HAZARD EVALUATION AND TECHNICAL ASSISTANCE REPORT
HETA 88-312-L1978
VETERANS ADMINISTRATION
MEDICAL CENTER
CLARKSBURG, WEST VIRGINIA
JULY 1989

Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations and Field Studies
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I. SUMMARY

On October 5-7, 1988, NIOSH industrial hygienists from the Atlanta and Denver regional offices visited the Veterans Administration (VA) Medical Center in Clarksburg, West Virginia to evaluate the potential for excess exposures to nitrous oxide (N_2O) originating from a piping leak discovered on June 16, 1988 in the Hospital's Surgical Services area. Although the piping system was deactivated, several Surgical Services employees were concerned about possible latent health effects from their potential exposures to N_2O from a leak that had gone undetected for over six months. A class-action suit was later filed against the VA by a group of physicians and nurses. To evaluate the potential exposure risk from working near the area of the leak, VA management, VA employees, and the U.S. Attorney's Office requested to have the piping system reactivated so that NIOSH investigators could monitor the buildup of N_2O created by the leak. No hospital personnel or patients were in the Surgical Services area during the reactivation test.

Using direct reading instruments and data recording equipment, NIOSH investigators found N_2O concentrations in the hallway near the leak ranging from about 10 to 12 parts per million (ppm). These levels were below the 25 ppm exposure limit recommended by NIOSH for N_2O exposures during surgical procedures. These levels were also below the proposed 50 ppm 8-hour time weighted average threshold limit value (TLV) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). Concentrations in the offices and operating rooms, which received 100% outside air from the hospital's heating ventilation and air-conditioning (HVAC) system, were below 4 ppm. During the survey, NIOSH investigators also leak tested all anesthetic carts. Low pressure leaks were detected in three of the four carts tested. A high pressure leak was detected on one N_2O wall outlet when connected to a cart's high pressure hose. NIOSH also evaluated exposures to N_2O and halogenated anesthetic vapors (isoflurane) during an actual surgical procedure performed in Operating Room A. During the surgery, no OR personnel exposures exceeded NIOSH's recommended exposure limits for N_2O (25 ppm) or halogenated anesthetic vapors (0.5 ppm).

II. INTRODUCTION

On October 5-7, 1988, NIOSH investigators conducted a health hazard evaluation at the Veterans Administration (VA) Medical Center in Clarksburg, West Virginia. This evaluation was requested by the Medical Center Director in response to concerns from the Surgical Services staff about possible excess exposures to N_2O from a leak

discovered in the Surgical Service's pipeline system on June 16, 1988. The leak was located above the ceiling in a hallway which received no direct ventilation. Although the VA deactivated the system after discovering the leak, many Surgical Services employees were upset about latent health problems which might possibly result from their exposures to N_2O. Based on N_2O purchase records and usage rates, it was suspected this leak may have gone undetected for over six months. To evaluate the potential exposure risk from working near the area of the leak, the VA Medical Center agreed to have the system reactivated so that NIOSH investigators could monitor the buildup of N_2O. Subsequently a class-action lawsuit was filed by several VA employees to have the nitrous oxide pipeline leak evaluated. As a result of this action, a court order was issued by the U.S. Attorney's office to have NIOSH conduct this evaluation during the first week in October 1988.

III. BACKGROUND

The VA Medical Center in Clarksburg, WV, is a 253 bed hospital. The Surgical Services area has four operating rooms (Rooms A, B, E, and F) located on the 5th floor. Other Surgical Services rooms include a recovery room, the anesthetist's work room, the O.R. Supervisors Office, a supply room, and a clean-work room. The Surgical Services staff consists of eight nursing personnel, two anesthetist technicians, and two staff physicians. Operating room (OR) E is used most often (about six times a day) for minor surgical procedures. OR F is used for cistology procedures about four times per day. Major surgery is performed in ORs A or B about once or twice per day. Each room contains an anesthetic cart equipped with a vacuum scavenging system. With the deactivation of the N_2O delivery system, all carts were supplied with N_2O from pressurized cylinders installed on each cart.

IV. EVALUATION DESIGN AND METHODS

The evaluation consisted of: (1) activating the nitrous oxide pipeline system and measuring airborne concentrations near the vicinity of the leak; (2) reviewing the design and operation of the Surgical Services heating, ventilation and air-conditioning (HVAC) system; (3) leak testing anesthetic gas delivery equipment; and (4) monitoring personal exposures to nitrous oxide and halogenated anesthetic gases during actual surgical procedures.

Real time air monitoring for nitrous oxide (N_2O) was accomplished using a Foxboro Miran Model 103 Specific Vapor Analyzer equipped with a 4.5 micrometer interference filter and meter scale for measuring nitrous oxide concentrations ranging from zero to 250 ppm. The instrument was calibrated using a closed-loop calibration system. Known concentrations of N_2O (obtained from an anesthetic cart N_2O cylinder) were injected into the loop, and meter responses were recorded. Pre- and post-use calibrations of the instrument were done for each day of the survey. For continuous monitoring of N_2O levels, the analyzer was connected to a Metrosonics Model 332 data logger. Voltages produced by the analyzer (zero to one volt DC, representing zero to full-scale

deflection of the meter) were recorded and stored by the data logger once each second. The data logger was programmed to store and report the minimum, average, and maximum readings detected by the analyzer during each five minute interval of the monitoring process.

On the morning of October 6, 1988, at 8:45 a.m., VA maintenance personnel were instructed to reactivate the N_2O pipeline system. Pressure gauges on the system regulator registered 600 pounds per square inch (PSI) on the high pressure side (cylinder pressure), and 45 PSI on the low pressure side (pipeline system pressure). To purge the lines, an anesthetist technician connected the four anesthetic carts to the system and bled off N_2O through the hospital vacuum system. The Miran gas analyzer was then brought into the Surgical Services main hallway and placed directly under the leak. Initial readings were higher than expected. Concentrations were even higher in the ORs because all four anesthetic carts were still bleeding off N_2O and were overloading the vacuum system. The carts were shut off at 10:50 a.m.

To permit the hospital ventilation system to flush out the excess N_2O unintentionally released from the anesthetic carts, monitoring was delayed until 11:15 a.m. After N_2O levels had stabilized, the monitoring equipment was placed in the hallway near the wall between the entrance doors to ORs A and B, a location about 10-12 feet from the N_2O pipeline system leak. To represent normal conditions, all ceiling tiles were left in place during monitoring. At 11:18 a.m., the data logger was activated to continuously monitor and record N_2O concentrations. No surgical services were scheduled on this day of the survey. A meeting was scheduled at 1:30 p.m.to brief all concerned VA employees on the sampling methods and objectives of the NIOSH survey. Local union representatives (American Federation of Government Employees, Local 2384) were invited to attend the meeting, but no official representative was present.

Area air samples were collected from other locations in Surgical Services, by using battery powered air sampling pumps. The sampling pumps were operated at a flow rate of about 200 cc/min with their exhaust ports connected, via vinyl plastic tubing, to Tedlar[tm] air sampling bags. The N_2O concentrations in the bags were measured later that day with the Miran analyzer according to NIOSH Analytical Method 6600.[1] Other locations in the general vicinity of the leak were also checked directly with the Miran analyzer.

After continuous monitoring in the hallway was completed, leak detection for N_2O was conducted on the four anesthetic carts. All tests were made using a simulated lung with N_2O and oxygen flow meters set at 2 liters per minute (Lpm). All high pressure and low pressure hose connections and system components were checked directly using a flexible sampling probe attached to the Miran analyzer. The N_2O pipeline system was still active during these tests, but only the cart in OR A was connected to the system. The

other carts were equipped with a cart-mounted N_2O cylinder. After completing the leak tests, the N_2O pipeline system was deactivated.

On the morning of October 7th, personal breathing zone exposures to N_2O and the halogenated anesthetic agent isoflurane were monitored during an actual surgical procedure in OR A. Area samples were also collected at each floor-level exhaust vent inside the OR, and immediately outside the OR in the main hallway. The personnel sampled during surgery were the circulating nurse, scrub nurse, and anesthetist technician. During surgery, NIOSH investigators also leak tested the anesthetic equipment and hose connections using the Miran analyzer.

Air samples for N_2O were collected with air bags using the methods previously described. For personal breathing zone sampling, air sample pumps and bags were worn by the people being sampled. Because of space limits, the Anesthetist's N_2O air sample was collected by placing the sampling pump on the anesthetic cart to estimate the anesthetist's personal exposure. Samples were collected for the duration of the surgical procedure (about 4.5 hours), with air sample bags changed about every 60 to 90 minutes.

To evaluate employee exposures to halogenated anesthetics (isoflurane), personal and area samples were collected concurrently at the same locations as the N_2O samples. Sampling pumps were operated at approximately 200 cc/min, with each pump connected via vinyl tubing to a cartridge containing a vapor adsorbing charcoal tube. A known volume of air was pulled through this device and the charcoal tube from each sampler was later sent to the NIOSH laboratory for analysis according to NIOSH Analytical Method 1003 [1]

NIOSH investigators were unable to measure air exchange rates in the ORs, because the large laminar flow air supply diffusers exceeded the dimensions of the air flow measuring equipment.

V. EVALUATION CRITERIA

A. Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff use environmental evaluation criteria for assessment of many chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. However, not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the

level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes which could potentially increase the total exposure. Lastly, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH criteria documents and recommendations, (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[2] and (3) the U.S. Department of Labor (OSHA) occupational safety and health standards.[3] Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, employers should note that they are legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

B. Anesthetic Gases

Reports by Vaisman and Askrog and Harvald 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.[4,5] In 1974, the American Society of Anesthesiologists (ASA) published the results of a study suggesting "that female members of the OR-exposed group were subject to increased risks of spontaneous abortion, congenital abnormalities in their children, cancer, and hepatic and renal disease." This report also showed an increased risk of congenital abnormalities in offspring of male OR 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.[6]

In a study published by NIOSH in 1976, "N_2O 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.[7] 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.[8,9] Reports of audiovisual effects on test subjects exposed to 50 ppm N_2O have not been confirmed in other studies of similar design to the NIOSH study. Twenty-four male student volunteers exposed to 50 ppm N_2O for two sessions of four-hour durations completed a battery of psychomotor tests which included an audiovisual task. Exposures at this concentration failed to produce any statistically significant changes in performance. However, mood changes were observed which included sleepiness, and physical or mental tiredness.[10]

Mortality and other epidemiologic studies have raised the question of possible carcinogenicity of anesthetic gases, but sufficient data are now lacking to list N_2O or isoflurane as suspected carcinogens.

In a study of dentists, Cohen et al.[11] compared exposed persons who used inhalation anesthetic more than 3 hours per week with a control group who used no inhalation anesthetic. The exposed group reported a rate of liver disease of 5.9%, in comparison with a rate of 2.3% in the control group. Spontaneous abortions were reported in 16% of pregnancies of the wives of exposed dentists, in comparison with 9% of the nonexposed. This difference was statistically significant; however, it should be noted that the rate of spontaneous abortions for all pregnancies ranges from 10 to 20%.[12] This study did not identify the specific anesthetic being used by the dentists surveyed, that is, whether they used N_2O alone or in combination with a halogenated agent.[11] However, in a review of that study, NIOSH concluded that "the halogenated anesthetics alone do not explain the positive findings of the survey and N_2O exposure must be a important contributing factor, if not the principal factor."[13] This conclusion is based on a calculation which assumed that as many as 1 in 10 of the dentists using an inhalation anesthetic employed a halogenated agent. If the actual fraction is less than 1 in 10, the conclusion has added strength.

In a document recommending a standard for occupational exposure to waste anesthetic gas, NIOSH recommended a maximum exposure of 50 ppm N_2O on a time-weighted average basis during the anesthetic administration in dental offices.[8] This recommendation is based primarily on available technology in reducing waste anesthetic gas levels in these environments.

When N_2O is used as the sole anesthetic agent in medical procedures, NIOSH recommends that occupational exposures be controlled so that no worker is exposed at TWA concentrations greater than 25 ppm during the period of administration. NIOSH recommends that occupational exposure to halogenated anesthetic agents be controlled so that no worker is exposed at concentrations greater than 2 ppm of any halogenated anesthetic agent during the period of anesthetic administration. When used in combination with N_2O, halogenated anesthetic agents should be controlled to 0.5 ppm, which, generally, can be arrived at by controlling N_2O to a TWA concentration of 25 ppm during the period of anesthetic

administration.[8] There is presently no OSHA standard for N_2O or isoflurane. However, in its "Notice of Intended Changes" for 1988-89, ACGIH has proposed a TLV of 50 ppm for N_2O as an 8-hour TWA.[2]

VI. EVALUATION RESULTS

A. Ventilation

The ventilation system for Surgical Services is a "one-pass" system, meaning the the HVAC supplies 100% outside-air to the ORs and offices in this area. No air supply or exhaust vents were located in the hallway. Ventilation for the hallway was dependent on the air flow from surrounding rooms. According to the medical center engineering department, the HVAC system provides 15 air changes per hour to the ORs. The ORs were maintained under a slight positive pressure relative to the connecting hallway. Outside air is pulled into Surgical Services through a vent on the south outside wall of the hospital building, five stories above ground level. Exhaust air is vented out through the roof.

B. Nitrous Oxide Pipeline Leak Testing Results

Shortly after the system was activated, N_2O concentrations in the hallway exceeded 50 ppm. Upon realizing that N_2O was still venting from the anesthetic carts used to purge the lines, the carts were shut down and disconnected from the system. N_2O levels then slowly fell to about 15 ppm and stabilized. As expected, the higher concentrations were found above the suspended ceiling, and increased as the analyzer sampling probe was moved closer to the leak. Various spot checks were made directly with the Miran analyzer throughout the day of the test. The results from these tests are presented in Table 1.

The continuous monitoring results obtained from the data logger are graphically displayed in Figure 1. The source data for this graph was the time history section of the full data logger output report downloaded to a portable computer. The full data record is included as Attachment 1 to this report. As shown in Figure 1, at no time did the N_2O concentration exceed 25 ppm. The data logger was placed in standby mode at about 1:00 p.m. for about 15 minutes while the Miran analyzer was used to make a series of measurements in other locations. A 3 ppm upward drift was noted during post calibration of the Miran analyzer. The higher readings detected after 1:15 p.m., as shown in Figure 1, were likely caused by instrument drift, rather than an actual increase in N_2O concentration. Generally the hallway concentrations ranged from 10 to 12 ppm throughout the monitoring period.

The results obtained from bag collection of air samples at other locations in the Surgical Services area are shown in Table 2. The highest concentrations were detected in the hallway. One-hour averages ranged from 10 to 15.6 ppm. As expected, the outside air being supplied to ORs and offices prevented most of the N_2O leaking

from the piping system from entering these locations. N_2O concentrations in these areas ranged from non-detectable to 3.9 ppm.

C. Anesthetic Cart Leak Testing Results

High and low pressure leak testing results for the four anesthetic carts are summarized in Table 3. Only in OR A was the anesthetic cart connected to the N_2O supply wall outlet. The wall outlet leaked only if the high pressure hose from the anesthetic cart was connected. Low pressure leaks were detected on carts used in ORs B, E, and F. These leaks were identified to appropriate VA staff for corrective actions or repair.

D. N_2O Exposures During Surgery

The results of the air samples collected for N_2O during surgery in OR A are presented in Table 4. Because the N_2O piping system had been shut down the night before, the anesthetic cart was being supplied with N_2O from a cart-installed cylinder. Cumulative TWA concentrations of N_2O for the five sampling locations ranged from 7 to 15 ppm. The highest TWA was for the sample collected from the anesthetist's cart. Leak testing of anesthetic delivery equipment during surgery revealed that the exhaust port on the carbon dioxide (CO_2) monitor was the only significant point source of N_2O. Because the monitor was not needed for the surgery being performed, the monitor was turned off at 12:35 p.m. The N_2O concentration at the anesthetist's cart before shutting down the monitor was 16 ppm. After the monitor was turned off, the level dropped to 7 ppm. An even greater reduction (14 ppm down to 3 ppm) was noted at the floor level exhaust vent nearest the cart. No N_2O was detected in the hallway outside the OR. All exposures were below the 25 ppm limit recommended by NIOSH.

E. Halogenated Anesthetic Agent Exposures During Surgery

Table 5 shows the results of the environmental samples collected for isoflurane during surgery being performed in OR A. TWA concentrations for isoflurane ranged from below the limit of detection to Ø.3 ppm. None of the personal samples detected exposures exceeding the NIOSH REL of Ø.5 ppm for halogenated anesthetic agents used in combination with N_2O. The highest personal exposure detected was Ø.3 ppm for the anesthetist.

VII. DISCUSSION AND CONCLUSIONS

As evidenced by the results of this survey, the leaking N_2O piping system generated a background concentration ranging from 1Ø-12 ppm in the Surgical Services hallway. Staff employees working in ORs or surrounding offices supplied with 1ØØ% outside air were not likely exposed to N_2O from the leak except when walking through the hallway. There is no evidence that the leaking piping system would have created exposures to N_2O above the proposed ACGIH 8-hour TWA TLV of 5Ø ppm.

During an actual surgical procedure in OR A, no exposures to N_2O exceeded the NIOSH recommended exposure limit of 25 ppm for the period of administration. Exposures to the halogenated anesthetic agent isoflurane were also below 0.5 ppm, the limit recommended by NIOSH for halogenated anesthetics when used with N_2O. The other ORs were not being used during the NIOSH survey and therefore actual personal exposures to anesthetic agents when performing surgery in these rooms could not be evaluated.

Several factors can influence the extent of exposures to anesthetic agents during surgery. While it is possible that the lack of general ventilation may play an important role in allowing a buildup of waste anesthetic gases and vapors, other factors such as leakage from anesthetic cart fittings and components, and work practices must also be considered. Since the exact magnitude by which these factors may influence employee exposures cannot be accurately determined, it is necessary to examine all areas of exposure control frequently to identify needed improvements. A brief discussion of exposure control procedures are presented below.

A. Equipment Maintenance

Of primary importance in maintaining waste anesthetic concentrations within acceptable levels is the regular maintenance of anesthetic equipment in order to prevent leakage. Recent data show that leaks from the high and low pressure anesthetic delivery system resulting from poor maintenance of the anesthetic unit is a primary source of employee exposures in the OR.[14] Background N_2O levels of 5 ppm and greater generally have been associated with leaks in the high pressure gas delivery system, which includes the N_2O supply lines, the ceiling or wall outlet connections to the anesthesia machine, and the connector-control valve from the flowmeter.[14] During anesthetic administration, low pressure leaks occurring between the flowmeters and breathing hoses (including the flowmeter, vaporizer, reservoir bag, popoff valve, endotracheal tube, automatic ventilator, and CO_2 absorber) can be a significant source of exposure. Leak testing of the anesthetic carts has revealed leakage from the respirometer to be a consistent problem in the ORs.

B. Scavenging

Scavenging systems consist of a collecting device, means of disposal, and pressure balancing device if necessary. Depending on the particular type of anesthetic equipment in use, scavenging adapters should be located at the popoff valve for the circle absorber, nonbreathing valve, T-tube, and ventilator. In addition, scavenging may be necessary at locations such as the respirometer. As with all scavenging systems, it is important to ensure proper pressure balancing so that the gas system does not interfere with the proper operation of the anesthetic delivery system.

C. General Ventilation

While local exhaust ventilation (such as scavenging) is the preferred means of eliminating waste gasses at their point of generation, general room ventilation also plays an important role in maintaining acceptable waste gas levels in the OR. Reasons for maintaining good general ventilation exchange rates include the rapid removal of waste gasses generated as a result of anesthesia induction, poorly fitting face masks, improperly inflated endotracheal tubes, or low or high pressure leaks which may occasionally develop in the system. Since scavenging systems are not present in recovery rooms, general ventilation is relied on to remove the waste gases expired by the patient. As a minimum, ORs should be supplied with at least 20 total air changes per hour, and recovery rooms with at least 6 air changes per hour.[15]

Work Practices

Proper work practices are also a key element in controlling waste anesthetic gas exposures. One study estimated that 94% to 99% of all waste gas exposure in OR's equipped with properly designed scavenging components may be the result of poor work practices of the anesthetist.[16] Improper work practices include the use of poorly fitting face masks, insufficient inflation of endotracheal tubes, and spillage of volatile anesthetic agents while filling vaporizers. Despite constant attention to good anesthetic techniques, it is not always possible for the anesthesiologist to be aware of possible leakage from these sources. Therefore, it is important that the general ventilation be adequate to remove any waste anesthetics that might result from this source.

Exposure Monitoring

To evaluate the success of the total exposure control program within the hospital, testing of anesthetic delivery equipment should be supplemented by periodic monitoring of actual employee exposures. This could be best accomplished using a direct reading infrared analyzer such as the one used by NIOSH during this investigation. Controlling exposures to N_2O below 25 ppm will normally ensure that exposures to the halogenated anesthetics are also controlled. Sampling and analytical procedures, such as those provided in NIOSH method 6600, should be referenced for further guidance.[1]

VIII. RECOMMENDATIONS

While Surgical Services was equipped with engineering controls and had implemented work practices which were generally effective in controlling exposures to waste anesthetic gases and vapors, two additional areas where further attention was needed were identified during this survey. These included:

(1) correction of the leakage from respirometer slip-ring connectors used on the anesthetic carts, and

(2) leak testing and repair of high pressure wall outlets for the nitrous oxide piping system when or if the N_2O delivery system is ever repaired and reactivated. The test should be initiated at least quarterly in each operating room with the anesthetic cart's high pressure gas supply hoses attached, and after the N_2O flowmeter has been turned off for at least one hour. The results should show less than 2 ppm N_2O in the room.[16]

In addition, continuing efforts are necessary to ensure that safe exposure levels are maintained in the future. Detailed recommendations regarding specific control procedures, work practices, and monitoring procedures are included in the NIOSH criteria for a recommended standard occupational exposure to waste anesthetic gases and vapors.[8] Adherence to the recommendations specified in this document should help to maintain exposures within acceptable levels and protect the health of the employees in this area.

IX. REFERENCES

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TABLE 1
NITROUS OXIDE CONCENTRATONS DURING PIPELINE LEAK TESTING
(direct measurement using infrared analyzer)

HETA 88-312
VETERANS ADMINISTRATION MEDICAL CENTER
CLARKSBURG, WEST VIRGINIA

October 6, 1988

TIME	SAMPLE LOCATION	NITROUS OXIDE CONCENTRATION (ppm)
8:45 AM	System activated	
10:50 AM	Hallway, directly under leak	50 (1)
11:06 AM	Above ceiling btw. opr. rooms A & B	60
11:06 AM	Below ceiling btw. opr rooms A & B	15
11:08 AM	Above ceiling at pipeline leak	Off Scale (>250 ppm)
1:04 PM	Below ceiling directly below leak	13
1:05 PM	Above ceiling 3 feet from leak	58 ppm
1:06 PM	Above ceiling btw. opr. rooms A & B	12
1:08 PM	Above ceiling at pipeline leak	Off Scale
1:10 PM	Inside opr. rooms A and B	3
1:12 PM	Anesthetists' work room	0.5
2:35 PM	Below ceiling btw. opr. rooms A & B	10
3:45 PM	Above ceiling at pipeline leak	Off Scale
3:47 PM	Below ceiling btw. opr. rooms A & B	11

1. High reading at this time was caused by nitrous oxide flowing from the four anesthetic carts (one in each operating room) used to purge the piping system. Carts were turned off at 10:50 AM.

Nitrous Oxide Levels in Central Hallway
(from leaking piping system)

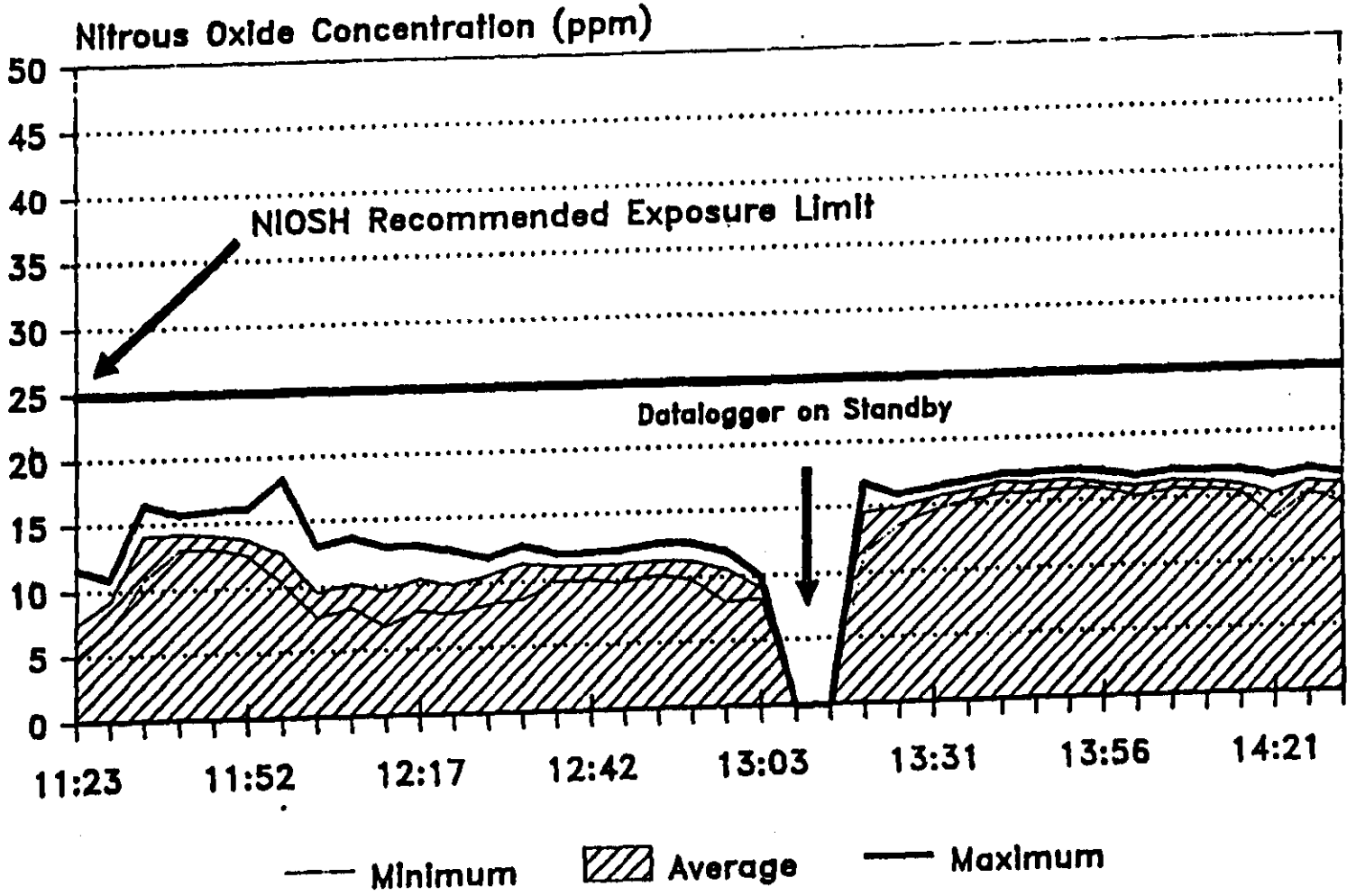


Figure 1

October 6, 1988

TABLE 2
NITROUS OXIDE CONCENTRATONS DURING PIPELINE LEAK TESTING
(samples collected with air sampling bags)

HETA 88-312
VETERANS ADMINISTRATION MEDICAL CENTER
CLARKSBURG, WEST VIRGINIA

October 6, 1988

SAMPLE DESCRIPTION	SAMPLING PERIOD	NITROUS OXIDE CONCENTRATION (ppm TWA)
Anesthetist's Work Room	12:10-13:19	ND
Operating Room A	12:12-13:18	1.7
Operating Room B	12:13-14:28	2
O.R. Supervisors Office	12:16-13:17	3.9
Supply Room (inside window counter)	12:16-13:18	15.6
Inside main entrance to O.R. area	12:18-13:18	10
Evaluation Criteria - NIOSH Recommended Exposure Limit =		25 ppm

TWA = Time Weighted Average
ppm = Parts Per Million

TABLE 3
ANESTHETIC CART LEAK TEST RESULTS
HETA 88-312
VETERANS ADMINISTRATION MEDICAL CENTER
CLARKSBURG, WEST VIRGINIA
October 6, 1988

Operating Room A

Anesthetic Cart - Modulus II (new machine)
General Area Nitrous Oxide Concentration = 3 ppm

High Pressure Side
-wall fitting leaking when hose connected

Low pressure Side - no leaks found

Operating Room B

Anesthetic Cart - Modulus
General Area Nitrous Oxide Concentration = 4-5 ppm

High Pressure Side - no leaks found
(wall outlets not being used)

Low Pressure Side
-leaking slip connector near respirometer

Operating Room E

Anesthetic Cart - Modulus
General Area Nitrous Oxide Concentration = 3 ppm

High Pressure Side - no leaks found
(wall outlets not being used)

Low Pressure Side
-leaking slip connector near respirometer
-leaking pop-off valve gasket
-leak near breathing bag

Operating Room F

Anesthetic Cart - Ohio Heidbrink Compact
General Area Nitrous Oxide Concentration = 1 ppm

High Pressure Side - no leaks found
(wall outlets not being used)

Low Pressure Side
-slight leak at slip connector near respirometer
-leaking pop-off valve gasket

Note: All tests were made using simulated lung with nitrous oxide and oxygen flow meters set at 2 liters per minute.

TABLE 4
NITROUS OXIDE LEVELS DURING SURGICAL PROCEDURE
(Operating Room A)

HETA 88-312
VETERANS ADMINISTRATION MEDICAL CENTER
CLARKSBURG, WEST VIRGINIA

October 7, 1988

SAMPLE TYPE	SAMPLE DESCRIPTION	SAMPLING PERIOD	NITROUS OXIDE CONCENTRATION (ppm)
Personal	Scrub Nurse	0843-0950	11
		0950-1105	5
		1105-1200	6
		Cumulative TWA =	7
Personal	Anesthetist	0839-0945	21
		0945-1100	13
		1100-1235	16
		1235-1318	7
		Cumulative TWA =	15
Personal	Circulating Nurse	0838-0942	12
		0942-0958	7
		0958-1225	8
		1235-1318 (*)	8
		Cumulative TWA =	8
Area	Exhaust Vent (near door)	0848-0950	16
		0950-1107	12
		1107-1239	14
		1239-1318	3
		Cumulative TWA =	12
Area	Exhaust Vent (opposite door)	0850-0950	8
		0950-1108	8
		1108-1239	6
		1239-1318	7
		Cumulative TWA =	7
Area	Hallway (outside room A)	1001-1101	ND
		1101-1242	ND
		1242-1318	ND
		Cumulative TWA =	ND

Evaluation Criteria - NIOSH Recommended Exposure Limit = 25 ppm
(TWA for the period of administration)

TWA = Time Weighted Average for the period of administration
ND = None Detected

* Carbon dioxide monitor was turned off at 12:35.

TABLE 5
ISOFLURANE LEVELS DURING SURGICAL PROCEDURE
(Operating Room A)

HETA 88-312
VA MED CENTER
CLARKSVILLE, WEST VIRGINIA

October 7, 1988

SAMPLE NUMBER	SAMPLE DESCRIPTION	SAMPLE TYPE	TIME START - STOP	TIME HR:MN	TWA PPM
H-1	Scrub Nurse	Personal	08:43 - 13:18	04:35	0.2
H-2	Anesthetist	Personal	08:39 - 13:18	04:39	0.3
H-3	Circulating Nurse	Personal	08:38 - 13:18	04:40	0.2
H-4	Exhaust vent near door	Area	08:48 - 13:18	04:30	0.3
H-5	Exhaust vent opposite door	Area	08:50 - 13:18	04:28	0.2
H-6	Hallway outside Opr Rm. A	Area	10:01 - 13:18	03:17	0.0

Evaluation Criteria - NIOSH Recommended Exposure Limit = 0.5
(When used with nitrous oxide)

TWA = Time Weighted Average

ATTACHMENT 1

DATA LOGGER PRINTOUT
NITROUS OXIDE LEVELS IN CENTRAL HALLWAY
(during piping leak)

HETA 88-312
VETERANS ADMINISTRATION MEDICAL CENTER
CLARKSBURG, WEST VIRGINIA

"TEST START DATE: 10-06-88"
"TEST START TIME: 15:55"
" TEST LOCATION: VA Med Ctr. Clarksburg WV"
" EMPLOYEE NAME: ——"
"EMPLOYEE NUMBER: ——"
" DEPARTMENT: ——"
"COMMENT FIELD 1: ——"
"COMMENT FIELD 2: ——"
" NUMERIC CODES: —— —— —— —— ——"
METROSONICS dl-332 SN 1289 V2.4 12/86

CURRENT DATE: 10/06/88
CURRENT TIME: 15:56:06

CALIBRATION
-0.0065 V = 0.00 ppm
0.1833 V = 25.00 ppm

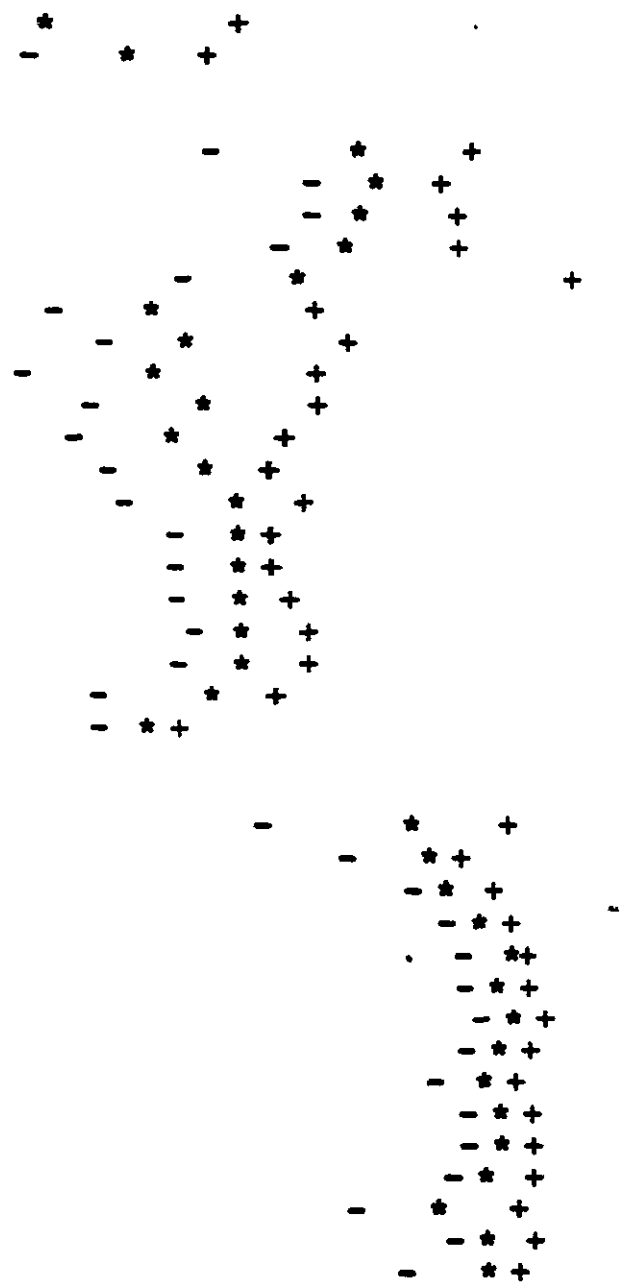
LOWER ALARM: 0.86 ppm
UPPER ALARM: 0.86 ppm

UNITS: ppm

INPUT READS: 0.86 ppm
TEST STARTING DATE: 10/06/88
TEST STARTING TIME: 11:17:59
ELAPSED TIME: 0 DAYS 2:51:04
OVERALL AVG: 13.24 ppm
OVERALL MIN: 4.96 ppm
MIN OCCURRED 10/06/88 @ 11:21:31
OVERALL MAX: 18.31 ppm
MAX OCCURRED 10/06/88 @ 11:54:20
STEL: 16.67 ppm
STEL OCCURRED 10/06/88 @ 13:36:51

TIME HISTORY
PERIOD LENGTH: 0:05:00
OF PERIODS COMBINED: 1

	MIN	AVG	MAX
DATE: 10/06/88 TIME: 11:17:59			
	4.96	7.40	11.70
@	7.05	9.32	10.88
DATE: 10/06/88 TIME: 11:32:44			
	10.83	14.10	16.55
	13.00	14.23	15.67
	13.04	14.12	16.01
	12.46	13.72	16.10
	10.37	12.58	18.31
	7.64	9.58	13.00
	8.41	10.24	13.68
	6.87	9.63	12.90
	8.07	10.50	12.94
	7.71	9.94	12.48
	8.43	10.57	11.89
	8.74	11.44	12.74
	9.99	11.16	12.04
	10.04	11.13	12.07
	9.76	11.16	12.20
	10.28	11.35	12.65
	9.82	11.27	12.56
	8.07	10.62	11.92
@	8.32	9.17	9.98
DATE: 10/06/88 TIME: 13:16:01			
	11.46	14.56	16.84
	13.51	14.93	15.90
	14.61	15.56	16.34
	15.23	16.05	16.82
	15.78	16.70	17.25
	15.76	16.50	17.26
	16.02	16.78	17.46
	15.89	16.38	17.26
	15.18	16.05	16.81
	15.74	16.46	17.23
	15.61	16.34	17.13
	15.39	16.06	17.17
	13.20	15.16	16.60
	15.31	16.14	17.14
@	14.33	15.97	16.72



AMP DIST
SAMPLES LOGGED: 10264

ppm	SAMPLES		%
3.50	45	+	000.43
6.13	521	*****	005.07
8.76	2933	**********	028.57
11.40	1891	**********	018.42
14.03	4123	**********	040.16
16.67	751	*******	007.31