64% of operating time is spent in water depths of less than 180 metres (600 feet), 1% in depths between 180 and 700 metres and the reamining 35% in depths beyond 700 metres where neither rescue nor escape is possible. Statistically therefore, the most probably situation is for a DISSUB to be on the bottom in less than 180 metres of water.

9. The Immediate Situation Once the DISSUB has settled on the bottom, pressure-tight bulkheads shut-down and secured, and indicator buoys released, personnel in the DISSUB will find themselves in one of three situations depending on their position when the bulkheads were shut-down.

a. In a compartment where pressure is rising due to uncontrollable flooding.

b. In a compartment pressurised by flooding elsewhere in the submarine but now at a stable pressure.

c. In a compartment remote from the flood which was shut-down before it could be affected significantly by the pressure rise in other parts of the submarine.

10. Pressure Considerations Animal research with goats shows in Figure 1, the effect of pre-exposure to increased pressure (i.e., above 1 bar) on the 50% probability of bends point during simulated submarine escape for goats. A bend occurring in the body which affects the brain or central nervous system can be fatal. The curve is a

computer prediction based on experimental data points. A similar curve for men could be produced (the safe escape curve), but to date only one data point is available. This point indicates that, as a minimum, men saturated to a pressure of 1.8 bars have a greater than 50% chance of suffering bends if they attempt to escape even from a submarine at 10 metres (point B). At the other end of the scale, there is a proven escape capability in depths of water of 180 metres providing the saturation pressure is 1 bar (point A). The shape of the 'man' curve is vital to the decision-making process of men trapped in the DISSUB on when to escape and of whether to escape or to await rescue.

11. Escape or Rescue Decisions by personnel in the bottommed DISSUB on whether to escape or to await rescue will depend on their position and on the pressure effects of the depth of water.

a. Compartment Flooding Uncontrollably Before the advent of a modern tower escape, compartment escape required controlled flooding through dedicated and costly compartment flooding systems. In the event of serious uncontrollable flooding the primary instinct and the best solution is to evacuate to another compartment. When evacuation is not possible escape should be carried out quickly to reduce time under pressure. Until compartment pressure has equalised tower escape should be used. Once the pressure has equalised, remaining personnel can make a compartment escape through the tower. Thus compartment size and deisgn need not be deliberately constrained to facilitate compartment escape for large numbers.

b. Stable Pressurised Compartment Men in a stable pressurised compartment must consider the depth of the submarine and the absolute pressure within the compartment. If these two parameters show they are well inside the safe escape curve predicted for men, their considerations and options are the same as for men in an unpressurised compartment. However, if the depth and pressure parameters show them to be on or outside the curve their best change of survival is to await resuce providing their location and its environmental conditions make rescue a reasonable proposition. If the chances of rescue are low, and the DSRV could take 6 days from alerting to arrival on scene, they have little option but to await the arrival of surface forces with recompression chambers and then escape.

c. The Un-pressurised Compartment Men trapped in an unpressurised compartment have time on their side. They have time to await the arrival of surface forces and with those forces a better assessment of the prospects of rescue. They may well have time to await rescue by submersible and throughout that waiting time, in appropriate depths of water, they always have escape as an alternative. Their maximum waiting time is primarily a function of the endurance of life-support stores. The required endurance of 11 days was recommended in the 1971 review. The present review endorsed the previous recommendation, although it noted with concern that this endurance has not been implemented in all current classes of submarine due to the difficulty in finding space.

Table 1 summarises the relative merits of the 2 options of escape or awaiting rescue. It shows that there is a balance between the two options; it does not attempt to list an order of priority.

EXTERNAL COMMAND AND CONTROL

12. The Senior Survivor in each compartment in the DISSUB will make the best decision he can, but irrespective of that decision, the chances of ultimate survival will increase significantly with the early assistance of external forces. It is therefore essential that Operational/Shore Authorities are alerted to a submarine accident as soon as possible.

13. Alerting The review considered that the present Indicator Buoy Radio Unit should be supplemented by an SSE launched expendable UHF transmitter which can access a communication satellite. Such an improvement in this area would make a most significant contribution to the survival of men in a DISSUB. Without this improvement and in the absence of positive evidence of a submarine sinking, authorities ashore must await negative alerting.

14. Negative Alerting Negative alerting requires the authorities ashore to be alerted to the possibility of a submarine accident when a submarine does not report in by a specified time (Check Reports). The system explicitly imposes a delay in providing assistance at the scene of a DISSUB, and, depending on the type of operations the submarine was conducting, that delay can vary from as little as a few hours to, in defined instances, a maximum of a few weeks.

15. Assistance Once the shore authorities are alerted, they must start moving any and all available resources towards the area of a DISSUB and only minor administrative improvements to achieve and control this are desirable. The resources required to

assist escapees are well documentated in SUBMISS procedures but there is no documentated organisation to provide additional recompression chambers. Plans exist and have been exercised to provide a mother ship for, and to use, the USN DSRV for rescue. However, there are significant delays inherent in this system, and the Review Committee considers that commercial submersibles and other commercial equipments (Remotely Controlled Vehicles) with trained crews should also be alerted.

16. Locating Locating a DISSUB is likely to be a problem, particularly if it was operating in a moving exercise area. In this case the area to be searched could be many thousands of square miles with only a weak HF signal to home on. This again points to the need to accelerate improvements in equipment. Once close range acoustic communications have been established with the DISSUB, the requirement for rescue as opposed to escape should be known. If rescue is needed, the complete rescue cycle time of the DSRV and commercial submersibles, typically 12 hours, could be reduced by up to 15% if the DISSUB were equipped with acoustic beacons for homing the submersibles, and pingers to assist them to locate escape tower hatches.

SURVIVAL

17. Escapees Escapees who have been able to delay their escape until the arrival of surface forces in the vicinity of the DISSUB have a good chance of survival, particulary in daylight. The chances for those forced to escape immediately following an accident or at night are not so good. They are likely to have been in the water for some time and are likely to be suffering from hypothermia. In all but the very lowest sea-states they can expect to be very seasick. Not least they may well have drifted a long way from the DISSUB by the time surface forces arrive on scene. For example bodies from the TRUCULENT disaster were recovered many miles from the accident position.

18. The Rescued Those men rescued from the DISSUB have a very good chance of survival providing they can be recompressed should this be required. Those awaiting rescue have a good chance of survival providing their life-support stores can be replenished. Life support items consist of oxygen generating candles, carbon dioxide absorption cannisters, barley sugar and water. Action is in hand to modify escape towers to accept pods filled with life-support stores, which can be passed without the need for dry transfer.

19. Salvage Because of the delay, salvage of the DISSUB by bringing it to the surface is not seen as a means of survival. However under certian circumstances it might be possible using dynamically positioned diving vessels to connect air hoses to the DISSUB to revitalise its atmosphere and to control compartment pressure.

CONCLUSIONS OF THE REVIEW

20. The main conclusions of the Review in order of importance were:

a. Analysis of submarine peacetime operations indicate that for 64% of the time they operate in water depths of less than 180 metres, 1% of the time in water depths of between 180 and 700 metres, and 35% beyond 700 metres. Therefore future activity to improve the overall survival chance of escapees and personnel rescued by submersible should be concentrated in water depths of less than 180 metres. A major corollary to this conclusion is that future submarines need not be specially designed to provide escape bulkheads for depths greater than 180 metres. (2)

b. Escape and rescue are not necessarily alternative options even in depths of water less than 180 metres; both escape and rescue may be required depending on the circumstances. Either may be the only method of survival and it is therefore imperative that both systems should be retained. (3)

c. The present alerting and locating systems in British submarines were unacceptable. (4)

d. Men in all main watertight compartments fitted with escape towers do not have sufficiently accurate monitoring equipment or instructions to enable them to make decisions for survival both inside the DISSUB, and/or when to escape safely or whether to await rescue. The information provided by the safe to escape curve for men in fundamental to a correct decision on when to escape or to await rescue by men in the DISSUB.

e. Submarine design need not be constrained to facilitate compartment escape for large numbers.

f. Life-support stores endurance to meet the minimum levels recommended by the 1971 Review are endorsed. Financial and space constraints over the last ten years have not allowed these recommendations to be implemented fully.

g. Minor improvement to SUBMISS administrative planning is desirable.

h. Recovery of a DISSUB to the surface by salvage will not assist survival because it will take too long.

FIGURE 1: Graph to Show the Relationship between Pre-Exposure Pressure, Depth and Predicted 'No-Bend' Curve for Men

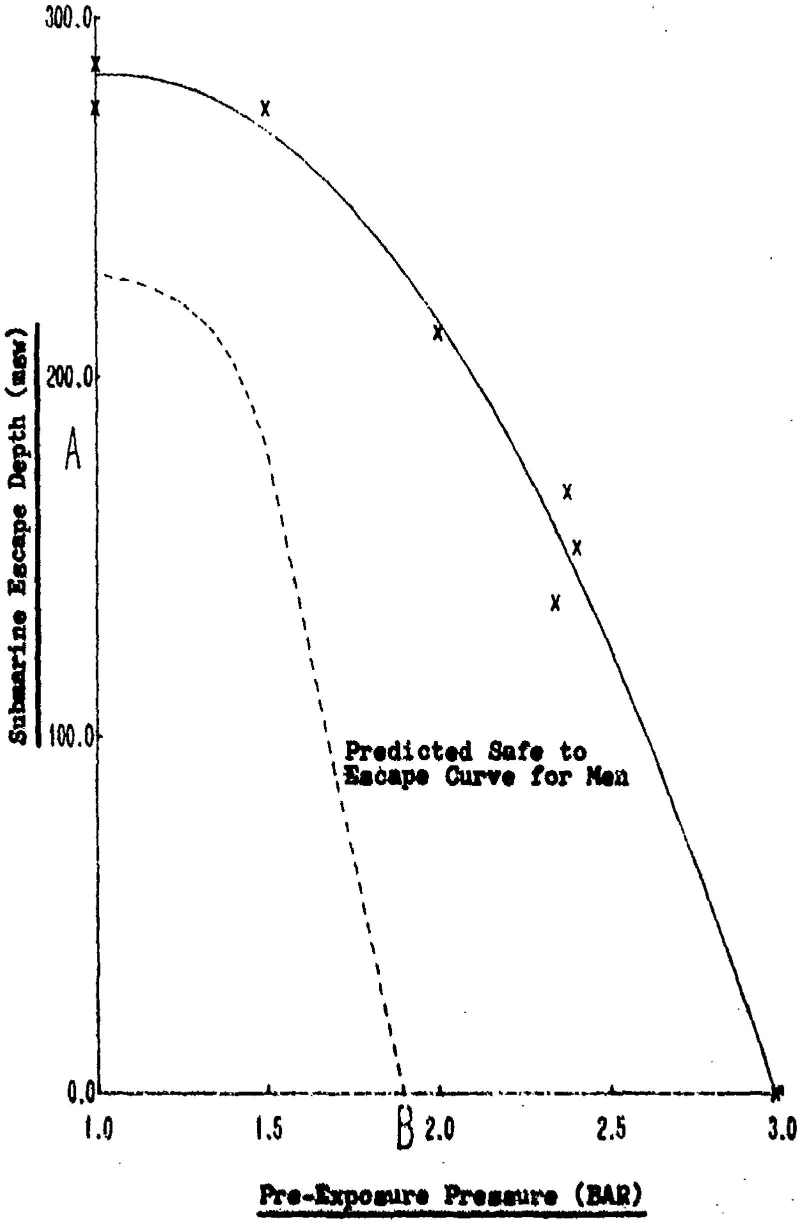


TABLE 1

ADVANTAGES AND DISADVANTAGES

	ESCAPE			RESCUE		
FACTOR	EFFECT	PLUS +	MINUS -	EFFECT	PLUS +	MINUS
Time	Escape can be made at any time according to circumstances.	/(A)		DSRV arrival will take considerable time and is dependent on a long chain of events.		/
Exposure	Exposure to escape profile pressures, and sea water and weather can radically reduce survival probability.		/	No problems.	/(B)	
Decompression Sickness	Pulmonary barotrauma and bends are probable, and increase with escape depth.		/	Can be conducted at pressure in DISSUB of 1 - 3.3 bars.	/(B)	
DISSUB Environment	Available when atmosphere or pressure becomes untenable.	/		Can be conducted at pressure in DISSUB of 1 - 3.3 bar.	/	
Evacuation Rate	Quickest evacuation from DISSUB possible.	/		Slow evacuation, dependent on DSRV round trip time.		/
Depth	Only proven to 180 metres.		/	Can be mounted at NCD of submarine, provided hull pressure tight.	/	
Psychology	Regular training makes escapees confident of system, but survival after escape an unknown.		/	Waiting time may reduce morale of survivors but knowledge that once DSRV has arrived, survival is near certain, is important.		/
Simplicity	Simple.	/		Dependent on complex mix of human and material factors outside DISSUB control.		/
Autonomy	Under direct control of senior survivor.	/		Outside control of DISSUB.		/
Familiarity	Familiar through regular training.	/		Unfamiliar - but no training required by survivors.	/	
Sea Conditions	Not affected by poor visibility.	/		Strong currents and poor visibility could inhibit rescue.		/
Cost	Little maintenance.	/		Regular training of pilots and exercising of system required. Regular maintenance needed.		/

A. The overriding reason for retaining an escape facility.

AMTE(PL) PROPOSED RESEARCH PROGRAMME

By D.W. Burgess, Head Marine Physiology
AMTE(PL) now at RAF Institute of Aviation
Medicine.

At the conclusion of the 1982 SEPRC deliberations, a series of recommendations were proposed that placed certain actions upon AMTE(PL), (APPENDIX A). To meet these actions, a research programme has been proposed, that should on its completion answer all those recommendations relevant to the physiology of escape and rescue.

Recommendation A

In this block of recommendations the main theme is to maintain the current escape and rescue capability in the light of the changing role of the British Navy.

Two main areas are under investigation. First, that of transfer under pressure, using the DSRV or similar vessel, and secondly, emergency methods of survival in an enclosed space.

For rescue under pressure it is intended to investigate the problems of transfer from the DISSUB at pressure, to a mothership, also possibly at pressure, together with the added effects of raised CO_2 in the DISSUB. This then is the basis of the ISLANDER programme at AMTE(PL) which will address such questions, as to determining the maximum safe decompression step from shallow saturation, with pressures up to 2 bar. On completion of this phase, further experiments are proposed to investigate the effects of raised CO_2 and differing levels of nitrogen partial pressures on this maximum safe decompression step.

As part of the recommendation directed towards survival at pressure, AMTE(PL) also proposes to continue work on the emergency life support foot pump (AMTE R81 402), to determine its operating parameters at pressures up to 5 bar. Further research on emergency life support is considered an essential part of the work programme, as at pressure this may be the only available means of prolonging life, while waiting for rescue in conditions where escape may be no longer possible.

Recommendation C

Research in this block, has as its main aim, the improvement of the present escape system, to achieve safe escapes from depths of water up to 180 metres and saturation pressures up to 1.8 bar.

Initial research on goats has indicated that on air, a relationship exists between the maximum safe to escape depth and the initial saturation pressure.

Using this determined animal data, an initial predicted safe to escape curve has been drawn for men. However, this curve contains many assumptions, many of which we now, in the light of modern analysis, are in doubt. As the determination of this safe to escape curve, for man, is only a best guess fit, a research programme is proposed to determine the lower part of the curve by manned experiments. The lower part of the curve below 50 metres is considered a safe area for experiments as animal experiments in this area have shown that the end point is minor limb bends. Using this data, together with the complete goat curve, a computer fit will be made to obtain a more accurate calculated safe to escape curve. On completion of this phase of the programme, it is proposed to vary the saturation gas mixture and in this manner determine the effects of raised CO_2, raised nitrogen partial pressures and the use of high oxygen escape mixes on this safe to escape curve.

This then is the basic outline of the submarine physiology programme at AMTE(PL) for the next few years, with its aims directed at saving life in the unfortunate event of a submarine accident.

REFERENCES

1. BURGESS, D.W. Deep Submarine Escape.

   Submarine Escape Rescue Workshop, HMS Dolphin, Nov 1969, Pages C64 - C68.

2. AMTE(E) Report 81/402

   Emergency Clearance of Carbon-Dioxide in a Confined Space. Synopsis of Trials using either Man-Power, Salt-Water Batteries or Passive Absorption System. P. Prenderville.

APPENDIX A

RECOMMDATION BLOCK A

Both Current Escape and Rescue Capability should be maintained

A2 Procures for rapid decompression from 3.3 bars in the DSRV to 2 bar in the DSRV mothership should be prepared and proved.

A3 Procedures for the supply of life-support and the theraputic decompression from 2 to 1 bar of a large number of survivors arriving in the mothership over a prolonged period should be prepared and proved.

RECOMMENDATION BLOCK C

Submarine Compartments fitted with Escape Towers should be fitted with an accurate means of Determining Depths, Absolute Pressures and of Atmosphere Monitoring.

C1 Research and development should be carried out to improve the atmosphere and temperature monitoring equipment to measure accurately under pressures up to 5 bar (DSRV maximum Pressure).

C2 The future research to determine the predicted safe escape curve for men should be given a high priority.

C3 The safe escape depth limit for all internal DISSUB pressures up to 1.8 bar should be researched.

C6 Improved gas mixtures for the Hood Inflation System and Built-in Breathing System (BIBS) should be investigated with a view to reducing the hyperbaric limitations on safe escape in depths of water of 180m or less.

AD P001892

SOME CONSIDERATIONS ON THE TREATMENT OF DECOMPRESSION ILLNESSES ARISING FROM SUBMARINE ESCAPE OR RESCUE.

SURGEON CAPTAIN R R PEARSON RN. SUBMARINE FLOTILLA MEDICAL OFFICER

It seems probable that the arrival on the surface of a large number of submarine escapes requiring recompression therapy for decompression illness would pose a tremendous problem even in the most ideal circumstances and with the best of the currently available surface support in situ. Equally, the rescue of survivors from pressurised compartments is a technique which may be technically possible but requires a considerable amount of research work to identify and quantify the decompression hazards and their therapy. Against this unsatisfactory background, it is still possible to offer some facts and some empirical solutions which may be of assistance in the situations requiring treatment of decompression illnesses.

The Royal Navy currently bases its ability to treat decompression illnesses in escapees on a number of strategically placed portable compression chambers, one of them being air transportable and located at an appropriate Royal Air Force base for instant deployment All the chambers are dedicated to submarine escape support and are equipped with a full range of medical stores and equipment.

In theory, these compression chambers are capable of treating up to 12 men but in practice this would pose great logistic problems and, in the case of numerous escapes requiring recompression, the selection of cases to treat requires careful consideration.

Additionally, the Royal Navy's current deep diving ship, MV Seaforth Clansman, has a saturation diving system capable of providing recompression therapy for up to 40 men. Our new Seabed Operations Vessel, HMS Challenger, has been designed to recompress up to 75 men and has several design features specifically devoted to submarine accidents. It will be commissioned within a year and, by then, will have the additional capability of a dedicated submersible capable of rescuing up to 6 men from pressurised compartments and transferring them under pressure to the on-board saturation diving chamber complex. This capability is a relatively late concept and certain logistic problems will need to be solved.

Finally, the Royal Navy is fortunate to have access to, and the capability to use, the United States Navy Deep Submergence Rescue Vehicle. However, we are aware of the need to solve some of the problems of disposal of survivors rescued by this system from pressurised compartments and Dr Burgess of the Admiralty Marine Technology Establishment (Physiology Laboratory) will discuss some research addressed to this particular problem.

Needless to say, all the above systems can only be effective if deployed at the site of a submarine accident when escapes are taking place and the speed with which escapees can be treated will be prejudiced by the inevitalbe delays which will be associated with recovery on board the surface vessel equipped with recompression facilities.

However, assuming the ability to treat escapees suffering from decompression illnesses is available, we still need to consider certain priorities related to recompression therapy, particularly in view of the fact that our capability to provide such therapy may, at best, be very limited.

It is considered that the therapeutic problem related to decompression illnesses applies only to decompression sickness and pulmonary barotrauma with arterial gas embolism. Further, three distinct, albeit arbitrarily defined, situations need to be considered:

A. Escapes from depths $<$ 180 msw

B. Escapes from depths $>$ 180 msw

C. Rescue from compartments, pressurised to $\leq$ 5 bar.

Any over-pressure in compartments will effectively and proportionately alter the arbitrary limit of 180 msw chosen for categories A and B above to a shallower limit.

Dealing first with pulmonary barotrauma complicated by arterial gas embolism. This potentially lethal decompression illness is likely to occur in escapes from any depth but, assuming the escapees have had adequate training, is unlikely to affect more than 1 per cent of escapees. This figure is purely empirical but is at least 10 times greater than any figures published for pulmonary over-inflation accidents occurring in Submarine Escape training. The accepted optimal treatment for arterial gas embolism is recompression to 6 bar but the wisdom of embarking on such therapy needs re-considering in situations where further survivors have, or may be expected to have, decompression sickness, particularly serious decompression sickness. With limited facilities for recompression, it would be better, in most circumstances, to recompress escapees with arterial gas embolism to 2.8 bar on oxygen thereby allowing easier therapy of escapees with serious decompression sickness who may have to be introduced into the compression chamber at a later stage.

Turning to escapes from $>$180msw in terms of decompression sickness, some information is available although very limited in terms of human experience. DONALD,[1] referring to a possibly over-simple concept of a time - depth multiple, suggests that escapes from $>$ 288msw would lead to a great majority of the escapees suffering from decompression sickness whereas escapes from $<$ 227msw would not result in a significant amount of decompressionsickness. These figures tally well with ex rapolations from animal work which will be described by Dr Burgess and, in broad terms, it seems that escapes from $<$ 180msw will be safe in this respect Conversely, escapes from $>$ 180msw will be accompanied by an increasing amount of decompression sickness as the depth of escape increases. Further, all the evidence from animal work suggests that deep escapes may well produce serious (Type II) decompression sickness of relatively sudden onset.

The ability to distinguish between decompression sickness and arterial gas embolism may then be very difficult with deep escapes where neurological signs and symptoms occur very early. However, the differential diagnosis is only of importance in emergency situations if the therapeutic approach is to be different. It is suggested, therefore, that a common therapeutic approach be adopted based on the following broad outlines:

1. <u>Escapes from depths < 180msw</u>

a. Only escapees with symptoms/signs of decompression sickness should be treated.

b. Escapees with any evidence of decompression illness should be recompressed to 2.8 bar (18msw) on oxygen reverting to air breathing upon relief of symptoms/signs or at a point to be decided by the medical officer in attendance.

c. Final decompression from 2.8 bar will occur when there is no further expectation of escapees requiring therapy.

d. The "shape" of the final decompression could be based on rates of 1 m/hr up to 2.0 bar (10msw) and 0.5m/hr to the surface. Current research and previously published decompression tables for air/nitrox saturation diving may allow a more rapid final decompression.

e. Adjuvant therapy should be given as indicated rather than prophyllactically.

2. <u>Escapes from > 180 msw</u>

a. All escapees should be given oxygen to breathe as soon as possible. The length of time spent breathing oxygen will depend on the amount available to the surface support but a minimum of 15 minutes oxygen breathing should be aimed at. Needless to say, the facility to carry out this treatment for large numbers of escapees does not yet exist.

b. All escapees should be given steroids (eg, 16mg dexamethasone intravenously) and it is for consideration whether this might be supplemented by parenteral aspirin and hepari[n]. Such adjuvant therapy will, it is considered, favourably influence the course of any serious decompression illnesses which may ensue.

c. Escapees with joint pain only (Type I or "mild" decompression sickness) should NOT be given recompression therapy until it is clear that such treatment will not prejudice the ability to treat subsequent escapees with serious problems. Joint pain only problem[s] should receive suitably potent analgaesics in addition to oxygen breathing.

d. All necessary recompression therapy should be initiated at 2.8 bar on oxygen. Although not generally considered optimal for arterial gas embolism, treatment of this condition at 2.8 bar does have its proponents(2,3). Once a chamber is full or no further casualties are expected, treatment may continue as suggested in 1d above. If, however, casualties are being treated in a saturation diving complex, non-response at 2.8 bar may be treated by further recompression on oxygen-helium mixtures but this is a matter for expert advice and supervision, and should only be attempted once all the possible casualt[ies] are under pressure and can be redistributed throughout the available chambers according to their requirements.

e. It is for consideration whether escapees from > 180msw should not be given steroids, aspirin and heparin prior to escape providing sufficient time is available. A self-administered "auto-injection" of such a "cocktail" of drugs is feasible and allows the possibility of adding other drugs to combat motion sickness which might occur after surfacing. Further, current research appears to be raising the possibility of adding other drugs of potential prophyllactic or therapeutic value against various complication[s] of decompression illnesses affecting the central nervous system.

f. For escapees who require but can not be given recompression therapy, reliance will have to be placed on adjuvant therapy. Some guidance in this respect is available (4) but it is a neglected aspect of the therapy of decompression illnesses.

The foregoing is only a short version of what should be developed as guidelines for "triage" of escapees and ensuring maximum use of limited facilities for recompression therapy.

The problems associated with rescue from pressurised compartments are likely to be confined to decompression sickness. They will be highlighted in the presentation by Dr Burgess and many problems remain to be solved or even defined. Once the various possibilities associated with rescue from pressurised compartments have been defined, it will be possible to suggest guidelines for treatment. As it is, this is yet another area where much research needs to be carried out if a logical therapeutic approach is to be adopted.

In conclusion, one of the many problems associated with escape or rescue from pressurised compartments is the possible need to treat a number of personnel suffering from decompression illnesses. Clearly, we have much work to do before we are fully prepared to deal with such a situation.

References:

1. DONALD K W 1979 Submarine escape breathing air. A review and analysis of animal experiments by the Royal Navy. Bull. Europ. Physiol. Path. Resp. 15:739-754
2. HART G B 1974 Treatment of decompression illness and air embolism. Aerospace Med 45:1190-1193
3. SAKAKIBARA K, B SAKAKIBARA, H KIDOKORO et al. 1974 Clinical and experimental study on hyperbaric oxygen therapy for air embolism. In W G Trapp, W E Bannister, A J Davison and P A Trapp, Eds. Proceedings of 5th International Hyperbaric Congress. Burnaby, Canada: Simon Fraser University. pp890-894
4. SAUMAREZ R C, J F BOLT andR J GREGORY. 1973 Neurological decompression sickness treated without recompression. Brit. Med. J. 1:151-152.

DISCUSSION

HARRISON: I think that you should be aware that in the forthcoming DSRV exercise in August of this year, there is an intention of carrying out a pressurized rescue from a simulated DISSUB, but we have not yet had agreement on the level of pressure to be used - it will probably be about 1.2 to 1.3 ATA. The idea of this segment of the exercise is to back up what you have just said - to identify problems in hardware and procedures, which would in turn affect all of your studies and data.

ECKENHOFF: I am aware of these plans, and in fact, will be participating as an observer. The decision to perform the pressurized segment has not been made as yet, but I agree that it is vitally important, and should be done.

HARRISON: Dr. Giacomoni have you carried out any experiments with reducing the pressure in a submarine with hoses?

GIACOMONI: No, not at the moment.

HARRISON: That is do you intend to?

GIACOMONI: Yes. I think there are many reasons to do them.

ECKENHOFF: I have a remark on a point that was just mentioned. Since the DSRV requires a differential pressure of about 200 fswg on its mating skirt to make an effective seal, any internal pressurization of the DISSUB will cause the minimum mating depth to move deeper. In other words, 3 ATA in the DISSUB will make the minumum mating depth 330 fswg (10 ATA) instead of 200 fswg. Also, a question, have you actually pressurized one of your submarines to 2 BAR?

HARRISON: No, but we have an intention of doing this. All equipment that would be damaged by the pressure must first be removed, and there has been some reluctance on the part of the engineers.

ECKENHOFF: What happens to ventilation when one compartment is pressurized?

HARRISON: The air must be recirculated within the compartment, as it would be isolated from the remainder of the submarine. This would, however, be a significant problem during long decompression. Dr. Burgess will be mentioning this area in his presentation, as we have done some studies with isolated compartment air purification.

CATRON: How do you arrive at a figure of six days when the internal temperature of the submarine is 8°C?

HARRISON: This was done by our engineering staff on an empirical basis. All of the variables involved, such as: initial temp, all sources of heat production, size of heat sink, conduction, etc, were calculated, and a curve produced. In an actual study during the last DSRV exercise, the data fit this curve with a correlation of 0.99. So we do have some confidence in the calculations, although it remains a rough approximation.

BONDI: Can you conceive of any situations where hyperthermia might be a problem?

HARRISON: The calculations indicate that a conventional submarine with a small compartment size in warm water could result in a hyperthermic environment. This does not appear to be a problem in the SSNs.

ECKENHOFF: I have a comment, and a question. First, the comment which is in response to a comment made by Dr. Pearson in his presentation. The latent period to which I was referring is defined from the onset of decompression, and not the moment of surfacing. If any intervening decompression stops take place, the latency period will be largely used up. Secondly, a question of Dr. Burgess, please tell me again how you intend to perform your saturation threshold exposures?

BURGESS: The intention is to saturate men at 8 meters for 48 hours and then ascent directly to the surface. The subjects are then to be observed for 24 hours for the development of symptoms. If the first set of subjects have no symptoms, then the exposures will be repeated in increments of 1 meter, until a pre-established incidence of bends is achieved. There is some controversy at present as to what the endpoint should be, bends or "hot spots" on bone scans.

ECKENHOFF: You mentioned that the oxygen level may be different than that of air.

BURGESS: The oxygen level will be maintained at 0.50 Bar for all of the exposures so that the data will be directly comparable to other, similar exposures we have performed.

ECKENHOFF: The reason I ask this question is that we are planning a very similar series of exposures in the next fiscal year. Perhaps if we could coordinate our experimental parameters, we might accumulate much larger amounts of data, from a larger subject pool - and therefore have a more meaningful study.

BURGESS: I think that would be a very good idea. We plan to start our exposures in a few months - if all goes as planned. The principle investigator of that project, Philip Bell, will be visiting your laboratory in a few weeks to discuss these sorts of options.

PEARSON: Dr. Eckenhoff, what sorts of things do you see with these surface excursion experiments? Where abouts do they occur? Do you see symptoms after of during recompression?

ECKENHOFF: Few symptoms of decompression sickness were produced in these exposures - a total of 4 cases as a result of the excursions, and 3 of the 4 were type I (pain - only), and one had very mild spinal cord symptoms in one upper extremity which completely cleared after a few hours back at depth. The symptoms generally occur after about 15-20 minutes on the surface, and resolve quickly on returning to depth. Only one of the four cases had initial symptoms well after the excursion was completed (about 2 hours).

ANOMALIES OF OCULAR REFRACTION IN RELATION TO STAY IN CONFINED SPACE

Médecin en Chef GIACOMONI Louis – CERTSM (FRANCE)

Staying a long time aboard a submarine develops a visual constraint connected with ~~on the one hand,~~ the permanent artificial lighting and ~~on the other hand,~~ the restricted and monotonous character of the visual environment.

With reference to this visual constraint we could note, on the first patrols of our nuclear submarines, ~~that the~~ submariners complained about visual discomfort. Some complained that during the days following their return from patrol they could not see as well as usual and ~~more particularly~~ that they had difficulties in driving at night. The specialists who examined these subjects, generally two weeks later, could not observe any objective anomaly.

We took advantage of the NEBALIA experiments to make a brief study of visual functions. In these experiments 18 subjects were confined, on three successive occasions for continuous periods of 45 days in an artificially lit chamber. The NEBALIA methodology was already widely developed during the previous three-party meeting. Therefore, I will only mention as a reminder that NEBALIA I was a simple confinement experiment while NEBALIA II and III involved one month exposure to low CO_2 concentrations (1% and 0.5%).

Our whole experimentation was made on 18 men ranging in age from 19 to 32 years. Nine of them were emmetropi six were myopic, two were hypermetropic and the last suffered from a mild myopic astigmatism.

Each subject was submitted to six successive examinations, on an average. One examination xas necessarily performed on the first day of confinement and another on the last confinement day.

Each examination included :

- a distance visual acuity measurement using the Monnoyer's scale,
- a measurement of the fusion power,
- a study of the ocular refraction using skiascopy under cyclopegic drugs,
- a retinography performed only on the first and last days of the exposure in the chamber.

Our results are as follows :

- as regards visual acuity (whose measurement with the Monnoyer's scale is not very precise). We noticed a slight decrement particularly during NEBALIA III were the mean visual acuity come from 9.91 to 8.5 (P = 0.001).

- in all subjects there was a considerable decrement of the fusion power which however returned to normal eight days after the subjects' return to daylight,

- in all subject there was also an ocular refraction change toward myopia which was more important among previously ametropics men (1.3 diopters on an average) than in emmetropes (0.45 diopter, on an average). Such a change was quite reversible and everything returned to normal two weeks after the end of the experiment.

- the retinographies used to check the arteriovenous caliber for possible changes showed no anomaly in this regard.

These results appear to be in accordance with the clinical observations made in submariners on their return from patrols.

In the CERTSM we do not have any specialist of vision physiology. Therefore, we have only tried to compare our experimental data with those to be found in the literature.

Following observations about anomalous myopias such as night myopia or empty-field myopia, the traditional view of accommodation, which is that the system is in a state of relaxation when the focus is at infinity, has given rise to much controversy since many years. Many authors argue that the eye is controlled by two opposing systems, one for near vision accommodation and the other for distance vision accommodation (negative accommodation). Such an idea is strengthened by the fact that it has been made possible, using a laser optometer, to clearly show an actual relaxed state of the eye corresponding to the dark-focus which Leibowitz observed to be at 1.52 diopters, on an average.

Positive accommodation is dependent upon the cholinergic parasympathetic nervous system while negative accommodation might be controlled by the usual antagonist of this system in physiological mechanisms, that is by the adrenergic sympathetic system.

Using both types of accommodation would therefore require a permanent effort both from the control systems and from the ciliary muscle. Leibowitz dwells on the importance of the part played, in such an adaptation of the vision, by the effectiveness of the various stimuli.

Without attempting to give any actual explanation of this we will compare such theoretical ideas with the fact that during NEBALIA experiments our subjects were exposed for 46 days, only to near visual stimuli. The maximum distances at which they could see didn't exceed 5 meters while a very monotonous environment could not arouse any visual interest.

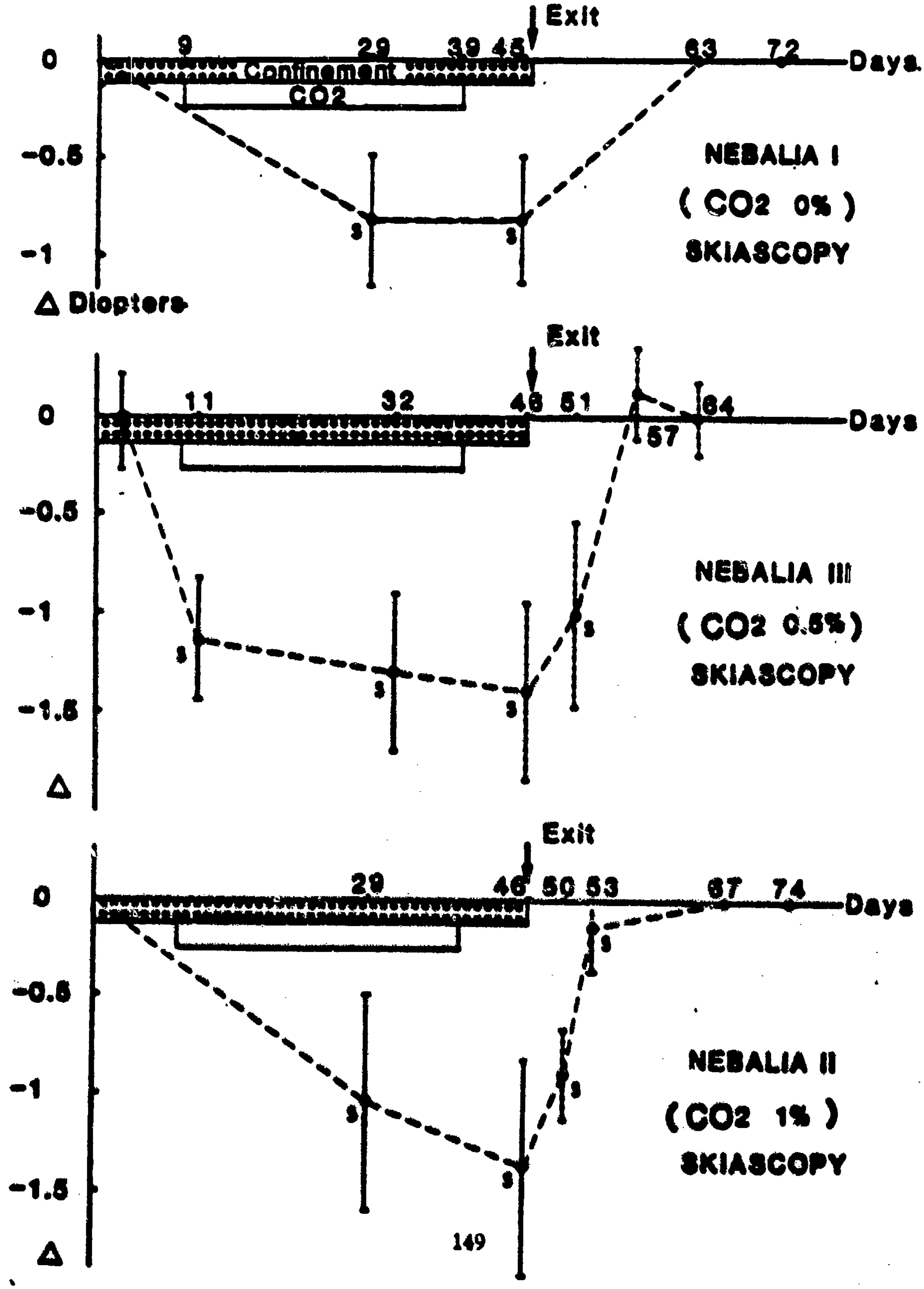
Besides our results seem to be in keeping with those of works carried out at the NSMRL by Dr. Kinney, Luria et al. who observed a slight tendency toward myopia and esophoria in submariners.

In practice, we think that the CERTSM experimentation should be completed. In this connection, the study of subjects at sea throught out a whole submarine petrol, may be with the use of a laser optometre, would certainly be a valuable experiment.

Should our results be confirmed, it will then be advisable to take some preventive measures aboard submarines. Such measures might involve a change in the environment so as to provide the submariners with distant visual centers of interest and to enable them to carry out true accommodation exercises.

NEBALIA 1.2.3
OBJECTIVE REFRACTION (SKIASCOPY)
Each Point : 6 Subjects

CHAMBER FLUORESCENT LIGHT
300 : LUX (1m up above the floor)

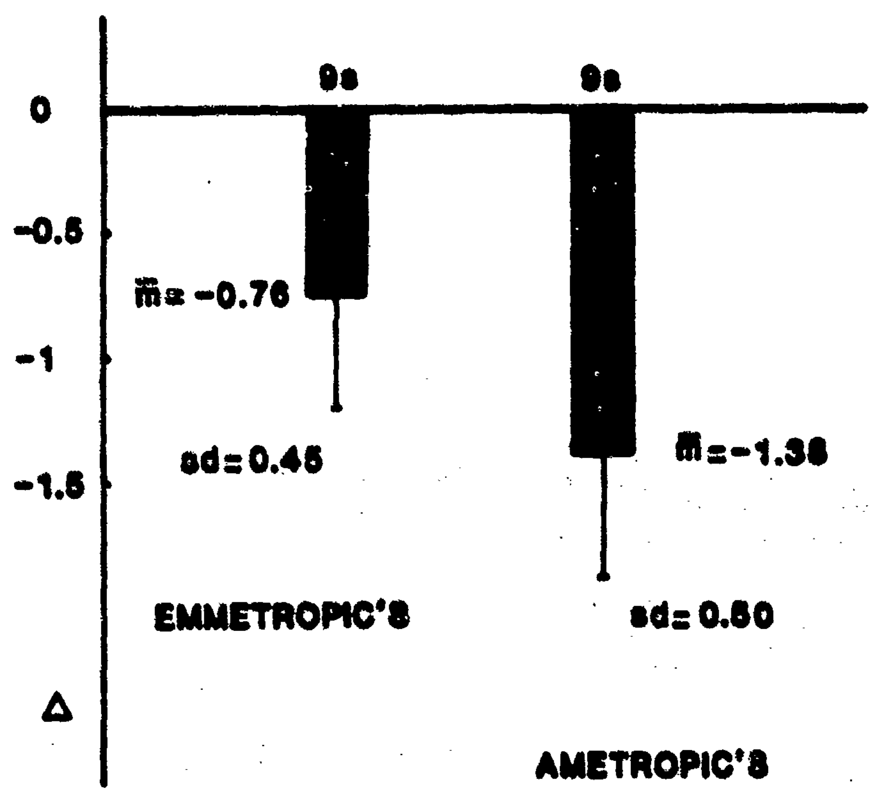


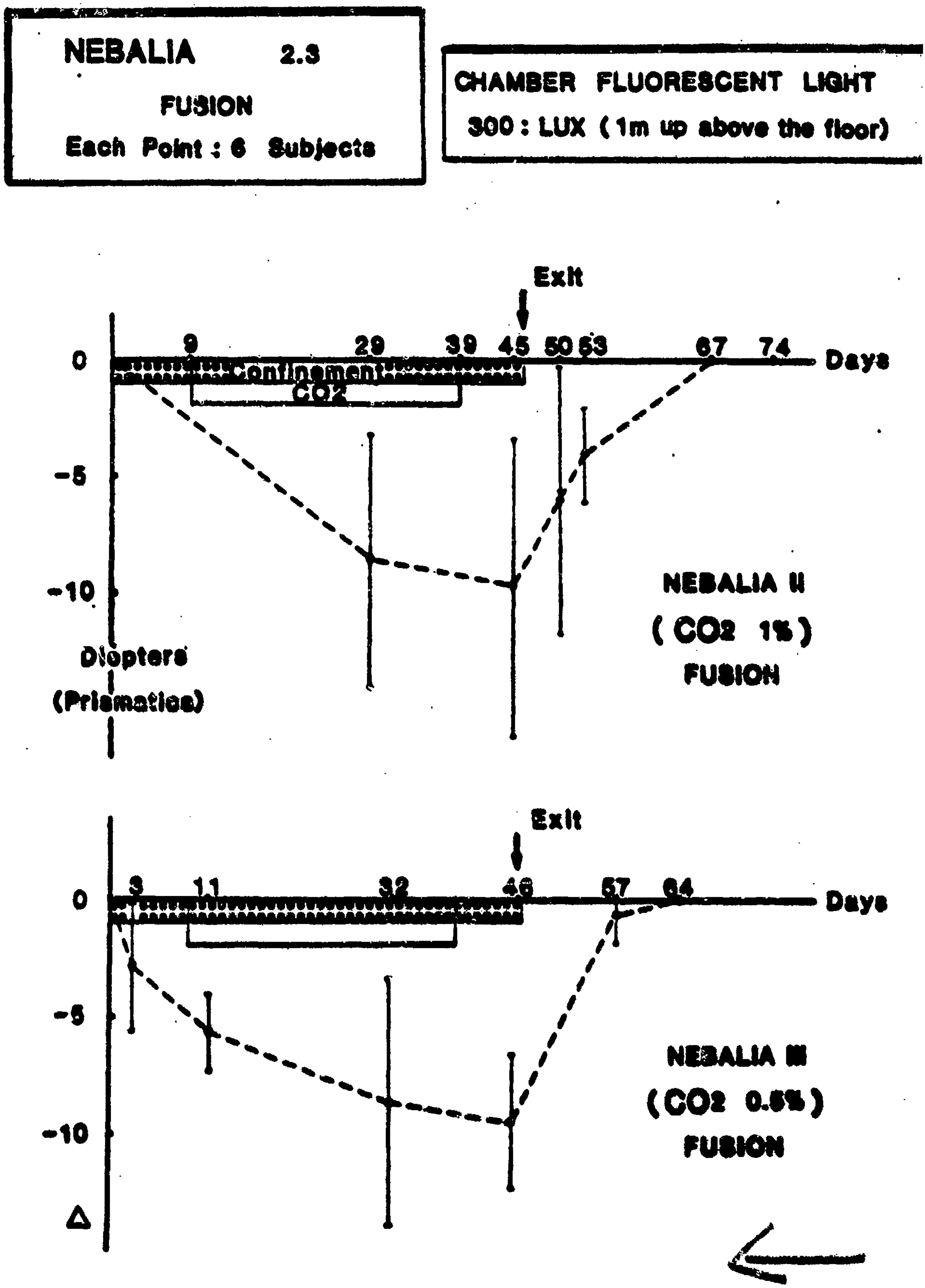
NEBALIA 1.2.3

OBJECTIVE REFRACTION

Comparison Between Ametropic's And Emmetropic's

(Maximum Variations)





NEBALIA 2.3
FUSION
Each Point : 6 Subjects
CHAMBER FLUORESCENT LIGHT
300 : LUX (1m up above the floor)
Exit
9 29 39 45 50 53 67 74
0
Days
Confinement
CO2
-5
-10
Diopters
(Prismatics)
NEBALIA II
(CO2 1%)
FUSION
Exit
3 11 32 46 57 64
0
Days
-5
-10
Δ
NEBALIA III
(CO2 0.5%)
FUSION

ANOMALIES DE LA REFRACTION OCULAIRE ET SEJOUR EN ESPACE RESTREINT

Médecin en Chef Giacomoni Louis

CERTSM DCAN - 83800 TOULON NAVAL - FRANCE

Le séjour prolongé à bord d'un sous-marin réalise une contrainte visuelle en rapport avec l'éclairage artificiel permanent d'une part, le caractère restreint et la monotonie de l'environnement visuel d'autre part.

En rapport avec cette contrainte, nous avions noté dès les premières patrouilles de nos SNLE, l'existance d'une revendication relative à une gène visuelle. Certains sous-mariniers se plaignaient pendant les quelques jours qui suivaient leur retour à terre, de ne pas y voir aussi bien que d'habitude et en particulier d'éprouver des difficultés dans la conduite automobile de nuit. Les médecins qui examinaient ces sujets, en général deux semaines plus tard, n'avaient pu mettre en évidence aucune anomalie objective.

Nous avons profité des expérimentations Nébalia au cours desquelles 18 sujets ont été confinés, en trois essais successifs, pendant des périodes ininterrompues de 45 jours en caisson artificiellement éclairé, pour procéder à une étude sommaire de la fonction visuelle. La méthodologie des Nébalias a été largement exposée lors de la précédente réunion tripartite et nous rappellerons seulement que Nébalia I constituait un essai de confinement simple, tandis que Nébalia II et III comportaient un mois d'exposition à de faibles concentrations de CO_2 (1 % et 0,5 %).

L'ensemble de notre essai a porté sur 18 garçons de 18 à 32 ans, neuf emmétropes, six myopes, 2 hypermétropes et le dernier porteur d'un léger astigmatisme myopique

Chacun de ces sujets a subi six examens successifs en moyenne, dont obligatoirement un prenant place le premier jour du confinement et un autre le dernier jour.

Chaque examen comportait :
- une étude de l'acuité visuelle de loin à l'échelle de Monnoyer
- une mesure de la puissance de fusion
- une étude de la réfraction oculaire par skiascopie sous cycloplégique
- une rétinographie effectuée seulement au premier et au dernier jour du séjour en caisson.

Les résultats observés ont été les suivants :

- l'acuité visuelle (dont la mesure à l'échelle de Monnoyer constitue un test peu sensible) subit une dégradation constante et passe, au cours de Nébalia III par exemple de 9,91 à 8,5 (variation significative p : 0,001),

- la puissance de fusion a subi un affaiblissement considérable chez tous les sujets qui récupèrent cependant totalement huit jours après le retour à l'air libre,

- la réfraction oculaire subit une modification dans le sens de la myopie plus importante chez les sujets préalablement amétropes (moyenne : $\overline{1,32}$ dioptries) que chez les emmétropes (moyenne $\overline{0,45}$ dioptries). Cette évolution est totalement réversible et tout rentre dans l'ordre deux semaines après la fin de l'expérience,

- les rétinographies exploitées pour rechercher d'éventuelles variations du calibre artério-veineux n'ont révélé aucune anomalie dans ce domaine.

Ces résultats semblent en accord avec les constatations cliniques effectuées dans le cas des sous-mariniers au retour de patrouille.

Le CERTSM, qui ne possède pas d'équipe spécialisée dans la physiologie de la vision, a simplement essayé de rapprocher ses données expérimentales de celles que peut fournir à ce sujet la littérature.

Depuis de nombreuses années, à la suite d'observations relatives aux myopies anormales (anomalous myopias) comme la myopie nocturne ou la myopie du champ vide (empty field myopia), la théorie traditionnelle pour qui le système accomodatif est au repos quand son point de fixation est à l'infini se trouve battue en brèche. L'idée suivant laquelle l'oeil serait soumis à l'action de deux systèmes antagonistes déterminant pour l'un une adaptation à la vision de près et pour l'autre une adaptation à la vision de loin (accomodation négative) est défendue par de nombreux auteurs.

Cette idée est confortée par la mise en évidence grâce à l'optomètre à laser, d'un véritable état de relaxation de l'oeil correspondant au foyer de repos (Dark jours) qui se situe suivant Leibowitz, à une puissance moyenne de 1,52 dioptries.

L'accomodation positive est sous la dépendance du système nerveux parasympathique cholinergique, cependant que l'accomodation négative pourraît être commandée par son antagoniste habituel dans les mécanismes physiologiques, le système sympathique adrénergique.

L'exercice des deux types d'accomodation ainsi défini, nécessiterait donc un effort permanent de la part de son système de commande et de son moteur musculaire. Leibowitz insiste sur l'importance du rôle que joue dans cette adaptation de la vision, l'efficacité des divers stimulis qui nous sont présentés.

Sans vouloir tenter une explication réelle, nous rapprochons ces notions théoriques du fait que les sujets des expériences Nébalias étaient seulement soumis pendant 46 jours à des stimulis visuels de proximité. Les distances maximales observables par l'oeil n'excédaient pas cinq mètres, cependant que l'environnement très monotone ne pouvait susciter aucun intérêt visuel.

Nos résultats ne nous semblent par ailleurs pas en désaccord avec ceux des travaux réalisés au NSMRL par les Dr Kinney, Luria et leurs collaborateurs, qui semblent indiquer, à terme, chez les sous-mariniers, une légère tendance à la myopie et à l'ésophorie. Nous croyons en pratique que le besoin se fait sentir de compléter l'expérimentation réalisée au CERTSM. L'étude des sujets à la mer pendant toute une patrouille de sous-marin, peut être, à l'aide d'un optomètre à laser, constituerait sans doute à ce sujet un bon essai.

Dans le cas où nos résultats seraient confirmés, il deviendrait sans doute utile de prendre à bord des sous-marins, certaines mesures de prévention. Il pourraît s'agir d'une modification de l'environnement, visant à présenter des centres d'intérêt visuel à distance et à réaliser une véritable gymnastique de l'accomodation.

Current Studies in Submariners

by Dr D. J. SMITH INM Alverstoke

Introduction and CO_2/CO Studies

At our previous meetings and over the past years, we have put much time and effort into the study of readily identifiable factors specific to the life of a submariner. Most notable has been our work on CO_2 and CO. These studies were important from both the engineerin and medical point of view. The CO_2 work, reviewed in detail at our last meeting in Toulon has now come to an end with the final reports either released or in preparation (refs 1-4). A synopsis of chronic CO_2 exposure studies is presented in Tables 1 to 4. From these results, we conclude that increases in $\dot{V}_E$ are dose related, changes being observable at the 0.5 to 1% level (refs 1,4,5,6). Good agreemen is obtained between the three nation's studies. PCO_2 results are similar. pH results are not so clear, the French being unable to show a significant acidosis below 1% CO_2 (ref 5), whereas, the UK demonstrated significant falls at 0.5%. The US Hideout study at 1.5% suggested an initial 0.06 pH unit fall with a return to control levels during the latter half of the exposure (ref 7). Our 1. study does not support this; we obtained a sustained fall of some 0.02 units. This is probably a reflection of methodology in an area with a low signal to noise ratio. Calcium excretion appears to fall during all chamber studies unrelated to the gas period.

In the case of CO, the work is not yet complete. Although we assessed the effects of the gas on mental performance, and were unable to show significant decrements at levels below 50ppm, the possible effects of CO on cardiac function have not been resolved. In our previous papers (refs 8 & 9), we reported changes in p wave amplitude and direction in a number of subjects exposed to levels as low as 15ppm. It is still our intention to follow up these studies with a further chamber trial, and INM would be pleased to have the views of the other two nations on their assessment of the relative importance of such a study in the overall field of submarine medical research.

In the interim we have activated an on-board study, carried out by one of our SSBN medical officers (ref 10). Six lead ECG records wer made on 31 crew members during the first and last weeks of a 58 day patrol. The mean CO level was 8.4ppm. All volunteers were non-smoking during the month preceding and during the patrol. One subject was excluded from the study with a pathological ECG, a second due to a wrong lead configuration on one of the recordings. Of the 29 pairs of good quality ECGs, it was clear that 5 pairs were different with, again, changes in p wave axis. All showed changes of 20 or more degrees. A follow-up study in the same submarine is now under way.

The subject with a pathological ECG showed a p wave axis of -90° indicating retrograde atrial activation from a nodal pacemaker. This subject had been consuming large quantities of coffee and was advised to stop doing so. One month later his ECG was normal.

The main reason for carrying out chamber trials rather than studies at sea was to avoid such confounding factors as this. However, perhaps now is the time to consider in more detail the overall lifestyle of a submariner and the multitude of factors which may impinge on his health and efficiency.

For the rest of this presentation I will be considering some of these factors, in particular, diet, fitness and other indices of health.

The Nutrition of Submariners

The nutritional allowance for submariners at sea is the same as the surface fleet ration, in principle a balanced diet calculated to give 4000 Cals per man per day. This is not an issue in kind but given as cash to the Coxswain or the Ship's Caterer to spend as he wishes. He also draws supplements as follows:

a) The Submarine Patrol Supplement. Designed to allow for the purchase of superior cuts of cold meat plus 5 Oz of fruit juice now rationalised into a single cash sum.

b) Extreme Latitude Supplement. A cash allowance based on the price of 1.75 Oz bone in beef and 1.75 Oz quick frozen vegetables.

c) Junior Supplement. A cash allowance whilst at sea to the value of 1/2 pint of milk for all under 18 years.

d) Watchkeepers Supplement. Calculated as 1/6 of daily rate for 15% of SSK and SSBN crew, and 1/6 of daily rate for 30% of SSN crew. The difference is due to the different watchkeeping systems and is currently under review.

e) Christmas Day Supplement. 75% of daily messing rate.

The daily messing rate is itself modified in boats with smaller crews, as the wastage (assumed at 15%) is somewhat higher.

Thus the Coxswain or Ship's Caterer has a cash sum representing the cost of a 4000 Cal diet per man per day plus the cost of the supplements. He is then in a position to purchase food stores for his forthcoming patrol.

The types of food he can buy are to some degree controlled by other unavoidable factors. These fall into two main groups: space limitations and perishability.

Space is always at a premium in submarines thus, inevitably, there is a tendency towards stocking with pre-packaged, refined, dehydrated and pre-processed food with a low bulk content. The second factor, perishability of food-stuffs, also necessitates the use of prepacked long-life food. Those foods which cannot be pre-packed or deep-frozen, for example fresh fruit and some vegetables, inevitably become in short supply within the first weeks of the patrol.

The quality of the diet to a very great extent depends on the skill and foresight of the Caterer, the 1st Lt. and the officer with supply duties. Nevertheless, it is likely to be high in refined carbohydrate low in fibre, low in vitamins - we know that vitamin D levels fall during a patrol (refs 11 & 12) and during chamber studies (ref 13).

There is obviously a lack of information on the effect of different components in this diet, or the effect of low levels of some. Perhaps this is an area where further ship-board research should be encouraged.

The consumption of additional items such as purchased canned drinks, beer and chocolate is additional to the provided diet and should be taken into consideration.

Physical Fitness

For submariners, physical fitness is very much a minority interest. Equipment is provided but it is entirely up tp the individual whether he uses it or not. Consideration must be given to the inevitable increases in Oxygen consumption and Carbon Dioxide production induced by any heavy work. This is unfortunately of paramount importance very particularly in our conventional submarines.

The interaction of age, smoking habits, the height/weight relationship and physical fitness were investigated by Edmonstone (ref 14). He observed that age and fatness bore no significant relationship to 'fitness' as measured by the Exercise Tolerance Index. However, he was able to demonstrate a mean 26.8% decrease in exercise tolerance of 132 crew members during a 6 week patrol.

One of the problems of fitness assessment is to choose a reliable test. We have currently started to look at the tests of physical fitness employed by the Royal Navy. The two tests most commonly used are a modified Harvard Step Test and the Step up to Physical Fitness Test. Both rely on recovery heart rates measured by palpation The former is fairly severe, particularly in unfit men, the latter complicated.

We have currently developed a simple 6 minute step test (step height 32cm stepping rate 20/min) which relies on heart rate measurement during the 6th minute of exercise. This rate is then entered into an equation containing both an age and a weight factor (either total body mass or, preferably, fat free mass). From this equation, $\dot{V}O_2$ max is predicted. We have used 30 subjects so far and the regression coefficient for the equation gives a value of r=0.87 against directly measured $\dot{V}O_2$max. The equation is as follows:

$$\dot{V}O_{2max} \text{ l/min} = 2.065 - 0.0148*HR + 0.0584*LBM - 0.0083*Age$$

where HR = Heart rate during the 6th minute of exercise,
and LBM = Lean body mass in Kg.

We are currently using this test to assess changes in fitness of the crew of an SSBN as part of the CO ECG study mentioned earlier. If this is successful, we will be in a position to carry out further studies of fitness changes during submarine patrols and link these to other factors such as smoking habit, exercise routines and diet.

<u>Height, Weight and Fatness</u>

If submariners do get too much food, possibly of the wrong type and take inadequate exercise, what is this doing to their physical shape? We have some very recent information in this area.

At the end of last year, a contract was placed by the Army with Prof. Durnin's department at Glasgow University. The intention of the survey was to produce more up to date height/weight tables and if possible to construct an alternative to this index using other simple indices of fat-free mass such as circumferences and condylar widths. The Army sample was some 1% there were also 2% samples of the Royal Navy and Royal Air Force.

From the information available, it was clear that useful preliminary information could be extracted. I proposed that the Naval population be divided into 4 subgroups irrespective of age and rank (these factors were balanced across the three services but at this time it is not known whether there is a balance between the subgroups). The subgroups were chosen as follows:

- Group 1) Manual and mechanical trades - the Active group.
- Group 2) Technical trades - Intermediate in activity beteeen Groups 1 & 3.
- Group 3) Logistic trades - The group with desk-bound jobs.
- Group 4) Submariners - these were not subdivided as with such a specialised lifestyle should form a group of their own. The sample was also rather small.

Preliminary results are as follows:

Mean Values	Group 1 Manual	Group 2 Technical	Group 3 Logistic	Group4 Submariners
Age yrs	25.6	26.8	32.5	28.0
Ht cms	175.7	177.0	176.3	175.4
Wt kg	73.9	74.1	75.4	77.0
% Fat	18.6	17.8	20.5	20.7
Ht/Wt	2.38	2.39	2.34	2.28
Fat-free Mass kg	59.8	60.8	59.6	60.8
No sampled	357	321	300	82

Information collected during the survey included questions on smoking habits and amount of exercise taken. These facts will be included in the final data analysis. The report should be completed within the next few weeks.

Lung Function

We have recently undertaken a further study with submariners. The aim of the study was to assess the possibility that divers have or develop larger lungs than a control population. 422 vitalographs were collected from 192 divers and 230 submariners. They were balanced for age. Of the divers 31% were smokers whereas in the submariner population, 46% smoked. As well as lung function data, ages, heights and weights were recorded. and sumarised below:

	Divers	Submariners
Mean Age yrs	27.8	28.5
" Height cm	178.1	179.0
" Weight Kg	78.0	79.3
" Ht/Wt	2.28	2.26

This data agrees well with the previous study although the heights and weights are slightly higher for the two groups, the ratios are remarkably similar. There is thus no evidence that submariners as a group are overweight when compared to the RN popolation as a whole.

From a multi-linear regression analysis of the Vitalography study, the following findings were obtained. Best fit equations for FVC and FEV_1 required a linear height term and a quadratic age term; for the ratio, only linear age was a factor. Submariners were found to have significantly smaller FVCs and FEV_1s than divers. However, using the predicted equations of Kory (ref 15), the mean value of FVC for submariners was 108% of predicted and even if the more stringent equations of Morris are used this falls by only 7%

to 101% (ref 16). FEV_1 showed a similar picture. The mean ratios of 82.9% for submariners and 81.6% for divers are also at or above the predicted values of Berglund (ref 17) at 102% and 100%, respectively. These values compare well with the mean value of 81.1% reported for 404 divers by Crosbie et al. (ref 18).

Thus there is no evidence that the life style of submariners induces reductions in lung function as measured by simple spirometry.

Conclusions

I have intentionally covered a wide range of topics and have thus been unable to take any in great detail.

There are obviously areas which require further work and I trust that with what the other speakers have contributed during the session we will be in a better position to identify those with the highest priority. The specific questions I would like to raise are:

(1) Where do we go with carbon monoxide?

(2) What areas in the nutritional field should we consider for further investigation?

(3) In the highly complicated field of fitness, in a service without compulsory physical training, which projects would be of the greatest value to the submarine service?

(4) Conversely, considering the apparent normality of body composition should we consider these two areas, fitness and fatness, to be of no consequence to the submarine force anyway?

Your comments are awaited.

Table 1 PCO2 mmHg

Study Nation	Level %	Mean Con. level	Mean Ist 15 days CO2	Mean 2nd 15 days CO2	Recovery level
UK	0	39.1	39.4		
France	0	39.9	41.1	41.1	39.7
UK1	0.5	40.7	41.9	41.5	40.3
UK2	0.5	36.5	37.6		36.1
France	0.5	39.7	41.1	41.5	40.2
France	1.0	30.3	42.1	41.4	40.2
UK	1.5	38.2	43.0	41.3	38.3
USA	1.5	37.8	40.2***	39.9**	39.9/37.2*

Table 2 pH

Study Nation	Level %	Mean Con. level	Mean Ist 15 days CO2	Mean 2nd 15 days CO2	Recovery level
UK	0	7.395	7.397		
France	0	7.416	7.407	7.407	7.416
UK1	0.5	7.365	7.346	7.348	7.366
UK2	0.5	7.398	7.387		7.398
France	0.5	7.405	7.408	7.402	7.405
France	1.0	7.408	7.404	7.395	7.396
UK	1.5	7.401	7.381	7.385	7.404
USA	1.5	7.37	7.31 ***	7.37 **	7.37/7.40*

Table 3 VE l/min

Study Nation	Level %	Mean Con. level	Mean Ist 15 days CO2	Mean 2nd 15 days CO2	Recovery level
UK	0	10.30	9.80		
France	0	7.50	7.10	7.40	7.40
UK1	0.5	7.95	8.58	8.18	7.72
UK2	0.5	9.32	9.48		8.64
France	0.5	6.80	7.00	6.50	6.60
France	1.0	8.90	10.50	9.90	8.70
UK	1.5	11.00	12.81	12.31	10.69
USA !	1.5	5.99	8.32	8.00	7.14

Table 4 Ca Excretion mg/24hrs

Study Nation	Level %	Mean Con. level	Mean Ist 15 days CO2	Mean 2nd 15 days CO2	Recovery level
France	0	386	420	392	379
France	0.5	314	268	258	228
France	1.0	315	324	281	259
UK	1.5	271	260	246	209

*** Mean of 1st 23 days Exposure
** Mean of last 18 days Exposure
* Early and late Recovery
! Assumes mean Body Surface Area = 1.8 sq m.

References

1. Duggan A, Smith D J, Harrison J R & Searing C S M (1982) Respiratory consequences of 30 days of exposure to 1.5% CO_2 in man. INM Report 51/82.

2. Searing C S M, Smith D J, Harrison J R & Duggan A (1983) Acid-base response to a 30 day exposure to 1.5% CO_2. INM Report 2/83.

3. Haus E, Smith D J, Harrison J R, Guillaume G C & Halberg F. Circadian relationships of circulating ACTH, Aldosterone, Cortisol, Growth hormone, Calcitonin and PTH in healthy men and the effect of exposure to 1.5% CO_2 upon their rhythm characteristics. In preparation.

4. Harrison J R & Smith D J (1981) Hazards of enclosed spaces - Raised ambient CO_2. J. Roy. med. Serv. 67 138-146.

5. Radziszewski E. (1981) Human experiments at low CO_2 concentrations. French Nebalia experiments at $PiCO_2$ 0, 0.5 and 1kPa. In proceedings of third Tripartite Conference, Toulon France. 1981 p38-46.

6. Schaefer K E, Hastings B J, Carey C R & Nichols G (1963) Respiratory acclimatization to carbon dioxide. J. Appl. Physiol. 18 1071-1078.

7. Schaefer K E, Nicols G & Carey C R (1964) Acid-base balance and blood and urine electrolytes of man during acclimatization to CO_2. J. Appl. Physiol. 19 48-58.

8. Davies D M & Smith D J (1978) The effects of continuous exposure to carbon monoxide on electrocardiographic activity in man. INM Report 52/78.

9. Davies D M & Smith D J (1980) Electrocardiographic changes in healthy men during continuous low-level carbon monoxide exposure. Environ. Res. 21 197-206.

10. Berth-Jones J, Smith D J & Harrison J R (1983) A preliminary report on the effects of continuous low-level carbon monoxide exposure on the electrocardiograms of submariners during a submarine patrol. INM Report 4/83.

11. Preece M A, Tomlinson S, Ribot C A, Pietrek J, Korn H T, Davies D M, Ford J A, Dunnigan M G & O'Riordan J L H (1975) Studies of Vitamin D deficiency in man. Quart. J. Med. 176 575-589

12. Davies D M & Morris J E W (1979) CO_2 and Vitamin D effects on calcium metabolism in nuclear submariners. Undersea Biomedical Research 6 Suppl. S71-S80.

13. Davies D M, Smith D J, Leitch D R, Morris J E W & Gray S P (1976) The effects on man of continuous exposure to 0.5% carbon dioxide. INM Report 22/76.

14. Edmonstone W M (1978) Exercise tolerance in nuclear submariners. J. Roy. Nav. Med. Serv. 64 29-34.

15. Kory R C, Callahan R, Boren H G & Syner J C (1961) The Veterans Administration-Army Cooperative study of pulmonary function. 1. Clinical spirometry in normal men. Amer. J. Med. 30 243-258.

16. Morris J F, Koski A & Johnson L C (1971)
Spirometric standards for healthy non-smoking adults. Amer. Rev. resp. Dis. 103 57-67.

17. Berglund E, Birath G, Bjure J, Grimby G, Kjellmer I, Sandqvist L & Soderholm B (1963)
Spirometric studies in normal subjects. 1. Forced expirograms in subjects between 7 and 70 years of age. Acta. med. scand. 173 185-192.

18. Crosbie W A, Reed J W & Clarke M C (1979)
Functional characteristics of the large lungs found in commercial divers. J. Appl. Physiol. 46 639-645.

AD P001895

A PRELIMINARY STUDY OF CARDIOVASCULAR RISKS IN RETIRED SUBMARINERS

D.V. Tappan, D.R. Knight, E. Heyder and K.R. Bondi

Submarine Medical Research Laboratory, Groton, CT 06349, USA

Despite the very serious stresses to which submariners are subjected: confinement, isolation, monotony, lack of exercise, and sometimes overeating, very little work has been done in our country on long-term health effects of submarine service.

A longitudinal health study, which was being conducted in this laboratory about 10 years ago on 1000 submariners, was not completed because of budgetary restraints and the high cost of returning the personnel to the laboratory for follow-up examinations. However, good initial data on the subjects were collected which now provide a useful profile of the men in the submarine service at that time (1).

Later a study of the health of retired submariners and non-submariners was aborted in its initial stages also because of financial shortages. Most of the results to be presented here are from this preliminary work conducted on 23 retired submariners and 29 retired non-submariner naval subjects who were randomly selected and had been retired for 5-10 years. Because of the small number of subjects, the conclusions are tentative.

The body weights and years of service of the subject groups were nearly identical, but because of the random choice of subjects and their small number, the submariners were slightly older than the non-submariners (53.4 vs. 50.2 yrs). However, two items from a questionnaire pertaining to the subject's habits and lifestyles deserve special attention. Significantly less exercise was reported by the submariners than the non-submariners for their years of service. No differences seemed to exist after retirement. The submariners also apparently had consumed higher quantities of alcoholic beverages than the control subjects. This finding confirmed data collected during the 1000-submariner study (1). The submariners reported drinking almost twice as many alcoholic beverages per week as did the non-submariners from before the time of their retirement to the present.

Among the results of the biochemical and physiological tests performed, mean glycosylated hemoglobin, and triglyceride values were higher in the submariners but the ranges of the values prevented their being statistically different. No differences were observed in the fasting serum glucose, or high density lipoproteins. Serum cholesterol and two-hour post-prandial glucose were lower in the submariners but again not by statistically significant margains. Likewise no differences were detected by the lung function examinations.

On the other hand, the maximum exercise tests indicated that the retired submariners may have been less physically fit than the non-submariners. The maximum pulse rates approached being significantly higher in the retired submariners, while the systolic blood pressures at stages 2, 3, and 4 of the Bruce exercise test were significantly higher in the ex-submariners than in the controls. These observations give tentative evidence favoring a hypothesis that careers of sedentary activities such as those aboard submarines may have deleterious effects on health in later years.

Finally attention should be drawn to data on the psychological health of the two populations of naval retirees as obtained from the Minnesota Multiphasic Personality Inventory (MMPI). Statistically significant differences were detected in three personality traits that may be important indicators of cardiovascular risks. Scores were significantly higher in the submariner group for the trait (K), symptom denial, and significatly lower than for the non-submariners for the factors, social introversion and psychasthenia or compulsivity (Si and Pt). While these personality characteristics may be interpreted in various ways, a comparison against a list of personality traits ranked in their order of association with cardiovascular risks in the 1000 submainer study (2) provides an interesting insight.

The factor, K, which was higher in the retired submariners, was the trait most strongly related to cardiovascular risk. Conversely, the factors, Si and Pt, which were lower in the retired submariners than in the non-submariners, were the two traits most negatively associated with cardiovascular risk in the 1000-submariner group.

These two sets of studies seem to agree that both retired and active duty submariners have increased levels of a personality component strongly related to cardiovascular risks and have lowered levels of at least two factors associated with reduced risk. One of the explanations for negative association of risk with personality traits suggested by Weybrew, who participated in the 1000-submariner study, is that these factors may be related to "environmental insulating mechanisms" protective against cardiovascular diseases or disease risks. (2).

None of the data which have been presented quantitatively defines cardiovascular risk in retired personnel; at best they are preliminary; but they present some areas worthy of investigation on the health of retired naval personnel. I would like to summarize the findings as they relate to the design of remedial programs for both retired and active duty submariners to promote a state of health for submariners that equals or surpasses the health of the general population at retirement age.

The first major problem faced by retired submariners appears to be a result of a severe lack of exercise during their careers aboard submarines. Both subjective recollections of exercise levels by the retirees and the results of physiological testing point to an exercise deficiency. We feel that the programs described by Dr. Bondi at this meeting will be very helpful toward promoting a much more adequate level of exercise for the men who are now on active duty. It is likely that part of the accumulated deficiency in retired personnel could be corrected by appropriate exercise programs that may be carried out either on an individual basis or sponsored by veterans groups.

A second general health risk of retired submariners may result from the habit of alcohol consumption which was acquired during their naval careers. Again remedial programs could greatly reduce the risks associated with alcohol utilization if individual subjects are willing to cooperate with such remediation.

A third group of results from the work with retired personnel may reflect some unique personality characteristics of sailors who choose submarine careers. Perhaps these traits reflect adaptive changes which have allowed the men to cope with submarine life and complete a career of submarine duty. Ingrained personality factors such as denial of faults, social introversion, or a tendency toward compulsive actions are, without doubt, not easily altered; nor are we certain that changing these traits would significantly reduce cardiovascular risk. However, further research into the relationships of the risks of illness to personality characteristics may result in the development of better procedures for management or control of disease states.

Our intent here has been to point out the need for more research into the effects of occupational factors aboard submarines on the long-term health of persons engaged in this group of occupations. Our efforts to date have pointed in a few directions that may eventually lead to solutions for some very challenging problems.

1. Tappan, D.V., L. W. Mooney, M.J. Jacey, and E. Heyder. Cardiovascular risk factors in submariners. Undersea Biomed. Res., Submarine Suppl. 6: s201-s214, 1979.

2. Tappan, D.V., and B.B. Weybrew. Relationship of personality factors and some social habits to cardiovascular risk in submariners. Aviat. Space Environ. Med. 53: 383-9, 1982.

CARBOHYDRATE METABOLISM IN SUBMARINER PERSONNEL

E. Heyder, L.W. Mooney, and D.V. Tappan

Naval Submarine Medical Research Laboratory
U.S. Naval Submarine Base
Groton, Ct 06349

INTRODUCTION

Submariners have been shown to have an increased rate of glucose utilization 2 hours after an oral loading test(1). Relative hypoglycemia due to excess insulin production has been considered a first indication of developing diabetes(2). However, diabetes can not be defined in terms of blood glucose level alone but rather in its relationship to insulin release, utilization, and effectiveness(2,3). The ability to interpret insulin response to a glucose load by separating normal from abnormal patterns provides for disease detection at its earliest identifiable point when maximum benefit might result from appropriate management(4).

The present study was undertaken to reevaluate potential pre-diabetes in submariners and assess the extent of defects in their glucose metabolism.

MATERIALS AND METHODS

Fifty-eight active duty submariners between the ages of 22 and 46 who had made no fewer than five FBM patrols and fifty-eight comparable non-submariners were studied. Of the submariners 35 were on a sea duty tour.

Following an overnight fast blood samples were taken. The subjects then consumed 100 gm. glucose. Blood was again drawn 1 and 2 hours after ingestion of the sugar.

Body weight, height, and abdominal circumference were measured. A questionnaire answered tendencies to gain or lose weight, and exercise habits. The subjects were categorized as having none or little, moderate, heavy, or daily heavy and lengthy exercise.

Glycosylated hemoglobin was measured in the fasting blood samples by column chromatography while glucose and insulin were determined enzymatically and by RIA, respectively, in the fasted and post-prandial serum.

Percent body fat was calculated using body weight and abdominal circumference(5). Each subject was categorized as obese or normal weight; Obesity being defined as 115% desirable body weight. The mean of the range for "medium frame" from the Tables of Desirable Weights for Men and Women (Metropolitan Life Insurance Co.)was considered 100%.

RESULTS

Despite significant differences in body weights, no differences were found between the submariners and non-submariners with respect to age, percent body fat, degree of fatness, glycosylated hemoglobin, or family history of diabetes. Highly significant differences in the amount of exercise were found between the two groups.

Significantly higher serum glucose levels occurred one and two hours following the glucose challenge in the submariners as compared to controls. Additionally, the submariners exhibited a delay in the return of insulin levels two hours after the glucose load. In an attempt to classify the nature of the defect in carbohydrate metabolism the Wilkerson Point System, for glucose values, used in conjunction with patterns of insulin response described by Kraft(4) serves as the means for classifying the type of defect. APPENDIX I

No significant differences between submariners and non-submariners occurred with respect to the amount of defect. However when the number of subjects with normal carbohydrate metabolism and the combined number of those with all carbohydrate defects are compared, 55% of the submariners exhibited a defect vs 45% of the controls. A Chi Square analysis reveals that 26% of the time could this ratio be attributed to chance alone. Generally, the more severe the defect the greater the percentage of submariners who exhibit it.

Regarding carbohydrate metabolism and fatness among the subject population as a whole, 35% normal weight and 61% obese exhibited defect ($p<.005$). A positive correlation was also found between carbohydrate defects vs. % body fat for both non-submariners (.520 $p<.001$) and submariners (.249 $p<.05$).

An inverse relationship between amount of exercise and carbohydrate metabolism characteristics occurred in both submariners and non-submariners.

An inverse relationship also seems to exist between exercise and severity of defect in both normal weight and obese.

DISCUSSION

At no time were any of the group mean values outside the limits of clinical normality and only three subjects of the entire population accumulated as much as one Wilkerson Point. At the same time a decrease in sensitivity to insulin in the submariners as a whole as seen by the higher one- and two-hour post-prandial glucose with increased two-hour insulin indicates some abnormality in these individuals as a group.

The effect of small population size may have contributed to the lack of statisical significance between the submariners and controls using Kraft's classification although a trend toward potential disease did occur in the submariners.

Differences between normal weight and obese individuals, for all subjects, with respect to defective carbohydrate metabolism reconfirms the positive correlations between obesity and diabetes have been frequently reported(6). The characterization of the subjects as normal weight or obese is used for comparative purposes(2,4). Although there was no difference between the two groups in fatness or % body fat, a somewhat more significant relationship exists between carbohydrate defects and % body fat in the non-submariners than in the submariners. This suggests that some factor in the submariner's environment or lifestyle such as fluctuating weight gain and loss may alter the relationship between amount of fat carried and the tendency to develop a carbohydrate defect.

The significantly greater amount of exercise by the non-submariners appears to play an important role in the maintenance of normal carbohydrate metabolism in these subjects. Exercise has a dramatic effect on glucose tolerance and increased insulin sensitivity in trained individuals(7). In the present study a significant negative correlation was also found between exercise vs one and two hour postprandial glucose and two hour insulin for all subjects in addition to the inverse relationship between exercise and carbohydrate defect. Despite reported insulin lowering effects of physical conditioning in obese subjects, their serum insulin concentration still remains higher than in comparably trained lean persons(7). That these individuals are not completely protected against defects in carbohydrate metabolism is further substantiated in our finding that at all exercise levels the obese exhibited a greater defect.

Conclusions: Submariners have a shift toward glucose intolerance resulting from increased peripheral insulin resistance and therefore a tendency toward development of carbohydrate metabolic defects. This increase in insulin resistance more likely results from decreased exercise among submariners rather than from increased carbohydrate intolerance associated with obesity since the submariners as a group were found to be no fatter than the controls.

REFERENCES

1. Tappan, D.V., Jacey, M.J., Heyder, E., and Harvey, C.A. Biochemical and hematologic profiles of 1000 submariners. Undersea Biomed. Res. 6(Sub Suppl.): S191-S199; 1979

2. McReynolds, C.R., Shah, S., and Stoffer, R.P. Computer assisted analysis of insulin response to glucose stimulus. Anal. Clin. Lab. Sci. 3: 454-464; 1973

3. Bagdade, J.D., Bierman, E.L., and Porte, D., Jr. The significance of basal insulin levels in the evaluation of the insulin response to glucose in diabetic and non-diabetic subjects. J. Clin. Ivest. 46: 1549-1557; 1967

4. Kraft, J.R. Detection of diabetes mellitus in situ (occult diabetes). Laboratory Med. 6: 10-22; 1975

5. Wright, H.F. and Wilmore, J.H. Estimation of relative body fat and lean body weight in a United States Marine Corps population. Aerospace Med. 45: 301-306; 1974

6. Stern, J.S. and Hirsch, J. Obesity and pancreatic function. In: Handbook of physiology. Sect I Endocrinology Vol.1 Ed. Steener,D. and Frankel,N. Amer. Physiol. Soc.,Washington, D.C. 1972

7. Ivy, J.L., Frishberg, B., Farrell, S., Miller, W., Sherman, W.M., Pate, R., and Caulfield, J. Control of glucose tolerance: Role of muscle glycogen. Med.& Sci. in Sport & Exercise 14: 150; 1932

APPENDIX I

From: Kraft, J.R. Detection of diabetes mellitus in situ (occult diabetes). Laboratory Med. 6: 10-22; 1975

WILKERSON POINTS

TIME	PLASMA	POINTS
Fasting	130	1
1 hour	195	1/2
2 hours	140	1/2
3 hours	130	1/2

Two or more points is considered diagnostic of diabetes.

When abnormal insulin patterns are associated with normal glucose tolerances the results are considered indicative of prediabetes or occult diabetes (also called diabetes in situ), the earliest detectable phase of diabetes mellitus.

The criteria used are as follows:

I. NORMAL

WILKERSON PT	INSULIN PATTERN
0	Fasting level between 0-30 uU Peak at either 1/2 or 1 hr. Sequential return to fasting levels at 2 to 3 hours. Two plus three hr value totals < 60 uU

II. BORDERLINE

WILKERSON PT	INSULIN PATTERN
0 POINTS	Normal peak 2 + 3 hr total > 60 uU < 100 uU

III. OCCULT OR PREDIABETES

WILKERSON PT	INSULIN PATTERN
0 POINTS	Normal insulin peak-delayed return 2 + 3 hr total > 100 uU
0 POINTS	2 hr delay in peak 2 + 3 hr total > 100 uU

0 POINTS	3 hr delay in peak 2 + 3 hr total > 100 uU
0 POINTS	High fasting > 50 uU 2 + 3 hr total > 100 uU

IV. DIABETES

WILKERSON PT	INSULIN PATTERN
1/2-3 POINTS	Normal peak 2 + 3 hr total > 100 uU
1/2-3 POINTS	2 hr peak delay 2 + 3 hr total > 100 uU
1/2-3 POINTS	3 hr peak delay 2 + 3 hr total > 100 uU
1/2-3 POINTS	High fasting > 50 uU Peak delay 2 + 3 hr total > 100 uU
2 or more POINTS	All values < 30 uU 2 + 3 hr total < 60 uU

PRESENT THOUGHTS ON EXERCISE, WEIGHT, AND PERFORMANCE ABOARD NUCLEAR SUBMARINES

KENNETH R. BONDI, CDR MSC USN
NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
NAVAL SUBMARINE BASE NEW LONDON
GROTON, CONNECTICUT 06349

Both the lay and scientific literature concerning exercise, weight control, and mental performance, both as separate or combined topics, have taken a quantum leap in volume over the past five years. Because of nuclear submariners long periods of long confinement and demanding mental tasks, these topics are of interest to both them and those concerned with their short and long term health. The following is a compilation of our present thoughts derived from reports and unpublished data concerning weight loss, exercise, and performance aboard nuclear submarines.

Weight

Among Navy Medical Officers and dieticians it is a widely held belief that submarine crewmen tend to gain weight while on patrol. A cursory examination of the life aboard a submarine reveals several factors which are conducive to gaining weight. A man's work generally does not require much physical exertion, and non-work physical activity is restricted by the confined quarters. If significant exercise is to be obtained, it must be in the form of a program of work-outs. Although such programs are now generally encouraged, it is often difficult to find the time to pursue one, as the workload averages 12 hours a day (Beare, Biersner, Bondi, and Naitoh, 1980). On the other hand, food (generally considered to be the most appetizing in the Navy) is almost continuously available in any quantity desired, and the mess decks are the social center of the ship.

Analysis of pre- and post-patrol body weights of 245 men from the crews of four submarines showed that 25% of the men gained weight, 67% lost, and 8% did not change (unpublished data). Of those gaining, only 9% (of the total) exhibited a significant gain, arbitrarily defined as an increase of 5 or more pounds. There is little support for the widespread belief that men tend to gain weight during submarine patrols. From the magnitude of individual weight losses, it was inferred that as many as a third of the men were actively dieting. The data presented strongly suggest that weight gain while on patrol is not a significant problem for the majority of submariners. This is not to say that overweight does not afflict a substantial number of men in the submarine force, but it does imply that the primary causes of such overweight are not to be found on board the submarine.

Exercise

Two American studies have shown that non-exercising submariners will become deconditioned during the course of a 40-70 day patrol as measured by pre/post maximum oxygen consumption tests (Knight, et al, 13% ; Bennett, et al, 7%). If we can conclude from the literature that the deconditioned state is not healthy and detrimentally affects performance (see below), how can we motivate submariners to exercise? The simple placement of exercise devices aboard the submarine to be used at the convenience and desire of the crew does not work. We estimated through an informal survey that only 15-25% of a crew use available exercise gear while underway (unpublished observations). This unfortunate fact was confirmed by Vickers, et al. The bicycle ergometer placed aboard had numerous feedback features, yet the following remarkable results were obtained from 102 of the 135 crew members who volunteered for the study: Participants averaged 2.3 rides for every 100 man/days (approximatley 1 ride per man every 4 weeks); only 58% rode the bike even once and only 10% rode as many as 10 times. This study could not conclude, from the use of a number questionnaires, why submariners did not exercise and thus the problem of motivation still exists.

Performance

We recently, through a thorough analysis of the literature, have taken a position on the relationship between job performance and exericse (Bennett and Bondi, 1982). We stated that "routine aerobic activity as specified by the American College of Sports Medicine has a direct association in the improvement and maintenance of physical and psychological function. Some physical activity can lessen anxiety and depression and improve mental function. It physiological restorative and health preventative functions are important to submariners." Furthermore we believe that "the nature of the submarine mission itself leads to somewhat stressful conditions. Limitation of physical activity, desynchronization of circadian rhythms, adverse work-rest cycles, lack of privacy, and altered sleep patterns, may add to the difficulty of obtaining adequate physiological and psychological adaptation during patrol. It is our opinion that routine physical exercise aboard submarines will prevent physical deconditioning and assist in maintaining psychological well-being. Ultimately the effects on physical and mental fitness will have a positive impact on the morale and operational efficiency of the crew. As a result, the Navy may see a decrease in absenteeism, medical costs, and an increase in morale, job efficiency, physical appearance, and military readiness."

Recently, we tried to determine if simple cognitive function tests, given while exercising, were sensitive enough to be significantly altered by exercise training. From the analysis to date, there seems to be no difference in cognitive function whether subjects are sendentary or have gone through an exercise program.

The Future

If we conclude that submariners do not exercise enough and this is apt to detrimentally affect their health and performance and furthermore that if they will not exercise even if given the opportunity to on a state of the art exercise machine - what can be done? We are gambling that if we can make exercise fun and include peer pressure and a system of awards and other recognitions of achievement that they will participate. To this end we have developed a novel exercise ergometer on which games can be played, i.e., a game piece can be moved as a function of the power of the rider. The system consists of two ergometers (so that one can play against another), a microprocessor, video screen, mass storage (2 discs drives) printer, and the proper A to D interfacing. The prototype system is being tested and shows great promise.

REFERENCES

Beare, A. N., K. R. Bondi, R. J. Biersner, and P. Naitoh. Work and rest on nuclear submarines. Ergonomics, 24(8): 593-610, 1981.

Bennett, B. L. and K. R. Bondi. The relationship of job performance to physical fitness and its application to U.S. Navy submariners. NAVSUBMEDRSCHLAB Report No. 962, 1981.

Bennett, B. L. and K. R. Bondi. Unpublished data, 1983.

Knight, D. The effects of occupational exposure to nuclear submarines on human tolerance for exercise. FASEB Meeting, Atlanta, Georgia, 12-17 Apr 1981.

Vickers, R. R., T. Conway, J. Hodgdon, M. M. Duett. Motivational predictors of use of a stationary exercise bicycle during submarine deployment. Naval Health Research Center Report No. 82-29, 1982.

THE ANALYSIS OF FRENCH SUBMARINE ATMOSPHERE CONTAMINANTS.

J.P. MALASPINA - CERTSM - DCAN TOULON
F 83800 TOULON/NAVAL

Two objectives are presently fixed for the analytical control of the French submarine atmosphere, that is :

- regeneration follow-up,
- monitoring of the gas and particle pollution level.

The regeneration follow-up, mainly ensured by a continuous measurement of O_2 and CO_2 contents, is not within the scope of this paper ; thus we will only deal with the analysis methods of the contaminants present in the atmosphere of our submarines, and we will state the main results obtained.

Whatever the submarine type (conventional or nuclear SNLE, SNA), analytical techniques used are identical. Their implementation, however, depends upon the submarine mission.

That is,

- For conventional submarines, the complete monitoring procedure is applied only for the long-duration dives (PLD) following the construction or a major refit of the submarine ;

- For nuclear submarines "SNLE", a 2-year experimental phase has just been set up to know -as completely as possible- the nature of the organic pollutants present either as gases or vapours in the SNLE atmosphere, and to evaluate their concentration level. This experimental procedure is very likely to be extended to all patrols in a near future.

- For the nuclear submarine SNA, which entered service at the beginning of the year, we only have at hand the results of the tests and of the first long-duration crossing (TLD). Some of those results are very interesting. Extensive monitoring is planned for long-duration patrols only.

The analytical techniques applied are illustrated in table 1. We are going to review them in succession.

1. GAS POLLUTION

1.1 Shipboard gas analyzers

• Among contaminating gases, hydrogen evolving from the accumulator batteries or leaking from the water-electrolysis type oxygen-generating plants must be monitored continuously because of its very low inferior explosivity limit.

The shipboard ICARE hydrogen-meters utilize the thermo-conductive properties of hydrogen. The unique possibility of interference is CO_2 contents higher than 1 %, which curtails the analyzer response.

The alarm threshold has been set to 2 %, but the concentrations obtained in the air of our submarines are substantially lower.

• We also found it necessary to equip our submarines with total freon analyzers, not because of a toxic hazard, relatively low, presented by those chemical compounds, but in order to detect readily any leaks liable to occur in the shipboard refrigerating plants.

The equipment consists of ICARE infrared spectrometers. The results obtained vary considerably from one patrol to another and highlight the random feature of such pollution.

• Carbon monoxide, in fact, is now the only contaminant to be continuously monitored in our submarines because of its toxicity.

The shipboard MAIHAK equipment is also based on the principle of the infrared radiation absorption at 4.6 μm

On board our conventional submarines, the concentrations generally reach the MAC 90 value, i.e. 25 ppm, at the end of a long-duration dive. In the nuclear submarines SNA and SNLE, the average concentration values are markedly less high, but excursions sometimes occur above the MAC 90 in close correlation with difficulties.

• Excepting the above three constituents, it was not deemed necessary to monitor continuously the concentration of other air contaminants. This decision is justified, no doubt, by the absence of tobacco smoke pollution on board our submarines.

The No Smoking imperative, which is very well accepted, entails a diminution of the demand of activated carbon required for air purification ; thus the activated carbon quantity embarked aboard the SNLE (viz. 270 kg) usually is amply sufficient.

Other individual air pollutants are evaluated punctually by sampling, assuming that the mean value of all the measurements thus made corresponds to the actual mean pollutant concentration during the patrol time. It is obvious that the higher the number of such spot measurements, the more numerous are the opportunities for this assumption to be corroborated by the facts.

• Side by side with that, a particular effort was made to gain a better knowledge of the origin of the contaminants identified. The possible sources of contaminants have been divided into 6 categories (Table 2) :

- human
- alimentary
- equipment and materials
- fuels and lubricants
- decomposition products
- indefinite

Thus, should a contaminant concentration reach a critical value during a patrol, a preventive action may be taken at the possible origin(s) of the contaminant.

1.2 Gas detector tubes (DRAEGER)

The first method applied for the above mentioned spot measurements employs the DRAEGER gas detector tubes. It is the only detection means available for mineral pollutants. Eleven of the mineral pollutants liable to be present in a submarine atmosphere are periodically monitored in this manner. Eleven organic pollutants, selected because of their high toxicity or because they are not exhibited by other analytical techniques, are also measured by those tubes.

The only contaminant iteratively found with concentrations in excess of the standard is ozone in the electrostatic precipitators section whilst the precipitators were erroneously mounted (polarity inverted) or carelessly cleaned.

1.3 Porous polymer traps

The advantages and drawbacks of organic contaminant analyses after absorption by porous polymers (Porapak and Tenax) are given in table 3. The technical details of this method having already been stated, we will underline the results obtained, presenting successively the various contaminants found, classed by chemical families with their concentration range in the air.

The concentrations vary from 10 $\mu g/m^3$ (detection threshold with this technique) to more than 400 mg/m^3.
For a given contaminant, the concentrations vary within relatively narrow limits from one submarine to another, and, for the same submarine, from one patrol to another. Each vessel, however, tends to have its own signature, and, comparing the chromatographic profiles obtained from the traps, one succeeds in obtaining a kind of "atmospheric finger-print".

The toxicologic interpretation of the results of those analyses is based on the definition of a toxicity index (TI) for each chemical family :

$$TI = \sum \frac{\text{average concentrations of the pollutants of a chemical family}}{\text{MAC 90 of those pollutants}}$$

There is a problem where TI becomes higher than 1, which sometimes occurred for the aldehydes and alcohols.

1.4 Activated charcoal

The analysis of the activated charcoal filters, recovered at the end of a patrol after thermal desorption under vacuum, has a dual purpose :

- to determine whether the filter is saturated, by measuring the carbon impregnation percentage, which permits one to deduce the periodicity of replacement ;

- to exhaustively identify the pollutants caught in the activated charcoal, and, by comparison with those found in the porous polymer traps, to set the pollutants that are not or little retained by those filters.

The "desorbat" obtained , formed by two phases called "aqueous" and "oily", is analyzed by GC^2/MS/DS.

Table 4 lists the number of organic contaminants, identified on the one hand in the traps and on the other hand in the activated charcoal , classifying them by chemical families. Numerous others exist, to be sure, but at such concentration levels ($< 10\ \mu g/m^3$, i.e. $\simeq 10$ ppb) that one may be certain, at the present state of our knowledge, that they will not entail any toxic effect for the time of exposure corresponding to a SNLE patrol.

2. PARTICULATE POLLUTION

In this domain, no analysis means exist permanently aboard our operational units, but fairly extended investigations were performed during the SNLE and SNA trials at sea and during the long-duration dives of conventional submarines.

2.1 Size distribution of particles

This distribution has been established for various types of submarines using a ROYCO type 218 instrument, and has been compared to results obtained on surface vessels and in land-based buildings. The particle number and distribution vary depending upon the sections of the building or vessel : the most polluted places being always located in the vicinity of the propelling machinery.

2.2 Concentration of inhalable particles

Some measurements have been made aboard a conventional submarine using a TSI 3500 piezoelectric balance. Results obtained vary very much with the place and time of the samplings, and cannot be correlated with those obtained with the ROYCO instrument. The mean value for the concentrations obtained stands around 0.15 mg/m^3, the full range being from 0.01 to 0.70 mg/m^3.

2.3 Chemical nature of particles

The chemical nature of particles has been determined by electronic microscopy associated to a system of microanalysis by spectrometry X (EDAX) from samples taken from cascade-mounted 5μ and 0.4μ nuclepore membranes.

Most of the dust particles contained several chemical elements ; this seems to be an indication of an exogen origin.

The number of asbestos mineral fibers is much lower than the permissible concentration in breathable air.

2.4 Aerobiocontamination

The technique employed is that of impaction onto appropriate culture media. The total number of germs, of course, is higher in a conventional submarine than in a SNLE, but, qualitatively, the contamination is fairly the same, although mycologic contamination is more important aboard the SNLE.

CONCLUSION

However still imperfect, the analytical control we can presently realize aboard our submarines enables us to affirm that there is no major toxicologic problem and that the contamination, both by gases and particles, remains at a very satisfactory level.

This control, however, is still liable to be improved, and, in the future, our efforts will be oriented towards :

- a more severe control of the volatile and gaseous pollution, carried out, in the short term, by multiplication of the samples taken from the traps and DRAEGER tubes, and, in the medium term, by the definition and development of a centralized metering device. The basic physical principle of that device is not yet decided (micro-chromatography ? Mass spectrometry ? Infrared spectrometry ?).

(cont on p 187)

cont fr p 186

(2) the implementation of an analysis procedure for the polycyclic aromatic hydrocarbons (PAH), either free or linked to the particulate phase. and (3)

Side by side with that, CERTSM will carry on their effort to settle contaminants MAC value and improve already existing values.

Table 1

Present conditions of analytical checking in french submarine atmosphere.

REGENERATION FOLLOW UP

continuous measure of :

- oxygen (paramagnetism oxygenometer)
- carbon dioxyde (infrared spectrometry)

POLLUTION ANALYSIS

gaseous pollutants

* Continuous measure of

  - hydrogen (thermal conductivity)
  - total freons (infrared spectrometry)
  - carbon monoxyde (infrared spectrometry

* Gas detector tubes DRAEGER

  11 mineral pollutants
  11 organic pollutants

* Solid polymer "traps"

  Volatile organic pollutants

* Analysis of oil and water desorbed from activated carbon

Aerosols and particulates

* Size distribution (ROYCO 218)
* Concentration of respiratory size particulates (piezo electric balance)
* Chemical character (electronic microscopy + x-ray spectrometry)
* Aerobiocontamination (impaction or swabs)

TABLE 2

ACTUAL OR POTENTIAL SOURCES OF CONTAMINANTS IN SUBMARINE ATMOSPHERES

1. - **HUMAN SOURCES** -

   - Expiration (Acetone, isopren, acetonitrile)
   - Other excretions (methane, H_2S)

2. - **ALIMENTARY SOURCES** -

   - Cooking (aldehydes)
   - Drinks (ethanol)

3. - **FUELS - LUBRICANTS** -

   - Leaks of diesel fuel (hydrocarbons)
   - Oils and greases (hydrocarbons - esters)

4. - **MATERIALS - EQUIPMENT** -

   By emission, leak, thrown out :

   - Frigorific fluids (halons)
   - Paints, glues, cements, adhesives, sealers
   - Heat insulation (styrene)
   - Electric batteries (hydrogene, arsine, stibine)
   - Infirmary (ether, halothan)
   - Cleaning materials (ammoniac , halogenated hydrocarbons)
   - Cosmetics (esters)

5. - **DECOMPOSITION PRODUCTS** -

   - Normal (HCl, HF, CO)
   - Undesigned (HCN)

6. - **INDEFINITE** -

TABLE 3

SOLID POLYMER "TRAPS" OF ATMOSPHERE : ADVANTAGES AND DRAWBACKS

-=-=-

ADVANTAGES

- Fast and easy sampling
- Good preservation during 3-6 months
- Concentration of contaminants by a one hundred factor
- Wide spectrum of organic contaminants checked
- Easy identification by GC/MS/DS
- Low limit of detection (< 10 ppb or 10 $\mu g/m^3$)

DRAWBACKS

- Punctual values
- Critical quantitative analysis ⟶ bad accuracy ($\pm$ 50 %)
- Long analysis ($\simeq$ 15 days) ⟶ difficulty in going back to the source of contamination in case of trouble
- No results for mineral contaminants

TABLE 4

VOLATILE ORGANIC POLLUTANTS IDENTIFIED ABOARD FRENCH SUBMARINES

-=-=-

Chemical structure	Traps	Actived carbon filters		
		Oil	Water	Both (O + W)
Alcohols	19	18	16	2
Aldehydes	13	9	2	-
Cetones	13	6	3	-
Esters	16	11	1	1
Aliphatic hydrocarbons :				
- Saturated	61	-	109	-
- Unsaturated	17	3	31	-
Aromatic hydrocarbons	35	-	65	3
Halogenated hydrocarbons	24	-	6	-
Others	14	33	19	4
Total	212	80	252	10

DISCUSSION

HARRISON: Dr. Giacomoni, do you have any results from your submariners? That is, have you carried out any surveys in the submarines?

GIACOMONI: No.

LURIA: Dr. Giacomoni, if you want to give your submariners exercises to see if you can prevent this myopia, I'm not sure why you are afraid to let them know what you're doinq - why would it matter if thev know what you're up to?

GIACOMONI: No, we have not. I don't think so. We don't mind lettinq them know - perhaps it would be a problem if we say that we have the same thing about the eyes that we don't know. I say to Dr. Harrison that these results concern only our experimental data and that the mine is not exactly the same environment. I think that maybe we can find about the mine more space or distance perhaps. I will prefer to hear some results acquired about the mine before I speak about this.

BONDI: Mr. Chairman, if you will allow me, I spoke with you earlier before the session began, and I really was not going to give my formal presentation at 1515 so maybe I can make one brief comment now and then we'll have time to make up for my particular formal that we'll leave out later on. I'd like to address some of the things you brought up, Doug, in terms of carbon monoxide. I'd like to give it some further thought, but my thoughts right now rely on the fact that it looks like we are only getting 7-9 parts per million fairly consistently on all our nations' submarines and probably lower on the French submarines because of no smoking. Is that true? My thought would be rather to put our efforts into the mixture of gases that we were talking about earlier in the conference - that is looking at the synergistic effects of CO, CO_2 and NO2. That's what I think might be more fruitful, but again, that may need some more consideration. In the area of nutrition, my guess is that you should continue with surveys and become better on maybe what the actual calorie intake is for submariners and then from there we can begin to look at ways in which to improve their diet. As you know, that's one of the pleasures - about the only pleasure you get in being aboard a submarine - having good food, and I would guess that to make some changes there one should have some very good evidence that their being detrimentally affected. And the third area, of course, is fitness. In the write up that you'll see - in the 1000-word write up that I did in lieu of giving the speech this afternoon - we surveyed 6 boats now in terms of pre and post weight - only body weight - and invariably they lose 5 pounds at the end of the patrol, plus or minus 1 or 2 pounds. Exactly opposite of what anybody would have thought. On a couple of experiments that we've done, we found no redistribution of weight at least statistically that we could find through skinfold thickness measurements. We were under the assumption when we did one study that a person would go from that kind of shape to that kind of shape at least to skinfold measurements. We found no change, but again, the skinfold measurement, as you know, there is a lot of noise in those kind of measurements and also our 'n' was not very large, 17 that happened to be in another group we were studying in depth for cariovascular fitness. In that regard, in terms of cardiovascular fitness, we have on one study done a few years ago found a decrease of 13% post patrol in maximum oxygen consumption. Recently, Mr. Bennett, who just came back from a patrol this past year, found a 7% decrease in maximum oxygen consumption after a 60-day patrol. Again, with small 'n' values; unfortunately it is extremely difficult to get people to come into the laboratory after a 60-day patrol, as you can well imagine.

SMITH: I think that's something we've been meaning to do for a long time.

BONDI: We are never going to attempt it again I can assure you and that's why with the bicycles that you saw this afternoon - we are here hoping to get them early and late patrol, self-administered.

SMITH: That's why I think that if you can develop a simple test which the doctor or whoever can take to sea with him.

BONDI: Or the corpsman could run in our case. Yes, I agree one hundred percent. And then in terms of what we really should be looking for in fitness, again, it has the same idea of nutrition aspect that I talked about. That is even though you demonstrate that there is a decrease in fitness in submariners, the operational people are going to want to know are going to say so what, I don't care if their VO_2 max goes down 7% or 13% they work perfectly fine for me. So my idea is that we probably - if we think that fitness affects performance. Now for me or anyone else to prove that is an extremely difficult thing to do, I think.

SMITH: I assume that that question is soley pertains to the submariner only.

BONDI: Yes, that's right. It goes across all lines in terms of exercise. At any rate, in Mr. Bennett's study, he tried 3 or 4 different kinds of cognitive tests post-patrol and, again, because of the small 'n' values and because of the difficulty in relating cognitive performance with exercise, found statisticall at least in the preliminary analysis of his data, no difference. There was a study on the West Coast as a Master's Thesis and those results in terms of decrease in cardiovascular fitness, they used some measure which I forget now - it was not VO_2 max - they found significant decreases in fitness and they also found that with a bicycle placed aboard and there for ad lib use, that the percentage of people who used it was very minimal. And they gave a number of questionnaries to determine why people did or did not exercise and it turns out, from those questionnaires, they unfortunately were unable to answer why people do not exercise.

SMITH: Good questionnaire.

BONDI: Yeah, good questionnaire. It probably points up the difficulty in trying to really get at these things in a proper and significant way. Next year we hope to look at the relationship between performance and fitness in a little more stringent manner by doing the tests aboard submarines and by doing some fairly more sophisticated tests on cooperation with the vision department looking at visual evoked responses. My hopes aren't high but at least we're trying.

RADEZISZEWSKI: As regards the effects of lifestyle aboard submarines, we found to distinguish two kinds of effects. First, the rapid effect of confinement which starts from the beginning to the fourth or fifth day of confinement and which is significantly marked by an increase of weight so when one describes a five-pound increase of the weight of the submariner, the question is, is this an increase on the total 90-day submarine dive or is it a fast effect during the beginning 4 or 5 days of the patrol and then a plateau during the remainder. All our trials in our confined chamber, climatic chamber, we've observed the same thing - that's to say, a very quick increase -

BONDI: You mean decrease? I did say decrease, you realize a decrease of five pounds.

RADEZISZEWSKI: Oh, excuse me. I'm sorry, I misunderstood 'increase.'

BONDI: That's OK because everything you've said so far is all right. I suspect that there is an increase at the beginning of the patrol and then a not only getting back to normal but going below normal when people for a number of reasons are getting excited and feel they want to look a little more masculine for whom they're coming back.

RADEZISZEWSKI: The last point concerned the synergistic effect of carbon monoxide oxygen, and carbon dioxide. These effects concern only the level of carboxy-hemoglobin in the blood first and the kinetic effect of the third during the first day of exposure. The resident of the two parameters, carbon monoxide, hypoxia, and carbon dioxide, is the level of HbCO. So to study this effect, you must simplify the problem if you want to know the effect of carboxyhemoglobin, you can acquire a litre of carboxyhemoglobin in the climatic chamber without hypoxia and without carbon dioxide. The problem is legword - do you understand?

BONDI: I understand.

RADEZISZEWSKI: But there is no reason to have a specific effect of oxygen, a specific effect of carbon dioxide. I feel that it's determining the level of the kinetic effect of the ....curves on this kind of. There is no evidence of a specific and synergistic effect of these two gases on the different parameters. Maybe on the ECG but it is a problem. There is no way to separate the different gases.

HARRISON: I think it is important from what Dr. Bondi has said because the situation is different in the submarine and in the climatic chamber or environmental chamber. In our studies with carbon monoxide, we have looked at carbon monoxide alone. Now, is it a direct effect of carbon monoxide or is it related to the carboxyhemoglobin level. What you're suggesting is that the carboxyhemoglobin level will be different if you have variable oxygen levels and we accept that. But if all we're really interested in is the direct effect of the carbon monoxide, what was shown in this most recent study is that the number of people with p-wave changes is the same that is what we would have expected when a straight line verses a curve.

RADEZISZEWSKI: What do you mean the direct effect of carbon monoxide?

HARRISON: We don't know. I mean, we don't know why this effect has occurred. We don't know whether it is the carbon monoxide getting into the cardiac muscle or if it's a direct effect on the endocardium. We don't know whether it's an enzyme reaction inside the cardiac muscle, but all we can say is that the change has occurred.

RADEZISZEWSKI: But you discuss here of a possible mechanism which can explain the variations, the parameters which induce this variation, such as enzyme or electrical activity, is the decrease of the oxygen supply in use, or by hypoxia, or by carbon monoxide. And find which induce the variations is HbCO oxygen supply. There is more specific effect of carbon monoxide. All the explanation on the effect of carbon monoxide results show HbCO, even on anxiety.

HARRISON: Yes, but what I'm suggesting is that it may not be hypoxia, it may be a direct toxic effect of carbon monoxide. In other words, it may be a toxicological problem, not hypoxia.

SMITH: I think what John is suggesting, actually, is that although the CO_2 levels will be depending upon the oxygen pressure, the actual ^{P}CO will be different, will be more constant.

RADEZISZEWSKI: Can ^{P}CO induce a variation of oxygen supply in use or ....

SMITH: Accepted, that any particular ^{P}CO you're going to have a different percentage COHb which contains the oxygen, and I think that's what John is saying.

SMITH: The question is what about the differences, if you like, in the ^{P}CO-COHb ratio. Is it going to be of any consequence.

GIACOMONI: I have only to say that we have performed the same inquiries that Dr. Smith reported. On the population of 100 and 200 submariners and surface sailors, we find statistically the same concerning the deficient .... including the implementation of vitamins. The same results also for the weight-height-exactly the same and there was no difference after 15 years of study in submarines or in surface ships between the two samples for the men who were between 28 and 32 in age. But concerning the SDL cholesterol, we noticed first that it was the same for surface ships and for submariners but we noticed also and this is interesting - I don't make the study - we noticed that it ties in with your last slide, that in the first time of service in the navy, in our navy, these parameters are better for the sailor inquiry of some .... than in the first years of service it was better for the sailors but in the last years it was not so good. I think our sailors do not have good nutritional habits.

TAPPAN: Dr. Moeller has asked me to say something about the fact that 'k' the symptom denial should not be interpreted as denial of cardiovascular symptoms. Denial in the psychological sense is generally denying that anything is wrong.

HARRISON: This business that you were talking about that the submariners may be, as it were, supplicants of contagious disease, of becoming more social extroverts and less compulsive and more from the symptom denial. Is there any evidence that there is a personality change from the personality testing that you did on entry to the submarine service? In that you looked at submariners leaving against the sort of thing that you do on entry.

TAPPAN: I'm sure that there hasn't been any thorough examination or comparison on exiting submariners.

HARRISON: But I understand from when we visited the last time was that you carry out a fairly concentrated psychological screening test on submariners before they came into the submarine service. Is there any way in which you could look and see if there was any changes from entry?

TAPPAN: It would be very valuable I would think.

HARRISON: In effect you're effectively saying that the submarine service is perverting their personalities as it were. I mean that's a strong word to use, but I mean they are changing.

TAPPAN: Well, we don't know. I think that all this has shown is that in those 2 studies those particular factors seem to pop up but I don't know whether they were there originally.

MOELLER: May I interject something. We have been specifically trying to gain authorization to do follow-up testing and have now been successful.

HARRISON: Fine, thank you very much.

BONDI: Don, when you showed us the slides of submariners admitting to drinking twice as many drinks per week, the thought occurred to me just then that during the last year, well this was before they retired also, ten years before they retired.

TAPPAN: They said that had been their habits before they retired and the previous study was done on active-duty submariners.

BONDI: Right. Well the thought occurred to me that if they are out on patrol half their lives, are they just making up for it?

TAPPAN: There might also be some confusion there in the way they answered the question. That during the time they were drinking they drank a lot more. I don't think that has been completely cleared up.

CLOSING REMARKS

MARLOR: The hour is growing late and it's getting time to wrap up this phase of our meetings, but I think we still have one piece of unfinished business to attend to and that is the agreement on the little STANAG 1206. I think that Commander Holt is ready to report out on that. Is that correct?

HOLT: Thank you, Captain Marlor. I will be very brief. We found agreement too difficult on the subject. We did all feel very strongly that representation should be made to the major medical panel to change the wording of the STANAG to make it more clear. We did not feel it was within our realm to propose that wording, but we would like to ask that representations be made to make it clear that it is repeated exposures and also that we've reduced it to what we would call critical gases and vapors. The figures we agreed on were all seen, in alphabetical order, Arsine .05 ppm which is what was already on the STANAG, carbon dioxide 1.5%, and we decided we did not wish to specify that it was time rated, carbon monoxide 25 ppm, dichlorodifluoromethane 500 ppm, hydrocarbons - we felt they had no feel for because the information is lacking. We decided that we'd prefer to leave that one subject only to the view that we would expect that a practical recommendation would lie somewhere in the rate of 50-100 milligrams per cubic meter. Hydrogen, 2%. Oxygen 17-22%, and Stibine .05 ppm that is currently in the STANAG. Thank you sir.

MARLOR: Thank you very much. I think it speaks well for this type of a meeting where we can get together and come to agreements of this nature since, according to my records, this is standard consideration now for at least the last 5 years. I think part of the problem there was that on my list of custodians for STANAGs, I had the United Kingdom listed for 1206 and the United Kingdom had the U.S. listed for 1206. I think we've got that one straightened away now and hopefully we can get it on the road. I would remind you that the IEP B-52 meeting will be held in the morning beginning at 8 o'clock and not to forget, the continuation of these meetings, the visit to NMRI on Thursday and the visit to the Naval Research Laboratory on Friday. Before we close, I would like to ask Captain Marblé if he has any further comments or questions to make at this time.

MARBLÉ: (Translator) Thank you very much, Captain Marlor, for giving me the floor. First, I would like to express my thanks to you for having invited us to this conference. And second, we would like to thank Captain Milroy for the very nice party we had at his home and at the laboratory as well, the good work we have there. We would like to thank Captain Knight as well, who contributed I'm sure, to a very great extent to the organization of this meeting. I have a few comments: first, the working atmosphere was excellent between our delegations. Supporting evidence of that fact is that we all agreed on the list that was just mentioned. I think that the same thing will be applied to the other topics, and as far as STANAG 1184 - no decision has been taken yet. I find the other topics which are of a medical nature, I'm sure, will be discussed in the future between our experts. I think you told me you would like a meeting of that type to be held every year. I think that would be a good cruising speed. Maybe we should start thinking now on the subject of the next meeting next year. I would like, again, to express my thanks and I would like to add special thanks to the U.K and U.S. delegations for the nice gesture they had for our Eugeniuch Radeziszewski. Thank you again.

MARLOR: Commander Harrison, do you have some final words for us?

HARRISON: Captain Marlor, sir, thank you very much, indeed, for organizing this conference and for acting as the catalyst in setting it up in the United States. I would like first of all to thank Captain Milroy for the use of his laboratory and facilities and, in particular, Captain Knight for the splendid way in which he has organized the conference.

We agree with the French delegation that there is a need for a regular review and meetings in submarine medicine. It is the only way in which we can get together and we would help the research which is carried out, for example, in the submarine escape and rescue area, that this can be complimentary and that it can dovetail together so that possibly we could get to a situation where protocols, if not the same, are similar and the work - you can build up a better dose-response curve for the saturation type of experiment. Perhaps we can look into that. I would like to formally invite the United States Navy and the French Navy to participate in the 4th meeting in submarine medicine - tripartite meeting - next year at the Institute of Naval Medicine. We would hope that the program would include another section on submarine escape and rescue and in particular the lessons which we learn from the DSRV FLYAWAY exercise this summer and some of the research which by then will have been completed in our Physiology Laboratory. I don't have other subjects which I particularly feel should be on the agenda, but that is an area which I feel we would have some worthwhile discussion and have worthwhile evidence to report. It only remains for me to say on behalf of the United Kingdom delegation, a very, very big thank you.

MARLOR: Thank you, Commander. As most of you know, I'm not a researcher, I'm a bureaucrat and as a bureaucrat I shuffle papers. And most of the work that has been done for this conference has been done by Captain Milroy and his staff, especially by Captain Knight, because I was able to shuffle the paper up his way. So other than a few phone calls to the French and the U.K. embassies, I had very little part in the doing. Additionally, the cooperation of NMRI and NRL in hosting additional portions of this meeting are greatly appreciated. I appreciate all the effort, Bill, that you and your crew have put into this and I think it has been a worthwhile meeting. I'm sure that we have all at least had a chance to look at one another. I'm still not very good at dice, especially after one or two bits of libation. With that, I think we will call these proceedings closed.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NSMRL Special Report 83-1	2. GOVT ACCESSION NO.: AD-A133150
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Proceedings of the Third Tripartite Conference on Submarine Medicine—France, United Kingdom and United States, 9 and 10 May 1983	5. TYPE OF REPORT & PERIOD COVERED: Proceedings report
	6. PERFORMING ORG. REPORT NUMBER: NSMRL Special Report 83-1
7. AUTHOR(s): D. R. KNIGHT and K. R. BONDI	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Submarine Medical Research Lab. Box 900 Naval Submarine Base Nlon Groton, CT 06349	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Medical Rsch & Dev. Command Naval Medical Command, National Capital Region Bethesda, Maryland 20814	12. REPORT DATE: 1 June 1983
	13. NUMBER OF PAGES: 200
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

submarine medicine; submarine atmospheres; atmosphere contaminants; bone density; submarine escape and rescue; decompression illness; cardiovascular risk factors; carbohydrate metabolism

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The proceedings of the third tripartite conference on submarine medicine are reported. Five sessions were included in the 2-day conference, namely; 1) (STANAG 1206) Maximum Concentrations of Toxic Substances during Operational Conditions; 2) (STANAG 1184) Emergency Conditions at 1 ATA; Maximum Concentrations in Conventional Submarines; 3) The Toxicology of Atmosphere Contaminants in Submarines; 4) Escape or Rescue from Distressed Submarines; and 5) Effects of Lifestyles aboard Submarines on Human Performance and Function. (over)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

201

item 20--continued

Participants included scientists from the three nations -- France, the United Kingdom and the United States.

END