

CONTROL TECHNOLOGY FEASIBILITY STUDY OF  
THE USE OF ENGINEERING CONTROLS IN HOSPITALS

PRELIMINARY SURVEY REPORT  
OF

VETERAN'S ADMINISTRATION MEDICAL CENTER  
CINCINNATI, OHIO

SURVEY CONDUCTED BY.  
Stephanie E. Spottswood  
Sharon L. Kercher  
G. Edward Burroughs

DATE OF SURVEY.  
September 29, 1982

REPORT WRITTEN BY  
Stephanie E. Spottswood  
Sharon L. Kercher

DATE OF REPORT.  
September 1983

National Institute for Occupational Safety and Health  
Division of Physical Sciences and Engineering  
Engineering Control Technology Branch  
Materials Processing Section  
Cincinnati, Ohio

PURPOSE OF SURVEY:

To conduct a preliminary study of sterilization and anesthetic gas administration operations with intent to document exemplary control methods.

EMPLOYER REPRESENTATIVES

CONTACTED:

Joe Payer, Assistant Chief, Engineering Services  
Paul Buckner, Chief, Supply, Processing &  
Distribution  
Bobbie Maybrier, Supervisor, Operating Rooms

EMPLOYEE REPRESENTATIVES

CONTACTED:

None

STANDARD INDUSTRIAL  
CLASSIFICATION CODE

General Medical and Surgical Hospitals (SIC 8062)

## INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. NIOSH was formally created by the Occupational Safety and Health Act of 1970. This legislation--which also gave rise to the Occupational Safety and Health Administration (OSHA) in the Department of Labor--called for a separate organization, NIOSH, to provide for research and education programs related to occupational safety and health. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards.

Health care facilities such as hospitals and medical clinics can pose a number of health risks to employees. Routinely used materials such as anesthetic gases, antineoplastic drugs and ethylene oxide sterilant are but a few of the potentially hazardous chemical agents encountered in the occupational environment of the hospital. These agents, in particular, may demonstrate reproductive, carcinogenic and mutagenic effects in chronically exposed individuals. It is estimated that approximately 50,000<sup>(1)</sup> operating room personnel (excluding anesthesiologists) are exposed to waste anesthetic gases, and approximately 75,000<sup>(2)</sup> health care workers employed in sterilization areas are potentially exposed to ethylene oxide (EtO). An additional 25,000 other employees may be incidentally exposed to EtO due to improper engineering and administrative controls.<sup>(2)</sup> These data serve well to emphasize the need to determine the level of exposure and evaluate the efficacy of the technologies and practices used to control exposures to such potentially harmful chemical agents. Good engineering controls and work practices should prevent health effects caused by acute exposures and significantly reduce risks associated with long term exposures.

The objective of this control technology feasibility study is to obtain information on the techniques and procedures used for maintaining low concentrations of hazardous chemical agents used in hospitals by means of

practicable and commercially available control technology. The NIOSH study has as its focus the control of waste anesthetic gases, antineoplastic drugs, and ethylene oxide sterilant. The documented findings of the feasibility study will be the basis for a determination of need to perform an in-depth control technology assessment of one or more of these specific areas of interest. A subsequent in-depth study will result in a technical report designed to assist hospital personnel in their efforts to prevent employee exposures to occupational health hazards.

#### Hazard Description and Exposure Sources

Ethylene oxide (EtO), anesthetic gases, and antineoplastic drugs present hazards to exposed employees with both short and long term health effects. Evidence of these effects has been demonstrated in animal and human studies as well as epidemiologic investigations. Use of each of these agents is confined to a particular area of the hospital where several exposure sources may present a hazard.

#### Ethylene Oxide

Ethylene oxide is a major industrial chemical, and while hospital sterilization procedures are estimated to use only about 0.02% of the annual United States production of EtO, NIOSH estimates that as many as 100,000 hospital personnel may be exposed<sup>(3)</sup>. Because of the large number of potentially exposed employees and the growing evidence of serious health effects, occupational health professionals and agencies are becoming increasingly concerned.

Ethylene oxide has several short term effects. At concentrations as low as 200 parts per million (ppm) EtO exposure may cause irritation of the eyes, nose, and throat. Direct contact of EtO with the skin or eyes may result in burns and an allergic rash. With extended low level exposures and brief

exposures to concentrations above 1,000 ppm, EtO can result in irritation of the lungs, coughing, chest pain, headaches, nausea, vomiting, drowsiness, weakness, and lack of coordination<sup>(4)</sup>.

In assessing the long term effects of EtO exposure, animal, human, and epidemiologic studies are necessary. Animal studies have shown ethylene oxide to be a carcinogen in male and female rats (through inhalation exposure) and to produce malignant tumors in mice (by injection). The carcinogenicity of EtO in terms of human exposures is more difficult to define. Several epidemiologic studies have indicated an increased risk for cancer and leukemia, but the results can not be considered conclusive<sup>(5)</sup>.

Several in vitro tests including Salmonella typhimurium, Drosophila melanogaster, Escherichia coli, and in vivo tests such as micronucleus, dominant lethal, and the heritable translocation test have shown ethylene oxide to be mutagenic. Other long term animal studies involving rabbits and monkeys show an increased frequency of sister chromatid exchanges and chromosomal aberrations. Two studies of workers exposed to EtO have also demonstrated an increased frequency of sister chromatid exchanges<sup>(5)</sup>.

Evidence of ethylene oxide induced reproductive effects is inconclusive. Rats treated with EtO have significantly reduced litter sizes, however, EtO inhalation by rats did not produce teratogenic effects. Intravenous injection of EtO in mice is teratogenic but is not in rabbits similarly injected. Human studies have been limited. One study reported a reduced sperm count in exposed male workers but the small sample size rendered the results inconclusive<sup>(5)</sup>.

Since some of these effects have occurred at levels below the current Occupational Safety and Health Administration (OSHA) exposure standard of 50 ppm, the American Conference of Governmental Industrial Hygienists has established a threshold limit value of 10 ppm and is recommending a reduction

of the standard to an eight-hour time weighted average (TWA) exposure of 1 ppm <sup>(7)</sup>. OSHA is presently considering that change.

Because EtO is explosive, it is usually used in combination with Freon 12 (dichlorodifluoromethane) in the sterilization process. The mixture is typically 12% EtO and 88% Freon. Freon exposure may cause eye and skin irritation, and high exposures (2300 ppm) in animals have been found to cause intoxication, weakness, dizziness, and loss of balance with convulsions. Excessive levels are expected to produce the same results in humans. Low level exposure to Freon causes irregular heartbeats and is considered to be the most significant effect <sup>(6)</sup>.

Exposure to ethylene oxide is effectively limited to the area of the hospital where sterilization takes place. The highest exposure occurs when the sterilizer door is opened after a cycle, when the concentration of EtO may reach 1,000 ppm for a short time. During the exhaust cycle, high EtO concentrations can occur at the gas discharge point, usually a floor drain beneath the sterilizer. Transferring materials from the sterilizer to the aerator is an important source of exposure, especially since approximately 5% of the EtO in the sterilizer stays in the sterilized materials and packaging. <sup>(4)</sup> Changing the EtO gas cylinder can also cause exposure to the worker both by inhalation and by skin contact.

#### Anesthetic Gases

Inhalation anesthetics have been in use for 140 years. Approximately 20 million patients are anesthetized annually in an estimated 25,000 operating rooms <sup>(6)</sup>. The potential for worker exposure is tremendous and has caused growing concern for the past decade. Eight anesthetic agents are used extensively in the United States: nitrous oxide (N<sub>2</sub>O), halothane, methoxyflurane, cyclopropane, enflurane, fluroxene, trichloroethylene, and

diethyl ether Nitrous oxide and halothane are the most frequently used agents. NIOSH estimates that approximately 50,000 workers are exposed to anesthetic gases.<sup>(1)</sup>

Health effects of exposure to anesthetic gases have both short and long term consequences. Human volunteers exposed to various anesthetic gases showed decreased mental capacity and impaired motor skills during and immediately after the exposure<sup>(6)</sup>. Halothane can cause headaches, irritability and depression, and has been linked to hepatotoxicity (liver disease) in female anesthetists, and some rare cases of hepatitis. Methoxyflurane has been shown to impair normal kidney function. It is suspected that operating room personnel metabolize anesthetic gases at an increased rate, resulting from changes in the liver function. This increased metabolic rate magnifies the potential toxic effects for these workers<sup>(6)</sup>.

Anesthetic gases are strongly implicated in the higher rate of spontaneous abortions and congenital malformations experienced by nurses, anesthetists, and operating room assistants. Research findings have indicated higher rates of spontaneous abortion and congenital malformations among exposed female workers and the spouses of male workers as compared to unexposed workers. Some recent studies suggest that female anesthetists have a higher rate of infertility than unexposed women<sup>(6)</sup>.

The question of carcinogenicity of anesthetic gases has been raised by several researchers. A comparison of the chemical structures of several inhalation anesthetics and known human carcinogens reveals similarities, giving some reason for suspicion.<sup>(1)</sup> Epidemiologic studies of operating room personnel have presented conflicting evidence. There is an indication of increased incidence of cancer in exposed female workers, however, more studies are needed to substantiate the results<sup>(1)</sup>.

Extensive animal studies have been conducted to assess the effects of anesthetic exposures. Some of the studies demonstrated a dose related response for particular gases. Generally, anesthetic gases produced damage to

or changes in liver and kidney function, and neuronal tissues. Other effects included fetal skeletal anomalies, limb developmental defects, reduction in fetal weight, and an increase in fetal resorptions<sup>(1)</sup>.

Sources of exposure to anesthetic gases in the operating room are a function of the equipment and the work practices of the anesthesiologist. Equipment related exposure sources include. high pressure connections of the gas supply to anesthesia machine, low pressure connections to control valves and patients, scavenging hoses and connections, rebreathing bag, and suction connections. Equipment that is poorly designed or maintained is the major source of gas leakage. The anesthesiologist can also be a contributor to gas leakage by improperly connecting hoses, not checking for loose fittings, improperly filling the vaporizer, and leaving the vaporizer turned on after the patient is disconnected. The fitting of the anesthesia mask or endotracheal tube can also be a leak source. In the recovery room, nurses can also receive significant exposure while working near the patient's breathing zone. Anesthetics are exhaled for several hours after surgery<sup>(1)</sup>.

Presently, worker exposure standards for most inhalation anesthetics have not be promulgated. OSHA standards regulate only two substances: diethyl ether (400 ppm, TWA), and trichloroethylene (100 ppm, TWA). NIOSH recommends a nitrous oxide standard of 25 ppm, TWA<sup>(6)</sup>.

#### Antineoplastic Drugs

Pharmacists who prepare antineoplastic drugs and nurses who administer them are potentially at risk. One study has found increased levels of mutagenic activity in the urine of exposed nurses. Many of these agents are known to cause carcinogenic, mutagenic, or teratogenic effects in animals. The effects on human health of chronic exposure to low doses of these agents is unknown<sup>(8)</sup>.



## Hospital Description

The Veteran's Administration Medical Center is a 30 year old facility located in central Cincinnati, Ohio. The 400-bed hospital occupies approximately 670,000 ft<sup>2</sup>, which includes the main building, trailers and other detached operations or research buildings.

The operations of interest, gas sterilization and anesthesia administration, are performed in the Supply Processing and Distribution (SPD) Department, and Operating Rooms (O.R.), respectively.

## Gas Sterilization

### Process Description

Sterilization procedures are routinely conducted to decontaminate medical supplies and equipment, including various surgical instruments. Most materials are subjected to steam sterilization. Heat sensitive items for which steam sterilization is impractical (e.g., plastic and rubber goods, telescopic instruments and various surgical instruments and equipment) are sterilized using EtO.

The sterilization process takes place in the SPD Department (Figure 1). The department contains offices, storage and supply areas, and isolated locations for the sterilizers. The two EtO gas sterilizers are enclosed in a completely separate room, adjacent to the steam sterilization area (Figure 2).

The sterilization process in the SPD Department is basically conducted as follows (Figure 3)

1. Contaminated materials are delivered to the SPD decontamination area for washing or cleaning.
2. After cleaning, the materials are dried and wrapped or packaged for sterilization. Heat sensitive items are gas sterilized, the other items are steam sterilized.
3. Sterile items are either stored in the SPD supply area, or sent to the operating rooms, dental clinic, gastric lab, or cardiac catheterization lab for use.

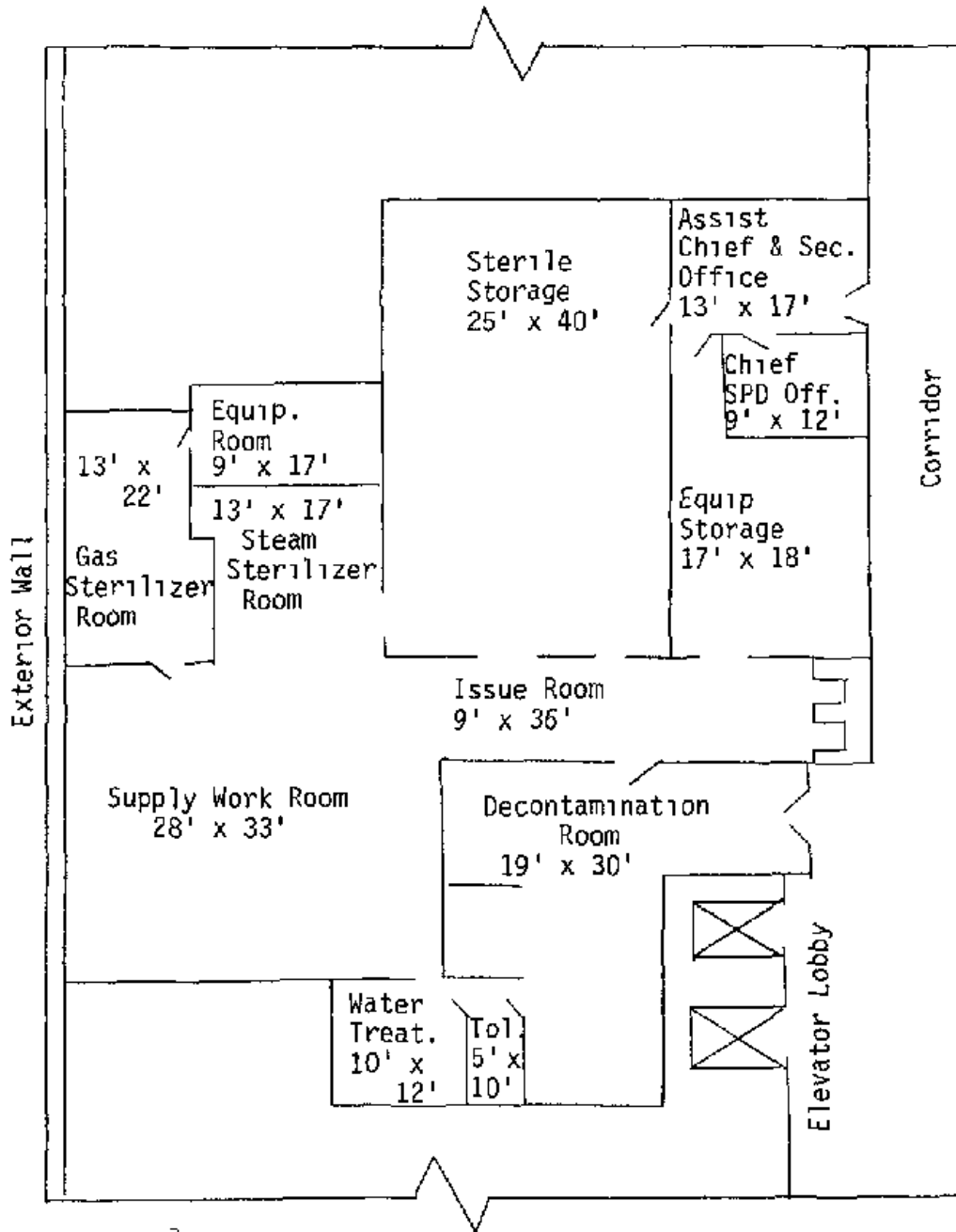


Figure 1. Supply, Processing and Distribution Department

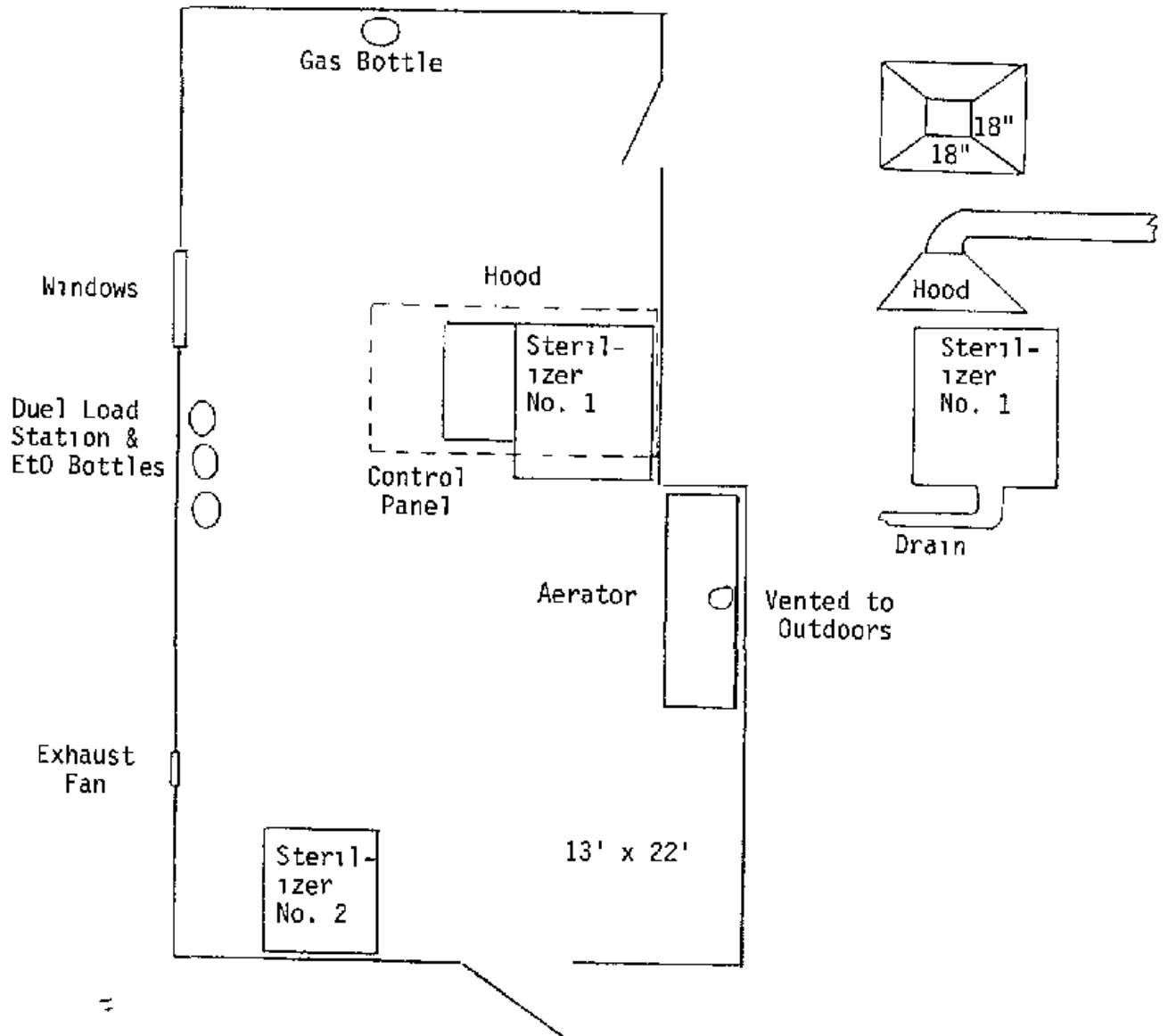


Figure 2. Gas Sterilizer Room, SPD

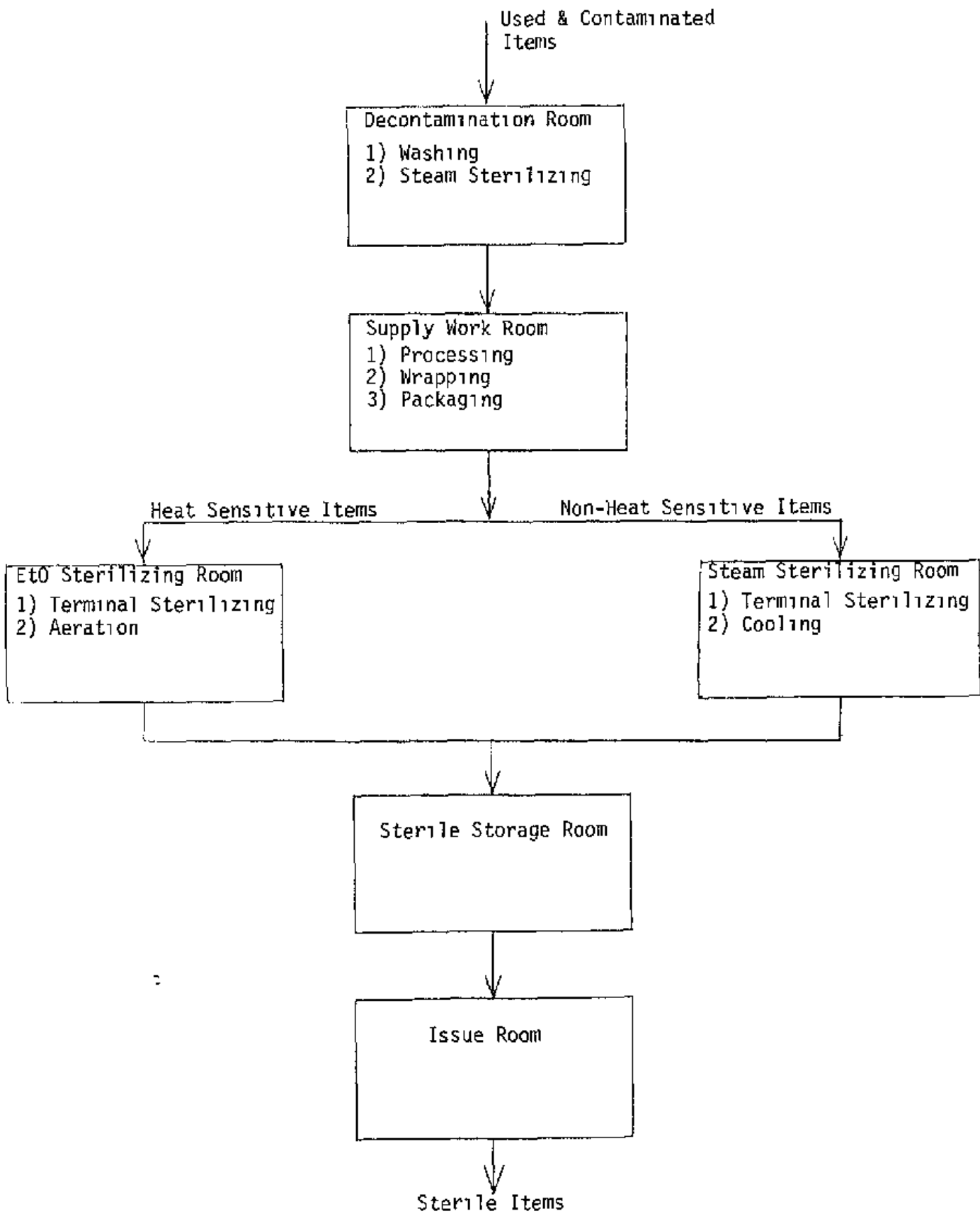


Figure 3. SPD Process Flow Design

Gaseous chemical sterilization procedures make available sterile disposable supplies. The chemical sterilant is capable of killing viable microorganisms or their by-products thus decreasing the incidence of bacterial infections. EtO, mixed with Freon-12 in a 12.88 concentration by weight, is the chemical sterilant used. It is supplied by two gas cylinder tanks, using a "dual load" system such that one tank acts as a reserve when the other is empty.

The gas sterilizer, manufactured by Sybron Castle, is of moderate size, with an approximate chamber volume of 70 cubic feet. The gas sterilization process is basically conducted as follows:

1. Articles to be gas sterilized are placed in baskets and loaded on a cart to be rolled into the gas sterilizer room.
2. The temperature on the sterilizer is set at 130<sup>0</sup> (standard temperature for EtO sterilization) and the humidity set at 50%. The chart in the attached recorder is changed.
3. Articles (in baskets) are manually loaded into the sterilizer.
4. The timer is set (usually) for 4 hours.
5. The door is closed and a lock button is depressed.
  - a. Indicator lights show that the door is locked. The vacuum cycle begins.
  - b. When the vacuum cycle is complete, humidity will enter the chamber for approximately 30 minutes.
  - c. When humidification is complete, EtO gas enters the chamber.

- d. After 4 hours, the sterilization cycle is complete and a vacuum will be pulled on the chamber to evacuate all gas. The chamber is exhausted repeatedly (approximately 15 times) to maximally evacuate all of the gas.
  - e. When all the gas is evacuated, air enters the chamber through a bacterial filter. The chamber pressure returns to 0.
6. The master switch is turned off.
  7. The sterilizer door is opened 6 inches and employees leave the immediate vicinity for 20 minutes.
  8. Sterilized items are manually removed and transferred to the aerator.

The gas sterilizer is operated for one cycle per day.

#### Gas Aeration

Aeration of supplies and materials after sterilization is performed to eliminate hazardous residual quantities of ethylene oxide and its reaction products, ethylene glycol and ethylene chlorohydrin. The aerator, a Sybron Castle Model 4041, has a chamber volume of approximately 30 cubic feet.

The aeration process is as follows.

1. The aerator is manually loaded, allowing ample space for air circulation.
2. The doors are closed to the "locked" position. A pilot light indicates when the doors are locked and the "heating" pilot light indicates that the heaters are operating (temperature is maintained at 135°F.)

3. The air in the chamber is circulated and exhausted for 12 hours.
4. After the 12 hour minimum aeration period, the chamber door is opened.
5. The materials are manually removed and transferred to a cart for transport to the storage and distribution areas, where they are assigned control numbers and expiration dates.

## Control Technology

### 1. Engineering Controls

The principal engineering controls used are isolation, general dilution ventilation, and preventive equipment maintenance procedures. The sterilizers are located in a isolated room within the SPD Department, along with the aerator. The door is kept closed and the room is accessible only to authorized employees.

General dilution ventilation is provided by a fresh air supply from an open window and a window fan exhaust, and by a large canopy hood over sterilizer #1 (see Figure 2). The hood exhausts through an 18 inch square duct directly to the outside of the building. The room has a negative pressure with respect to the outside SPD area. Hospital personnel report that the ventilation system design provides 8 to 10 air changes per hour. Effluent waste gas is discharged with water through two floor drains during a scavenging cycle. Plans have been made to locally exhaust these drains as this emission source can contribute to the total background levels of EtO in the room.

The hospital staff has established an equipment maintenance program with written guidelines for inspection and repair. Periodic inspections are made by the hospital engineering staff. Records are kept on all sterilizer malfunctions and repairs. Soap and water leak testing is performed on the cylinder valves and connections and on the gas carrier



lines to the sterilizer units. Should a leak be detected, a safety shut-off valve is activated. A strip chart recorder which records the chamber temperature and pressure runs throughout the cycle. Changed daily, the strip chart can reveal whether there is leakage occurring from the sterilizer chamber. The front door gasket is also changed daily prior to use.

The aerator is equipped with 12 narrow (approximately 1/4 inch) air vents along the ceiling of the chamber. These vents supply filtered air which circulates around the items in the chamber. A 2-inch vertical duct exhausts the excess gas from the top of the aerator to outside the building. The minimum aeration time is 12 hours.

## 2. Control Monitoring

Routine air sampling is conducted by the VA's district safety engineer, using a Miran 103 portable infrared analyzer. Reportedly, EtO concentrations measured in February ranged from 0 to 18 ppm, during the sterilization exhaust cycle. Pressure monitoring charts are studied to observe possible leaks from the door gasket or solenoid valve--as indicated by a sawtooth pattern.

## 3. Work Practices

Work practices and procedures for minimizing exposure to ethylene oxide are outlined in the hospital's Supply Service Policy and Procedures Manual. Additionally, annual training seminars are held to discuss safe and healthful work practices to be followed during operation of the equipment.

The greatest potential for high EtO exposure is during the exhaust cycle (at the end of the sterilization cycle) and when the chamber door is opened to remove sterilized items. To limit exposure during this

operation, the sterilizer door is only partially opened (approximately 6 inches), the employee immediately leaves the area, and items are not removed for 20 minutes. This procedure allows any unevacuated gas from the chamber to be emitted and captured by the exhaust hood. After 20 minutes, materials are transferred immediately to the aerator, to prevent prolonged breathing of any ambient vapors.

When changing gas cylinders, employees take precautions to avoid contact with liquid sterilant which may remain in connecting lines.

#### 4. Personal Protective Equipment

When transferring sterilized materials from the sterilizer to the aerator, polyvinyl gloves are worn by personnel. The gloves are immediately disposed of after leaving the gas sterilizer room. A full-face piece self-contained breathing apparatus (manufactured by "Guardman") is accessible for emergency use immediately outside the gas sterilizer room. There is no formal respirator protection program.

### Anesthesia Administration

#### Process Description

The VA hospital has a total of six operation rooms. Each operating room (O.R.) is approximately 17 ft. by 21 ft. and is situated along either side of a sterile corridor. A floor plan for the Operating and Surgery Department is featured in Figure 4.

Each O.R. is equipped with anesthesia machines manufactured by Ohio Medical Company. Each machine is designed to deliver accurately measured concentrations of anesthetic gases (nitrous oxide mixed with oxygen) and vapors (of liquid halothane and enflurane) into the breathing system. The gas source is a central pipeline system, but gas cylinders are affixed to the

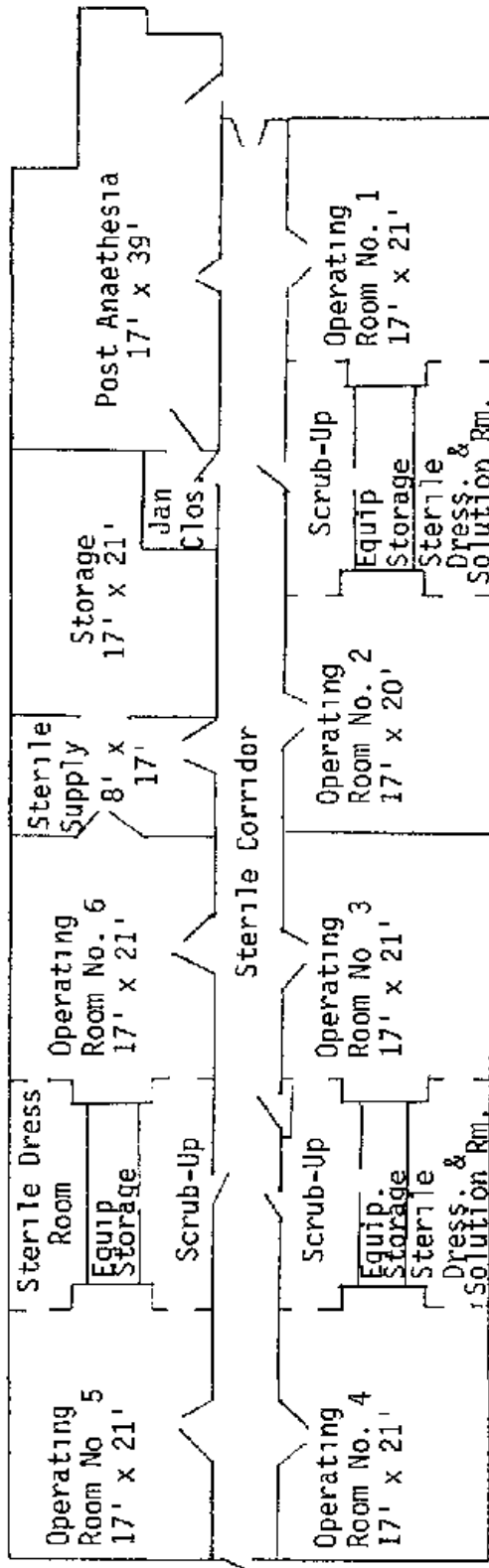


Figure 4. Operating & Surgery Department Floor Plan

anesthesia machine for supplemental use. The gases are administered in controlled concentrations by means of rotameters calibrated in liters per minute. The flow rate is controlled by the anesthetist with associated valves. The machine is equipped with a vaporizer which converts the volatile liquid anesthetic agent into a vapor and administers a controllable volume or concentration to the breathing circuit, in a mixture with the nitrous oxide and oxygen. A schematic of a typical anesthesia machine and breathing circuit is shown in Figure 5.

During anesthesia, the patient may breathe "spontaneously" without assistance from the anesthetist, or breathing may be assisted by the anesthetist, who periodically squeezes a breathing bag near the end of exhalation to augment the amount of inspired air. "Controlled" ventilation can also occur by use of a ventilator, a pneumatically operated mechanical pump which automatically ventilates the patient's lungs.

Sufficient anesthetic is delivered to last the duration of the procedure, and the patient is then wheeled into a post-anesthesia recovery room.

## Control Technology

### 1. Engineering Controls

Engineering controls in the O.R. include general dilution ventilation and local exhaust ventilation (scavenging) of the waste anesthetic gases.

Figure 6 shows a typical operating room arrangement. General room air is exhausted through two 1 foot by 1 foot exhaust grilles situated 6 inches above the floor on opposite walls. Two ceiling diffusers supply fresh air above the operating table. A positive pressure relative to the outside corridor results. Hospital engineers report that 15 air changes occur every hour in the O.R.

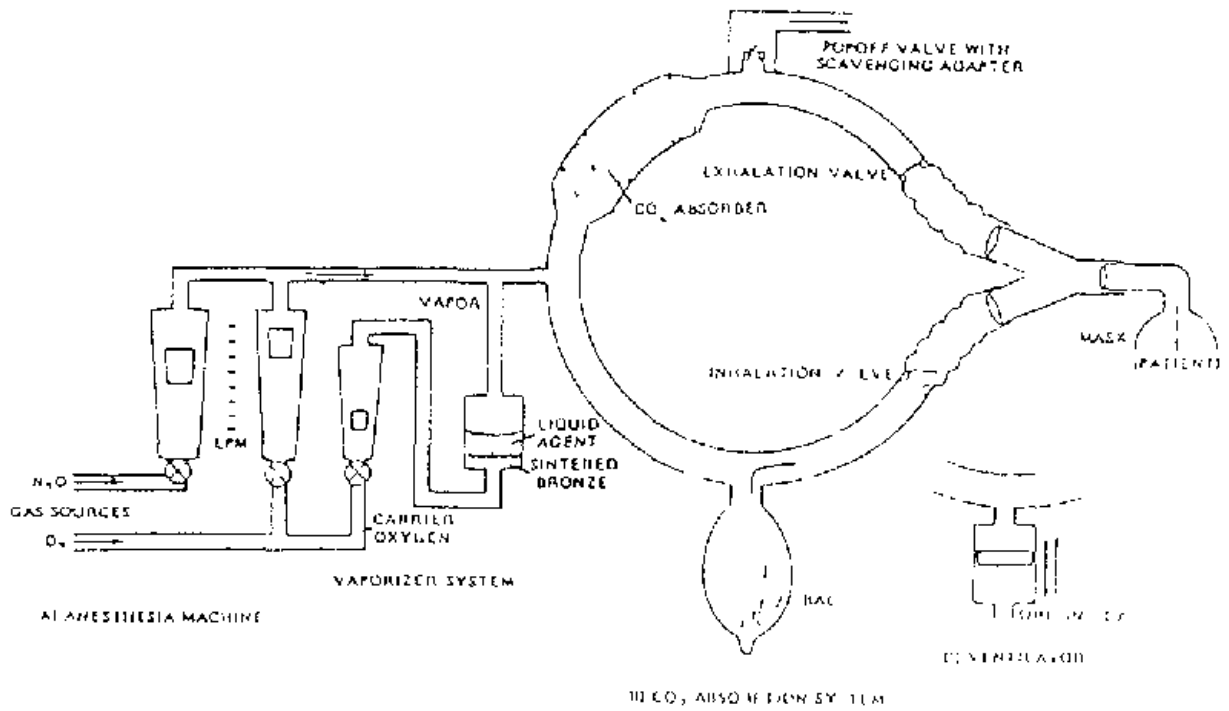


Figure 5. Typical Anesthesia Machine and Breathing Circuit

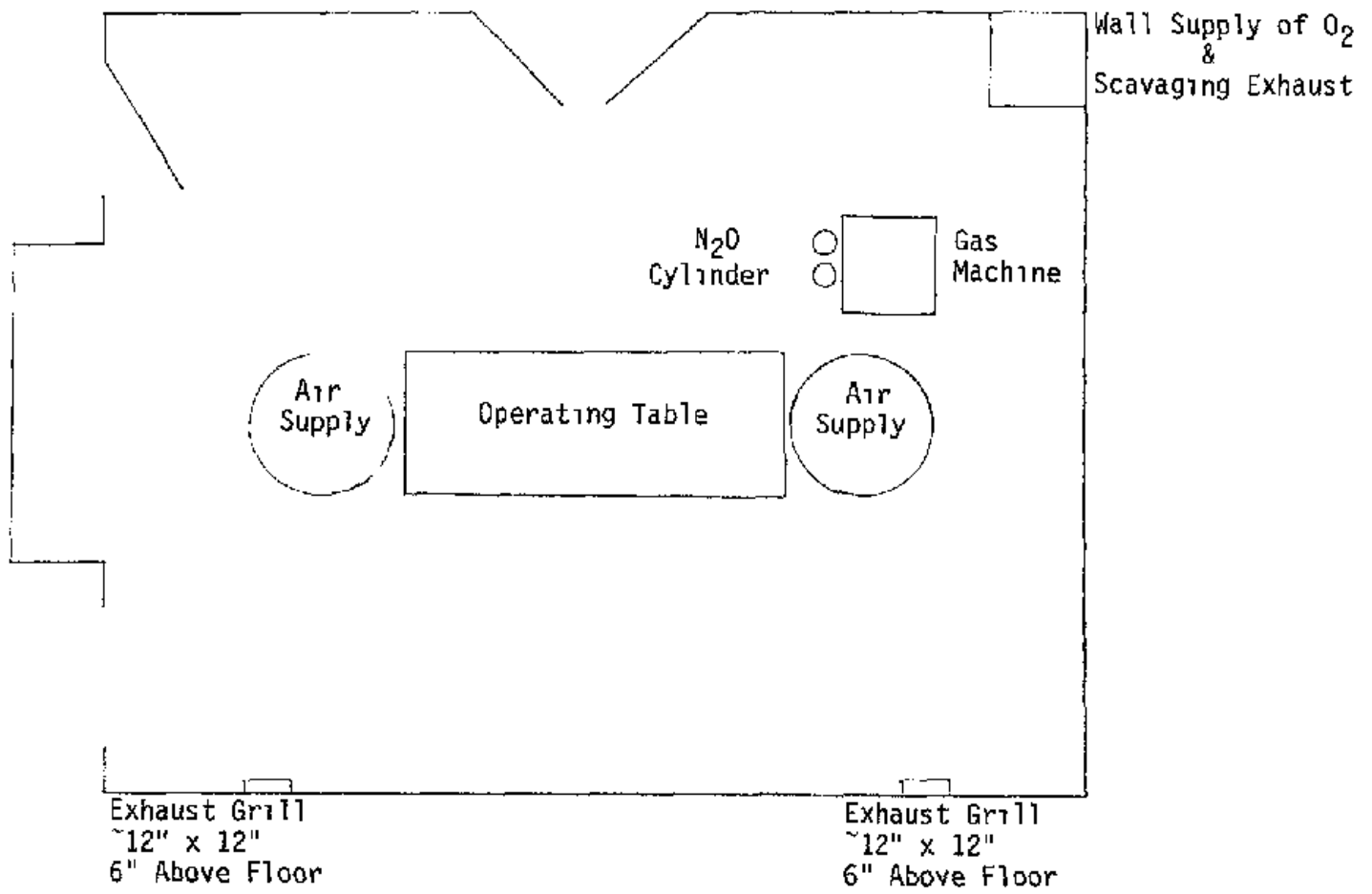


Figure 6. Typical Operating Room

The gas discharge from the breathing circuit is controlled by a scavenging system consisting of a hose extending from the pop-off valve, which attaches by a Y-connector to the ventilator, and leads to a wall suction source. The exhaust of the suction pump is located outside the building at a point remote from air intakes.

## 2. Control Monitoring

The anesthesia machines are serviced four times yearly by Ohio Medical, the manufacturer. The service contract includes pressure testing the system and replacement of any worn parts.

Air sampling for nitrous oxide is performed annually by the regional safety engineer. Recent monitoring in O.R. #1 revealed a TWA for four hours of 20 ppm with a peak of 60 ppm. During the measurement period, 60% nitrous oxide was administered to the patient.

### Sampling Methodology

Air sampling was conducted in the O.R.'s using a Wilks Miran 103 Specific Vapor Analyzer. This direct reading instrument is an infrared analyzer equipped with a selective filter for nitrous oxide analysis. A built-in sample pump allows for continuous measurement. When exposed to infrared light, the resulting absorbance is indicated on a meter calibrated directly in parts per million, with approximately 5% accuracy.

Nitrous oxide measurements were made at several potential leak points in the high pressure gas supply system connections on the anesthetic equipment itself, and in the low pressure breathing circuit. Additional measurements were made in the breathing zones of the anesthetist and the patient.

## Air Sampling Results

Ambient nitrous oxide concentrations in O.R.'s #3 and #5 are reported in Tables I and II. Values ranged from less than 5 ppm to more than 300 ppm. It was observed that concentrations at several connections in the system were significantly reduced when the anesthesiologist tightened hose connections at the request of the survey team. In O.R. #5, however, very high concentrations observed at the pop-off valve of the ventilator indicated a substantial leak from the system. This leak was probably the source of the elevated background levels in this O.R.



Table I

Nitrous Oxide Concentrations in O.R. #3  
By Sample Site, with Scavenging in Use

Sample Site	N <sub>2</sub> O Concentrations ppm
High Pressure O <sub>2</sub> valve at anesthesia machine	10
Scavenging hose connection to wall suction	10
General Air	10
Scavenging System. Vacuum connection insert into large diameter scavenging hose	10
High Pressure N <sub>2</sub> O connection at anesthesia machine	10
Exhaust Dome Valve	317
*Exhaust Dome Valve	35
"Y" Connection between ventilator and exhaust	15
Breathing Zone of Anesthetist	10
Breathing Zone of Patient	10
NIOSH Recommended Standard <sup>1</sup>	25

\*After adjustment and tightening of fittings

Table II

Nitrous Oxide Concentrations in O.R. #5  
By Sample Site, with Scavenging in Use

Sample Site	N <sub>2</sub> O Concentrations ppm
High Pressure Valve at anesthesia machine (prior to anesthetization)	7
General Air	35
Dome Valves	190
Pop-Off Valve on Ventilator	310 variable
Anesthesia machine connection to ventilator	125 variable
Anesthesia machine pop-off valves	310
Air between machine and patient	47
Floor near exhaust grille	27
*Air between machine and patient	25-30
*Anesthesia machine connection to ventilator	27-35
*Pop-off Valve on Ventilator	310
Breathing Zone of Anesthetist (prior to anesthetization)	3-5
Breathing Zone of Anesthetist (during anesthetization)	310
Breathing Zone of Anesthetist (after initial anesthetization)	35-60 variable
NIOSH Recommended Standard <sup>1</sup>	25

\*Sample taken after adjustment and tightening of fittings and connections

## Discussion

The purpose of this evaluation was to assess the efficacy of control measures used to reduce exposures to EtO and N<sub>2</sub>O. In the SPD Department, EtO levels are reportedly maintained at less than 20 ppm TWA which is below the current OSHA PEL of 50 ppm<sup>9</sup>.

This level, however, exceeds the current ACGIH Threshold Limit Value of 10 ppm<sup>7</sup>. Although this is not a legal limit, it would be prudent to maintain airborne concentrations below 10 ppm to avoid such effects as irritation of the respiratory passages, and organic injury to the liver, kidneys and adrenal glands.<sup>10, 11</sup>

Subsequent to the 10 ppm EtO recommendation, evidence of possible carcinogenicity, mutagenicity and teratogenicity in humans and in laboratory animals has prompted the ACGIH to recommend the reduction of the TLV for EtO to 1 ppm.<sup>12</sup>

In the O.R., the mean breathing zone concentration of nitrous oxide for the anesthetist was 35 ppm. During the initial anesthetization procedure nitrous oxide levels were significantly higher (over 310 ppm). In O.R. #3, a significant reduction in nitrous oxide concentration was noted after the anesthetist adjusted and tightened loose connections in the low pressure and scavenging system. It should be noted that the values obtained do not represent time-weighted average concentrations, but rather, instantaneous samples read from a direct-reading instrument.

Although NIOSH has been unable to identify a safe level of exposure for waste anesthetic gases, it recommends that the risk be minimized by reducing exposures to the greatest extent possible. Where halogenated agents are used in combination with nitrous oxide, data relative to control techniques

currently available indicate that, for anesthetics delivered as mixtures for use in operating rooms, concentrations of 0.5 ppm for halothane and other volatile anesthetics, and 25 ppm for nitrous oxide are feasible.<sup>1</sup>

#### Conclusions and Recommendations

Findings of this evaluation indicate that EtO is controlled to a time weighted average concentration within the limits of the OSHA PEL, however, more stringent engineering controls are recommended to reduce EtO levels during the exhaust cycle and during door opening. A local exhaust hood at the drain area would effectively reduce airborne concentrations during the exhaust cycle. Work practices used in the SPD area are adequate.

It is recommended that to aptly anticipate any new OSHA rule making on EtO, and for optimal protection of employee health, the best possible engineering controls and work practices should be instituted to maintain the lowest practicable levels of ambient EtO.

In the O.R., anesthetic gas scavenging equipment was effectively employed, however, periodic leakage from the equipment was observed. It is recommended that anesthesia equipment be checked and maintained on a regular basis. Face masks, tubing, breathing bags and endotracheal tubes should be visually checked for cracks and other leak sources. Both high and low pressure components, should be leak tested. The high pressure components, from nitrous oxide and oxygen supply up to the flow meter control valves, can be tested by applying soap solution to all connections and observing any bubbles. This should be performed quarterly. Low pressure components, including breathing bags and tubing, can be tested using the procedure presented in Appendix I of the NIOSH criteria document on waste anesthetic gases<sup>1</sup>. This procedure is outlined below:

- (a) Assemble the anesthesia machine as in the usual manner for clinical anesthesia with breathing tubes, Y-piece, breathing bag, and high pressure hoses or cylinders connected.
- (b) Occlude the Y-piece securely with the thumb or palm of hand.
- (c) Pressurize the breathing system to 30 cm water, observed on the absorber pressure gauge. This may be accomplished by using the oxygen flush valve.
- (d) Add a sufficient flow of oxygen through the low-range flowmeter to maintain a constant pressure of 30 cm water in the breathing system. The oxygen flow required to maintain the pressure is a measure of the leak rate. This test may be abbreviated by using an oxygen flowrate of 100 ml/minute. If pressure in the system increases, the breathing system is below the maximum allowed leak rate.
- (e) Determine the presence of check valves downstream from the flowmeters by consulting the manufacturer or a serviceman. These valves must be tested differently. With oxygen flowing, briefly turn off in turn each flowmeter which is equipped with a check valve until there is a rise in pressure on the absorber gauge. An increase in pressure indicates absence of leakage in the circuit tested.

The low pressure leak rate should be below 100 ml per minute.

Small components such as breathing bags and hoses can be leak tested separately by pressurization, immersion in water and observation of any bubbles. In situations where this is not practical, it is recommended that fittings and seals be checked periodically to make sure gaskets and o-rings are in place properly, that connections are tight and not worn, and that moisture or chemical action has not caused corrosion or degradation of materials. Typical places to

check, and where leaks have been found in other studies, include the seals at the domed unidirectional valves, seals at the top, bottom, and center of the CO<sub>2</sub> absorber, and fittings where the breathing tubes connect to the machine and to the Y-piece.

In addition to a scavenging system and proper equipment maintenance, the anesthetists can reduce exposure by good work practices. Improper practices, such as poor choice of face mask, insufficiently inflated endotracheal tubes, and spillage of volatile anesthetic agents when filling vaporizers, are chief contributors to exposure.

## References

1. Criteria for a Recommended Standard--Occupational Exposure to Waste Anesthetic Gases and Vapors, U.S. Dept. of HEW Pub. No. (NIOSH) 77-140, 1977.
2. Glaser, Z. R., Special Occupational Hazard Review with Control Recommendations for the Use of Ethylene Oxide as a Sterilant in Medical Facilities. U.S. Dept. of HEW Pub. No. (NIOSH) 77-200, 1977.
3. NIOSH Current Intelligence Bulletin 35, Ethylene Oxide, NIOSH Pub. No. 81-130, May, 1981.
4. Hazard Alert #3, Ethylene Oxide (EtO) Hazard Evaluation and Information Service, CAL/OSHA, July, 1982.
5. Quint, Julia, The Toxicity of Ethylene Oxide, Hazard Evaluation System and Information Service, State of California, May, 1982.
6. Coye, Molly J., and Mooser, Stephen B., Health and Safety Manual for Hospital Workers, NIOSH (draft report), 1981.
7. Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment with Intended Changes for 1982. American Conference of Governmental Industrial Hygienists, Inc., 1982.
8. Zimmerman, Paul F. et. al., Recommendations for the Safe Handling of Injectable Antineoplastic Drug Products, American Journal of Hospital Pharmacy, Vol. 38, Nov. 1981.
9. Code of Federal Regulations - 29., Part 1910.1000 Department of Labor, OSHA, 1980.
10. Documentation of the Threshold Limit Values, Fourth Edition, American Conference of Governmental Industrial Hygienists, Inc., 1980.
11. Hollingsworth, R. L. et. al., Toxicity of Ethylene Oxide Determined on Experimental Animals. Archives of Industrial Health, Vol. 13., pp 217-227, 1956.
12. Documentation of the Threshold Limit Values, (1982 revision of 4th edition), American Conference of Governmental Industrial Hygienists.