U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

HEALTH HAZARD EVALUATION DETERMINATION REPORT
NO. HE 80-4-706

SMALL ANIMAL SURGERY DEPARTMENT
AUBURN UNIVERSITY
AUBURN, ALABAMA

JUNE 1980

I. SUMMARY

On December 3 and 4, 1979, the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation at the Small Animal Surgery Department of Auburn University in Auburn, Alabama, to evaluate possible health hazards arising from exposure to anesthetic gases. This evaluation was conducted in response to a request from the Department Head and the Campus Safety Engineer. Environmental and personal breathing zone samples were collected during normal operations and analyzed for nitrous oxide, methoxyflurane, and halothane.

In the Client Surgery Area exposure to nitrous oxide exceeded 150 parts per million (ppm) for surgeons and ranged from 30 to 80 ppm for other operating room personnel. The NIOSH recommended standard for nitrous oxide is 25 ppm. Personal breathing zone samples taken when halogenated anesthetics were used instead of nitrous oxide revealed exposure levels of 2.56 ppm methoxyflurane and 0.133 ppm halothane. In the Student Surgery Laboratory, area samples revealed an average exposure of 1.36 ppm methoxyflurane while personal breathing zone samples averaged 2.12 ppm methoxyflurane. The NIOSH recommended standard for halogenated anesthetic agents is 2 ppm.

On the basis of the data obtained in this investigation, NIOSH determined that operating room personnel in the Client Surgery Area are exposed to levels of nitrous oxide and halogenated anesthetic gases in excess of the recommended exposure limits. In the Student Surgery Laboratory students are exposed to concentrations of halogenated anesthetics at or slightly above the recommended exposure limits. Recommendations concerning scavenging, administration techniques, and maintenance of equipment for reducing these exposure levels are contained in the latter portion of this report.

II. INTRODUCTION

In accordance with the Occupational Safety and Health Act of 1970*, the Head of the Department of Small Animal Surgery and the Campus Safety Engineer requested a survey to determine if a possible health hazard existed due to the presence of waste anesthetic gases in surgical areas. The School of Veterinary Medicine has several departments, however, NIOSH was not requested to evaluate areas outside the Department of Small Animal Surgery. On December 17, 1979, letters were sent stating the preliminary results of the nitrous oxide sampling.

III. BACKGROUND

Within the Department of Small Animal Surgery, surgical procedures are performed in three areas: The Student Surgery Lab, the Client Surgery Area, and the Research Surgery Area. The Student Surgery Laboratory is a large open room in which as many as 20 operations are performed simultaneously by student surgical teams on essentially healthy animals. Approximately 60 students and 2 instructors are present during these laboratory sessions. Methoxyflurane is the anesthetic most frequently used in this area. Typically, scavenging equipment is not available within this area. The Surgical Corridor opens to four Client Surgery Operating Rooms and two Research Surgery Operating Rooms. The Research Surgery Areas were not evaluated during the survey because no research surgeries were scheduled. Client Surgery services animals from surrounding communities in need of surgical treatment. Each case is treated individually and surgeries are performed by the more advanced students. Nitrous oxide is the most frequently used anesthesia in this area, but halogenated anesthetics are also used as dictated by the needs of particular surgical procedures. Some of these operating rooms are equipped to accommodate scavenging systems.

Scheduling is such that surgical procedures within the department receive maximum usage on Tuesdays and Thursdays. The survey was scheduled for the last Tuesday of the semester, a time of maximum activity when exposures are expected to peak. The Student Surgery Lab was used only in the morning and the Client Surgery Area was used only in the afternoon. This allowed the survey team to concentrate on one area at a time.

---

*Section 20(a)(6) of the Occupational Safety and Health Act, 29 USC 669 (a)(6), authorizes NIOSH following a request by an employer or an authorized representative of employees to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

IV. EVALUATION DESIGN AND METHODS

Nitrous oxide sampling was accomplished by using battery powered sampling pumps to fill 22-liter inert plastic bags with air drawn from the subject's breathing zone. The bags were then brought to a central location, analyzed, purged twice with clean air and reused. After analysis and purging, air from within the bags was exhausted outside the building to prevent recirculation of contaminated air. Analysis of nitrous oxide was done with a MIRAN IA Portable Ambient Air Analyzer, an infrared spectrophotometer*. A more portable spectrophotometer, the MIRAN 103 Portable Gas Analyzer, was used to measure nitrous oxide concentrations at various locations within the Client Surgery Area. Both spectrophotometers were calibrated before and after the survey to insure accuracy. Both instruments had maximum upper-range capabilities of approximately 150 ppm. Off-scale readings were obtained for a number of samples. Dilution methods could have been used to determine these concentrations but time did not permit this. Exact determination of these concentrations was not necessary since potential health hazards exist at levels far below 150 ppm, and the purpose of the survey was to determine whether exposure levels presented a health hazard.

To sample for the halogenated agents, methoxyflurane and halothane, air was drawn through charcoal adsorption tubes via low flow sampling pumps. These tubes were then analyzed by gas chromatography methods.

V. EVALUATION CRITERIA

NIOSH recommends environmental limits of 25 ppm nitrous oxide and 2 ppm halogenated anesthetic agents. Most of the information currently available on occupational exposure to waste anesthetic gases concerns exposure to a combination of nitrous oxide and a halogenated agent. However, evidence suggests that either anesthetic by itself is potentially toxic with chronic exposure. The following is a summary of such evidence.

Reports of Vaisman (1967), as well as Askrog and Harvald (1970) were among the first to identify an increased incidence of spontaneous abortion in women exposed to anesthetic gases and in wives of men exposed to anesthetic gases. Results of a more recent and comprehensive nationwide survey of occupational disease among operating personnel were published in 1974 by the American Society of Anesthesiologists. The results of this study indicate "that female members of the operating room-exposed group were subject to increased risks of spontaneous abortion, congenital abnormalities in their children, cancer, and hepatic

---

* Mention of manufacturer's name does not constitute a NIOSH endorsement.

and renal disease." This report also showed an increased risk to male operating room personnel. No increase in cancer was found among the exposed males, but an increased incidence of hepatic disease similar to that in the female was found.

In a study published by NIOSH (1976), "nitrous oxide and halothane in respective concentrations as low as 50 ppm and 1.0 ppm, caused measurable decrements in performance on psychological tests taken by healthy male graduate students. Nitrous oxide alone caused similar effects. The functions apparently most sensitive to these low concentrations of anesthetics were visual perception, immediate memory, and a combination of perception, cognition, and motor responses required in a task of divided attention to simultaneous visual and auditory stimuli". Headache, fatigue, irritability, and disturbance of sleep were also reported.

Mortality and epidemiological studies have raised the question of possible carcinogenicity of anesthetic gases, but sufficient data are presently lacking to list nitrous oxide or halothane as suspected carcinogens.

In an epidemiological study among dentists, Cohen et. al. (1975) compared exposed persons in that profession who used inhalation anesthetic more than three hours per week with a control group in the same profession who used no inhalation anesthetic in their practice. The exposed group reported a rate of liver disease of 5.9 percent in comparison with a rate of 2.3 percent in the control group. Spontaneous abortions were reported in 16 percent of pregnancies of the wives of exposed dentists, in comparison with nine percent for the unexposed. This data was statistically significant. This study did not identify the specific anesthetic being used by the dentists surveyed; that is, whether they used N_2O alone or if a halogenated agent was used. However, in a review of that study, NIOSH (1977) concludes that "the halogenated anesthetics alone do not explain the positive findings of the survey and that N_2O exposure must be an important contributing factor, if not the principal factor." This conclusion is based on a calculation assuming that as many as one in ten of the dentists using an inhalation anesthetic employs a halogenated agent. If the actual fraction is less than one in ten, then this conclusion would be even more significant.

VI. RESULTS

Within the Student Surgery Laboratory area samples averaged 1.4 ppm and personal breathing zone samples averaged 2.1 ppm methoxyflurane. The recommended standard is 2.0 ppm. See Table 1 and Figure 1.

Within the Client Surgery Area personal samples for halogenated agents averaged 2.5 ppm methoxyflurane and 0.13 ppm halothane or a combined exposure of 2.7 ppm halogenated agents. See Table 2.

Nitrous oxide samples were also taken in the Client Surgery Area. Of the six personal samples taken for surgeons, assistants, and anesthetists, five were off-scale, that is, in excess of 150 ppm. The sixth sample was 130 ppm. Exposure levels for other personnel in this area ranged from 30 to 80 ppm. See Table 3. Area samples taken late in the afternoon ranged from a low of 30 ppm in Post-Op Recovery to 75 ppm in the Pre-Op General Area and Surgical Corridor to off-scale readings (in excess of 150 ppm) in the operating rooms. All these samples were above the recommended standard of 25 ppm. See Table 4.

VII. DISCUSSIONS AND CONCLUSIONS

A. Discussion of Results

Sampling results indicated overexposure to both halogenated anesthetic agents and nitrous oxide.

In the Student Surgery Lab, area samples for halogenated agents were within acceptable limits averaging 1.4 ppm. However, these samples were not indicative of actual student exposures which averaged 2.1 ppm. See Table 1 and Figure 1. Because students by necessity stand so close to the source of contamination, their exposures exceed the recommended standard of 2 ppm. Scavenging systems were not in use in the Student Surgery Lab. They should be.

Samples were taken within the Client Surgery Area for halogenated agents. See Table 2. Two operations were sampled. Total halogenated agent exposure levels averaged 1.8 ppm during the first operation and 3.6 ppm during the second. Exposures during the first operation were within acceptable limits. Exposures during the second operation were well above the recommended standard. Clearly control measures in the form of scavenging systems are needed.

Within the Client Surgery Area samples were also taken for nitrous oxide. Both personal and area samples were taken as Tables 3 and 4 indicate. Limited scavenging capabilities exist in this area. For comparison purposes, sampling strategy called for the sampling of one operation with a scavenging system (OR #2) and one without (OR #3). Unfortunately, complications arose during surgery which necessitated removal of the endotracheal tube from the animal in OR #2. This negated the effectiveness of the scavenging system and resulted in the off-scale reading listed for OR #2 in Table 4. This precluded any comparison of a scavenged system vs. an unscavenged system.

B. Importance of Results

When one considers the ages of the students and faculty, overexposure to anesthetic gases takes on an added significance. These are people of child-bearing age. The primary health concern associated with exposure to anesthetic gases is the increased incidence of miscarriages and birth defects. In view of the students' youth and their long-term occupational association with anesthetic gases it is imperative that they learn to utilize scavenging equipment to minimize exposures from the start of their training in surgery. Habits developed as a student could have a significant impact on a veterinarian's total lifetime exposure to anesthetic gases.

Another area of concern involves the effect of low-level exposures on the central nervous system. Studies indicate that a mixture of 50 ppm nitrous oxide and 1 ppm halothane produces statistically significant decrements in audiovisual task performance.

C. Discussion of Control Measures

1. Anesthetic Technique

When low leakage equipment is used in conjunction with scavenging equipment, the work practices of the anesthetist account for the greatest portion of the exposure level within the operating room. When an endotracheal tube is used, it is estimated that anesthetic technique accounts for 94% of the environmental exposure level! When a face mask is used, technique accounts for 99% of the exposure level. Proper anesthetic technique should be taught and stressed to minimize gas leakage through improperly connected scavenging tubes, poorly fitting face masks, leaky cuffs on endotracheal tubes, and precautions should be taken to prevent the spilling of anesthetic liquids.

2. Maintenance and Leak Testing

To prevent gas leaks, anesthesia machines should receive regularly scheduled preventive maintenance according to the manufacturer's instruction by service representatives or equally qualified personnel. Routine leak testing should be conducted on a schedule commensurate with usage. Maintenance and leak testing are addressed in Appendix A.

VIII. RECOMMENDATIONS

The following recommendations are offered as means of achieving effective, on-going control of exposure to anesthetic gases:

1. Scavenging equipment should be purchased, installed, and utilized to capture anesthetic gases before they reach the breathing zones of operating room personnel. Such gases should be vented to the outdoors in a manner which precludes the reentry of contaminated air.

2. "Low leakage" anesthetic techniques should be taught and stressed as part of the curriculum.

3. Preventive maintenance of anesthetic equipment should be scheduled on a regular basis. Routine leak testing should be conducted on a frequency commensurate with usage.

4. Students and staff should be alerted to the health hazards associated with anesthetic gases and taught how to minimize personnel exposure by following the above recommendations.

IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared By:	Richard Patnode Industrial Hygienist Industrial Hygiene Section Hazard Evaluations and Technical Assistance Branch Cincinnati, Ohio
Assisted By:	Richard Gorman Paul Pryor Industrial Hygienists Industrial Hygiene Section Hazard Evaluations and Technical Assistance Branch
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations, and Field Studies Cincinnati, Ohio
Report Typed By:	Monica Whitlock Clerk-Typist Industrial Hygiene Section

X. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this report are currently available upon request from NIOSH, Division of Technical Services, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, this report will be available through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

Copies of this report have been sent to:

1. Campus Safety Engineer, Auburn University

2. Chief, Department of Small Animal Surgery, Auburn University

3. U. S. Department of Labor, Region IV

4. NIOSH, Region IV

For the purpose of informing the "affected employees," the employer shall promptly "post" this report for a period of 30 days in a prominent place near where exposed employees work.

TABLE 1

Methoxyflurane Exposure in the Student Surgery Laboratory
December 4, 1979

	Personal Samples			Time	Area Samples		Time
	Surgeon	Assistant	Anesthetist				
Table 2	2.30	3.60	2.78	9:22-10:35	Table 1	0.74	9.29-11:01
Table 7	1.48	1.84	1.67	9:23-10:54	Table 4	1.78	9:23-11:05
Table 10	2.61	2.40	3.58	9:25-11:18	Table 5	1.76	9:30-11:08
Table 15	1.78	1.48	N.D.	10:52-11:30	Table 12	1.18	9:23-11:20
Average	2.04	2.33	2.01			1.37	

For table locations see Figure 1.
N.D. = none dectected

TABLE 2

Personal Exposures in Client Surgery Area
December 4, 1979

	Methoxyflurane	Halothane	Combined Halogenated Agent Exposures	Time
Operating Room 1				
Surgeon	1.63	N.D.	1.63	2:15-3:42
Anesthetist	1.63	0.34	1.97	2:15-3:45
Operating Room 5				
Surgeon	4.00	N.D.	4.00	4:15-5:16
Anesthetist	2.96	0.19	3.15	4:15-5:16
Average	2.56	0.13	2.69	

N.D. = none detected
All concentrations in parts per million

TABLE 3

Personal Exposure to Nitrous Oxide in Client Surgery Area
December 4, 1979

Location	Person	Time	Exposure in ppm
OR #2	Surgeon	1:55 p.m.	90
		2:30 p.m.	off-scale
		2:55 p.m.	71
		3:05 p.m.	off-scale
	Assistant	3:10 p.m.	off-scale
OR #3	Surgeon	3:25 p.m.	off-scale
		3:50 p.m.	off-scale
	Assistant 1	3:50 p.m.	130
	Assistant 2	4:05 p.m.	off-scale
Ward	(Teeth Cleaning Procedure)		
	Student 1	2:45 p.m.	76
	Student 2	2:50 p.m.	80
Pre-op	Attendant	3:30 p.m.	38
		3:55 p.m.	31
Post-op	Attendant	3:15 p.m.	off-scale
		3:45 p.m.	38
		4:30 p.m.	20

Off-scale indicates am exposure in excess of 150 ppm

TABLE 4

Area Nitrous Oxide Exposure Levels
December 4, 1979

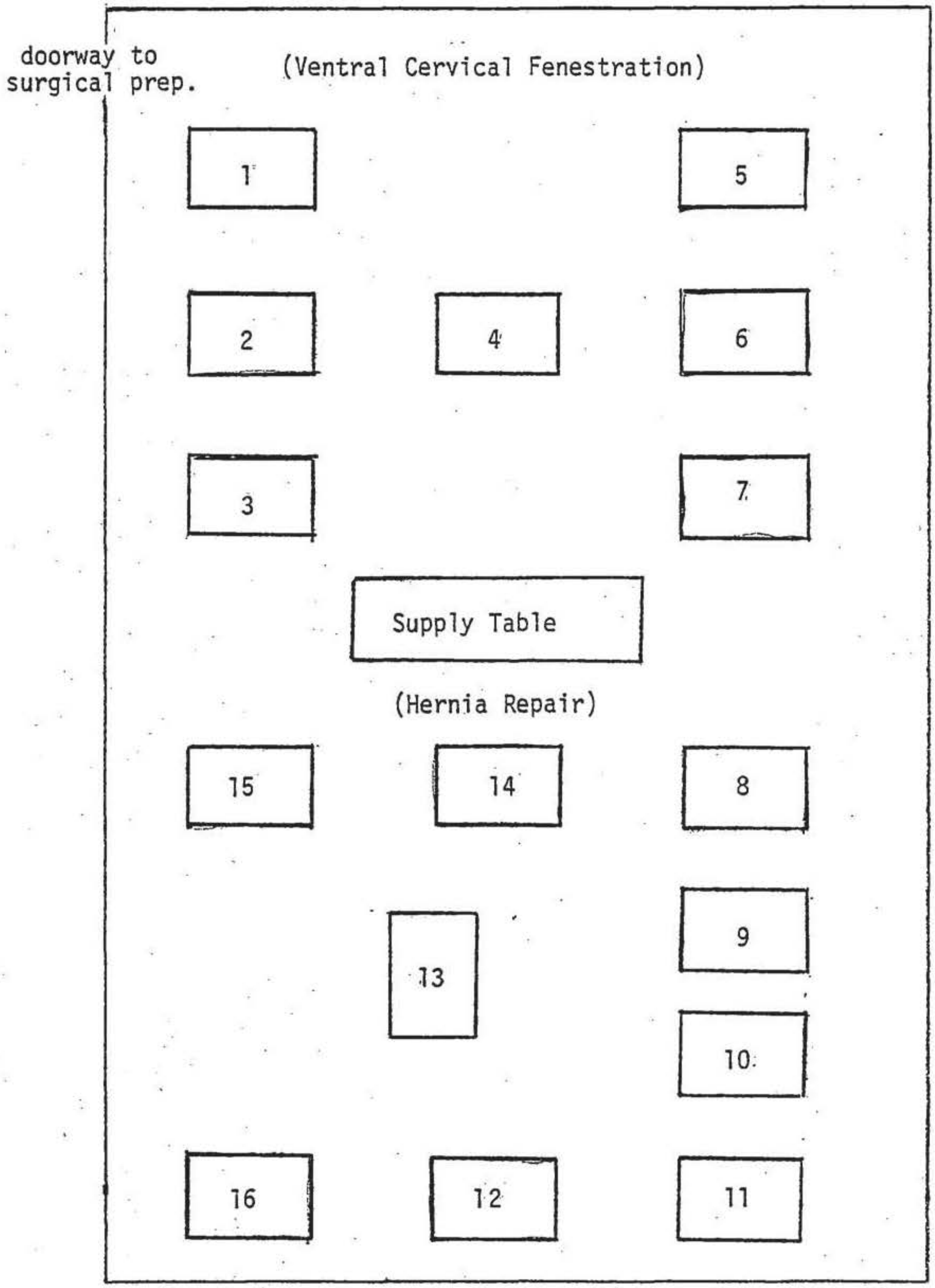
Area	Exposure Level, ppm
Ward Corridor	25 to 30
Surgical Corridor	75
Pre-op General Area	75
Pre-op Nitrous Oxide Administration Area	off-scale, >150
Post-op Recovery	30
OR #2 General Area	150
OR #2 Anesthetist Area	off-scale, >150
OR #3 General Area	off-scale, >150
OR #3 Anesthetist Area	off-scale, >150

Off-scale readings indicate an exposure level in excess of 150 ppm.
OR #3 was not using a scavenging system when sample was taken.

Figure 1

Student Surgery Laboratory

Location of Operating Tables



APPENDIX

I. EQUIPMENT MAINTENANCE

Equipment maintenance is a key factor in the prevention of anesthetic gas leaks and in the prompt correction of leaks that do occur. The objective is to secure low leak performance (defined as a maximum leak rate of 100 cc/min at a pressure of 30 cm H_2O) for all anesthesia machines. It must be emphasized that such performance requires rigid standards of preventive maintenance and servicing beyond that necessary for the administration of clinical anesthesia.

Maintenance Schedules and Leak Tolerances for Anesthesia Machines and Related Equipment:

(1) Anesthesia machines receive preventive maintenance at four-month (minimum) intervals by manufacturer's service representatives or by other qualified personnel. Following such maintenance, with the cylinder valves and flowmeters turned off at the end of the workday, high pressure systems should hold pressure overnight with less than 10 percent loss of the normal working pressure, approximately 50 psig. The low pressure leak rate should be less than 50 cc/min at 30 cm H_2O.

(2) The low pressure systems of the anesthesia machines (from the flowmeters to the breathing tubes) are leak tested at monthly (minimum) intervals and whenever the soda-lime is changed. This is readily done by hospital-based personnel. Leakage should be less than 100 cc/min at 30 cm H_2O.

(3) Ventilators receive preventive maintenance at four-month (minimum) intervals by service representatives or other qualified personnel.

(4) Breathing hoses attached to the anesthesia machines are leak tested as part of the low pressure test. Breathing hoses associated with the T-tube, non-rebreathing system, and ventilators are tested at four-month intervals. All leaky hoses are replaced.

(5) Breathing bags attached to the anesthesia machines are leak tested as a separate procedure at the time of the low pressure test. Other breathing bags associated with the T-tube, non-rebreathing system, and ventilators are tested at four-month intervals.

(6) Waste gas disposal tubing is leak tested at four-month intervals. Leaky tubing is replaced.

(7) New equipment should be leak tested by the manufacturer before being placed in service. Minimum standards should be met.

II. LEAK TESTING

The leak testing procedures that follow are taken from NIOSH Publication No. 77-171, Control Of Occupational Exposure to N_2O in the Dental Operatory. Although developed for use in dental offices, these procedures should be readily adaptable to anesthetic equipment used in veterinary operating rooms. These methods have the advantage of requiring no special equipment, thereby minimizing expense. The reader is cautioned to check with the manufacturer to determine the most suitable procedures for a given machine since the suggested pressurization test may damage certain equipment. These procedures are included to demonstrate the scope of an effective leak testing program.

Detection of leakage in the high-pressure components of the N_2O system is accomplished by observation of the pressure gauge for the central N_2O supply. With the cylinder valves and flowmeters turned off at the end of the work day, tight systems hold pressure overnight with less than 10 percent loss of the normal working pressure, approximately 50 psig.

Leakage in the low-pressure components of the anesthesia machine is easily determined (Figure 2). The breathing bag is tested on the anesthesia machine by overfilling with O_2 to several times its normal volume. Palpation of the surface reveals any significant leakage. Breathing hoses and the other low-pressure components are leak tested as a unit. Preparations for this test include removing the bag from the machine and adapting a blood pressure gauge to the bag outlet. The breathing connections of the nasal mask are connected. This test condition results in an air-tight, noncompliant pneumatic system of small volume.

Following the above preparations, leak testing of low-pressure components is performed by either of two methods. The first method is to turn on a low-range O_2 flowmeter at a rate sufficient to maintain a constant pressure of30 mm Hg. The flowrate, when equilibrated with the leak, provides a quantitative measure of the leak rate. A tight machine leaks less than 100 cc/min at 30 mm Hg. Precautions in performing this test include careful observation of the pressure gauge since over-pressurization could damage the gauge.

The second test is employed when the O_2 flowmeter does not have a low calibrated range. This method consists of closing the low-pressure system as described above. The system is the filled with O_2 to a pressure of 30 mm Hg. The O_2 is then turned off. The machine is considered tight if it lost less than 10 percent if its pressure over a 30-second period of observation.

Machines which are equipped with O_2 flush valve, low-range O_2 flowmeter, and built-in pressure gauge are easiest to leak test because all components are attached as for routine analgesia, including the breathing bag. The O_2 flowmeter is set for 100 cc/min; the outlet hoses at the nosepiece are occluded by kinking; and the flushvalve is employed to pressurize the system to 30 cm H_2O. When the machine is tight, the 30 cm H_2O pressure will hold or slowly increase.

Leakage, once identified, must be localized and repaired. While an outside servicing concern may be needed to correct obscure leakage, a preliminary search may be initiated by applying soap solution to suspected leak sites or direct immersion of waterproof pressurized components (Figure 3).

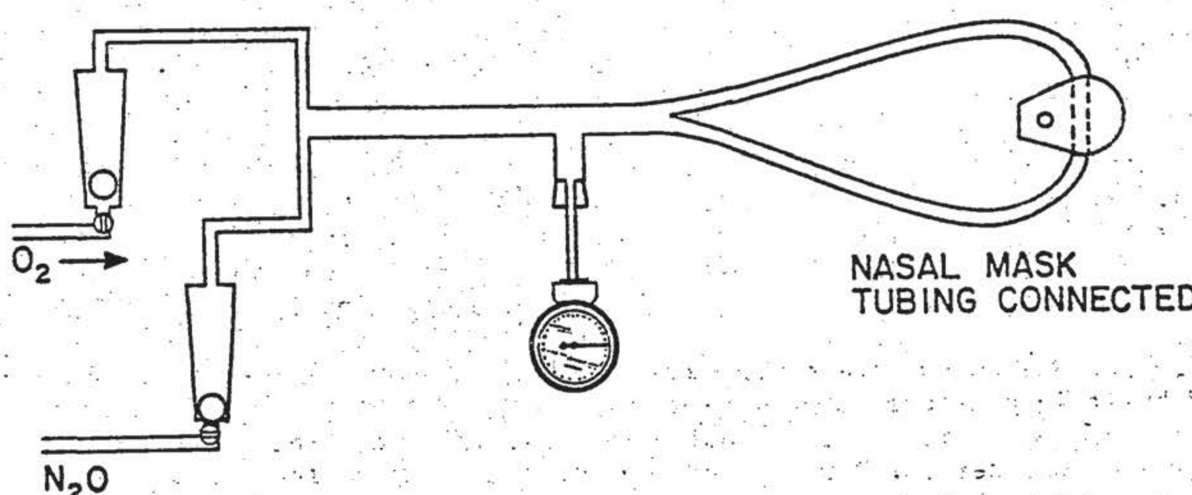


Fig. 2 LEAK TESTS FOR LOW PRESSURE N_2O SYSTEM

Bag (not shown) is tested by over-inflating with O_2 and palpating its surface. With bag removed, other components are tested as a unit by establishing that flowrate of O_2 which maintains a static pressure 30 mm Hg.

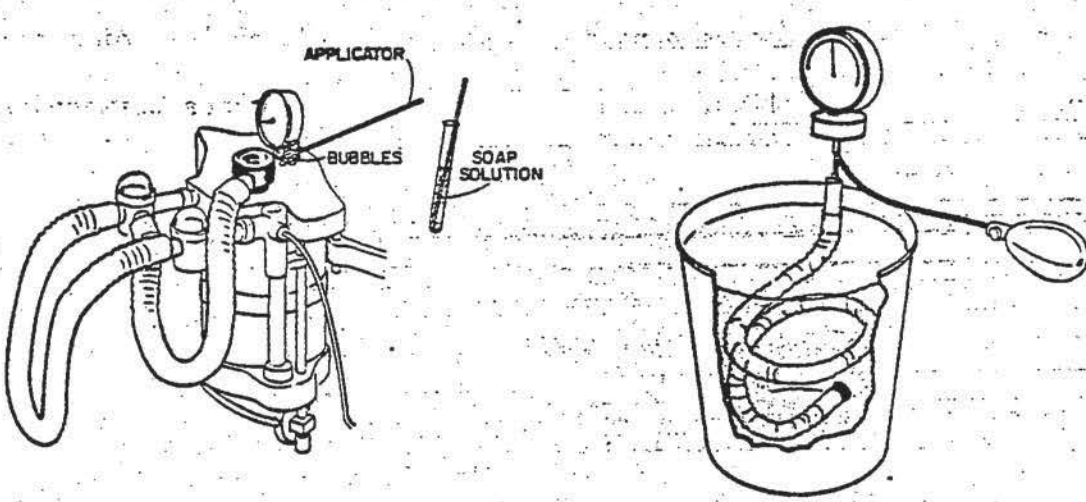


Fig. 3 LEAK LOCALIZATION PROCEDURES

When auscultation and palpation fail to reveal leak sites, pressurized components can be tested with soap solution and immersion tests.

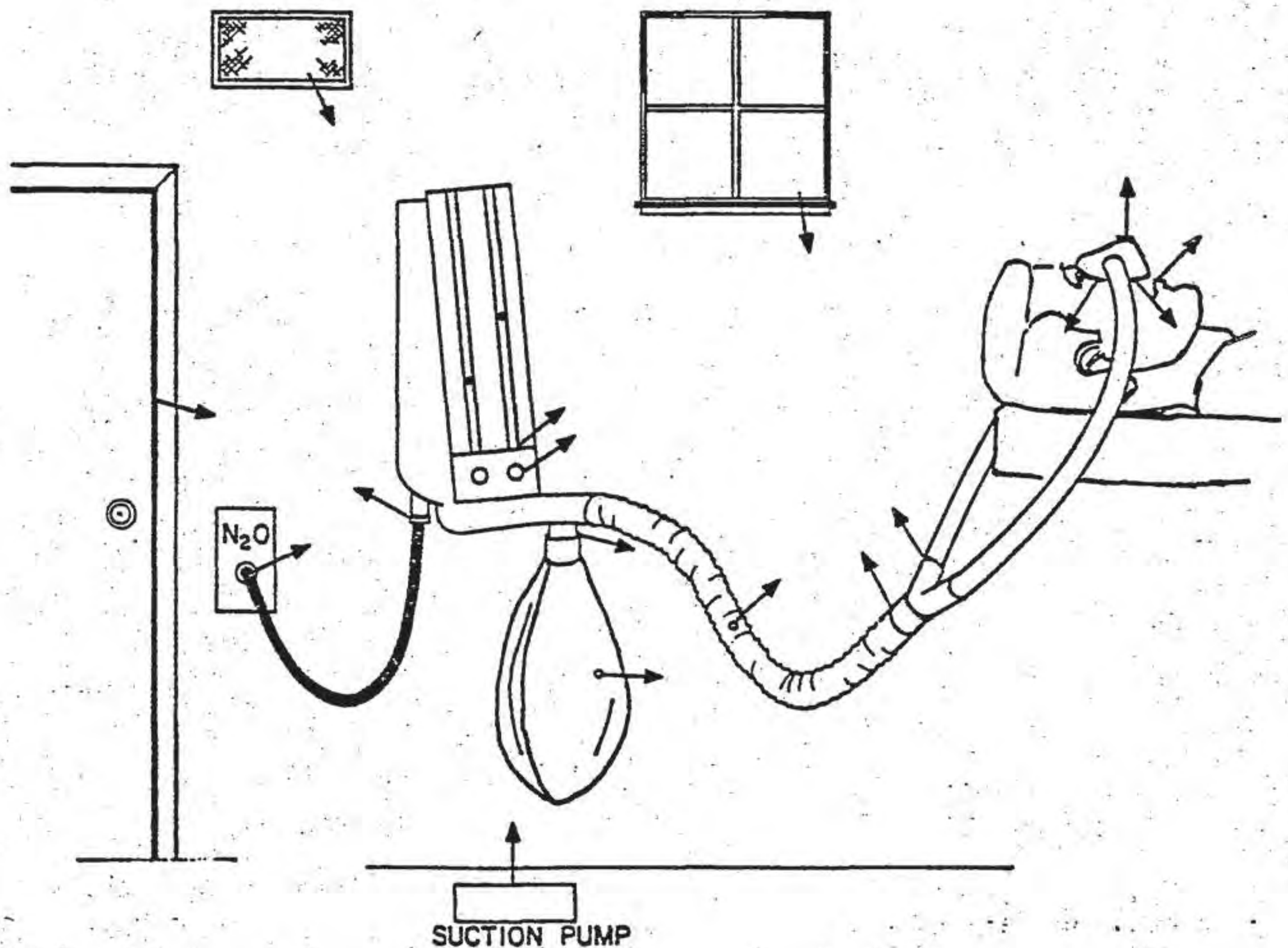


Fig. 4 SOURCES OF N_2O IN OCCUPATIONAL EXPOSURE

Arrows indicate leak sources frequently found in the operatory.