

## V. DEVELOPMENT OF STANDARD

### Basis for Previous Standards

The United States does not have occupational exposure standards for gaseous and volatile chemicals when used as anesthetics. Specific occupational standards for chloroform, trichloroethylene, and diethyl ether, as promulgated by the Occupational Safety and Health Administration, Department of Labor (29 CFR 1910.1000) are:

Chloroform - 50 ppm, 8-hour TWA concentration;

Trichloroethylene - 100 ppm, 8-hour TWA concentration, with a ceiling limit of 200 ppm and a 300 ppm maximum peak above the acceptable ceiling for 5 minutes in any 2 hours;

Diethyl ether - 400 ppm, 8-hour TWA concentration.

The chloroform and diethyl ether standards were adapted from the recommendations of the American Conference of Governmental Industrial Hygienists (ACGIH). The chloroform recommendation [179] was based on CNS and liver effects while the diethyl ether value [180] was based on nasal irritation and possible narcosis. The trichloroethylene standard, which was based on CNS depression caused by the chemical, was adapted from the American National Standards Institute Z-37 standard. Subsequently, NIOSH recommended that the permissible level of exposure for chloroform be 10 ppm as a TWA with a ceiling of 50 ppm based on a 10-minute sample [81]. NIOSH also recommended that the trichloroethylene standard of 100 ppm as a TWA be retained but that the ceiling be reduced to 150 ppm based on a 10-minute sample [82]. Based on information from the National Cancer Institute (NCI) [Chloroform Bioassay Results, National Cancer Institute, March 1, 1976],

NIOSH revised its recommendation for exposure to chloroform and recommended that it be considered a carcinogen and that the allowable exposure levels be reduced to 2 ppm in a 45-liter air sample. NIOSH is currently reevaluating its recommendations for a trichloroethylene standard based on animal studies conducted by the NCI and discussed by Lloyd et al [129].

Sweden's Labor Protection Board issued the Narcosis Specifications guide in November 1974 [181] for the protection of personnel against health risks through exposure to gaseous anesthetics in patient casework. The guide noted that it was not possible to expect that health risks for personnel could be reduced by replacing anesthetics now in use with others, and that the only effective preventive measure was to conduct operations in such a way that operating room personnel would not be exposed to anesthetic gases. Operating rooms were required to have 17 air exchanges/hour; preparatory and anesthesia rooms, 10 exchanges/hour; and recovery rooms, 6 exchanges/hour. Point aspiration was required so that gases flowing out of valves on the anesthetic equipment would be carried away from the work area. The standard also required a program of educating workers about the potential risks that may be associated with working with anesthetic gases. There were no environmental limits promulgated in the Swedish standard [181] for any of the anesthetic agents.

The Hospital Engineering Cooperative Groups of Denmark made recommendations in 1974 to prevent pollution by anesthetic gases in operating rooms, recovery rooms, and similarly equipped rooms [182]. The document was developed on the principle of practical experience available and information in the medical literature on possible health effects and procedures for exposure control [69,72,73,75,132,136,139,176,178,183,184].

The authors stated that the lowest concentration of anesthetic gases which offers any risk upon long term exposure is unknown, making it necessary to attempt to remove all excess gases and vapors. The highest average concentrations recommended as allowable in the breathing zone of anesthesia personnel by the Denmark group are presented in Table V-1. Recommendations were also made for high- and low-pressure leak tests. An air monitoring program, taking six samples over 1 hour with glass pipettes, was recommended.

TABLE V-1

HIGHEST PERMISSIBLE AVERAGE CONCENTRATION  
 IN BREATHING ZONE OF ANESTHESIA PERSONNEL  
 RECOMMENDED BY THE HOSPITAL ENGINEERING  
 COOPERATIVE GROUPS OF DENMARK

Anesthetic Agent	Highest Permissible Average Concentration, ppm
Chloroform	1
Halothane	1
Methoxyflurane	1
Vinyl ether	2
Diethyl ether	3
Fluroxene	3
Trichloroethylene	3
Cyclopropane	5
Nitrous oxide	10

Derived from reference [182]

The Council of the Association of Anesthetists of Great Britain and Ireland [185] set up a Working Party in 1974 which issued a special notice to members recommending that steps be taken to lower anesthetic agent concentrations in exposure areas to the lowest practicable levels and not

to wait for the development of adequate monitoring programs or an agreed standard on maximum permissible environmental limits. Passive and active scavenging procedures were presented with some suggested work practices.

#### Basis for the Recommended Standard

A number of epidemiologic studies have been conducted among operating room and dental personnel exposed to anesthetic gases [12,13,69,72-80]. Spontaneous abortions in increasing numbers were the most frequently encountered adverse health effect in anesthetists and nurses exposed to anesthetic gases. Most of the epidemiologic studies used control groups of female physicians and nurses who were not exposed to anesthetic agents in their work environment [12,13,73,74,76,80]. Environmental levels of anesthetic agents were not presented in the epidemiologic studies but the large number of environmental determinations made have established the usual occupational exposure levels at 1-10 ppm for halothane and other volatile agents, and 400-3,000 ppm for nitrous oxide [131-150,170].

An increased number of resorptions (similar to abortions in humans) was seen in pregnant animals exposed to halothane and nitrous oxide at concentrations of 10-8,000 ppm halothane and 1,000-700,000 ppm nitrous oxide [108-110,116,117,122]. One study reported no significantly increased number of resorptions per pregnancy when pregnant mice were exposed to halothane at 16 ppm, 7 hours/day, 5 days/week for 6 weeks [123].

An increased incidence of congenital abnormalities among children of exposed personnel was also identified in the epidemiologic studies [12,13,74,76,77,80]. Organ and skeletal anomalies were seen in the offspring of pregnant animals exposed to halothane, chloroform, and nitrous

oxide. The halothane exposures ranged from 10 ppm for 8 hours/day, 5 days/week for 8 weeks, to single anesthetic doses of the agent. Chloroform exposures ranged from 30 to 300 ppm 7 hours/day on days 6-15 of pregnancy in rats. Nitrous oxide exposures in rats ranged from 1,000 ppm for 1 day during pregnancy to 700,000 ppm. Reproductive effects were seen following acute exposures to all three agents. The animal studies did not identify a level at which the anesthetic agents had no teratogenic effects.

In three studies, the wives of exposed personnel exhibited a higher incidence of spontaneous abortion and of congenital abnormalities in their children than did the wives and offspring of unexposed men [12,13,72]. One animal study [124] demonstrated a detrimental effect by nitrous oxide on spermatogenesis in male rats. Extended exposures to nitrous oxide at 200,000 ppm had a detrimental, but reversible, effect on spermatozoa production.

In addition to the adverse effects on reproduction, which are the primary concern in developing a recommended standard, three epidemiologic studies report evidence of increased incidence of liver and kidney diseases among personnel exposed to anesthetic gases [12,13,78], especially among female workers. Many animal studies have been conducted with anesthetics to investigate their liver and kidney toxicities. Organ damage has been found following acute exposures [83,85-90,93-95], and liver and kidney damage has been reported in some animal studies following chronic, low level exposure but the levels at which the damage was seen were usually above those considered usual for occupational exposure [61,96,98,99]. Animal studies of chronic exposure would indicate that the lowest levels at which liver and kidney damage is seen were 200 ppm for methoxyflurane [96],

50-150 ppm for halothane [61], 1,500 ppm for isoflurane [61], and 10,000 ppm for diethyl ether [61]. It must be pointed out that these were short-term (4-8 weeks) experiments attempting to induce and identify basic liver and kidney lesions and not any carcinogenic potential of the anesthetic agents. Also, decrements in performance, cognition, audiovisual ability, and dexterity have been shown in human volunteers at exposure levels as low as 50 ppm nitrous oxide, with or without 1 ppm halothane. Significant effects were not seen when the subjects were exposed to nitrous oxide at 25 ppm with 0.5 ppm halothane [47-49]. These results bear on the question of possible CNS effects following chronic exposure to anesthetic gases. Three animal studies [97,113,119] have demonstrated damage to the CNS of unborn and young rats following exposure to halothane at 8-12 ppm, 8 hours/day, 5 days/week throughout the pregnancy of the mother or during early life of offspring (to age 60 days).

NIOSH recognizes both adverse reproductive effects in exposed female personnel and congenital abnormalities in the offspring of exposed personnel as the primary health concerns in the development of the recommended standard for exposure to mixed anesthetic gases or to halogenated agents when used alone. Based on the available health information, a safe level of exposure to the halogenated agents cannot be defined. Since a safe level of occupational exposure to halogenated anesthetic agents cannot be established by either animal or human investigations, NIOSH recommends that exposure be controlled to levels no greater than the lowest level detectable using the sampling and analysis techniques recommended by NIOSH in this document. The weights of anesthetic agents given in Chapter I, Section 2(a)(1), are the smallest

weights of each compound which can be analytically detected with reliability and reproducibility using charcoal adsorption sample collection and gas chromatographic analysis. These weights, when collected from a 45-liter air sample, result in a concentration of 2 ppm for each compound. This is the method recommended by NIOSH for field use. Controlling exposure to these levels should also help to prevent the occurrence of adverse effects on the liver and kidneys in humans as well as prevent decreases in psychologic performance and any other CNS effects.

Most of the human studies mentioned were based primarily on hospital operating room personnel. Since the available information associates the health effects in these areas with exposure to anesthetic gases, and taking into consideration the seriousness of such effects, NIOSH recommends that a similar degree of concern be given to other areas where inhalation anesthetics such as halothane, methoxyflurane, and enflurane, are used. The recommended standard, therefore, is applicable to all occupational exposures to anesthetic gases. The recommended standard should protect against adverse health effects associated with exposure to a number of anesthetic agents. Most routine occupational exposures involve mixtures of agents and usually more than two agents/day. The heaviest exposures are to nitrous oxide, halothane, methoxyflurane, enflurane, cyclopropane, and diethyl ether (Tables XIII-9 and 10).

An estimated 100,000 dentists and their assistants are potentially exposed to anesthetics used in dental and oral surgical procedures. An epidemiologic survey was conducted among all 2,600 male members of the American Society of Oral Surgeons (ASOS) and in 4,800 members of the ADA [13]. No estimation was made of the number of dentists using nitrous oxide

alone versus mixed agents. The statistically significant findings were a 78% increase in spontaneous abortions among exposed dentists' wives and a 156% increase in the incidence of liver disease in exposed dentists. Dentists and oral surgeons exposed for less than 3 hours/week to the anesthetics were used as the control group. A 15% increase in congenital abnormalities among dentists' children and a 35% increase in the incidence of cancer were also found in the exposed group, but the increases were not statistically significant. Information on any possible adverse health effects among dental assistants or hygienists is not available. Such effects in exposed female operating room personnel [12] emphasize the need for more information from the dental profession.

Different concerns about adverse health effects are present in the information on nitrous oxide. Often, a situation arises where nitrous oxide is the sole anesthetic agent being administered and its effects alone must be considered.

Bruce and Bach [49] were able to demonstrate statistically significant decrements in audiovisual task performance in human volunteers exposed to nitrous oxide at 50 ppm. At 500 ppm, the subjects showed statistically significant performance decrements in all but one of the behavioral tests. Such decrements were seen in four of the seven tests when the volunteers were exposed to a mixture of 50 ppm nitrous oxide and 1 ppm halothane. A correlation to clinical performance was not established in this study.

Animal exposure studies with nitrous oxide have been directed primarily at reproductive effects [93,106,108,109,115,117,118,122,124]. Most of these investigations used very high concentrations of nitrous



oxide, except for a study by Corbett et al [122], where concentrations of nitrous oxide near the usual dental exposure values were used. A higher fetal death rate among exposed pregnant rats was seen but the effect was not proportional to the concentrations of the exposures. A second study by Doenicke et al [117] reported similar results using higher concentrations of nitrous oxide.

Based on the information on adverse health effects among hospital operating room personnel [12,69,72-80] and their association with exposure to anesthetic gases, similar exposures to nitrous oxide and halothane when used in dental and oral surgical procedures must be viewed with equal concern. The information available to support conclusions on reproductive effects resulting from exposure to nitrous oxide as a sole agent is not felt to be definitive. Nevertheless, a degree of concern should be associated with such exposures. The adverse effects of prime concern involve decrements in performance, cognition, audiovisual ability, and in dexterity during exposures to nitrous oxide. Such effects have been observed at exposure levels to nitrous oxide at 500 ppm. At levels as low as 50 ppm, audiovisual decrements were observed in exposed volunteers. This demonstrates the potential for this substance to impair functional capacities of exposed workers. Similar decrements were not observed at 25 ppm nitrous oxide with 0.5 ppm halothane. Based on this information NIOSH recommends that where exposures are limited to nitrous oxide alone, the permissible level of exposure should be a TWA concentration of 25 ppm during the period of administration.

### Basis for Control Procedures and Work Practices

The control procedures and work practices required in the recommended standard, or their equivalent, have been demonstrated to reduce anesthetic gas concentrations to the recommended levels and are commercially available and reasonably attainable [159,172].

Scavenging in combination with good room ventilation is recommended over trapping volatile anesthetic agents on an adsorbing medium such as activated charcoal. Charcoal adsorption canisters may be used to control limited quantities of halogenated agents but they have little effect in controlling the levels of nitrous oxide and other gaseous agents released into the work environment [186-188]. Simple scavenging techniques and adequate ventilation reportedly resulted in fewer health complaints from operating room personnel [20,69]. It is believed that the control procedures and work practices recommended can effectively reduce occupational exposure levels to the concentrations presented in the recommended standard.

The procedures and practices will reduce occupational exposures, as evidenced in Table XIII-3. These controls will also provide the necessary reductions in anesthetic gas concentrations for agents that have nonanesthetic occupational exposure limits, including chloroform, trichloroethylene, and diethyl ether. Based on operating room engineering control studies, the attainable TWA concentrations during administration of mixed anesthetics are 0.5 ppm for halothane and other volatile agents, and 25 ppm for nitrous oxide. Therefore, instituting engineering control procedures and work practices to control exposure to all anesthetic agents to the lowest feasible level should also keep exposure to halogenated agents well below the 2-ppm recommended limit.

During inhalation anesthesia and analgesia in dentistry, the anesthetic agents leak into the room air from the exhalation valve, around the nasal mask, and through the patient's mouth. Dentists deliver anesthetics at higher flow rates than those used under usual operating room conditions. Because of the open breathing systems, high flow rates of anesthetics, and the proximity to the patient's head, the dentist, anesthetist, and dental assistant may be exposed to high concentrations of anesthetic agents. Nitrous oxide receives the greatest amount of use by dentists and is sometimes given in combination with halothane by oral surgeons. Environmental levels of nitrous oxide, halothane, and trichloroethylene in dental operatories have been reported in the literature [142,143,145,146] and this information is summarized in Table V-2.

TABLE V-2  
SUMMARY OF DENTAL PERSONNEL EXPOSURES  
TO ANESTHETIC AGENTS

Anesthetic	Exposure		Ref.
Halothane	5.5-68 ppm	Oral surgeons' breathing zone	142
Trichloroethylene	25-50 ppm	Anesthetists' breathing zone	143
Nitrous oxide	94-3,000 ppm	Dentists' breathing zone	145
Halothane	1.5-36 ppm	"	145
Nitrous oxide	5,900 ppm (mean)	Dental assistants' breathing zone	145
"	6,800 ppm (mean)	Dentists' breathing zone	146

Devices and procedures for controlling exposures of dental personnel to anesthetics have been developed by Whitcher et al [172]. These procedures have been shown to be feasible, available, and effective in

attaining TWA concentrations approaching 50 ppm during administrations of nitrous oxide when it is used as the sole anesthetic. Tables III-5, 6, and 7 summarize the major adverse health effects identified in epidemiologic surveys of hospital and dental personnel.

Similarities in practice and in anesthetic agents used result in many of the same problems of exposure in veterinary personnel as among hospital operating room personnel. Nitrous oxide, halothane, and methoxyflurane are the anesthetics most frequently used in veterinary anesthesia and the equipment used to administer anesthetics is basically the same as that used in human hospital operating rooms. Problems of good fit with nose and face masks and frequent use of the T-tube for smaller animals could result in significant exposure to veterinary personnel. NIOSH, therefore, recommends that work practices and control procedures be instituted in veterinary facilities to control occupational exposure to waste anesthetic gases to the same levels recommended for mixed anesthetic agent use.

#### Basis for Environmental Monitoring

Personal monitoring using long- or short-term monitoring is not required in this standard because of the critical nature of the work performed by personnel in the occupational environments covered by the standard. Sampling the breathing zone or the immediate work area of those most heavily exposed (anesthetist, oral surgeon) should provide an adequate index of exposure. Waste anesthetic gas distributions in inhalation anesthetizing areas have also been shown to be relatively uniform, except for normally expected hot spots. With good distribution studies, locations for general area monitoring can be determined. The nonrequirement for

personal monitoring does not preclude that such monitoring be used to sample for effectiveness of implemented work practices and control procedures, utilizing appropriate sampling and analytical techniques.

The recommended standard does not require the monitoring of all anesthetic agents used. Only the agent(s) most frequently used needs to be monitored, since the recommended work practices and control procedures should reduce all agents proportionately.

Charcoal adsorption sampling and gas chromatographic analysis is recommended for monitoring exposure to halogenated anesthetics. This method is economical and readily available to an individual in charge of an air monitoring program and is the method most often used to monitor halogenated hydrocarbons. However, it does not have the sensitivity of other methods. The halogenated anesthetics are usually administered with nitrous oxide. In this situation the recommended standard requires monitoring nitrous oxide. Sample collection and analysis techniques are presented in Appendices II-IV. Direct infrared analysis of nitrous oxide is the most desirable method. Gas bag or syringe sampling followed by infrared or gas chromatographic analysis is acceptable. Halothane may be measured by using gas bag or syringe sampling if the analysis is performed within a short time of sample collection. Proper work practices and scavenging procedures should reduce the levels of halogenated anesthetics, when administered with nitrous oxide, to below the sensitivity limit of the charcoal tube method. Because of this, it is recommended that nitrous oxide be monitored.

### Basis for Medical Monitoring

Medical monitoring of exposed personnel is recommended but is not a required part of the recommended standard. Maintenance of medical histories, with emphasis on the outcome of pregnancies in exposed women and in wives of exposed males, is required. The most significant adverse health effects seen among exposed personnel are the reproductive effects among exposed women and among wives of exposed personnel. Medical counseling and care should be available to women of child-bearing age who feel their exposure to anesthetic gases may result in an adverse reproductive effect. Until some direct causal relationship between exposure to anesthetic gases and reported adverse health effects in exposed personnel is either proved or disproved, it is recommended that the medical histories of exposed personnel, especially women, be maintained during their period of employment plus 20 years.

## VI. ENGINEERING CONTROLS AND WORK PRACTICES

Using well-designed, low-leak anesthesia equipment and scavenging systems, the work practices employed by the anesthetist may be the principal contributors to anesthetic gas levels in the operating room. Other relevant factors include poorly connected scavenging hoses, improperly fitted face masks and endotracheal tubes, spillage of volatile anesthetic agents during filling of vaporizers, and leaving vaporizers turned on when not in use. Whitcher et al [159] estimated that anesthetist work practices may contribute from 94 to 99% of the waste anesthetic gases in the scavenged operating room.

A complete waste anesthetic gas management program includes (1) application of a well designed waste anesthetic gas scavenging system, (2) anesthetists' work practices minimizing gas leakage, and (3) application of a routine equipment maintenance program so gas leaks are minimized. Equipment maintenance requirements are given in Chapter I, Section 3.

### (a) Scavenging Systems

A scavenging system consists of three major components: (1) a collecting device (scavenging adapter) to collect waste anesthetic gases; (2) a disposal route (ventilation) to carry waste gases from the operating room; and (3) a method or device for limiting both positive and negative pressure variations in the breathing circuit which may be caused by the scavenging systems. The first waste control system was described by Hirsch and Kappus [19] in 1929. Epstein and Berlin [189], in 1944, used charcoal adsorption to collect waste ether vapor. Bullough and Lond [190] described

a simple gas scavenging system in 1954.

A variety of waste anesthetic gas collection systems [159,183,184,191-210] and several methods of waste anesthetic gas disposal [173,188,211] have recently been developed and described in the literature. However, with few exceptions, the efficiency of these devices has not been documented. Studies of scavenging techniques have shown them to be effective. However, other methods not mentioned may also be used, if they are as effective as scavenging techniques and present no safety hazard to the patient, such as the application of excess negative or positive pressure to the anesthesia breathing system.

(1) Methods of Collecting Waste Anesthetic Gases from the Breathing Systems

(A) Circle Absorber

All popoff valves for circle absorber breathing circuits must be equipped for waste gas scavenging. These valves must be leak-proof, as determined by the low-pressure leak test described in Appendix I. One such typical device is shown in Figure XIII-1.

(B) Nonbreathing Systems

In a nonbreathing system, fresh anesthetic gases enter at the breathing bag and all excess gases leave through the scavenging systems. Nonbreathing valves equipped for scavenging are commercially available. One typical nonbreathing valve equipped for scavenging is shown in Figure XIII-2.

(C) T-Tube Systems

A commonly used T-tube system is the Summer's modification to allow for assisted breathing. An acceptable scavenging



adapter for this system has been designed and successfully applied by Whitcher et al [159]. This device is shown in Figure XIII-3. A clamp permits adjustment of gas outflow to maintain proper bag filling with a plastic tube inserted to prevent accidental occlusion of the tail of the bag. The system shown in Figure XIII-3 or an equivalent system should be used for all T-tube breathing system applications.

#### (D) Ventilators

All new ventilators are equipped for waste anesthetic gas scavenging and old ventilators can be adapted [206]. One convenient method for connecting ventilators for scavenging is shown in Figure XIII-4. With this method, both the ventilator and gas machine are interconnected to the scavenging exhaust, thus eliminating the need to reattach the disposal tubing when alternating between ventilator and manual breathing. Some ventilators (Ohio 300 series, Monaghan, Ventimeter and Bird) may require a one-way check valve to be located at point "C" in Figure XIII-4 to prevent gas leakage through it from the anesthesia machine when the circuit is attached to the disposal system but disconnected from the patient.

#### (2) Disposal of Waste Anesthetic Gases

Waste anesthetic gases, once collected at the anesthetic breathing machine, should be vented to the atmosphere at a point away from personnel areas and in such a manner that contamination of hospital intake air or of areas where personnel are working does not occur. All applicable air pollution rules and regulations should be met. Three systems have been successfully used for this purpose. These include (1) the nonrecirculating air-conditioning system, (2) the central room suction system, and (3) a separate duct system devoted solely to disposal of waste anesthetic gases.

(A) Air-Conditioning Exhaust Grille Method

If the operating room air-conditioning is of the nonrecirculating (one pass) design, disposal of waste anesthetic gases via this route can be inexpensive and effective. As shown in Figure XIII-5, the scavenging tube terminates at the air-conditioning exhaust grille where the sweeping effect of the air flowing into the grille carries away all waste gases. Negative pressure in the waste gas disposal system is minimal [159] when this method is used and no excess pressure relief device (pressure balancing) is needed. Pressure compensation is easily accomplished with the usual popoff valve resistance adjustment.

In some rooms, the air-conditioning exhaust vent may be distant from the anesthesia machine, requiring a long disposal tube. This objectionable feature can be eliminated by arranging the tube to follow the same path as the anesthetic gas supply hoses. A wall or ceiling service panel may be connected to a permanently concealed waste anesthetic gas line joined to the air-conditioning exhaust duct in the crawl space, as shown in Figure XIII-6. If such a connection is made, pressures should be balanced so that the patient's breathing is not compromised. This may be accomplished by careful selection of the point of connection to the air-conditioning system (negative pressure in the duct increases with proximity to the fan) or using pressure relief techniques described in later sections of this chapter.

(B) Room Suction Method

Providing sufficient flow capacity is available, the room central suction system may be used as a waste gas disposal route. If such a method is used, a vacuum break (pressure balancing system) should be

located between the central vacuum suction outlet and the anesthesia breathing circuit so that negative pressure at the breathing circuit is less than 5 mmHg [159].

Ideally, three separate suction outlets, entering the same suction line, should be provided with one line devoted to waste gases. However, a single line may be branched as shown in Figure XIII-7. A suction flow meter, control valve, and reservoir bag should be provided with all suction/scavenging systems. The pressure relief apparatus shown in Figure XIII-7 is described in the following sections of this chapter. A scavenging flow of at least 20 liters/minute should be maintained [159]. Explosive agents must not be disposed of by this method [212] except when a water-sealed central vacuum pump is used [159]. The exhaust of the suction pump should be located outside the exposure area at a point remote from air intakes.

#### (C) Specialized Duct Systems

A duct system solely for disposal of waste anesthetic gases can be used for one or more rooms. One such system which has been successfully used is shown in Figure XIII-8.

If the special duct system is used, a scavenging flow of at least 30 liters/minute should be provided to each machine scavenged. If negative pressures exceed 5 mmHg [159] at the connection to the anesthesia circuit, negative pressure relief shall be provided as described in the following sections of this chapter. Explosive anesthetic gases should not be vented in this system unless they are diluted to less than their lower explosive limit. Alternately, a nonsparking exhaust fan can be used. The scavenging system should exhaust at a point remote from hospital air intakes or

employee work areas. All ducts should be constructed of materials resistant to anesthetic gases.

(3) Pressure Balancing or Interfacing

Marked pressure differences between the anesthetic breathing system and the waste anesthetic gas disposal system must not be allowed to interfere with operation of the breathing system, such as collapse of the breathing bag. Pressure balancing is also necessary to ensure patient safety.

If the disposal system presents a negative pressure of 5 mmHg or less, balancing can be achieved by the usual adjustment of the scavenging popoff valve. Nonrebreathing systems, which are particularly sensitive to slight negative pressure balancing, require special attention. The bag outlets and the inhalation valve are connected so that waste anesthetic gases from the nonrebreathing valve are introduced into the exhalation valve and passed through the popoff valve to the disposal system. Proper bag inflation is maintained by adjustment of the circle popoff valve.

Negative pressures greater than 5 mmHg should be reduced using interfacing equipment for additional pressure equalization. Pressure balancing equipment is commercially available. An example of an interfacing unit, developed by Whitcher et al [159], that can be used for all scavenging disposal systems is shown in use (liquid-sealed interface device) in Figure XIII-9. Figure XIII-10 shows a scale drawing of this device. A reservoir bag of at least 2-liter capacity should be used with this system, as shown in Figure XIII-9. A scavenging flow of at least 30 liters/minute should be used with this device.

(b) Nose Mask Applications

Nitrous oxide is the most commonly used gas when nose masks are utilized in dental surgery, although sometimes volatile anesthetic agents, such as halothane, are used. These gases are delivered with a nose mask through an open breathing system with intermittent or continuous gas flow.

Whitcher et al [172] developed appropriate control procedures for nose mask applications. This system includes the use of a nose mask designed to scavenge any gas leakage, regardless of mask fit, and a small concentration-equalizing fan located so any anesthetic gases leaking into the dentist's breathing zone will be diluted and blown away from dental personnel.

The essential features of the scavenging nose mask are shown in Figure XIII-11. Such a device, or its equivalent, should be used for all anesthesia requiring a nose mask. A vacuum (scavenging) flow of at least 45 liters/minute should be maintained at the mask with the popoff valve adjusted to maintain proper breathing bag inflation.

(c) Anesthetist Work Practices

Whitcher et al [159] estimated that work practices of the anesthetist may contribute from 94 to 99% of all waste anesthetic gases in an operating room equipped with properly designed scavenging components. Improper practices, such as poor choice of the face mask, insufficiently inflated endotracheal tubes, and spillage of volatile anesthetic agents when filling vaporizers, are the chief contributors. Anesthetist work practices, as required in the recommended standard portion of this document, must be followed to reduce this contribution.

(d) 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 maintenance procedures presented are based on the findings of the studies on equipment leakage discussed by Whitcher et al [159]. Leak test procedures are presented in Appendix I.

(1) Anesthesia machines should receive preventive maintenance at 3-month (minimum) intervals by the manufacturer's service representatives or by other qualified personnel. Following this maintenance, high-pressure leakage should be less than that which will raise room concentration to 2 ppm nitrous oxide. The low-pressure leak rate should be less than 100 ml/minute at 30 cm water, or an equivalent pressure drop in the breathing circuit.

(2) The low pressure systems of the anesthesia machines (from the flowmeters to the breathing tubes) should be leak-tested daily and whenever the soda-lime is changed. This can be readily done by hospital-based personnel.

(3) Ventilators should receive preventive maintenance at 4-month (minimum) intervals by service representatives or other qualified personnel.

(4) Breathing hoses attached to the anesthesia machines should be leak-tested as part of the low-pressure test. Breathing hoses associated with the T-tube, nonrebreathing system, and ventilators should be tested at 4-month intervals. All leaking hoses should be replaced.

(5) Breathing bags attached to the anesthesia machines should be leak-tested as a separate procedure at the time of the low-pressure test.

Other breathing bags associated with the T-tube, nonrebreathing system, and ventilators should be tested at 3-month intervals.

(6) Waste gas disposal tubing should be leak tested at 3-month intervals. Leaking tubing should be replaced.

(7) New equipment should be leak-tested by the manufacturer before being placed in service. Requirements of the recommended standard should be met.