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CONTROL OF OCCUPATIONAL EXPOSURE TO INHALATIONAL ANESTHETICS - --ETC(U)
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Report OEHL TP-78-1

USAF OEHL TECHNICAL REPRINT

CONTROL OF OCCUPATIONAL EXPOSURE TO INHALATIONAL ANESTHETICS - CURRENT STATUS

JANUARY 1978

USAF Occupational and Environmental Health Laboratory
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

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1. REPORT NUMBER: OEHL-TP-78-1	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE *(and Subtitle)*: Control of Occupational Exposure to Inhalational Anesthetics - Current Status,	5. TYPE OF REPORT & PERIOD COVERED: Technical ~~Reprint~~ rept.,
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Charles E. Whitcher, MD, Stanford Univ Med Ctr James C. Rock, Major, USAF	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS USAF Occupational and Environmental Health Laboratory Aerospace Medical Division (AFSC) Brooks AFB TX 78235	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: January 1978
	13. NUMBER OF PAGES: 21
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*: 25p.	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)*

Anesthesiologists	Inhalation Anesthetics
Anesthetic Agents	Operating Room Environment
Anesthetic Gas Scavenging System	Occupational Exposure
Anesthetists	Occupational Health
Environmental Health	Waste Anesthetic Gases

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A complete waste anesthetic gas management program includes application of a well designed waste anesthetic gas scavenging system, anesthetists using work practices which minimize gas leakage, and application of a routine equipment maintenance program so gas leaks are minimized. Work practices of the anesthetist may contribute from 94% to 99% of all waste anesthetic gases in an operating room equipped with properly designed and maintained scavenging components. Improper practices, such as poor choice of the face mask, insufficiently inflated endotracheal tubes, and spillage of volatile anesthetic agents when

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filling vaporizers, are the chief contributors. Once the proper equipment has been installed, and proper work practices have been established, the Environmental Health Section should initiate a periodic monitoring program geared to detect leaks and the Medical Equipment Section should initiate a compatible preventive maintenance program. This report provides anesthesia-oriented personnel with information necessary to minimize occupational exposure to inhalational anesthetics. (15 References)

USAF OEHL TECHNICAL REPRINT NUMBER 1

CONTROL OF OCCUPATIONAL EXPOSURE TO INHALATIONAL ANESTHETICS - CURRENT STATUS

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JANUARY 1978

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PREFACE

This Report represents the first in a series of technical reprints to be offered by USAF OEHL. Whenever we find a good reference which we believe to be timely and of immediate use to bioenvironmental engineers throughout the Air Force, we will do our best to put that information into your hands.

Many bases are facing the problem of establishing some sort of waste anesthetic scavenging system in medical and dental surgical suites. At the present time, NIOSH has published a recommended standard for occupational exposure to waste anesthetic gases and vapors, the draft of an AFOSH standard is being reviewed, the draft of a revision of the National Fire Protection Association NFPA 56-A is being reviewed, and there is much confusion. We believe that this Report, prepared by Dr. Charles E. Whitcher, Stanford University Medical Center, and amended in accordance with his letter of December 1977 to Major James C. Rock, USAF OEHL, represents the best advice currently available on this subject.

FOREWORD

Control of waste anesthetic gases in the operating room environment must be a team effort. The team should include representatives from the Environmental Health Section, the Medical Equipment Repair Section and the Anesthesiology Section of the hospital. Failure of any team member to complete his task may negate the efforts of the team as a whole. To emphasize this point, let me summarize from DHEW (NIOSH) Publication No. 77-140, "Criteria for a Recommended Standard . . . Occupational Exposure to Waste Anesthetic Gases and Vapors," March 1977.

A complete waste anesthetic gas management program includes (1) application of a well designed waste anesthetic gas scavenging system, (2) anesthetists using work practices which minimize gas leakage, and (3) application of a routine equipment maintenance program so gas leaks are minimized. Whitcher et al (DHEW-NIOSH Publication No. 75-137, Reference 14) estimated that work practices of the anesthetists may contribute from 94% to 99% of all waste anesthetic gases in an operating room equipped with properly designed and maintained scavenging components. Improper practices, such as poor choice of the face mask, insufficiently inflated cuffs on endotracheal tubes, and spillage of volatile anesthetic agents when filling vaporizers, are the chief contributors. Once the proper equipment has been installed and proper work practices have been established, the Environmental Health Section should initiate a periodic monitoring program geared to detect leaks and the Medical Equipment Section should initiate a compatible preventive maintenance program.

James C. Rock

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CONTROL OF OCCUPATIONAL EXPOSURE TO INHALATIONAL ANESTHETICS - CURRENT STATUS

Charles E. Whitcher, M.D. Stanford, California

INTRODUCTION

The purpose of this course is to provide anesthesia-oriented personnel with information necessary to minimize occupational exposure to the inhalational anesthetics. Such exposure may be hazardous to the health of exposed personnel. Without control measures N_2O may be present in the operating room air in concentrations of 100-1000 ppm. The methods described have reduced N_2O to approximately 10 ppm; halothane and enflurane to approximately 1/60 and 1/30 respectively of the prevailing N_2O concentrations. These methods are compatible with modern, safe anesthetic practices and are easily employed by the anesthetist.

Evidence of health hazards in the operating room is based on epidemiological survey studies and laboratory experiments both in man and in animals. The results of three large retrospective survey studies completed in this country and in the United Kingdom have recently been combined and consistent findings include: (1) A significant increase in spontaneous abortion among female physicians who work in the operating room; (2) A significant increase in birth defects in live-born children of women physicians exposed to the operating room; (3) Male anesthetists compared to non-anesthetist physicians show a significantly increased incidence of liver disease.

Experimental evidence is supportive of the suggestion that health hazards are actually caused by anesthetic exposure. Rats and other animals show decreased survival upon chronic exposure to trace concentrations of various anesthetics. Rats exposed to trace concentrations of halothane during gestation show decreased performance in solving maze problems. Ultrastructural changes have been described in rat brain, liver and kidney as a result of a single maternal exposure to halothane during fetal life. Exposure to 20% N_2O causes testicular damage in rats. Skeletal abnormalities are regularly caused by chronic exposure to anesthetic concentrations of various inhalational anesthetics. Performance of humans in completing complex tasks is compromised upon acute exposure to trace concentrations of N_2O, and mixtures of this gas with potent agents.

Not all investigators are convinced that the health hazards of the operating room are caused by anesthetic exposure. Stress has been cited as a possible alternate cause. Attempts to repeat the performance studies mentioned above have been unsuccessful, but methods employed were different.

The evidence of toxicity has proved sufficient to recommend the use of control measures to hold occupational exposure to the lowest feasible levels. Such

a recommendation has previously been made by pertinent ad hoc committees of the ASA and the ADA. JCAH is also concerned. The National Institute for Occupational Safety and Health has drafted a standards criteria document which is presently under review by the Occupational Safety and Health Administration (OSHA). If approved, control measures will be required by law.

SOURCES OF GASES, DISTRIBUTION, CONCENTRATIONS

Anesthetic gases are present in the operating room air whenever they are administered to the patient. In the absence of control measures, the most important leak sources are the relief valve of the absorber and the ventilator. When effective control measures are in use, other leak sources become more noticeable. These include the high pressure N_2O system which is comprised of the wall connector and various components of the anesthesia machine up to the flowmeters. Further leakage is present in the low pressure components, comprised of the flowmeters, absorber and breathing tubing. An important leak source relates to careless handling of anesthetics, such as, turning the gases on, then engaging in unnecessary conversation with the patient prior to application of the facemask.

Whatever gases leak into the room are quickly distributed by the air conditioning system. Air conditioning systems of two main types are in use including the one-pass or nonrecirculating system in which fresh air is taken in from the outside and circulated through the room; 100% is returned outside. With such systems waste gases can be disposed of at the exhaust grille.

Recirculating systems return part of the exhaust air to the intake. With recirculating systems waste gases cannot be disposed of at the exhaust grille. Recirculation is practiced to increase operating economy. However economy can be achieved by other means. For example nonrecirculating systems can include heat exchangers. When anesthetic gases are released into the room air, they are stirred by the air conditioning system. The heavier agents do not settle to floor level. When leakage is well controlled, mixing of anesthetic gases with room air may be efficient, and air samples obtained anywhere in the room may contain similar concentrations of anesthetic agents. In this circumstance, concentrations of gases are predictable and depend on the rate of leakage in relation to room volume and fresh air dilution by the air conditioning system. For example, when 100 cc/min of a gas leaks into a typical operating room, 20 x 20 x 10 feet provided with 10 fresh air exchanges/hour, the concentration of gas at equilibrium is 5.3 ppm. If the fresh air exchange rate is doubled the gas concentration is halved.

In the absence of control measures, N_2O may be present in the operating room in concentrations of 100-1000 ppm; halothane 1.5-15 ppm. With an effective control program it is feasible to hold N_2O concentrations in the operating room below 5-10 ppm, and halothane below 0.1-0.2 ppm. In the dental operatory N_2O may be held slightly higher. OSHA standards presently under consideration allow N_2O up to 25 ppm in the operating room, 50 ppm in the dental operatory; potent agents up to 1 ppm.

CONTROL MEASURES

To reduce concentrations of inhalational anesthetics in the operating room to a minimum, no single control measure by itself is sufficient. Scavenging is one of the essential measures and is defined as the collection of waste anesthetic gases at the various breathing systems and their disposal outside the building. Carelessness in handling anesthetic gases must be avoided. Preventive maintenance standards for the anesthetic equipment must be higher than in the past and supplemented by frequent leak testing procedures by in-house personnel.

Even the above procedures do not assure the lowest achievable inhaled concentrations. Leakage, especially of N_2O, is prone to occur in unexpected locations where detection is difficult. Assurance of effective control is provided in the air monitoring program in which gas concentrations present in the operating room air are actually measured.

Low-Leakage Anesthetic Equipment

Anesthetic equipment should be designed not only for the safe, effective administration of anesthesia but also with the intent of minimizing occupational exposure. Certain equipment presently in use is incompatible with minimal environmental gas concentrations, particularly older relief (popoff) valves and certain ventilators. Appropriate equipment has been cited; a performance standard presently under development (ANSI) should further protect the purchaser.

Equipment Maintenance

Periodic preventive maintenance of anesthetic equipment by qualified servicing personnel is essential. Leakage in the absorber system following preventive maintenance can be held to less than 20 cc/min at a pressure of 30 cm H_2O. Proposed OSHA standard calls for preventive maintenance at least quarterly following which leakage in the absorber is to be held to less than 100 cc/min at a pressure of 30 cm H_2O.

Leak Test for Absorber

Leakage in the CO_2 absorber system occurs frequently. As a replacement for the usual relatively crude, qualitative pressurization test a more sensitive quantitative test can be performed with almost equal speed and ease. The new test depends on the principle that a relatively gastight absorber system leaks less than 100 cc per minute at a constant pressure of 30 cm H_2O. To perform this test the absorber is assembled for clinical use, with breathing hoses, bag and Y-piece attached. A flow rate of O_2, 100 cc/min, is established on a low-range flowmeter. With the Y-piece occluded the flush valve is opened until a pressure of approximately 30 cm H_2O should either hold or slightly increase during a few seconds of observation. If desired the flowrate of O_2 can be adjusted to hold constant pressure thus precisely quantitating the leak rate.

Collection of Waste Gases, CO_2 Absorption System; Ventilator.
Because the anesthetist often switches between hand-breathing and ventilator, we suggest the use of a Y to receive the overflow simultaneously from the ventilator and the absorber (Figure 1). This arrangement permits all connections before anesthesia is induced, and reduces the possibility of pollution due to oversight in changing connections.

Pediatric Breathing Systems.
Pediatric breathing systems present a challenging scavenging problem. Several devices have been marketed without documentation of scavenging performance. An exception is a nonrebreathing valve with scavenging attachment (Dupaco) which is gastight. The devices which we have developed for use with the Jackson-Reese system are also gastight. They offer a high degree of protection against accidental occlusion of the outflow tract due to twisting of the tail of the bag. The first arrangement (Figure 2) prevents outflow occlusion by means of a plastic wafer which is inserted through the bag tail. For intermittent positive pressure breathing the tail is easily compressed either with the fingers or with a clamp. We have also described the use of a length of plastic tubing (Figure 3) inserted through the bag tail. Intentional occlusion for IPPB must be secured with a clamp. Neither of these devices have been marketed but they are easily assembled using readily available components.

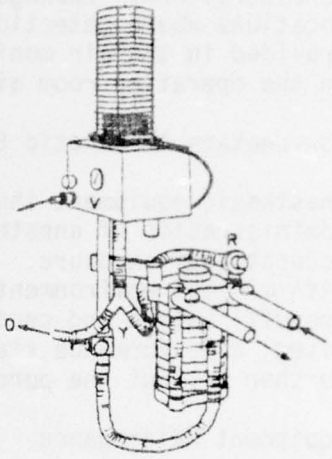

Figure 1

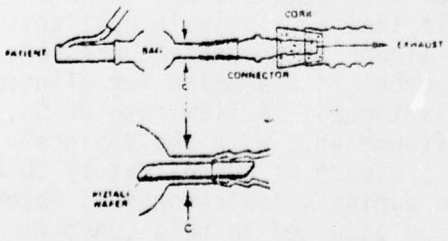

Figure 2

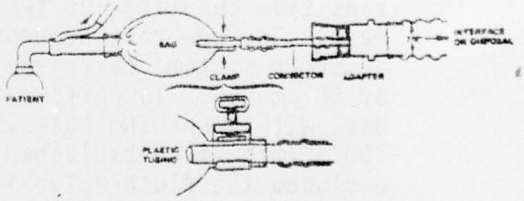

Figure 3

Dental Anesthesia/Analgesia. A difficult scavenging problem is presented by the dentist who employs N_2O. The dentist often prefers loose application of the nosepiece. An effective, satisfactory scavenging nasal mask has been developed (McKesson, (Figure 4) which is essentially a mask-within-a mask, with suction in the space between masks. Leakage does not occur even when the mask is not applied to the patient.

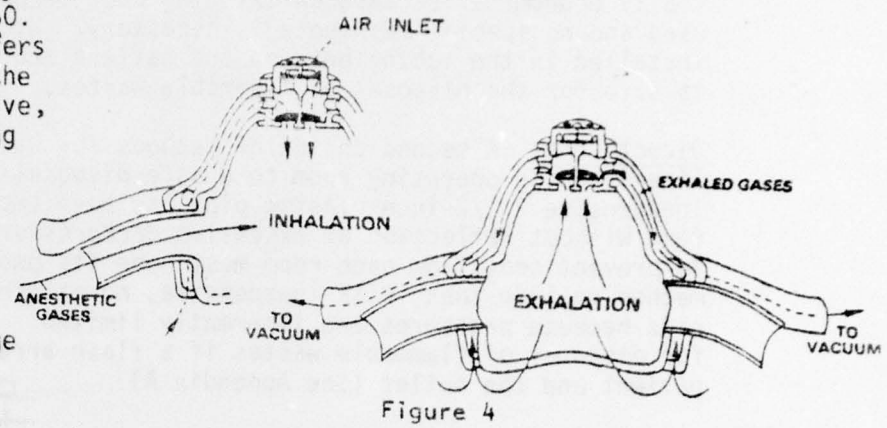

Figure 4

Disposal of Gases. Disposal of anesthetic gases is a frequent source of concern. Methods which are not effective include dumping the overflow gases at floor level. Activated charcoal will absorb halogenated agents but is relatively ineffective for N_2O. Use of the closed breathing system does not obviate the need for control measures. Acceptable disposal methods include the exhaust of the nonrecirculating air conditioning system, a direct line outside the building, and the central vacuum system.

Air Conditioning Exhaust. When the air conditioning system does not recirculate, the preferable disposal method usually employs the air conditioning exhaust. The use of this system is facilitated when an exhaust grille is conveniently located close to the anesthesia machine. The effluent from the relief valve and ventilator is terminated at the grille where the rapid flow of exhaust air sweeps the waste gases into the duct.

Unfortunately, many operating rooms are not equipped with conveniently located exhaust grilles. In this event it is a temptation to run long lengths of tubing across the floor, a practice which is hazardous. Where the grille is inaccessible, the tubing should follow the perimeter of the room. If the tubing must pass a doorway, it should follow the door frame. Protection against occlusion is provided by the use of collapse-resistant tubing such as industrial-grade garden hose. A more satisfactory method is to conceal the piping to the air conditioning exhaust duct. The waste gas line takes the same route as the lines for fresh gases and suction. If a ceiling-supported gas/suction source is used, the waste gases are conducted via the standpipe to enter the exhaust duct above the ceiling. If a wall-supported gas/suction source is used, the waste gases are conducted to the wall and then to the exhaust duct. If negative pressure in the disposal line should be excessive as indicated by the anesthetist's complaint that the breathing bags are being collapsed, this pressure can be brought closer to atmospheric levels by joining the disposal line to the exhaust duct at a point closer to the exhaust grille.

Advantages in the use of the air conditioning exhaust include that negative pressure is low and therefore not hazardous to the patient. It is potentially economical because an existing duct or pathway to the outside is used and no special machinery is necessary. With a suitable flash arrestor installed in the tubing between the patient and the ventilator, this method is safe for the disposal of flammable wastes.

Direct Vent. A second choice of methods for waste gas disposal is a direct line from the operating room to a safe disposal site outside the building. Inexpensive 2 1/2-inch plastic pipe has been employed in lengths of 200 feet without reflection of excessive backpressure to the breathing system. To prevent crossflow each room must have its own line. Advantages of this method include that it is inexpensive, no machinery is required and it is safe because pressures are inherently limited. This method is only safe for disposal of flammable wastes if a flash arrestor is used between the patient and the outlet (See Appendix A).

Flammable agents may be disposed of via the nonrecirculating air conditioning system. When this route is not available, a dilution method is appropriate (Figure 5) in which an exhaust fan provides a flow sufficient to dilute all gases below the flammable range (Kenneth F. Wiley of Collins and Rimer, Cleveland).

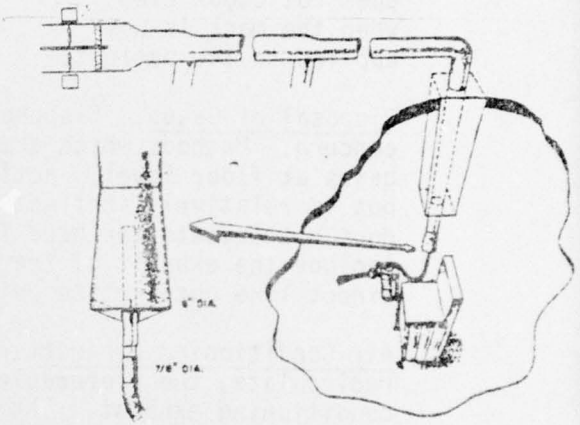

Figure 5

Central Vacuum System. The central vacuum system may be considered for disposal of nonflammable agents. Usually this method is complex and expensive in comparison to the method compatible with the dentist's scavenging mask and it may be preferred in certain institutions.

To protect the patient, unregulated line vacuum must not reach the breathing system. This requires a means of pressure balancing (interfacing). Design is critical in providing both protection of the patient, and low-leakage performance. With the interface shown (Boehringer) (Figure 6) the effluent from the relief valve enters at P, where a scavenging reservoir bag R provides compliance, absorbing surges due to IPPB thus preventing leakage. Suction flow is continuously measured with the flowmeter and adjusted slightly in excess of fresh gas flow. This excess is made up by room air which enters the relief opening N. Anesthetic gases enter at the bottom of surface where they are removed by suction.

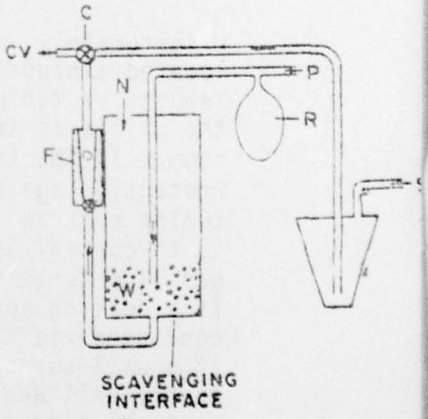

Figure 6

The ideal is to provide separate suction outlets for scavenging and for removal of secretions. If only a single outlet is available, the complete system shown (Figure 6) should be employed. Suction catheter for the patient enters suction bottle at S. Relief valve from absorber enters at P as mentioned above. Suction line to wall is attached at CV. Selector valve C permits emergency diversion of all suction for removal of secretions, without disturbing flowmeter setting. Maximum convenience is achieved by mounting all suction equipment on the gas machine, including pressure balancing system, scavenging suction flowmeter and selector valve and patient suction bottle. Maximum safety is achieved when all controls are located within easy reach of the anesthetist.

A compact valvular pressure relief system is available (Foregger). Negative relief valve prevents excessive negative pressure. Scavenging reservoir bag for breath-by-breath storage of exhaled gases holds positive pressure below levels capable of opening the positive relief valve thus preventing leakage except in case of accidental occlusion of the disposal line.

Educational Program

Leakage resulting from thoughtless or careless handling of anesthetics is minimized through continuing educational and public relations programs. Anesthetists should be encouraged to fill vaporizers with minimum spillage, to employ meticulous care in the choice and application of face masks, to avoid unnecessary conversation with the patient, once the gases are turned on, to employ anesthetic techniques whenever possible which are subject to scavenging (minimize use of unscavengable open techniques) and to make consistent use of the available scavenging equipment. When the air monitoring program is properly conducted, it provides a subtle constructive method of reminding the anesthetist to continually strive to minimize occupational exposure to anesthetic agents.

AIR MONITORING PROGRAM

Only by measuring anesthetic gases actually present in the operating room air can it be assured that the other waste gas control measures are truly effective.

Gas Analysis; Infrared Analysis

Air samples obtained in the operating room may be sent to a commercial laboratory. Such a laboratory (Boehringer) can supply all sampling equipment and report concentrations of both N_2O and potent agents. A serious disadvantage of this method is the delayed reporting. The precise circumstances of sampling are likely to be forgotten and the effect of corrective measures cannot be immediately assessed. Moreover, the analysis of a large number of samples is expensive.

A more satisfactory method is to perform gas analysis in-house. The available infrared analyzers for N_2O easily measure trace concentrations of this gas in

the operating room. Certain infrared analyzers are capable of determining the halogenated anesthetics, but such analysis is fraught with many technical difficulties. Infrared analyzers do not distinguish among the various potent agents. Results are subject to artifact due to contaminants often present in the operating room such as isopropyl alcohol, formalin, ammonia and freons. Other analytical methods such as gas chromatography and mass spectroscopy are difficult or expensive. Technological limitations in the analysis of the potent anesthetics, considered with the concept (described later) that N_2O can serve as a tracer of the potent agent administered with it have led to the recommendation that the air monitoring program be based on the infrared analysis of N_2O alone.

Infrared analyzers operate on the principle that most gases present unique infrared absorption spectra. A typical infrared analyzer for N_2O (Figure 7) includes a pump which continuously perfuses the sample cell with N_2O in air. The infrared source generates a light beam which is filtered to pass the infrared component at a wavelength restricted to approximately 4.5 microns. This beam is transmitted through the windows of the sample cell and then sensed by the detector. The higher the concentration of N_2O the greater the absorbance of infrared light and the lower the energy level at the detector. The resultant signal is processed and displayed in terms of ppm N_2O. Suitable analyzers are available from Cavitron, Foregger, Ohio and Wilks.

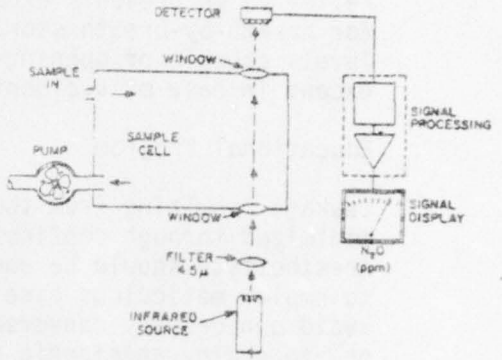

Figure 7

Air Sampling Techniques; Time-Weighting

The air sampling technique is critical in obtaining samples which are representative of gas concentrations inhaled by personnel. An important consideration is that anesthetic gas leakage is apt to be intermittent. Figure 8 represents a chart recording of N_2O concentrations continuously measured during routine clinical anesthesia. All N_2O control measures are in effect. Sampling site is the exhaust grille of the air conditioning system where an average mixed sample of room air is obtainable. N_2O concentrations shown vary from 4 to 97 ppm. It is apparent that the presence of such leakage makes for difficulty in obtaining any single grab sample which is representative of inhaled concentrations.

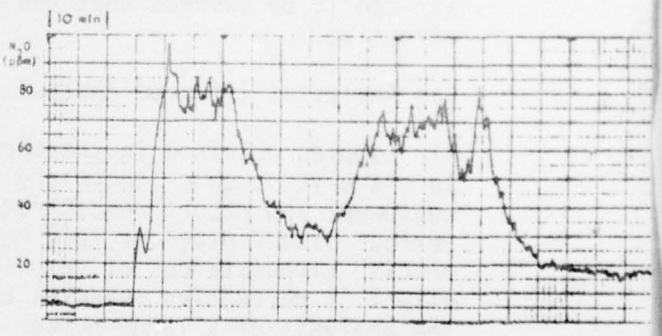

Figure 8

A representation of the average inhaled concentrations can be obtained in a time-weighted sample collected throughout the anesthetic period. Such a sample could be obtained with a battery powered sampling pump operating at a constant rate with storage of the sample in a gas-tight bag. Analysis of N_2O in the bag yields the time-weighted value.

Another method of time weighting is to average the results of many "grab" samples. Such samples obtained at a later hour each day of sampling average short-term variations in gas concentrations related to anesthetic techniques employed and induction and recovery phases.

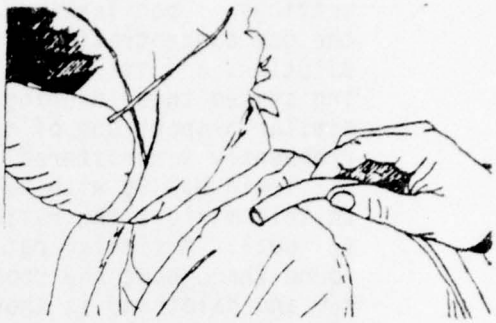

Figure 9

Air samples obtained within the breathing zones of personnel are representative of gas concentrations actually inhaled. The breathing zone has been defined as a frontal area within 6-10 inches of the nose. A convenient breathing zone site is the midpoint of the clavicle (Figure 9).

Breathing zone sampling is to be distinguished from general area sampling. Area sampling is justifiable only when it has been clearly demonstrated that gases are evenly distributed. This requires the analysis of multiple samples in each room.

In the operating room when all leakage is under effective control, gas concentrations are apt to be similar throughout the room. In this event, area sampling is appropriate. In the dental operatory, even with the most effective available control measures, considerable gas leakage is apt to occur from the region of the mouth and nasal mask. Here distribution in the room is always uneven and breathing zone sampling is strongly indicated.

Gases to be Monitored: N_2O as a Tracer of the Potent Agent

The theoretically ideal air monitoring program might measure all anesthetic gases employed in the suite. However, it could be much simpler to monitor one agent rather than two. If the single agent selected for monitoring could serve as an indicator or tracer of the other, then information would be available on both agents.

The choice of agents for monitoring cannot be based on determined toxicity. It is not known whether N_2O is more or less toxic than the more potent halogenated anesthetics; no distinction among the potent agents is possible. N_2O is chosen for monitoring on the basis of frequency of occurrence of

insideous leakage and technical feasibility of routine measurement. Further indications for an air monitoring program based on N_2O is that this gas can serve as a tracer of the potent agents administered in combination with it.

The tracer concept is applicable to high flow breathing systems in which the concentrations of gases are controlled by the flowmeter settings. Upon leaking into the room air, the gas concentrations are reduced by dilution, and stirred by the air conditioning system thus insuring the persistence of similar proportions of gases. A gas mixture frequently administered to the patient includes 3:2 l/min N_2O/O_2 with halothane 0.05 l/min. In this mixture the ratio of N_2O to halothane is 60:1. A similar ratio is likely to be found throughout the room. Parallelism of N_2O and halothane is shown in simultaneous measurements obtained during clinical anesthesia (Figure 10). Non-steady state conditions and leakage, not measured by flowmeters could disturb an approximately 60:1 ratio of N_2O to halothane. Such disturbance is often transient and possibly insignificant for purposes of routine air monitoring. Transient increases in gas concentrations may occur when high pressure N_2O lines are disconnected and when vaporizers are filled.

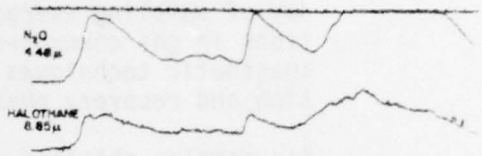

Figure 10

Measurement of Total Leak

N_2O concentrations determined during clinical anesthesia measure total leakage, including that related to the techniques of the anesthetist, high and low pressure components of the anesthesia machine, and the ventilator. A practical method of determining total leak is to survey the operating suite, employing the N_2O analyzer operating on battery power. If the N_2O concentration is low (less than 25 ppm), the result is recorded and the analyzer is moved to the next room. If a high value is obtained, the analyzer is employed as a leak detector in a brief search for the source of leakage. If the leak is corrected, a reduced N_2O concentration is noticeable within minutes. This test might be completed at least weekly; proposed OSHA standard is at least quarterly.

A persistently high concentration of N_2O present in a room without obvious explanation suggests leakage in the anesthesia equipment. Significant leakage in low pressure components including the absorber is easily excluded by the leak test previously described. Leakage in the high pressure N_2O system likewise is easily determined when the infrared N_2O analyzer is available as described below.

Measurement of High Pressure Leak

The N_2O analyzer provides a practical method of rapidly surveying the entire suite for high pressure leakage. Conditions for the high pressure leak survey include having the high pressure hoses attached to the gas machines, with flowmeters off. Anesthetics must not have been used for at least an hour before this test. With the analyzer warmed up, zeroed, and operating on battery power, each room is surveyed in sequence. A concentration of N_2O less than approximately 2 ppm indicates reasonably tight high pressure components. If a higher concentration is found, it is quickly localized, employing the analyzer as a leak detector. Results of a high pressure leak test are shown (Figure 11). The operating rooms in the suite are noted on the horizontal axis. It is apparent that a high concentration, 57 ppm is present in Room 1. This room had demonstrated a concentration of only 1 ppm a few days earlier. Leakage was localized to a crack in an N_2O line within the anesthesia machine.

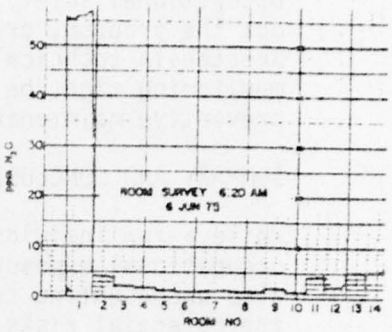

Figure 11

This machine, however, was serviceable for clinical anesthesia. In the absence of the high pressure survey, leakage could have gone undetected for a long time. This test might be completed monthly, and in the proposed OSHA standard, this test is required at least quarterly.

The N_2O analyzer is a useful teaching device and it can enhance the safety of the patient. When the N_2O analyzer is continuously operated during anesthesia, it can instantly inform the anesthetist of work practices which pollute, and immediately demonstrate the results of corrective measures as well as providing objective evidence of gas-tight fitting of the face mask. The earliest warning of disconnection in the breathing system has been repeatedly observed as a rise in room concentration of N_2O. The sensitivity of this method is suggested in the recording of N_2O concentrations shown (Figure 12). Here the breathing system was intentionally disconnected for suctioning the patient. The prompt rise of N_2O within a few seconds, is notable. Conversely, evidence of gas-tight fittings throughout the breathing system including the endotracheal cuff is provided in low prevailing concentrations of N_2O.

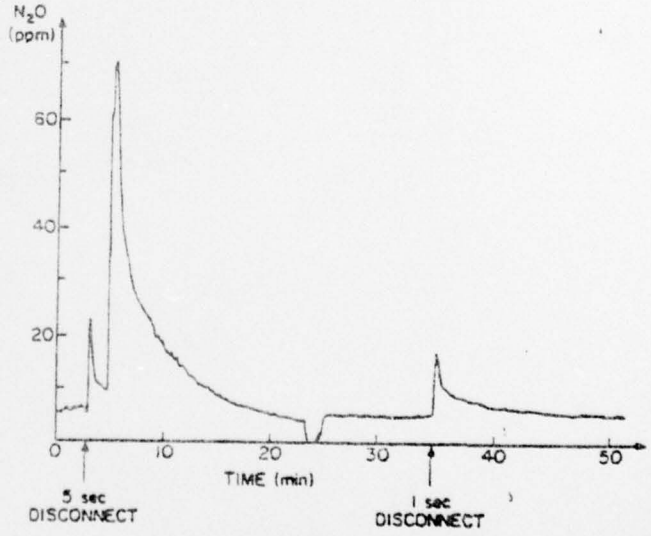

Figure 12

Air monitoring should be accomplished by a suitably trained person. The occupational safety and health department of the hospital might carry out the program, or selected individuals among the anesthetists or anesthesia technical staff. Where no N_2O analyzer is available, air monitoring might be done by the servicing organization responsible for preventive maintenance of the anesthetic equipment.

SUMMARY AND CONCLUSIONS

While a few individuals might choose to accept the undefined risks of occupational exposure, to do so is to expose not only ourselves, but also unconsenting surgeons, nurses and technicians. In the light of the potential risks, it seems reasonable to make use of all available control measures whenever inhalational anesthetics are employed.

It appears that in the near future we will be required to make regular use of effective control measures that are compatible with widely employed anesthetic techniques. These measures include use of low-leakage anesthetic equipment, regular preventive maintenance and leak testing procedures and low-leakage work practices. The effectiveness of these measures is best assessed via the air monitoring program.

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APPENDIX A

STANFORD UNIVERSITY MEDICAL CENTER
STANFORD, CALIFORNIA 94305 • (415) 497-6411

STANFORD UNIVERSITY SCHOOL OF MEDICINE
Department of Anesthesia

December 9, 1977

James C. Rock, Major, USAF, BSC
Consulting Bioenvironmental Engineer
Department of the Air Force
USAF Occupational and Environmental Health Laboratory
Brooks Air Force Base
Texas 78235

Dear Major Rock:

It seems that I should respond in writing to your thoughtful letter of November 3 and our telephone conversation of December 1, 1977.

The use of a flame arrester such as you have suggested should make it perfectly safe to dispose of flammable mixtures via the direct line connecting the relief valve of the anesthesia machine to the atmosphere outside the building.

The direct line then becomes a universal disposal method, applicable regardless of anesthetic agents whether flammable or nonflammable and irrespective of the air conditioning system whether recirculating or nonrecirculating. Any necessity for the use of complex disposal methods would be markedly reduced of not obviated, such as dilution of the anesthetic mixture in the operating room by means of fans and the use of the central vacuum system with water sealed vacuum pumps.

In suggesting the probable safety of disposal of flammable anesthetics via the spark-arrester protected direct line you cite the extensive and favorable experience of the military in the use of flame arresters in venting storage tanks of flammable fluids. I suspect that a similar favorable experience has been achieved in the petroleum industry. I have contacted a firm which manufactures and distributes flame arresters. We shall obtain a suitable arrestor and install it here after we have considered some independent tests.

As to any necessity for the use of water-sealed vacuum pumps in the disposal of flammable anesthetics, Mr. David McWhinney of the Compressed Gas Association is aware of at least two documented cases of explosions in central vacuum systems employed in the disposal of flammable agents. It is thus possible that the CGA position is reasonable.

A more delicate question is whether flammable anesthetics should be employed at all. A strong tide is in motion to eliminate the use of such agents. The most reasonable case might be made for the use of fluroxene, because of its unique pharmacological properties, but even this agent has been removed from the market because of borderline flammability. It appears to be purely a question

of time until flammable anesthetics are totally unavailable.

My final point is that with one qualification, you are welcome to use my publication on control of occupational exposure as mentioned in your letter. This is that you include mention of your suggestion of the use of flame arresters and my positive reaction to it, possibly by using this letter or appropriate excerpts from it.

Again, thank you very much for your valuable suggestion.

Sincerely,

Chas Whitcher

Charles Whitcher, M.D.
Professor of Clinical Anesthesia

CW:rbs
cc: Richard diMonda
John Lecky
Robert Piziali
Ellis Cohen