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SUMMARY

On June 2, 1993, the National Institute for Occupational Safety and Health (NIOSH) received an employer request to conduct a health hazard evaluation (HHE) at the Hodges and King, DDS, dental office in Atlanta, Georgia. The request asked NIOSH to evaluate employee exposures to nitrous oxide (N_2O) during administration of this anesthetic gas to patients. The request was prompted by a previous NIOSH HHE (HETA 93-0622) conducted to assess general indoor air quality at the dental office.

In response to this request, NIOSH investigators conducted a site visit on September 15-16, 1993. The purpose of this visit was to review dental practices regarding the use of N_2O, inspect the anesthetic gas delivery system, and conduct personal air monitoring for N_2O. Both real-time and integrated air monitoring were conducted. Because all offices on this floor (Plaza Level) are ventilated through a common mechanical room, monitoring to assess N_2O levels outside the dental office was also conducted.

Following this survey, dental office management tested the N_2O delivery system, repaired all detectable leaks, and installed ventilation systems referred to as "scavengers" to control N_2O at the point of use. On October 12, 1993, NIOSH investigators conducted follow-up air monitoring to assess the effectiveness of these control measures.

During the September survey, personal exposures to N_2O, averaged over the duration of N_2O administration, ranged from 205 - 456 parts per million (ppm) for dentists, 144 - 465 for dental assistants, and 1950 ppm for a dental hygienist. The NIOSH Recommended Exposure Limit (REL) for N_2O is 25 ppm averaged over the duration of anesthetic administration. General dental office levels ranged from 19 - 277 ppm (average = 109 ppm), and 32 - 65 ppm (average = 48 ppm) in the Plaza Level Lobby. Monitoring prior to administering N_2O to patients indicated the presence of significant leakage in the N_2O delivery system.

On October 12, 1993, personal exposures to N_2O averaged 60 - 347 ppm for dentists, 80 ppm for a dental assistant, and 93 ppm for a dental hygienist. General dental office levels ranged from 22 - 51 ppm (average = 30 ppm), and 14 - 27 ppm (average = 19 ppm) in the Plaza Level Lobby. The results of the October 12, 1993, monitoring indicate controls implemented by the dental office reduced N_2O concentrations in both the dental office and Plaza Level Lobby, but further reductions are warranted.

Concentrations of nitrous oxide (N_2O) exceeded the NIOSH REL for all activities assessed in the dental office. N_2O levels exceeding the NIOSH REL were also found in common areas of the Plaza Level. Offices located on the second floor or above would be expected to have negligible levels since they have separate air handling systems. Lack of proper controls, delivery system leaks, and extensive patient use are the primary contributors to the high N_2O levels. Exfiltration to other Plaza Level offices is due to the common return air system. After implementing controls, follow-up monitoring indicated that measures taken were somewhat effective in reducing N_2O exposures in the dental office and in common areas of the Plaza Level; however, personal exposures to dental workers still exceeded the NIOSH REL for all activities assessed. As long as N_2O is used in this dental office with the existing ventilation system design, exfiltration of waste N_2O to other areas outside the dental office will continue to occur. Recommendations to reduce exposures, including ventilation and improved work practices, are provided in the Recommendation section of this report.

KEYWORDS: SIC 8021 (Offices and Clinics of Dentists) nitrous oxide, waste anesthetic gas, ventilation, scavengers

INTRODUCTION

NIOSH received a request from the dental office of Hodges and King, DDS, on June 2, 1993, to evaluate airborne concentrations of nitrous oxide (N_2O) during the administration of this anesthetic gas to patients. The request indicated employees had experienced health symptoms including fatigue, headache, and eye irritation that were possibly associated with their work environment. Because all offices on the same floor (Plaza Level) as the dental office are ventilated through a common mechanical room, air monitoring for N_2O was also conducted in the Plaza Level Lobby. This request was initiated as a result of a previous NIOSH investigation (HETA 93-0622) at this building. During the previous investigation, NIOSH investigators identified N_2O as a potential contaminant and recommended that employee exposures to N_2O be evaluated. Dental office management subsequently asked NIOSH to conduct this evaluation.

On September 15-16, 1993, NIOSH investigators conducted a survey at the dental office to determine airborne N_2O concentrations during various dental procedures. Information on the anesthetic gas delivery system, work practices, and the existing ventilation system was also obtained. Pre- and post-survey meetings were held with dental office personnel, and building management was informed of the results. Following this survey, the dental office discontinued administering N_2O and implemented several actions before they resumed using it.

On October 12, 1993, NIOSH investigators conducted a followup survey to assess current N_2O concentrations, and evaluate the effectiveness of the control measures taken by the dental office. On October 18, 1993, an interim report was sent to the dental office, building management, and all tenants on the Plaza Level.

BACKGROUND

Facility Information

The dental offices of Hodges and King are located in one quadrant on the lobby (Plaza) level of an 8-story square office building (Building 1000) in a commercial office area on the northwest side of Atlanta, Georgia (Figure 1). Building 1000 is a 100,000 square foot (ft^2) facility constructed of reinforced concrete with precast architectural concrete facades, concrete floors, and a flat built-up roof. Construction was completed in 1974. None of the single pane windows in the building can be opened. The core of the building on each floor contains two elevators, restrooms,
two stairwells, a telephone closet, and a mechanical equipment room housing water-source heat pump air handling units (AHUs). A corridor around this core serves the perimeter office areas. This core is enclosed by a fire-rated wall, built slab to slab. There are approximately 325 occupants in the building. Smoking is not allowed in common areas of the building (e.g., restrooms, lobby, hallway). Each tenant, however, determines whether or not smoking is allowed in their space.

Each floor (including the Plaza Lobby) is divided into eight zones, each of which is served by a constant volume heat pump unit controlled by a zone thermostat. The heat pumps are on a circulating water loop system which provides either chilled or heated water. Two heat pump units support the dental office, one of which also serves the perimeter of the lobby area and an adjacent suite of offices. Supply air is distributed through ceiling diffusers connected by flex ductwork to the main supply manifold. Return air (RA) is conveyed to the mechanical room by a common plenum above the false ceiling. There is no zone isolation for RA. RA from each zone passes through transfer grills (with fire dampers) installed in the fire rated zone walls before entering the mechanical equipment room. Outside air is obtained at the roof level and is supplied to a vertical shaft with branch ducts to the mechanical equipment room on each floor. The mixed air in the mechanical room is then filtered and reconditioned at each individual heat pump prior to distribution to occupied areas. Restrooms are vented into a common vertical exhaust manifold connected to a roof mounted exhaust fan. There are no other exhaust systems in the facility. The heat pump units are on an automatic night-time set-back cycle with on times between 5:00 a.m.and 6:00 p.m.

Dental Offices

The dental offices consist of a waiting room, insurance room, six operatory rooms, an x-ray development darkroom, laboratory, breakroom, and two enclosed offices. Nine employees work in this 1750 ft^2 suite. The waiting room is isolated from the rest of the suite by a door and sliding glass admittance window. All operatory rooms are open and contiguous with the other areas. Only the two enclosed offices and the x-ray development lab have doors. Three of the operatory rooms and the break room face a window. Drapes are used when necessary for shading. The suite has been occupied by the Hodges and King dental firm since 1975. In 1981, the area was expanded from 1300 ft^2 to 1750 ft^2 when the insurance room, break room, and enclosed office were added to the west side of the suite.

Activities conducted in the dental office include routine dental hygiene as well as more extensive dental work, administrative activities (record keeping, filing, etc.), preparatory work in the laboratory (preparing molds/casts, polishing, buffing, grinding), and x-ray development. Dental equipment is disinfected by soaking in a 3% glutaraldehyde solution and sterilizing in an autoclave.

Nitrous Oxide Administration

Approximately 75% of the patients at Hodges & King who require anesthesia, either alone or in conjunction with numbing agents, use nitrous oxide (N_2O) as an anesthetic agent. N_2O is delivered to the operatories via copper piping from a cylinder located in the laboratory, and is administered to patients through 3/8" tubing connected to a nose-only mask. The N_2O system has been in use since 1978. The N_2O is mixed with oxygen just prior to delivery to the patient. In each operatory flow control is achieved by a dual rotameter (one for oxygen, one for N_2O). Each system is equipped with a breathing bag and a fail-safe device to shut off the N_2O if the oxygen flow is interrupted (falls below 1 liter per minute [Lpm]). Typical flow rates for a patient are 2-3 Lpm N_2O, and 5-8 Lpm oxygen. Delivery flow rates may vary based on the dentists' or dental hygienists' historical experience with a patient. The duration of anesthetic gas administration during a typical procedure ranges from 30 (teeth cleaning) to 60 minutes (dental surgery). The N_2O cylinder is shut-off at the close of business each day, and is turned on in the morning. Dental office personnel indicated that N_2O consumption averages approximately one standard cylinder per week (approximately 140 cubic feet).

EVALUATION PROCEDURES

The NIOSH investigation consisted of the following:

1. An inspection of the anesthetic gas delivery system and review of work practices, procedures, and protocols followed by dental office personnel regarding the use of N_2O.

2. Air sampling for N_2O to assess personal exposures and area concentrations as summarized below:

   September 15 Sampling

- Ambient concentrations in the closet containing the vacuum pump and suction equipment.
- Dentist and assistant exposures in Operatory #4 (no scavenging equipment), and in Operatory #2 (with scavenger).
- Ambient concentrations in the building 1000 Plaza Level mechanical room.
- Ambient concentrations in the breezeway entrance to the building 1000 Plaza Lobby, and on the lobby of the sixth floor.

September 16 Sampling

- Ambient concentrations in the dental office prior to turning on the nitrous oxide cylinder, after turning on nitrous oxide at the cylinder but prior to administering to patients, and during and after patient administration.
- Ambient concentrations in the Plaza Lobby and breezeway entrance, prior to and after using nitrous oxide in the dental office.
- Dental hygienist exposures in Hygiene Room #1.
- Ambient concentrations in the employee breakroom.

October 12 Sampling (After Implementing Controls)

- Ambient concentrations in the dental office and employee breakroom.
- Ambient concentrations in the Plaza Level Lobby and outside air.
- Dentist and assistant exposures in Operatory #4 .
- Dental hygienist exposures in Hygiene Room #1.
- Dentist exposures in Operatory #1.

3. Evaluation of the controls installed after the September 15-16, 1993, survey. This entailed measuring the scavenger flow rates, and reviewing the system leak repair report.

Environmental Monitoring

Air monitoring was conducted using a Brüel and Kjaer (B & K) model 1302 multi-gas continuous monitor. The principle of detection is infrared absorption at a specific wavelength with subsequent analysis via the photoacoustic effect. The monitor, which records N_2O concentrations in parts per million (ppm) approximately every minute, was calibrated prior to use. Calibration was verified at the B & K calibration laboratory in Decatur, Georgia, on September 14, 1993, and checked by preparing and analyzing known concentrations using N_2O obtained from the dental office. In addition to monitoring in the continuous sampling mode, air sampling bags were also used to collect samples. These bags were filled using a portable air sampling pump and subsequently analyzed with the B & K monitor. Personal samples were obtained by attaching the sample tube inlet of the B & K monitor to the collar of the individual being monitored. The sample tubing was of sufficient length to allow the person to move freely in his/her work area. When using the bag sampling technique, the inlet tube of the air sampling pump was attached to the collar of the individual being monitored to collect breathing zone samples.

Ventilation

A Gilian Gilibrator® with a 30 liter volumetric cell was used to measure flow rates of scavengers in each operatory. The Gilibrator® is an electronic bubble flowmeter that provides instantaneous air flow readings and a cumulative average of multiple readings. The time interval necessary for a soap bubble, stretched across a cell, to travel a known volume is calculated to determine the flowrate. The system is considered a primary standard airflow measurement device in that all values are absolute; a known and fixed volume divided by time provides the airflow.

EVALUATION CRITERIA

General

As a guide to the evaluation of hazards posed by workplace exposures, NIOSH field staff use established environmental criteria for the assessment of a number of chemical and physical agents. These criteria 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. It should be noted, however, that not all workers will be protected from adverse health effects if their exposures are below the applicable limit. A small percentage may experience adverse health effects due to individual susceptibility, pre-existing medical conditions, and/or hypersensitivity (allergy).

Some hazardous substances or physical agents may act in combination with other workplace exposures or the general environment to produce health effects even if the occupational exposures are controlled at the applicable limit. Due to recognition of these factors, and as new information on toxic effects of an agent becomes available, these evaluation criteria may change.

The primary sources of environmental evaluation criteria for the work place are: (1) NIOSH Criteria Documents and recommendations, (2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and (3) the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) standards.[(1-3)] Often, NIOSH recommendations and ACGIH TLVs may be different than the corresponding OSHA standard. Both NIOSH recommendations and ACGIH TLVs are usually based on more recent information than OSHA standards due to the lengthy process involved with promulgating federal regulations. OSHA standards also may be required to consider the feasibility of controlling exposures in various industries where the hazardous agents are found; the NIOSH Recommended Exposure Limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease.

Nitrous Oxide

Nitrous oxide has been used as an anesthetic agent since 1844, and is often used in conjunction with other anesthetic gases.[2] However, with the development of more effective local anesthetics, N_2O is now used primarily to relieve anxiety in patients.[4] For many years, the only adverse health affects associated with exposure to N_2O have been those of asphyxiation when there is insufficient oxygen due to physical displacement by N_2O.[2,5] However, over the past 30 years, other specific toxic effects have been found in both animal and human studies. An early observation was that N_2O, when clinically used at very high concentrations (50% or 500,000 ppm) caused a generally reversible (within 4 days after discontinuing use) bone marrow depression.[6,7] Carcinogen studies with laboratory animals (mice) have not shown any increases in tumors.[2,5] Cancer studies of humans exposed to N_2O and other anesthetic gases have shown mixed results. Some suggest a small increase in the incidence of cancer in women, while others have reported a negative correlation.[2,5,8] Some laboratory studies have also shown adverse reproductive effects (smaller litter, increased incidence of fetal resorption and skeletal anomalies) among rats exposed to high (e.g., 1000 ppm or greater) N_2O concentrations during the early stages of pregnancy.[9] Human studies have reported a higher than expected incidence of spontaneous abortions among female workers directly exposed to N_2O and other anesthetic gases.[10] Other studies suggest the incidence of congenital abnormalities and spontaneous abortion is slightly higher in the offspring of wives of exposed dentists, as well as reduced fertility in women occupationally exposed.[11,12] Studies have shown that adverse neurologic effects (e.g., numbness, tingling, weakness, audiovisual performance decrements) appear to increase in persons occupationally exposed to N_2O, while other studies have not confirmed these findings.[13-16] It has also been suggested that mood factors (sleepiness, mental tiredness, etc.) may deteriorate following exposures to as low as 50 ppm.[16] In many of these human studies, exposure concentrations are poorly defined and dose-response relationships are difficult to identify.

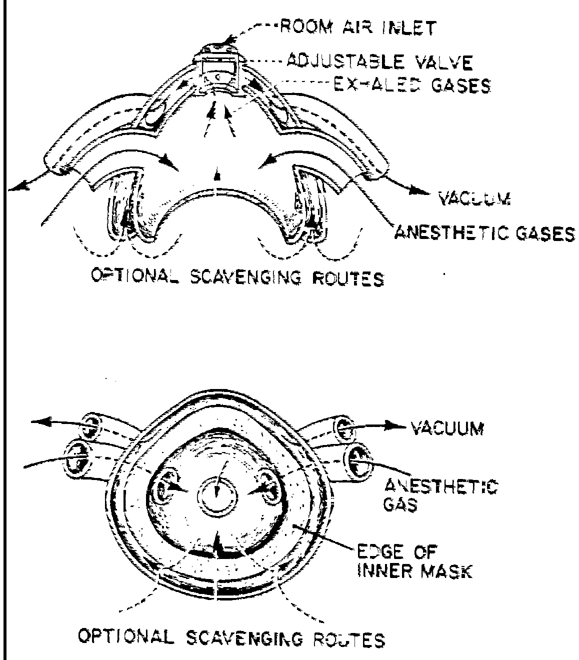
Nitrous Oxide - Exposure Standards

The Occupational Safety and Health Administration (OSHA), the agency responsible for enforcing compliance with workplace safety regulations, has not established a standard for nitrous oxide. NIOSH has established a REL of 25 ppm averaged over the duration of anesthetic administration. The NIOSH REL is based on a report of decrements in audiovisual tasks following exposure at 50 ppm.[8] The ACGIH has recommended an 8-hour time-weighted average threshold limit value (TLV-TWA) of 50 ppm.[2] The ACGIH TLV-TWA is based on prevention of embryofetal toxicity (spontaneous abortion) in humans and significant decrements in human cognitive functions.

Nitrous Oxide - Control Measures

Nitrous oxide is not metabolized and, following absorption, is rapidly eliminated unchanged from the body through the lungs.[17] As such, dental office personal may be exposed to N_2O that has either escaped from the delivery system or exhaled by the patient. A wide range of N_2O exposure concentrations in dental operatories have been reported ($\leq$ 25 ppm - 6700 ppm).[8,18-20] Factors influencing ambient N_2O levels include work practices, type of procedure, anesthetic gas flow rates, type of delivery system, general room ventilation, and the presence or absence of controls. Although specific measures for reducing exposure to N_2O have been developed, studies in dental operatories conducted by NIOSH and others have generally found that existing control technologies do not consistently reduce N_2O concentrations to the NIOSH REL.[19,20]

Measures for controlling exposures to N_2O in dental operatories include effective scavenging devices, proper anesthetic gas delivery equipment, maintenance and routine leak checks of the N_2O delivery system, and good work practices by dentists and assistants. Scavenging systems to control N_2O at the point of use is the preferred method. A common scavenging system design is the "mask within a mask" unit, with tubes supplying oxygen and N_2O to the inside of the interior mask, and two tubes ventilating the space between the two masks (where the patient exhales). The recommended flow rate for this type of system, shown in the following figure, is 45 liters per minute (Lpm).[8] As noted previously, these types of scavenging systems, while shown to be effective in reducing anesthetic gas exposure, do not consistently reduce N_2O to concentrations to below the NIOSH REL of 25 ppm.[20] Providing additional auxiliary ventilation has shown mixed results.[19] Once ventilated, the collected anesthetic gas must be properly vented to a point away from personnel. Non-recirculating air-conditioning systems, the central office suction system, and a separate duct system have successfully been used to accomplish this.[8] Complete descriptions of scavenging systems, proper maintenance protocols, and work practices are detailed in the NIOSH Criteria Document on Waste Anesthetic Gases.[8]



COMMON NASAL MASK WITH SCAVENGER

RESULTS AND DISCUSSION

Prior to implementing additional controls, two of the six operatory rooms were equipped with scavenging devices to control N_2O at the point of use. These scavenging devices consisted of 1/4" Tygon® tubing connected to the cap containing the nose mask exhalation valve. The other end of the tubing was connected to the general suction system used for a variety of dental procedures. Suction is created by a dual-compressor located in a closet in the laboratory. All suctioned materials are filtered and then flushed to the city sewer system. In the other four operatories, excess, or exhaled, N_2O was vented directly into the operatory.

Criteria for these scavenging devices was not available. There was no information regarding the necessary flow rates or vacuum necessary to control N_2O using these devices. Procedures for leak checking the N_2O delivery system, routinely calibrating the flow control devices, and evaluating the effectiveness of the scavengers had not been developed. Dental office personnel indicated work practices with the N_2O system included not turning on the anesthetic gas until the nose mask was in place on the patient, and shutting off the N_2O (flowing pure oxygen) for 3 minutes prior to removing the mask.

During the September 15-16 survey, N_2O use was considered "normal to above-normal." N_2O was in use for 3-5 hours/day on the days monitored. During the October 12 survey, N_2O use was considered "light to normal." On all days monitored, there were occasions where more than one operatory was using N_2O at the same time.

Monitoring Results

A summary of the air sampling results are shown in Table 1, and are graphically presented in Figures 2-7. Table 1 compares the results of the monitoring conducted prior to repairing system leaks and installing scavenger devices (September 15-16, 1993), with the results obtained after these controls had been implemented (October 12).

September 15-16 Survey

As shown in table 1, significant overexposures to N_2O were found in all activities and procedures assessed during the September 15-16 survey. The highest average personal exposure detected was 1950 ppm N_2O, in a bag sample from a dental hygienist in Hygiene room #1, obtained over the duration of anesthetic gas administration (30 minutes). The lowest average N_2O exposure detected was 200 ppm, obtained from a dental assistant in Operatory #2. The monitoring also indicated the existing scavenger system in Operatory #2 did not effectively reduce N_2O concentrations to near REL levels, and showed no substantial difference when compared with concentrations detected in Operatory #4 (no scavenger). This may be explained in part by the considerable variation in concentrations detected during different dental procedures. In Operatory #2, during a tooth filling procedure, the dentist was exposed to an average N_2O concentration of 205 ppm (range 137-402 ppm), while the dental assistant was exposed to an average concentration of 465 ppm. However, during a root canal procedure in this same operatory, the dentist was exposed to an average N_2O concentration of 456 ppm (range = 113-2840 ppm), and the dental assistant was exposed to an average concentration of 200 ppm (range = 144-256 ppm). During a tooth filling procedure in Operatory #4, the dentist was exposed to an average N_2O concentration of 285 ppm (range = 107-604 ppm). Figures 2 - 4 depict the variation in N_2O concentrations during these procedures.

N_2O concentrations in the general office area (employee breakroom) ranged from 19 to 277 ppm (average = 109 ppm) throughout the day. Concentrations varied depending on N_2O usage.

Measurements obtained outside the dental office indicated significant exfiltration of N_2O. A concentration of 33 ppm was detected in a bag sample collected at 11:00 a.m. on September 15 in the Plaza Lobby common mechanical room. An average N_2O concentration of 48 ppm (range = 32-64 ppm) was detected in the Plaza Lobby on September 16 (9:30 a.m. - 10:04 a.m.). This sampling was conducted after N_2O had been used for approximately 1 hour in the dental office. This was expected given the common return air system and HVAC design. Significant leakage to other floors of building 1000 was not found; a concentration of 1.8 ppm was detected in the sixth floor lobby.

The monitoring also suggested there were considerable leaks in the N_2O delivery system; most likely at the valves, fittings and quick-connects in each operatory. Monitoring in the dental office, conducted in the morning prior to turning on the N_2O cylinder, showed an average level of 1.9 ppm, and were similar to the concentrations in the Plaza Lobby. This indicates that once the N_2O is shut off, the air on the plaza level clears overnight. However, after turning on the N_2O cylinder, but prior to administering the gas to a patient, the concentrations of N_2O in the general dental office area increased to above-REL levels in 15 minutes (Figure 5). Similarly, monitoring in the Plaza Lobby prior to turning on the N_2O cylinder, and then after turning on the cylinder, showed concentrations to increase from 1.6 to 9 ppm prior to administering N_2O to a patient (Figure 6). The contribution of N_2O system leaks to the general dental office and Plaza Lobby concentrations was estimated to be 14-28%.

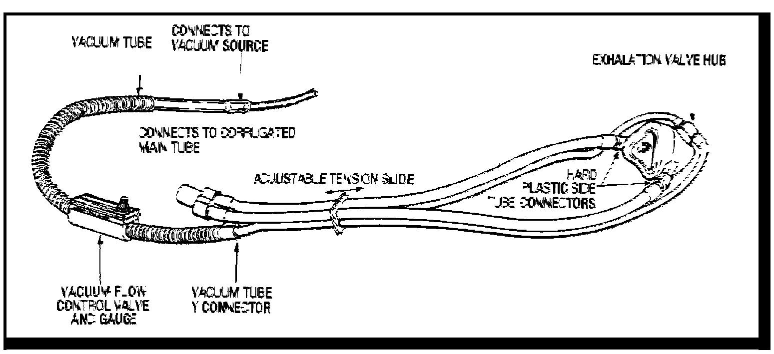
Monitoring conducted in the closet housing the vacuum pump detected an average of 296 ppm N_2O over a 24 minute period. This sample was obtained after N_2O had been in use for approximately 30 minutes. This indicates that N_2O collected by the house suction system may not be completely contained after collection.

October 12 Survey

The dental office discontinued administering N_2O when notified of the initial results, and implemented a number of actions before resuming its use. These actions reportedly consisted of inspecting the N_2O delivery system and repairing all leaks, minimizing the use of N_2O where possible, and ordering new N_2O delivery systems, including scavengers for all operatories.

The scavenger devices ordered and installed by the dental office after the September 15-16 survey were manufactured by Accutron, Inc. These units are not the "mask within a mask" design, but consist of two exhaust hoses connected to the exhalation valve hub of the nose mask. Vacuum is provided by the general dental office suction system. The exhaust tubes combine into one flexible hose equipped with a flow control valve and a rotameter for measuring flow. The manufacturer's instructions call for adjusting flow until the rotameter ball is within a yellow band area on the rotameter. According to an Accutron representative, there were no quantitative studies conducted to determine the optimum flow rate.[21] Two mask sizes (child and adult) are available.

As shown in Table 1, the monitoring results show the measures taken after the September 15-16 survey generally reduced N_2O concentrations. All personal monitoring results, however, were still above the NIOSH REL. The greatest reduction in exposure was found in the dental hygienist's monitoring in Hygiene Room #1 (N_2O average of 1950 ppm pre-control, 93 ppm post-control). Dentist and dental assistant exposures also appeared to be effectively reduced when



ACCUTRON N_2O SCAVENGING SYSTEM

compared with the concentrations detected during the September 15-16 survey. One exception was the concentration of N_2O detected during personal monitoring of a dentist conducting a crown seat/restorative procedure in Operatory #4. An average exposure of 347 ppm was detected during this procedure (Figure 7). Monitoring in this same operatory prior to implementing controls found an average personal exposure of 285 ppm during a tooth filling procedure. This may be explained by the considerable variation found depending on the dental procedure, as well as other work practices. Patient to patient flow adjustments of the N_2O system may also influence this variation.

General office N_2O concentrations also appeared to be reduced. Monitoring in the employee breakroom for approximately 2 hours after N_2O had been administered found an average concentration of 30 ppm (range 22-51 ppm).

Measurements obtained outside the dental office in the Plaza Lobby likewise showed that, although exfiltration of N_2O to other areas was still occurring, the concentrations were less than those previously detected. N_2O concentrations in the Plaza Lobby, obtained after N_2O had been administered in the dental office, showed an average of 19 ppm (range 14-27 ppm).

Leak Check

The firm conducting the leak test (pressure testing) on the N_2O delivery system reported finding leaks in hose fittings, quick connects, and general flowmeter assemblies. The firm re-evaluated the system after the dental office had replaced the flowmeter assemblies and fittings and reported that no leaks were detected.

Scavenger Ventilation Assessment

The flowrate of the Accutron Scavengers in five of the six operatory's was measured by removing one of the exhaust tubes from the nose mask and connecting this tube to the Gilibrator® electronic bubble meter. The flow was then adjusted until the rotameter ball was in the yellow band area. With the other exhaust tube still connected to the mask, multiple readings were obtained and averaged. This was repeated for the other exhaust tube and the two measurements combined to derive the total scavenger flow rate. The results of this assessment are shown in the following table:

Operatory	Flow Rate Side 1	Flow Rate Side 2	Flow Rate Total
#1	13.7 Lpm	13.6 Lpm	27.3 Lpm
#2	14.2 Lpm	14.4 Lpm	28.6 Lpm
#3	14.9 Lpm	15.0 Lpm	29.9 Lpm
#4	14.3 Lpm	14.0 Lpm	28.3 Lpm
Hygiene Room #1	15.9 Lpm	15.2 Lpm	31.1 Lpm

As shown in the above table, flow rates were less than the recommended 45 Lpm for other nose-mask scavenging systems. However, this 45 Lpm flow rate was based on the "mask within a mask" design, and may not be applicable to the Accutron systems.

CONCLUSIONS

On September 15-16, 1993, both personal and area air monitoring found high levels of N_2O in the Hodges and King dental office. All personal exposures exceeded the NIOSH REL of 25 ppm. Monitoring in common areas of the Plaza Level of building 1000 also found N_2O levels that exceeded the NIOSH REL, although they were much lower than the levels found inside the dental office. Specific concentrations to which Plaza Level office personnel outside the dental office were exposed could not be determined and will vary based on the extent of N_2O usage and the length of time spent inside the office. Offices located on the second floor or above would be expected to have negligible levels since they have separate air handling systems.

The primary contributors to the high N_2O concentrations in the dental office included the lack of proper controls for collecting waste N_2O, leaks in the delivery system, and extensive use on patients. Exfiltration to other Plaza Level offices is due to the common return air system. Additionally, the compressor used for house suction does not appear to contain all scavenged N_2O.

After the September survey, a number of actions to control waste N_2O were implemented. Follow-up monitoring on October 12, after implementation of these controls, indicated that the measures taken reduced N_2O exposures in the dental office and in common areas of the Plaza Level. However, personal exposures to dental workers still exceeded the NIOSH REL for all activities assessed. Evaluation of the Accutron scavenger units installed after the September 15-16 survey found the flow rates on these units to be less than the recommended 45 Lpm (flow rates averaged
27-31 Lpm), although the flow rates were in the manufacturer's recommended range (possibly because the units are not the "mask within a mask" design).

It does not appear that this control technology, as currently used, can consistently reduce N_2O exposures to below 25 ppm during the period of anesthetic gas administration. Additionally, as long as N_2O is used in this dental office with the existing ventilation system design, exfiltration of waste N_2O to other areas outside the dental office will continue to occur.

RECOMMENDATIONS

1. Limit the use of N_2O as much as possible. Investigate and utilize alternatives where possible. When using N_2O, be as conservative as possible (e.g., use minimum flow rates and decrease actual usage time).

2. All aspirated air from the scavenging units should be vented directly outside. One option may be to place the compressor outside the building, route the compressor exhaust outside, or enclose and ventilate the compressor cabinet.

3. Work with building management and qualified ventilation engineers to investigate alternative ventilation for the dental office. This may include providing additional local exhaust ventilation for each operatory. Ideally, the dental office ventilation should be isolated from the rest of the building (e.g., single-pass system).

4. Implement a preventive maintenance program that includes reviewing the N_2O delivery system and conducting periodic leak checks. Every time a cylinder is changed, the connections should be checked for leaks. This can be accomplished by applying a soap solution to the fittings and observing for bubbles, which would indicate the presence of a leak. Periodic monitoring of ambient N_2O levels should also be conducted (quarterly for the first year and annually thereafter). Monitoring data should also be obtained whenever the N_2O delivery system is modified to ensure exposures are maintained below the NIOSH REL.

5. Work practice controls should include inspecting the N_2O delivery system each time prior to use and insuring the scavenger exhaust is operating properly. Masks should be carefully fitted on the patient to reduce leakage. Continue with the practice of not flowing N_2O until the mask is placed on the patient, and flushing with oxygen prior to removal.

6. Ensure all personnel who administer N_2O are trained on the correct work practices to follow to reduce N_2O concentrations.

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5. Georgia State Department of Health

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

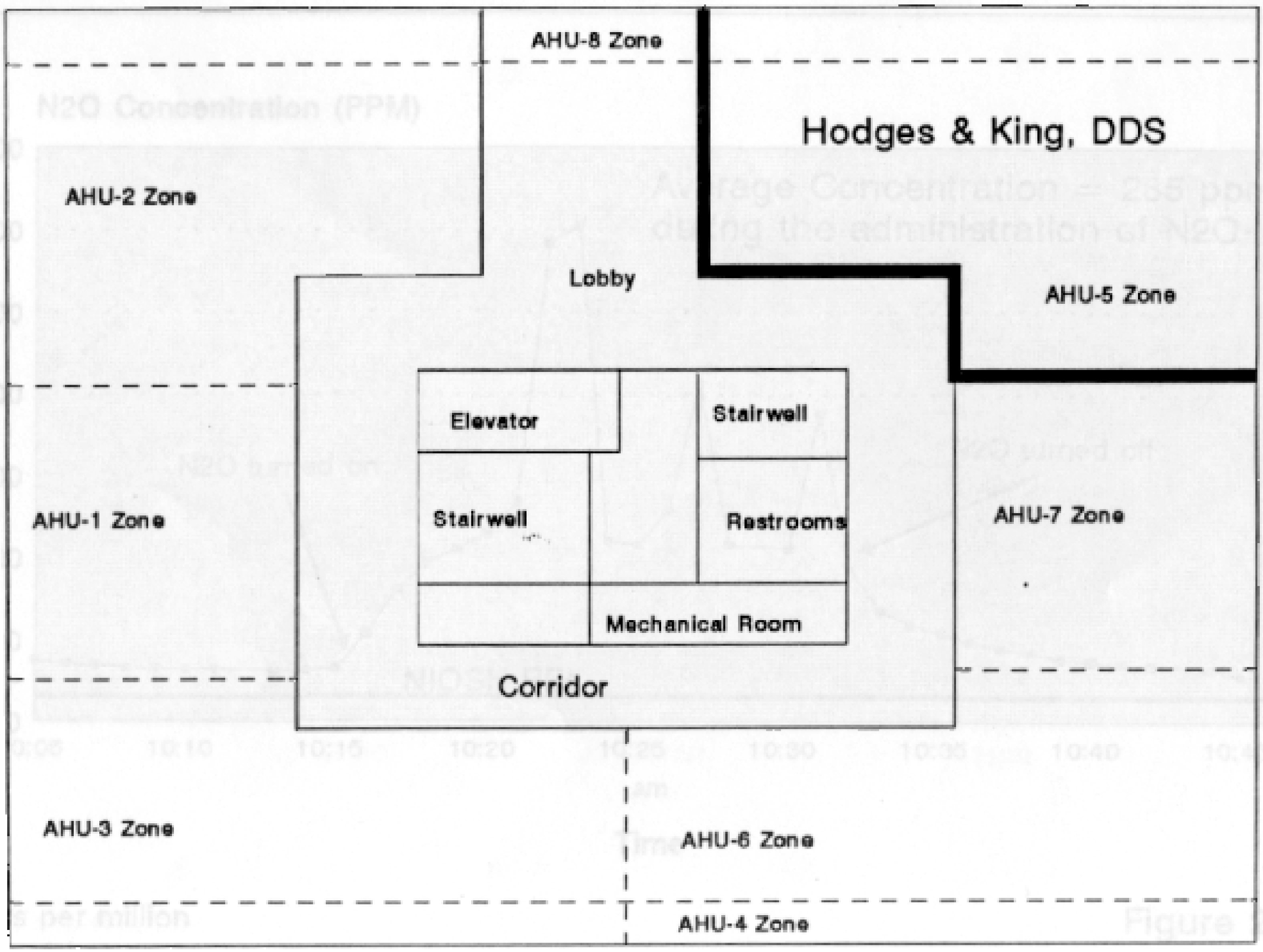
Table 1
Personal and Area Air Sampling Results: Nitrous Oxide Concentrations
Hodges & King, DDS
HETA 93-0951

Sampling location	**Concentration 9/15-16 Survey**		**Concentration 10/12 Survey**	
	Range	**Average**	**Range**	**Average**
Dentist, Operatory #4[P*]	107-604[NS]	285 (20)	58-1490[S]	347(35)
Dental Assistant, Operatory #4[P]			N/A	80 (35)[S]
Dental Hygienist, Hygiene Room #1[P]	N/A	1950 (30)[NS]	N/A	93 (30)[S]
Dentist, Operatory #2[P] (tooth filling)	137-402	205 (21)[S]		
Dental Assistant, Operatory #2[P]	N/A	465 (21)[S]		
Dentist, Operatory #2[P] (root canal)	113-2840	456 (52)[S]		
Dental Assistant, Operatory #2 [P]	144-256	200 (52)[S]		
Dentist, Operatory #1[P] (restoration)			N/A	60 (20)[S]
Bldg 1000 Mechanical Room (Plaza Level)[A]	N/A	33		
Breezeway, Plaza Level Entrance[A]	9-20	14 (20)	N/A	0.5
6th Floor Lobby, Bldg 1000[A]	1.7-2.0 (6)	1.8		
Dental Office prior to turning on N_2O Cylinder[A]	1.7-2.4 (14)	1.9		
Plaza Lobby prior to turning on N_2O cylinder[A]	N/A	1.7		
Dental Office, N_2O on at cylinder only[A]	5.1-31.7 (33)	25		
Plaza Lobby, N_2O on at cylinder only[A]	N/A	8.9		
Dental Office - After administering N_2O[A]	19-277 (255)	109	22-51	30 (110)
Plaza Lobby - After administering N_2O[A]	32-64 (34)	48	14-27	19 (43)
Vacuum Pump Closet[A]	242-355	296 (28)		
NIOSH Recommended Exposure Limit (for the duration of anesthetic administration)				25

NOTE: All results are in ppm (parts of gas per million parts of air)
N/A = not applicable - sample collected in bag
A = area sample
P = personal breathing zone sample
S = scavenger in use
NS = no scavenger in use
value in parentheses is the sampling time in minutes
* = The dental procedure evaluated during the 9/15-16 survey was a tooth filling. The procedure evaluated during the 10/12 survey was a crown seat and restoration

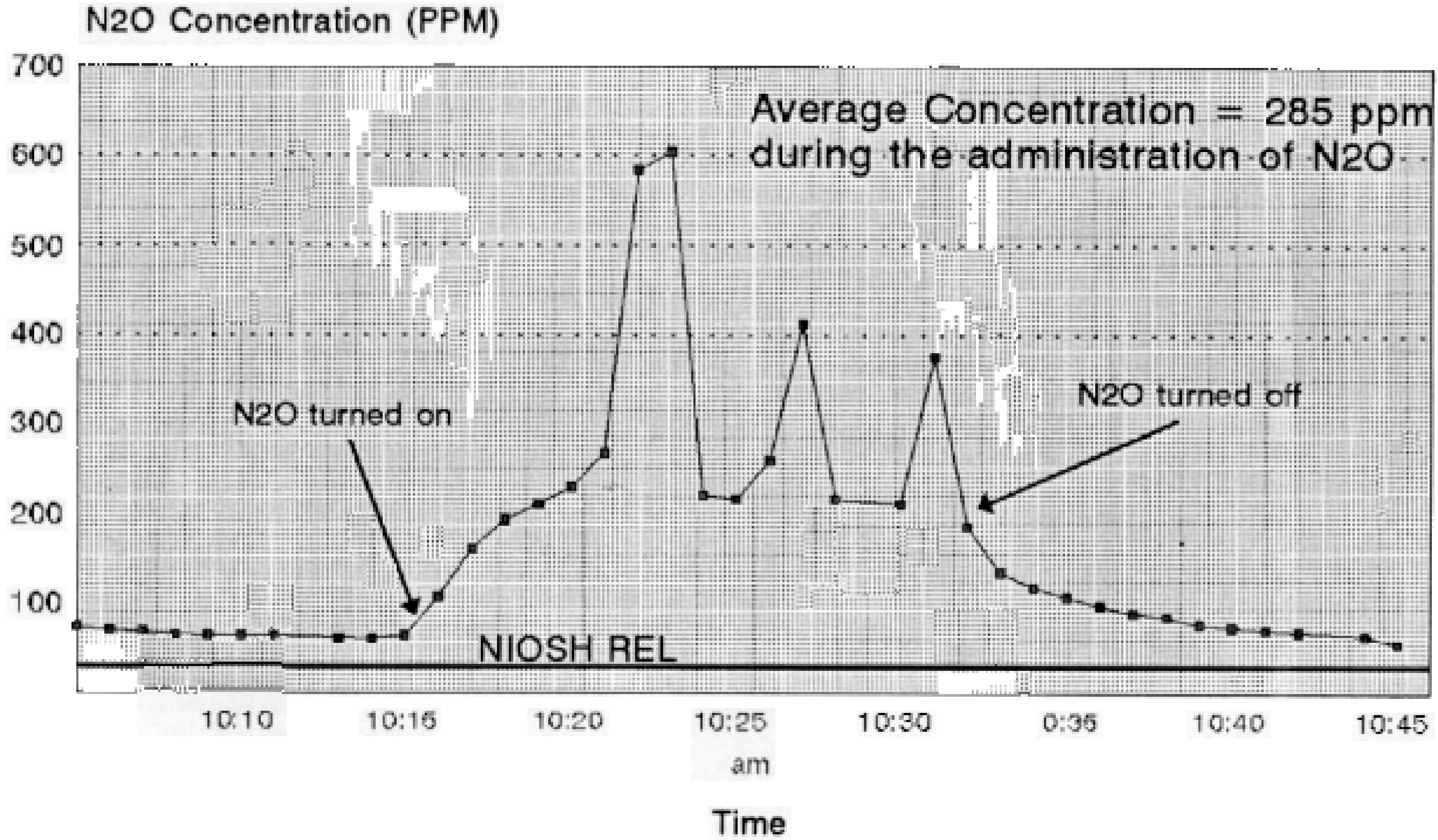
Figure 1: Plaza Level, Building 1000
Atlanta, Georgia
HETA 93-0951

AHU = Air Handler Unit



Nitrous Oxide Monitoring: Personal Sample Dentist

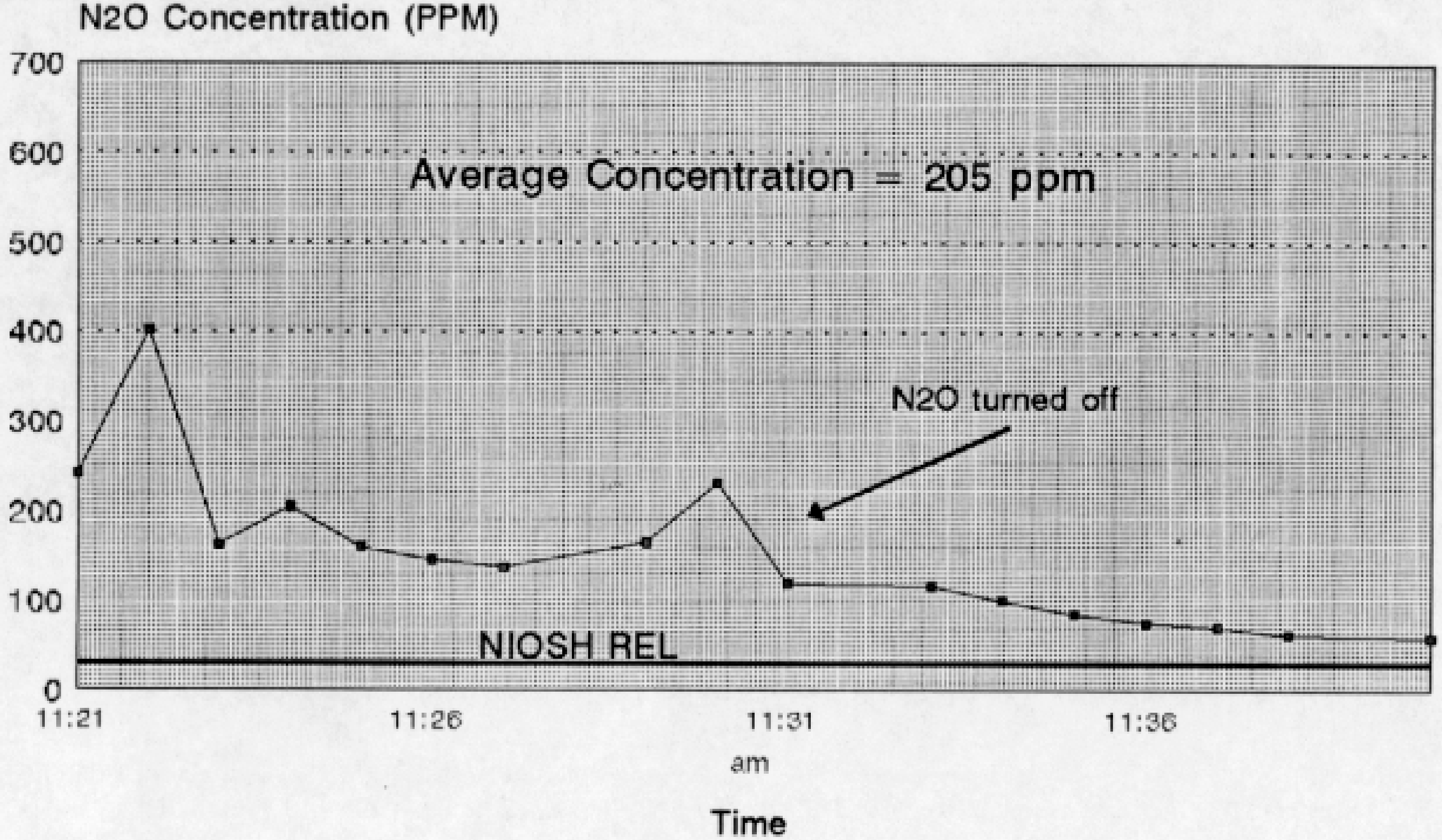
Operatory #4: Hodges & King, DDS, Tooth Filling
HETA 93-0951: September 15, 1993



PPM = parts per million
Scavenger not in use
NIOSH Recommended Exposure Limit (REL) = 25 ppm

Figure 2

Nitrous Oxide Monitoring: Personal Sample, Dentist
Operatory #2: Hodges & King, DDS, Tooth Filling
HETA 93-0951: September 15, 1993



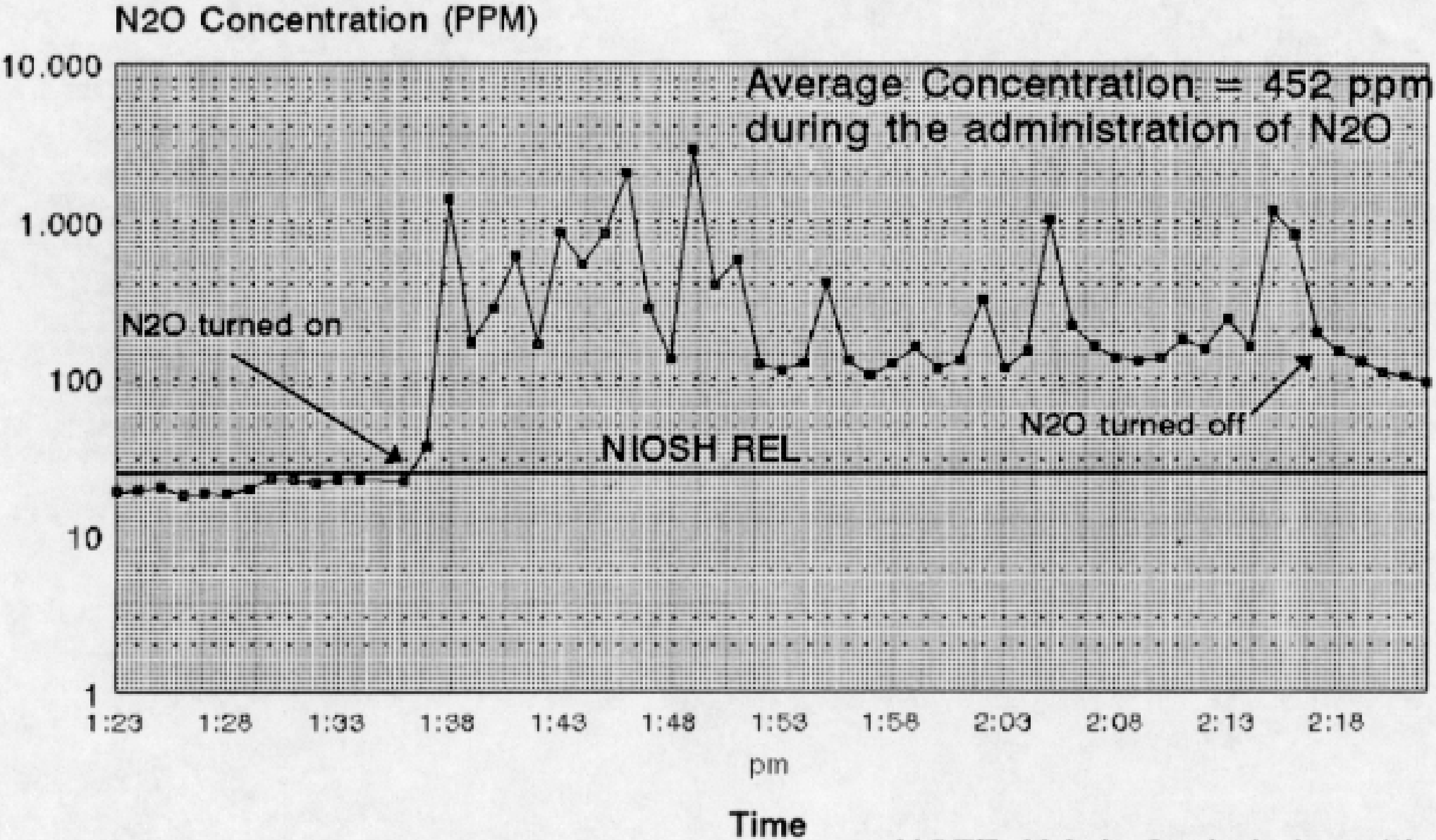
PPM = parts per million
Scavenger in use
IOSH Recommended Exposure Limit (REL) = 25 ppm

Figure 3

Nitrous Oxide Monitoring: Personal Sample, Dentist

Operatory #2: Hodges & King, DDS, Root Canal & Filling

HETA 93-0951: September 15, 1993



NOTE: Y-Axis Scale is logarithmic

PPM = parts per million

Scavenger in use

NIOSH Recommended Exposure Limit (REL) = 25 ppm

Figure 4

Nitrous Oxide Monitoring

General Office Area: Hodges & King, DDS
HETA 93-0951: September 16, 1993

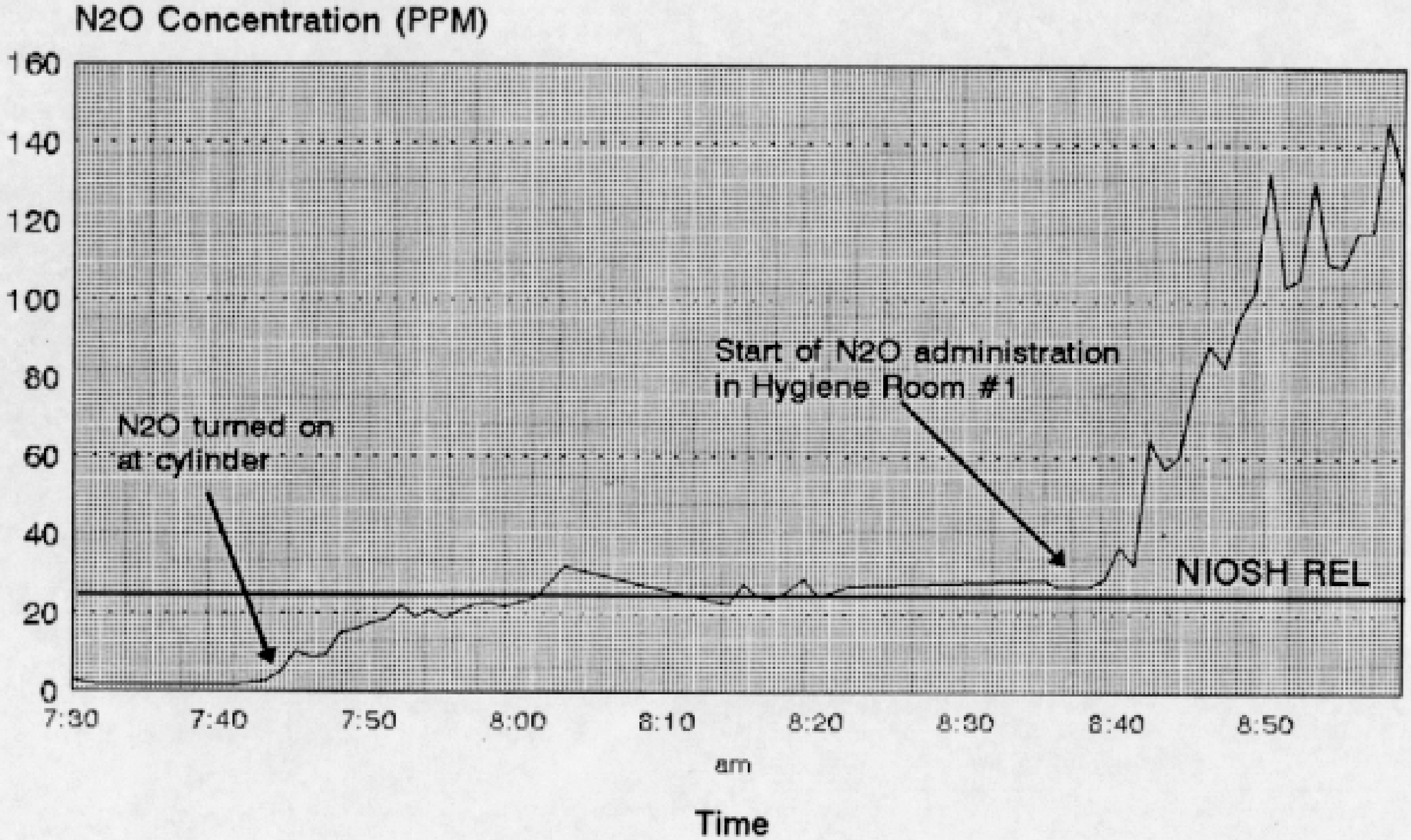


Figure 5

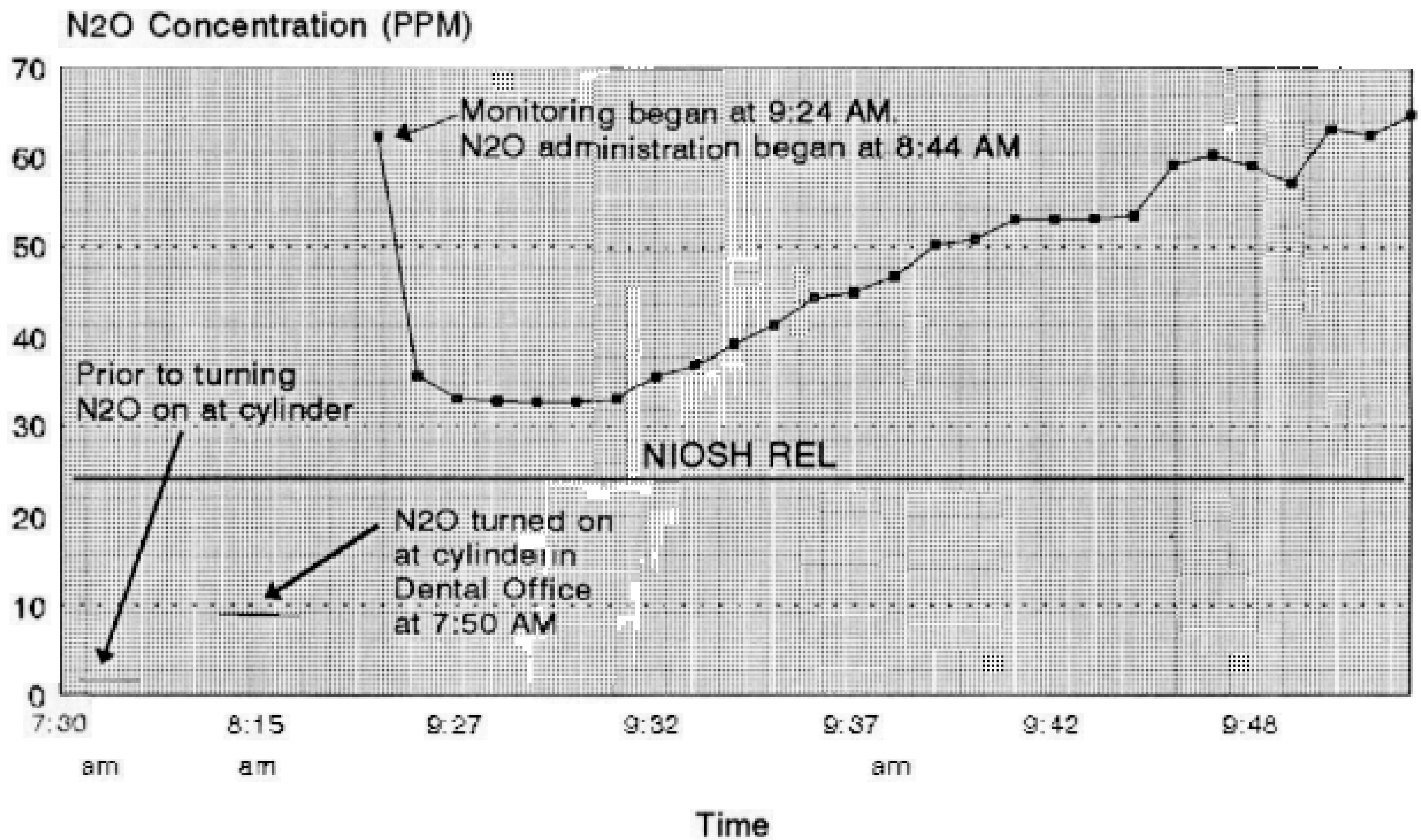
PPM = parts per million

NIOSH Recommended Exposure Limit (REL) = 25 ppm

Nitrous Oxide Monitoring

Plaza Lobby, Building 1000

HETA 93-0951: September 16, 1993



PPM = parts per million

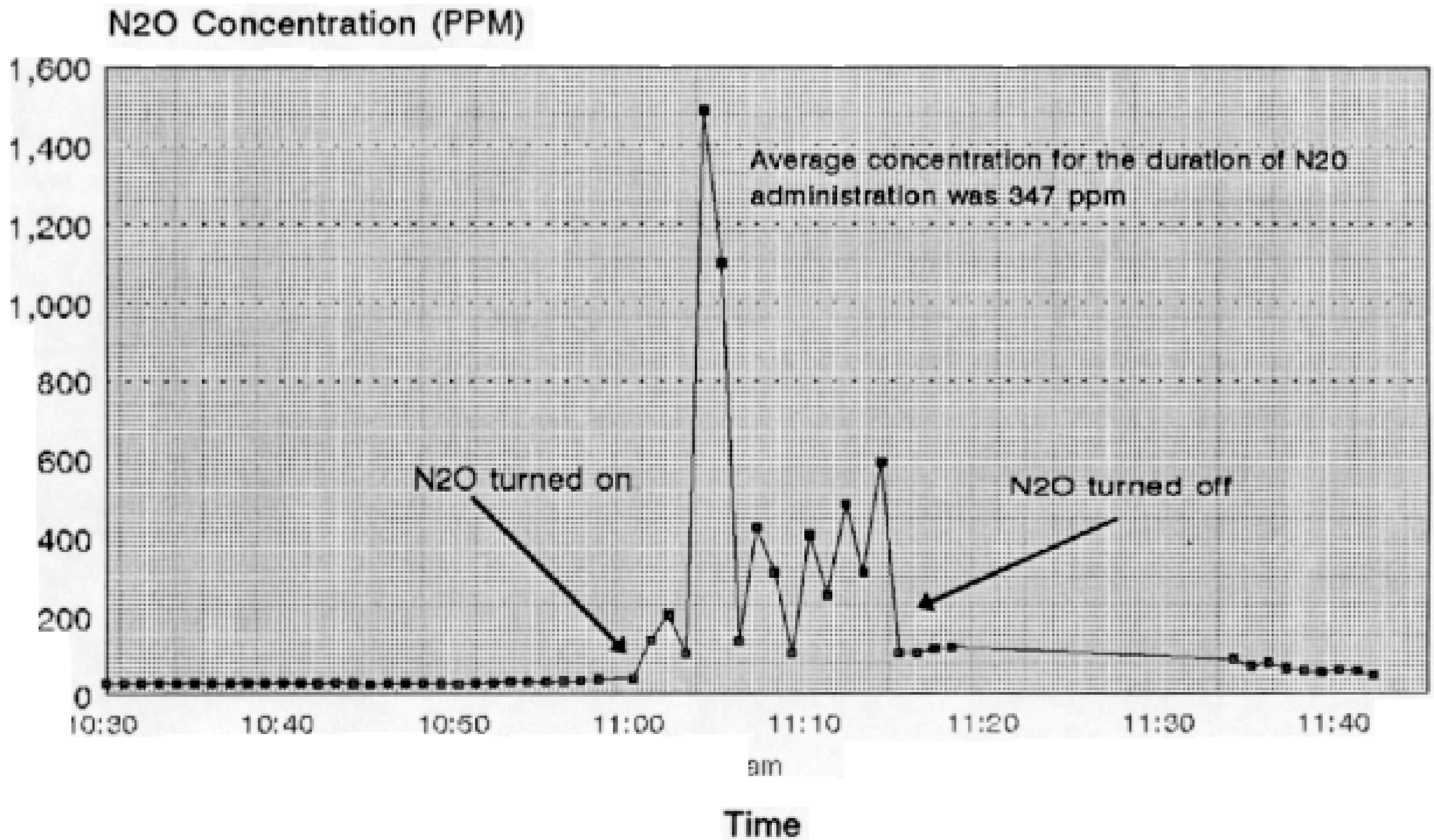
Figure 6

NIOSH Recommended Exposure Limit (REL) = 25 ppm

Nitrous Oxide Monitoring: Personal Sample, Dentist

Operatory #4: Hodges & King, DDS

HETA 93-0951: October 12, 1993



PPM = parts per million

Scavenger in use

NIOSH Recommended Exposure Limit (REL) = 25 ppm

Figure 7