WCB – FUNDED PROJECT

CHEMICAL EXPOSURE ASSESSMENT AT LANGLEY MEMORIAL HOSPITAL

Nurses' Exposure: Formaldehyde in the Dirty Core and Nitrous Oxide in Labour and Delivery

Langley, British Columbia

Summer 2001

SUMMARY

Nurses' exposure to formaldehyde in the dirty core and nitrous oxide in labour and delivery rooms was measured on July 10 and July 26 to August 2, 2001, using personal and environmental sampling methods, at Langley Memorial Hospital (LMH) in British Columbia. The project was funded by the Workers' Compensation Board (WCB) of British Columbia (BC) as part of a Chemical Exposure Risk Assessment for the South Fraser Health Region.

All formaldehyde samples taken in the dirty core were below the Workers' Compensation Board of British Columbia 8 hr exposure limit of 0.3 ppm and the ceiling limit of 1 ppm.

Instantaneous personal measurement of nurse exposure to nitrous oxide in the labour and delivery rooms varied between 0 and 566 ppm. Full shift average exposures for the nurses varied from 1.3 ppm to 15.1 ppm.

Conclusions:

Formaldehyde:

- Although worker exposure to formaldehyde in the dirty core area did not exceed WCB of BC exposure limits, exposures must be maintained at levels as low as reasonably achievable below the exposure limit (designated as a suspected human carcinogen).

Nitrous oxide:

- Average exposures were below the 12 hr limit of 12.5 ppm with the exception of one nurse
- 5 nurses' personal data logged samples exceed the 5X excursion limit of 125 ppm.
- The limit set by the WCB of BC of an 8 hour TWA of 25 ppm is attainable at this point in labour and delivery, where nitrous oxide is self-administered, but the 5X excursion limit of 125 ppm is not.

Recommendations

Formaldehyde:

- Implement an exposure control plan as per OHS Reg 5.57 (2) – Designated Substances. This regulation states that substances designated as ALARA substances must be substituted, however, if it is not practicable then the employer must implement an exposure control plan to maintain workers' exposure as low as reasonably achievable below the applicable exposure limit.
- It is recommended that the leaking spigot on the formalin container be discussed with the company representative. The leaking spigot must be maintained in good operating condition by the department in order to prevent leaks.

Nitrous Oxide:

- Management should continue investigations to reduce peak exposures to below the 5X excursion limit of 125 ppm.
- Install local exhaust ventilation. Few solutions are presented in the literature as to the type of local exhaust system that would decrease the peak exposures, however, it is possible that a slotted hood located at the head of the bed might be an effective solution.

  and/or
- Conduct a feasibility study to look at the costs and benefits of increasing the number of room air changes per hour.

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APPENDICES

1.0 INTRODUCTION

Between July 10, 2001 and August 2, 2001, Charlotte Ferguson, Masters student in Occupational Hygiene from McGill University, conducted a chemical exposure assessment at Langley Memorial Hospital (LMH) located at 22051 Fraser Highway in Langley, British Columbia. The assessment included a walk-through survey and sampling for formaldehyde in the dirty core area (outside operating rooms) and nitrous oxide in the maternity wards.

This project, funded by the WCB BC is part of a chemical exposure assessment for the South Fraser Health Region (which includes LMH). The purpose of the project was to quantify the nurses' exposure to formaldehyde and nitrous oxide and compare it to the WCB OF BC exposure limits. The British Columbia (BC) limit for formaldehyde is an 8hr exposure limit (EL) of 0.3 ppm and a ceiling EL of 1.0 ppm. An 8-hour exposure limit means the time weighted average (TWA) concentration of a substance in air which may not be exceeded over a normal 8 hour work period. Ceiling limit means the concentration of a substance in air which may not be exceeded at any time during the work period. Nitrous oxide has an 8hr EL of 25 ppm with no ceiling or short-term exposure limits. Occupational Health and Safety (OHS) Regulation 5.49 states that if only 8-hour exposure limit is provided then a worker's exposure to the substance does not exceed three times the 8-hour exposure limit for more than a total of 30 minutes during the work period and five times the 8-hour exposure limit at any time (3X and 5X excursion limits).

2.0 LITERATURE REVIEW

2.1 Formaldehyde

Formaldehyde is a volatile organic compound (VOC). When levels in the air are greater than 0.1 ppm it can cause burning sensations in the nose, throat and eyes, watery eyes, nausea, coughing, chest tightness, wheezing, skin rashes and allergic reactions (EPA, 1997).

Formaldehyde is used as a tissue preservative in hospitals as a 10% Formalin solution. This solution contains formaldehyde (3-4%), methanol (0.5-1.5%), sodium hydroxide (0.1-0.6%), phosphoric acid (0.1-0.6%) and water (balance). Formaldehyde is a known eye, skin, respiratory tract irritant and is considered by the American Conference of Governmental Industrial Hygienists (ACGIH) as a suspected human carcinogen (nasal cancer). It is also designated as a suspected human carcinogen by the WCB of BC. The International Agency for Research on Cancer (IARC) stated in 1995 that there is limited evidence in humans that formaldehyde is a carcinogen, however, there is sufficient evidence in animals. Their overall evaluation was that formaldehyde is probably carcinogenic to humans.

A study by Korczynski in 1994 examined formaldehyde exposure in the funeral industry. The findings revealed that exposure to formaldehyde in that profession was intermittent. Also, the length of time formaldehyde was used and the duration of the procedure was very case specific. Breathing zone samples taken during embalming of an intact body indicated levels varying from 0.1 ppm to 4.6 ppm with an average of 0.64 ppm. Exposure during autopsy sample preparation ranged from 0.09 ppm to 3.36 ppm with an average exposure of 0.65 ppm. Environmental air samples taken during these procedures varied from 0.04 ppm to 6.81 ppm with an average of 0.5 ppm (Korczynski, 1994). Exposures in the funeral industry would be expected to be much higher than in the dirty core area at LMH where formalin is dispensed in quantities less than 300 mL per aliquot.

A study by Korczynski in 1994 examined formaldehyde exposure in the funeral industry. The findings revealed that exposure to formaldehyde in that profession was intermittent. Also the length of time formaldehyde was used and the duration of the procedure was very case specific. Breathing zone samples taken during embalming of an intact body found levels varying from 0.1 ppm to 4.6 ppm with an average of 0.64 ppm. Exposure during autopsy preparation ranged from 0.09 ppm to 3.36 ppm with an average exposure of 0.65 ppm. Environmental air samples taken during these procedures varied from 0.04 ppm to 6.81 ppm with an average of 0.5 ppm (Korczynski, 1994). Exposures in the funeral industry would be expected to be much higher than in the dirty core at LMH where formalin is dispensed in quantities less than 300 mL.

In 1990 Blair et al., reviewed epidemiological evidence of the relationship between occupational formaldehyde exposure and cancer. They reviewed 32 epidemiological studies and found an excess of brain cancer, colon cancer and leukemia among embalmers, anatomist and funeral directors. They noted that these professions are exposed to a wide variety of chemicals and therefore there are many potential causes of these excess cancers. The excess colon, brain cancers and leukemia were not seen in industrial workers exposed to formaldehyde and therefore it is possible that other chemicals are responsible for the excess (Blair et al, 1990).

2.2 Nitrous Oxide

Nitrous oxide is used in the labour and delivery as a 50% oxygen/50% nitrous oxide mixture often referred to as Entonox or Nitronox. Nitrous oxide is an odourless, non-combustible gas that is manufactured by the thermal decomposition of ammonium nitrate and purification of its byproducts (McGlothlin et al., 1994). The gas has a density of 1.53 which is heavier than air (1.0) meaning that it will settle towards the ground. For this reason, it is recommended that the ventilation systems for rooms in which nitrous oxide is used have the fresh air supply located in the ceiling and the exhausts at floor level (Heath et al., 1994).

The main route of nitrous oxide exposure is inhalation and once it is taken into the body it is dissolved in blood as a gas and eliminated via exhalation from the lungs in a virtually unchanged state. A small amount is eliminated through the pores in the skin. After exposure has ceased, the majority of the nitrous oxide is eliminated from the body in 17 to 35 minutes (McGlothlin et al., 1994).

2.2.1 Labour and Delivery

The majority of studies examining nitrous oxide exposure have focussed on the operating room or dental offices. Very few articles have been written about nitrous oxide use in the labour and delivery room. Labour and delivery represents a unique situation where the nitrous oxide is administered by the patient.

An article written by Munley et al., in 1986 looked at midwives' exposure to nitrous oxide. They found mean exposures that were not significantly less than the Swedish 8hr TWA of 100 ppm and one average exposure was 360 ppm. These values were based on an unscavenged nitrous oxide delivery system and they noted that with scavenging in place the exposure could be reduced by a factor of 2 to 5. They noted that even with scavenging systems in place, they were unable to decrease the midwives' 8 hour time weighted average (TWA) exposure to less than 25 ppm (NIOSH and WCB OF BC standard).

Heath et al., in 1994 conducted a study looking at nitrous oxide pollution in the delivery suite in a hospital in New Zealand. They found unacceptable levels of nitrous oxide in labour and delivery suites that were unscavenged and that in most cases by adding a scavenging system the levels dropped to below the NIOSH 8 hr limit of 25 ppm. They noted that with some patients the levels were unacceptably high even with scavenging. The delivery room investigated in that study had an air inlet in the centre of the ceiling, an exhaust grill at floor level and a total of 12 room air changes per hour (Heath et al., 1994).

2.2.2 Exposure Limits

The 8 hour exposure limit for nitrous oxide has been set at 100 ppm in Sweden, Denmark, Germany, Italy, Norway and the United Kingdom. The Health Services Advisory Committee, (UK) stated reasons for setting the limit at this level were given including tests on rats at 1000 ppm for 8 hrs a day for the duration of gestation, and developmental toxicity was observed (HSAC, 1995). The experiments were repeated at 500 ppm and no adverse effects on the fetus were observed. The HSAC supports that nitrous oxide can inhibit the production of new cells and therefore set its limit at 100 ppm, 1/5 the level of no effect. When examining how to decrease exposure in labour and delivery the committee suggested that general exhaust (6-7 room air changes per hour) and good housekeeping practices would help keep exposure levels below the permissible limit.

2.2.3 Potential Health Effects

A wide variety of health effects have been potentially linked with occupational nitrous oxide exposure including: reduced fertility, increased incidence of spontaneous abortion, increased frequency of sister chromatid exchanges (SCE), interference with vitamin B12 metabolism and audiovisual disturbances. Hoerauf et al. found an increased number of SCE from exposure in the operating room to an 8 hr TWA of 12.5 ppm. The primary limitation with this study was that both nitrous oxide and isofluorane were used in the operating room and it is impossible to determine which was responsible this finding (Hoerauf et al., 1999).

Animal studies conducted in the 1970s and 1980s suggested that nitrous oxide was embryotoxic and fetotoxic in rats, caused smaller litters, increased incidence of fetal resorption and increased number of skeletal abnormalities. The main critiques of these studies were the unrealistic concentrations and duration of exposure the rats were being exposed (for example 24 hrs/day for 5-9 days at 1000 ppm or 15,000 ppm). The exposure levels used were unreasonably high when compared to levels encountered in occupational settings.

Many studies have found an increased number of SCE in workers exposed to nitrous oxide, however, the exposure and outcome were often self-reported, had low response rates and exposure data was lacking in the studies. Questionnaires were often the method used to collect the data which can lead to possible response and recall bias (Ahlborg et al., 1995). The main health concern associated with nitrous oxide exposure is an interference with the metabolism of Vitamin B12. The theory presented by many studies including Suruda et al., 1997, states that the gas oxidizes the cobalt atom in the Vitamin B12 from Co^{I} to Co^{II} which inactivates Vitamin B12–dependent enzymes including methionine synthetase and methylmalonyl coenzyme A mutase. These enzymes are required for Vitamin B12 activity. The Vitamin B12 deficiency is thought to lead to defective DNA synthesis.

In 1999, a study by Bodin et al. investigated the potential association between shift work and nitrous oxide exposure and its effects on pregnancy, birth weight and gestational age. This study used a questionnaire that was sent to the members of the Swedish Midwives Association. The findings were that nitrous oxide exposure was associated with reduced birth weight and the

frequency of nitrous oxide exposure occurred was associated with reduced fecundability (time required to get pregnant). They found no association between nitrous oxide exposure and spontaneous abortion. The main critique of this study was the lack of measured nitrous oxide exposure.

At this point in the research, no dose and effect relationship has been established concerning the health effects of nitrous oxide exposure in the work environment.

2.2.4 Control Measures

Control measures recommended to decrease exposure in labour and delivery include: tighter fitting masks, increasing air flow to the room and educating workers about the scavenging system and how to fit masks properly. NIOSH recommended in an Alert dated 1994 that if nitrous oxide levels are above the 25 ppm 8 hr exposure limit then air flow into the room should be increased or the amount of outside air brought into the room should be increased. It stated that if these methods do not decrease exposure to below the exposure limit then local ventilation in conjunction with a scavenging system should be used (NIOSH, 1994). Crouch et al, 2000 recommended that the scavenging system used in labour and delivery should have a minimum flow of 1.6 cfm. The study stated that the scavenging system and general dilution ventilation have a large effect on nitrous oxide exposures. One very important point made in the study was that it is impossible to control the patient who is mouth breathing, talking, crying, etc. and these are the main ways that nitrous oxide is released into the environment.

Bernow et al., in 1984, looked at using containment as a method of decreasing the nurses exposure to nitrous oxide in labour and delivery. This involved placing the mother's head in a plexiglass enclosure for the duration of the labour and delivery. This enclosure acted as containment and as an exhaust. With this system in place, levels below the NIOSH recommended exposure limit of 25 ppm were achieved (8 hr TWA 24 ppm), however, this system was barbaric and it is not likely to be widely accepted.

Studies have shown that intermittent flow apparatus produce far less pollution than continuous flow methods used by anaesthetic machines (Heath et al., 1994). One of the main problems in labour and delivery is that the mother controls the administration of nitrous oxide and removes the mask between contractions. Since the nitrous oxide is off gassed for 17 to 35 minutes after stopping it means the mother is off-gassing directly into the room between contractions. Heath et al., 1994, suggested that the gas only be used in the late first stage and second stage of labour to decrease the amount of nitrous oxide being used and offgassed which would in turn decrease the workers' exposure. This is not a viable option since nitrous oxide is often the first method of pain control offered to mothers in labour.

3.0 WORKPLACE DESCRIPTION

3.1 Dirty Core Area

The Dirty Core Area is located on the second floor of Langley Memorial Hospital in the area outside the operating rooms (OR). Biopsy samples from the OR are brought to the Dirty Core Area to preserve them in formalin prior to being sent for tissue analysis. A diagram of the room where the formalin is dispensed can be found in of this report Appendix 1 of this report. Photographs can be found in Appendix 2.

The room where the formalin is dispensed is approximately 14 m^2. It has two sinks, for gross cleaning of instruments, before they are sent down a dumb waiter to Central Supply (for sterilization), shelves with various containers and gloves and the biopsy sample fridge. The formalin is located on a shelf attached to a fixed station. It is stored in an 18.9 L plastic container fitted with a spigot. The container sits in the cardboard shipping box.

There is no one nurse assigned to dispense formalin in the dirty core area. The nurse working in the OR is responsible for bringing the biopsy from the OR to the dispensing station and covering the sample with formalin to a level approximately ten times the size of the tissue. The time spent in the formalin dispensing area was approximately 2 minutes per sample. The time required to cover the sample depended on the size of the biopsy, however, on average formalin

was dispensed for approximately 5-10 seconds and the remainder of the time was spent filling out the biopsy record sheet.

Nurses wore rubber latex gloves while dispensing the formalin. A plexiglass splash shield was fixed above the formalin container. The only ventilation located in the room was the general dilution ventilation provided by the HVAC system of the building.

According to the nurses, the formalin container is kept in its original cardboard shipping box because it often leaks around the spigot (see photo 5 in Appendix 2). A new spigot is shipped with each formalin container and is screwed into the new full container. This leak causes the cardboard around the container to become wet and give off formaldehyde vapours even after dispensing has stopped.

3.2 Maternity Ward

Labour and delivery is located on the third floor of Langley Memorial Hospital and contains 12 labour and delivery rooms. Once a patient is admitted they are assigned to a room where they will labour, deliver and recover prior to discharge. Nitrous oxide is piped into each room from a central supply located in the basement of the building. A sampling location plan is located in Appendix 1 of this report and photographs can be found in Appendix 2.

The delivery rooms contain a bed, sink, sofa, bathroom and have cupboards located behind the head of the bed that contain the nitrous oxide supply, mask, scavenging system and suction.

The nitrous oxide delivery system is a demand system. Gas is dispensed when the mother holds the mask tightly against her face and inhales and the scavenging system is activated when the mother exhales into the mask. Nitrous oxide exhaled into the mask is captured by the scavenging system and exhausted to the outside. Hospital protocol states that the mother must hold the mask at all times (and not have the father hold it) to prevent her from overdosing on the gas (unconsciousness would result before a lethal overdose could occur). If the mother did not have a good seal between the mask and her face then the gas could not be dispensed.

The ventilation control measures for nitrous oxide in the delivery room were the scavenging system (local exhaust ventilation) and the general dilution ventilation (three fresh air supply outlets located in the ceiling and two wall mounted exhaust grills located near floor level.

4.0 SURVEY EQUIPMENT AND PROCEDURE

4.1 Formaldehyde

4.1.1 Equipment

- Gastec Pump No. 830 (hand-held, piston type), last bench calibrated on June 14, 2001, asset number 002713 Gastec
- Gastec Detector Tube (Formaldehyde) No. 91LL (0.05 ppm to 1.0ppm), batch number 91220, valid until July 2003
- Gastec Detector Tube No. 91L (Formaldehyde) (0.1 ppm to 4.0 ppm), batch number 00453, valid until April 2003.
- Sampling pump charger –Model # YL7220LFS, August 1999, serial number 9080006
- Gilian Dual Mode Low Flow Sampler Model LFS 133DC SN-14288, Asset # 84147, WCB OF BC Laboratory Services checked May 6, 2001.
- Gilian Dual Mode Low Flow Sampler Model LFS 133DC SN-14343, Asset # 84188, Lab Services checked May 16, 2001.
- SKC Treated Silica Gel Tube, Lot No. 1481, Expires 03/02.
- Gastec Smoke Tester Tube No. 501, batch number 30622.
- Minibuck, A.P. Buck, Model # M-5, Serial # 50621 calibrated April 11, 2001.

4.1.2 Procedure

Formaldehyde levels at the formalin dispensing station were tested for 6.5 hours on July 12, 2001. Silica gel tubes (area samples), colorimetric detector tubes (personal samples) and smoke tubes (ventilation effectiveness testing) were used throughout the sampling day.

4.1.3 Silica Gel Tubes

Environmental (area) sampling was conducted using two personal pumps and treated silica gel tubes. The pumps were calibrated using a mini buck calibrator, model number M-5, Serial Number 050621 last calibrated on March 21, 2001. The pumps were field calibrated upon arrival at the hospital and at the end of the sampling day, each time requiring three readings within 5% to show that the pump had stabilized. The pumps were turned on for 10 minutes prior to calibration to allow them to warm up.

The two pumps were set up on the fridge immediately adjacent to the formalin dispensing station and the silica gel tubes were attached to the pumps using rubber tubing. The tubing was set up on the fridge allowing the sampling tubes to be located within one foot of the nurses breathing zone when the formalin was being dispensed. One pump was set up to sample for 317 minutes with a flow rate of 0.204 L/min and the tubes attached to the other pump were replaced after 98, 92 and 125 minutes respectively with a flow rate of 0.203 L/min. One blank was taken for the four tubes.

Lab analysis was conducted at the WCB lab as per WCB Analytical Method 5270 – Aldehydes in Air. This method involves analysis with a high performance liquid chromatograph with a UV-visible detector. This method has an error of +/- 3.3%.

4.1.4 Colorimetric Detector Tubes

Personal sampling was conducted using a Gastec pump and formaldehyde colorimetric detector tubes. One sample was taken each time a nurse brought a tissue biopsy to the dispensing station. The procedure for the Gastec tubes required five strokes and each stroke was drawn in the nurse's breathing zone. Since the pump required approximately one minute between the five strokes the nurses always left the dispensing area during the sampling period and the sampling continued in their breathing zone even after they had left the dispensing area.

This method has an error of +/- 10%.

4.1.5 Smoke Tubes

Smoke tube testing was conducted to visualize the effectiveness of the general exhaust ventilation in the dispensing area. The smoke tube was activated at intervals of one foot up to approximately seven feet from the exhaust. The ceiling mounted exhaust duct opening was located approximately seven feet away from the dispensing station.

4.1.6 Strategy

Direct reading colorimetric tubes with hand held pump and treated silica gel tubes with low flow pumps were used. The original intention was to sample from 7:30 am to 3:30 pm and the sampling equipment was all set up waiting for the first biopsy of the day to appear, however, the first two procedures did not yield a biopsy and therefore the sampling day was shortened.

The colorimetric detector tubes acted as personal samples since they were drawn in the breathing zone of the worker. The silica gel tubes were collected as environmental (area) samples. For the purposes of this study it was not practical to set the pumps and silica gel tubes on the nurses since it was often a different nurse that dispensed the formalin. The nurse that dispenses the formalin was the nurse that was in the OR where the biopsy was taken. If the unit had been attached to one nurse for the duration of the shift the data would represent only one exposure to formaldehyde. Since the units were set up near the formalin dispensing station they represented a worst case scenario.

4.2 Nitrous Oxide

4.2.1 Equipment

- Bacharach Medigas Model 3010 Nitrous Oxide Meter P/N 19-7109.

This machine was a new, hand held, infra-red (IR) analyzer that can be used for personal sampling. The unit can be worn on the waist belt and a small air sampling tube can be secured on the back and leading to the breathing zone. Several discussions occurred between the various Bacharach offices in Canada, United States and England concerning the operation and accuracy of the machine. The machine was developed in England and discussions also occurred with the

instruments developer at Geotechnical Instruments in England. Product information can be found in Appendix 11 of this report.

Several WCB of BC lab tests were conducted prior to testing this new instrument in the field. A sampling bag with 122 ppm N_2O was sampled for a three hour period. Testing was also conducted using a 25 ppm standard. The response time of the unit was verified by testing a 122 ppm standard for three 20 minute intervals. The machine was detached from the bag after 20 minutes and allowed to return to zero prior to re-connecting it. This machine has an accuracy of +/- 10 ppm.

Other exposure and ventilation monitoring equipment included:

- Telog Instruments 2101Analog Voltage Recorder, Model # 2101-61 N/A 6499
- Foxboro Miran 203 Specific Vapour Analyzer Serial # 000060 with high efficiency particulate filter 8F2B Serial # 40700853.
- Assay Technology Nitrous Oxide Badges, Lot # 2D01-4, Expiry Date 2/28/02, Item # N575AT (see Appendix 9 for product information)
- Alnor Balometer Jr., s/n 3927

4.2.2 Procedure

Sampling was conducted between July 26 and August 2, 2001. Specific dates and times were as follows:

Date	Time
July 26 to July 27, 2001	7:30 am to 7:30 pm straight through
July 27, 2001	7:30 am to 7:30 pm
July 31 to August 2, 2001	7:30 am to 7:30 straight through

The industrial hygienist (researcher) lived at the hospital during the sampling times and the nurses paged her to indicate that a woman was going to start using nitrous oxide.

The sampling procedure for this study consisted of using passive dosimeters, a Miran infra-red spectrophotometer and the Medigas 3010, personal infra-red active sampler. The nurse wearing the Medigas 3010 was followed for the duration of the nitrous oxide use and her activities were noted in an activity log.

4.2.3 Miran

The Miran air intake particulate filter was set up on the fetal monitor located approximately 3 feet from the mother's head and was turned on at the start of the delivery and turned off at the end of the delivery or after the administration of an epidural. A Telog data logger was attached to the Miran to allow the data to be logged and later downloaded to a personal computer. The telog records results in volts and a nitrous oxide response curve obtained from the WCB of BC lab was used to convert the values from volts to ppm.

The Miran was calibrated by injecting a 1 mL sample, from a sample bag containing 10,000 ppm N_2O, into the Miran when it was set up in a closed loop. The unit was considered stable when it was injected three times and the same concentration was indicated on the display. The unit was calibrated at the beginning and end of each 12 hour period and was kept on 'stand by' setting until it was needed.

4.2.4 Medigas 3010 personal sampler

The Medigas 3010 was attached to the nurse as soon as the mother indicated that she wanted to use nitrous oxide. The pump was attached to her waistband and rubber tubing secured to her back and over her shoulder and the end of the tube was located in the nurse's breathing zone (approximately six inches from her mouth). The tubing was taped to ensure that it did not interfere with the nurse's duties and so that it did not form a loop or kink. The unit was switched off at the end of the delivery or after Demerol or an epidural was administered and therefore nitrous oxide use ceased.

The nurse was followed the entire time she was wearing this device and her activities were noted in an activity log.

The Medigas 3010 was kept plugged in and on (with the pump off) during the down time. The Medigas 3010 had to be kept on due to the 15 minute warm up time required and only a few minutes warning was given prior to the use of nitrous oxide.

4.2.5 Passive Dosimeter Badges

At the beginning of each shift the charge nurse assigned patients to each nurse. Nitrous oxide passive dosimeter badges and badges were given to two to four nurses following this assignment. Badges were given to those nurses most likely to work with a labouring patient and were worn on the lapel for the duration of the shift (8 or 12 hours). The badges were removed at the end of the shift. The shift duration, number of deliveries and whether exposure to nitrous oxide occurred was recorded for each badge. One blank badge was analyzed for every 10 air samples taken.

It was noted at the end of the first shift that the badges kept falling out of their plastic holders. Conversations with Assay Technologies, manufacturer of the badges, indicated that problems have been reported with the holder and using masking tape to secure the disk containing the absorbent to the back of the badge would not interfere with sampling or the results. Masking tape was used for the remainder of the shifts.

Lab analysis was conducted at the WCB lab using Analytical Method 1102 Passive Dosimeter Method. This method involved analysis with a gas chromatograph equipped with an electron detector. The error of this method was +/- 25%.

4.2.6 Ventilation Testing

The volume of fresh air entering the room was tested in one of the labour and delivery rooms using the Alnor balometer Jr. The flow rate was tested for each of the three fresh air supplies in the room. A ventilation balance report, dated 1999, obtained from Chris Thompson, Systems Engineer, LMH, was used to calculate the number of air changes per hour.

4.2.7 Strategy

The sampling strategy using passive dosimeter, Miran and Medigas 3010 was chosen since there would be at least one personal and one environmental sample per delivery to a maximum of two personal samples and one environmental sample for each delivery. The Medigas and passive dosimeter badges are personal samples and their data can be compared to the WCB OF BC exposure limits. The Miran was an environmental sample and cannot be compared to the WCB OF BC limits but can be used to provide information concerning the amount of nitrous oxide in the room at any point during the labour and delivery.

5.0 RESULTS

5.1 Formaldehyde

5.1.1 Silica Gel Tubes – Area Samples

Silica gel sampling tubes were collected throughout the sampling day. Three tubes were used for short term sampling for less than 125 minutes and one tube was used for 317 minutes. The results of all tubes were below the detection limit of 1.0 µg/sample. The blank was also < 1.0µg/sample.

5.1.2 Colorimetric Tubes – Personal Samples

Gastec direct-reading colorimetric tubes were used to determine nurse exposure to formaldehyde while it was being dispensed. A table with the results can be found in Appendix 4 of this report. The results of breathing zone samples 1,2 and 5-8 were all below the detection limit of the tubes which was 0.05 ppm. Sample 3 was taken 3 cm above a container of formalin to determine the presence of formalin. Breakthrough (concentration exceeded tube capacity) was (>1 ppm) observed with 3 of the 5 strokes of the Gastec pump. Sample 4 was taken above the formalin stain located on the cardboard surrounding the formalin container. Breakthrough was also observed with this sample before the 5 strokes of the pump could be completed.

5.1.3 Smoke Tubes

The effectiveness of the general exhaust ventilation at removing the formalin vapours from the dirty core area was tested using a smoke tube. The formalin dispensing station spigot was located approximately seven feet from the ceiling-mounted exhaust grill in the dispensing room. At one to three feet from the exhaust the smoke was drawn quickly into the exhaust, at four feet the smoke lingered for a few seconds but it was still drawn to the exhaust; at five feet the general exhaust had little or no effect on the smoke. There was no effect on the smoke when it was tested right under the spigot of the formalin dispensing station.

According to the hospital ventilation system balance report from June 2000, the exhaust in the formalin dispensing area had a flow rate of 1518 cfm.

5.2 Nitrous Oxide

5.2.1 Miran

Miran (area) data was collected for 8 Deliveries. No Miran data was collected for Delivery 5 because there was not enough time to move the machine from the adjacent room where Delivery 4 was in the final stages of delivery and set it up in the Delivery 5 room.

Deliveries 1, 2, 4, 5, 6, 7, 8, and 9 had a minimum and maximum readings of 2.7 ppm and 312.6 ppm. Delivery 3 had a minimum reading of 2.7 ppm and a maximum of 259 ppm. The means for the deliveries ranged from 13.5 ppm to 194.5 ppm. In general, the Miran data fluctuated wildly between 2.7 ppm and 312.6 ppm. It is important to note that once the values were converted from volts (from Telog) to ppm, using a response curve generated by the WCB OF BC laboratory, the Miran gave readings between 2.7 and 312.6 ppm. This means that the values reported as 312.6 ppm may be greater than this value. Graphs of the Miran data can be found in Appendix 6 of this report.

5.2.2 Medigas 3010

Personal exposure data for nurses was collected by the Medigas 3010 during 9 deliveries. Of these deliveries, data from Deliveries 1, 8 and 9 are suspect because air calibration of the unit failed meaning the unit could not be re-zeroed and therefore the data was excluded from the results.

Data for Deliveries 2 to 7 ranged from 0 to 566 ppm. Nitrous oxide does not have a ceiling limit and therefore 3X (75 ppm of up to 30 minutes) and 5X (125 ppm) excursion limits apply. Deliveries 3 and 5 did not exceed 5X excursion limit. The remaining deliveries exceeded the 125 ppm ceiling for the following durations: Delivery 2: 12% (6 min) ; Delivery 4: 4% (5 min), Delivery 6: 14% (17 min) and Delivery 7: 5% (4 min). Large spikes were noted on all the graphs for these personal samples. Copies of these graphs can be found in Appendix 7 of this report.

Delivery 2 was monitored at the beginning of the labour and three large spikes were observed. Monitoring ceased after 47 minutes (3:00 am) because of a low battery warning on the Medigas unit.

Deliveries 3 and 5 had levels that were below 125 ppm for the entire delivery. Deliveries 4 and 5 were labouring at the same time. The entire labour and delivery was monitored for Delivery 4 and the Medigas 3010 was transferred to the nurse attending to Delivery 5 after the Delivery 4 baby was born. Delivery 5 nitrous oxide use started during the Delivery 4 monitoring and therefore only the last 20 minutes of gas use was recorded.

The nurse attending to Delivery 6 had the highest and longest exposure to nitrous oxide levels and was above the 5X excursion limit of 125 ppm for a total of 14% of the delivery (17 min).

Delivery 7 laboured from 5:57 am to 8:51 am, however, the delivery was only monitored using the Medigas 3010 for the first hour and a half of the delivery because at change of shift the replacement nurse did not want to wear the unit.

5.2.3 Passive Dosimeter Badges

Passive dosimeters were given to 2 to 4 nurses at the beginning of their shift. In total 31 badges were used in this study. Three were blanks, exposure to nitrous oxide was captured for 16 of the badges and the remainder were worn but exposure to nitrous oxide did not occur during the shift.

In the exposed badges (nitrous oxide exposure occurred during the shift) the values ranged from 1.3 ppm to 15.1 ppm for full shift readings (either 8 or 12 hour shifts). With the exception of BP19, all of the badges were lower than the WCB OF BC standard of 12.5 ppm (25 ppm * 0.5 for a 12 hour shift) and 6 were above the action level of 6.25 ppm. BP 19 had a value of 15.1 ppm. This nurse was exposed to nitrous oxide for one delivery during her shift. BP 11 had an average exposure of 4.1 ppm and the nurse had one delivery during the 8 hour shift but her patient did not use nitrous oxide. A graph and table of these results can be found in Appendix 5 of this report.

5.2.4 Overall results

Nurses wearing the Medigas 3010 were often also wearing a passive dosimeter. The nurse attending to Delivery 5 and wearing BP 13 had the lowest average of 1.3 ppm and the Medigas 3010 exposure did not exceed 125 ppm at any point in the delivery. Delivery 6, BP 19, had the highest average and it also corresponded to the greatest amount of time over 125 ppm during the delivery.

Delivery 3, BP 10, and Delivery 4, BP 14, had similar lengths of exposure and similar average exposures (6.3 ppm and 6.7 ppm) according to the passive dosimeters but the Medigas average exposures were 8.3 ppm and 37.9 ppm respectively. Both of the two nurses attended only one delivery during their shifts.

5.2.5 Ventilation Testing

The forced air supply to Room 339 was measured using a Balometer. The results for the three locations were 220 cfm, 215 cfm and 105 cfm giving a total of 540 cfm supply. Chris Thompson, Systems Engineer LMH, reported that the nitrous oxide scavenging system flow rate

is 10 cfm. The balance report also contained the flow rates for the two exhausts in the main room, which were 203 cfm each and the bathroom exhaust was 127 cfm. This gives a total of 9.9 air changes per hour for the room if the door was closed at all times.

6.0 DISCUSSION

6.1 Formaldehyde

The results from the silica gel tubes and colorimetric tubes indicate that the levels of formaldehyde in the dirty core did not exceed the WCB OF BC 8 hour exposure limit of 0.3 ppm.

In the summer months, only two of the six operating theatres are in use meaning that fewer nurses are working and therefore it is more likely that a nurse will dispense formalin more than once in a day. These measurements represent a type of worst case scenario and the results indicate that the general exhaust ventilation in the area, combined with the small and infrequent amount of formalin dispensed, is sufficient to keep exposures below the allowable limits.

One concern in the formalin dispensing area is the leaking spigot on the formalin bottle. In an effort to keep worker exposures to formaldehyde vapours as low are reasonably achievable (ALARA) below the WCB of BC exposure limit, it is important to ensure that the spigot does not leak and that an exposure control can be established for this suspected human carcinogen.

6.2 Nitrous Oxide

The data collected by the Miran indicate that the concentration of nitrous oxide in the environment fluctuate wildly as nitrous oxide is used. The Medigas 3010 data indicate that when the mother inhales and exhales into the mask the nurses exposure is relatively low, however, when the mother removes the mask from her face, between contractions, she is off-gassing into the room. Spikes were noted in the nurses exposure when working near the mother's face including when starting an IV or standing close to the mothers head and talking to her.

The average exposure data collected for the Miran were higher than the average exposure data collected by the Medigas 3010. This would be expected since the Miran was an environmental sample and was in the room with the patient for the entire labour and delivery. The nurse wearing the Medigas 3010 went in and out of the room during the early stages of labour and remained in the room during the active labour. The maximum exposures for the nurses (spikes on the graph) were higher with the Medigas 3010 when the nurses were working close to the mother's face. The Miran had a maximum of 312.6 ppm and therefore it is not possible to determine actual level reached. The Miran was located approximately 3 feet from the mothers face at all times and therefore one would expect the personal sampler to have higher levels if the nurse worked near the mother's face.

Deliveries 2, 4, 5, 6, 7, 8 used only nitrous oxide and no other means of analgesia during the delivery and Deliveries 1, 3 and 9 used nitrous oxide and Demorol/Gravol and/or an epidural.

Delivery 2 used nitrous oxide for the entire delivery and the overall exposure levels were quite low. The activity log for this delivery indicates that the mother used the gas very regularly, kept the mask on the majority of the time (continuous not intermittent use), did not talk very much and therefore did not off-gas high nitrous oxide levels into the room. This patient was monitored using the Medigas for the first 47 minutes of her labour.

The activity log for Delivery 3 indicates that the mother exhaled into the mask when the gas was being used and therefore the scavenging system was able to remove a large portion of the exhaled gas. An epidural was administered at 7:10 pm and nitrous oxide use ceased.

Delivery 4 walked around using the portable nitrous oxide from 2:20 pm to 2:39 pm. A large spike of 352 ppm occurred at 2:21 pm when the nurse was assisting the mother in the hallway. The labour then continued in the shower using the room (piped in) nitrous oxide until 3:10 pm when Entonox use ceased and the mother moved back to the bed. The baby was delivered at 3:32 pm and the gas was used during the stitches from 3:36 to 3:44. In this delivery, the nurse was situated close to the mother's head for all of the occasions when nurse's exposure exceeded 125 ppm.

Delivery 4 and Delivery 5 labour and deliveries occurred simultaneously. Delivery 4 was monitored for the entire labour and delivery and after the baby was delivered at and the Medigas was moved into the Delivery 5 room.

Delivery 6 used nitrous oxide from just before the Medigas 3010 unit was attached to the attending nurse and until 9:38 pm when the mother was taken to the high risk room and a cesarean section was performed under general anesthetic. The nurse who attended to this delivery had an average exposure of 15.1 ppm for her 12 hour shift. She was exposed to nitrous oxide during the mothers' self-administration and during the general anesthetic administration since it too involves the use of nitrous oxide.

Delivery 7 used nitrous oxide for the entire delivery, however, only the first hour and a half were captured using the Medigas 3010. Three spikes occurred during the first 30 minutes of the delivery. The mother used the gas intermittently and exhaled into the mask. Two of the spikes occurred when the nurse was near the mother's face between contractions and therefore the mother was off-gassing into the room.

The passive dosimeter results indicate that one nurse was exposed to an 8 hour TWA of 4.1 ppm of nitrous oxide during her 8 hour shift when the only delivery she attended did not use nitrous oxide. Discussions with Chris Thompson indicated that the exhausts from the delivery rooms are attached to a return system located in the sub-basement of the building and that the air is mixed with outside air before it is re-distributed throughout the building. This means that a portion of the air is recirculated, however, the likelihood of a significant concentration of nitrous oxide returning to the labour and delivery suites is very low under normal operating conditions. The scavenging system is an exhaust system that is vented directly to the outside via a tunnel that travels under a road and exits at ground level near a bush covered area. The reason for this nurses' level of exposure remains unclear.

The data collected in this study indicate that every delivery represents a unique situation. In some cases the mothers used the gas and kept the mask on between contractions, in other cases the mask was removed as soon as the contraction was over and the mother started talking or

screaming causing the nurse to be exposed to high levels of nitrous oxide. In other cases nitrous oxide was used for a short period of time and then Demerol/Gravol or an epidural were given.

Labour and delivery using nitrous oxide present a different situation than the gas is use in the operating room or the dental office. In this situation the mother controls the nitrous oxide administration. Hospital protocol states that the gas should only be used during contractions and not between them. In most cases the mothers removed the mask from their faces between contractions. This allowed them to talk or scream or just breathe the room air. It would be challenging to decrease nurses exposure to nitrous oxide in this situation using local exhaust ventilation. Bernow et al. conducted a study in 1984 using a plastic hood enclosing the mother's head. This was a very barbaric suggestion and even though they were successful in reducing the midwives exposure to less than 25 ppm it is not a solution that would be widely accepted.

Nitrous oxide is known to be off gassed for a period of up to 37 minutes after use. It is not realistic to force the mother to wear the mask at all times so that the scavenging system picks up all the nitrous oxide. This would cause the nitrous oxide to be delivered every time the mother took a breath and could result in an overdose and unconsciousness. A mask that provided nitrous oxide when the mother presses a button and stops when the button is not depressed could be worn all the time and oxygen alone would be delivered when the button was not depressed. The main problem is that it is next to impossible to talk and be understood while wearing the mask.

Control measures to decrease the nurse's exposure to nitrous oxide would be to increase the general exhaust ventilation from 9.9 air changes per hour (ACH) to 15 ACH or to increase the percentage of fresh air going into the room. Substitution or enclosure are not currently viable options for this situation.

The WCB OF BC 8 hour exposure limit has been set at 25 ppm which gives a calculated 5X excursion limit of 125 ppm. Previous studies and this study have shown that exposures occur up to 4X this level (500 ppm). Based on the data presented in this report, the 25 ppm 8-hour exposure limit can be met in the labour and delivery situation, however, a 125 ppm excursion limit is not consistently achievable based on the conditions present at the time of this study.

7.0 CONCLUSIONS

Formaldehyde:

- Although worker exposure to formaldehyde in the dirty core area did not exceed WCB of BC exposure limits, exposures must be maintained at levels as low as reasonably achievable below the exposure limit (designated as a suspected human carcinogen).

Nitrous oxide:

- Average exposures were below the 12 hr limit of 12.5 ppm with the exception of one nurse
- 5 nurses' personal data logged samples exceed the 5X excursion limit of 125 ppm.
- The limit set by the WCB of BC of an 8 hour TWA of 25 ppm is attainable at this point in labour and delivery, where nitrous oxide is self-administered, but the 5X excursion limit of 125 ppm is not.

8.0 RECOMMENDATIONS

Formaldehyde:

- Implement an exposure control plan as per OHS Reg 5.57 (2) – Designated Substances. This regulation states that substances designated as ALARA substances must be substituted, however, if it is not practicable then the employer must implement an exposure control plan to maintain workers' exposure as low as reasonably achievable below the applicable exposure limit.
- It is recommended that the leaking spigot on the formalin container be discussed with the company representative. The leaking spigot must be maintained in good operating condition by the department in order to prevent leaks.

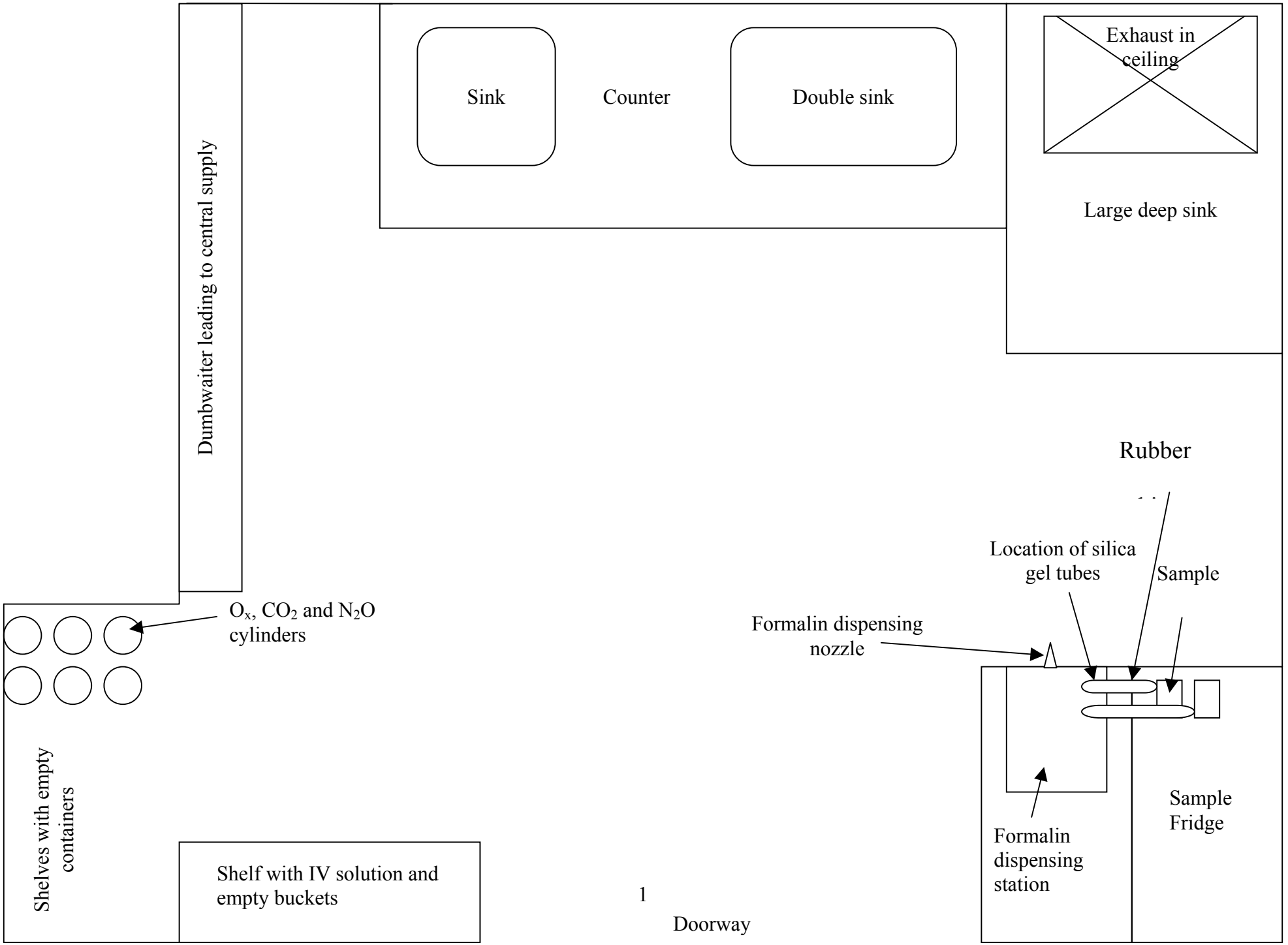
Nitrous Oxide:

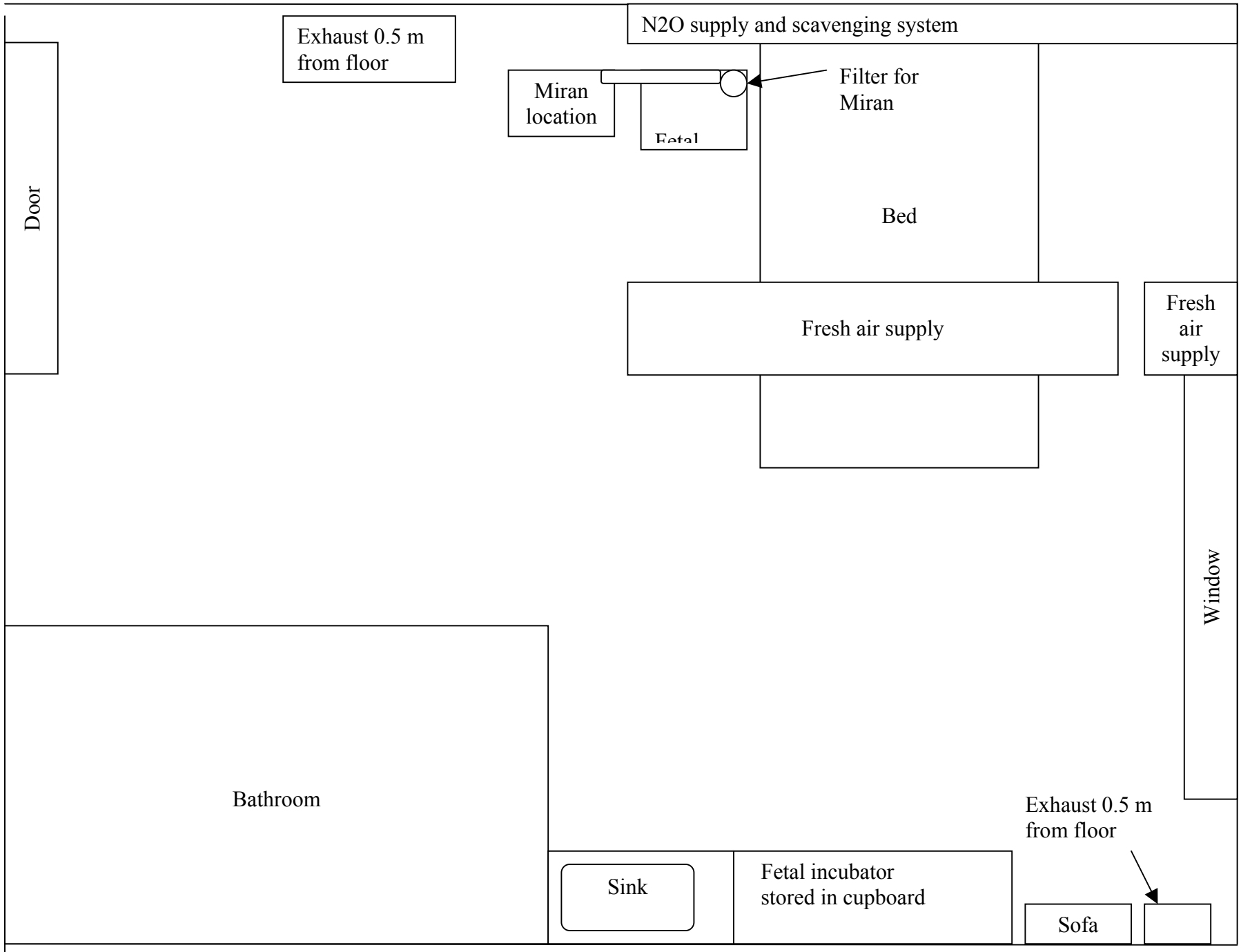
- Management should continue investigations to reduce peak exposures to below the 5X excursion limit of 125 ppm.
- Install local exhaust ventilation. Few solutions are presented in the literature as to the type of local exhaust system that would decrease the peak exposures, however, it is possible that a slotted hood located at the head of the bed might be an effective solution.

  and/or
- Conduct a feasibility study to look at the costs and benefits of increasing the number of room air changes per hour.

APPENDIX 1

SAMPLING LOCATION PLANS


Sink
Counter
Double sink
Exhaust in ceiling
Large deep sink
Dumbwaiter leading to central supply
Rubber
Location of silica gel tubes
Sample
Formalin dispensing nozzle
O_x, CO_2 and N_2O cylinders
Shelves with empty containers
Shelf with IV solution and empty buckets
Sample Fridge
Formalin dispensing station
1
Doorway


Exhaust 0.5 m
from floor
N2O supply and scavenging system
Miran
location
Filter for
Miran
Fetal
Door
Bed
Fresh air supply
Fresh
air
supply
Window
Bathroom
Exhaust 0.5 m
from floor
Sink
Fetal incubator
stored in cupboard
Sofa

APPENDIX 2

PHOTOGRAPHS

Plate 1: View of dirty core sample room on the 2nd Floor of Langley Memorial Hospital located in Langley, British Columbia.

Plate 2: View of the central portion of the dirty core room.

Plate 3: View of the left portion of the dirty core room.

Plate 4: View of the formaldehyde dispensing station.

Plate 5: Close-up of formaldehyde bottle. Note: staining from leaking around the spout.

Plate 1: View of typical labour and delivery room on the 3rd Floor of Langley Memorial Hospital located in Langley, British Columbia.

Plate 2: View of typical labour and delivery room.

Plate 3: View of typical labour and delivery room.

Plate 4: View of typical labour and delivery room.

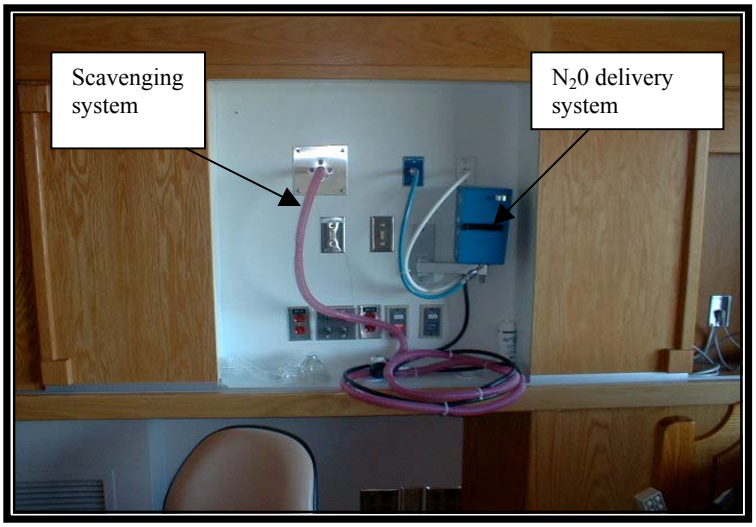


Plate 5: View of nitrous oxide delivery system and scavenging system.

Plate 6: View of scavenging face mask.

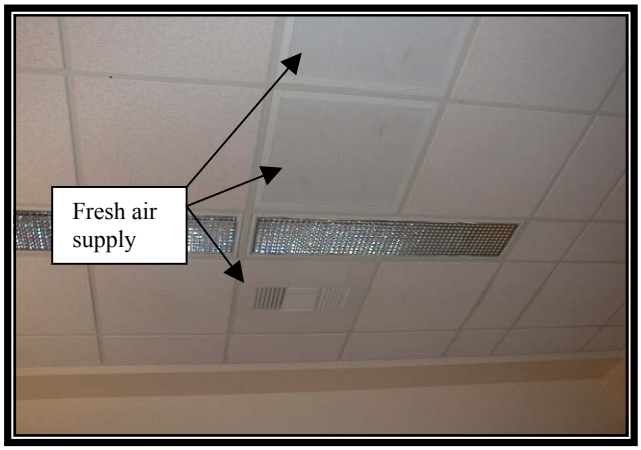


Plate 7: View of fresh air supply located in the ceiling of the labour and delivery room.

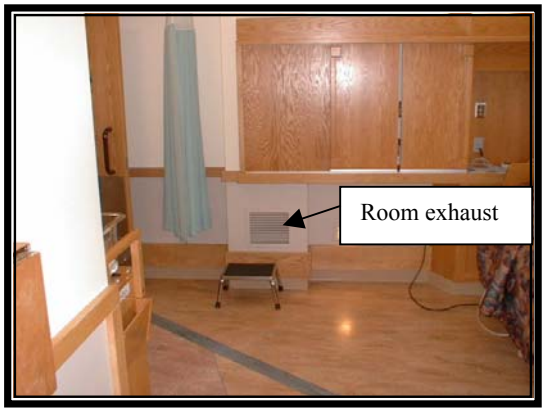


Plate 8: View of room exhaust located approximately 40 cm from the floor.

APPENDIX 3
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APPENDIX 4

FORMALDEHYDE GASTEC TUBE RESULTS

Langley Memorial Hospital, Formaldehyde Dispensing Station located in Dirty Core, July 12, 2001								
Sample Number	**Time (Amount of Time Dispensing)**	**Tissue Type**	**Volume Formalin (ml)**	**Nurse's Name**	**Shift Length (hours)**	**Break Lengths (hours)**	**Gastec Tube Type (Formaldehyde)**	**Reading (ppm)**
1	11:15 (5 sec)	uterus	300	Nurse 1	8	1x 0.5 and 2X 0.25	91L	<0.2
2	11:40 (5 sec)	gallbladder	250	Nurse 2	7.5	1x 0.5 and 2X 0.25	91LL	<0.05
3	12:30 (sample)	test sample taken 3 cm above plastic dish	50	None	N/A	N/A	91LL	>1.0 (breakthrough)
4	12:34 (sample)	test sample taken 1 cm above wet cardboard under dispenser	N/A	None	N/A	N/A	91LL	>1.0 (breakthrough)
5	1:25 (5 sec)	breast biopsy and node	250	Nurse 2	7.5	1x 0.5 and 2X 0.25	91LL	<0.05
6	1:25 (5 sec)	breast biopsy	250	Nurse 2	7.5	1x 0.5 and 2X 0.25	91LL	<0.05
7	2:07 (2 sec)	endometrial (uterine) curette	100	Nurse 1	8	1x 0.5 and 2X 0.25	91LL	<0.05
8	2:22 (2 sec)	polyp from anus	70	Nurse3	8	1x 0.5 and 2X 0.25	91LL	<0.05
Gastec Detector Tube # 91 L Batch Number 00453 Exp. July 2003; Gastec Detector Tube # 91LL 91220 Exp. Apr. 2003								

APPENDIX 5

NITROUS OXIDE
PASSIVE DOSIMETER RESULTS

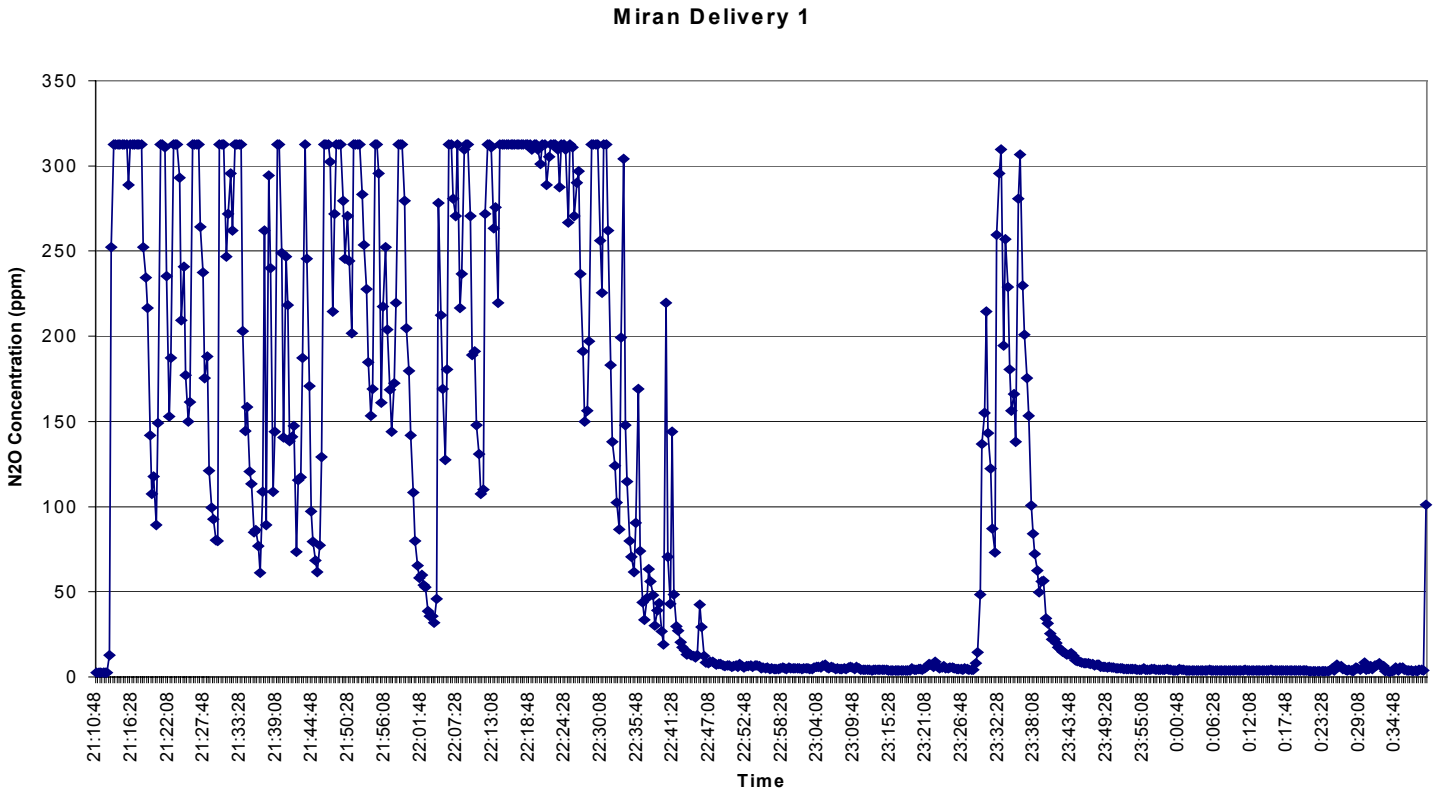
Nurses' Exposure to Entonox in Labour and Delivery *										
Langley Memorial Hospital, Langley, British Columbia										
Nurse Identifier	**Date**	**Field Sample Number**	**Start Time**	**Stop Time**	**Length of shift (show length of breaks)**	**# deliveries in shift**	**# N2O deliveries in shift**	**Badge problems? Yes/no**	**Results (ppm)**	**Comments**
Nurse 1	7/26/01	BP1	7:45	19:27	12 hrs (1X1 hr and 2X 15 min)	0	0	no	< 0.7 ug/sample	Below detection limits (BDL)
Nurse 2	7/26/01	BP02	7:45	15:15	8 (2 x 0.5 hrs)	0	0	yes	BDL	badge fell out of holder and hit floor (didn't break)
Nurse 3	7/26/01	BP03	7:45	17:35	10	0	0	no	BDL	
Nurse 4	7/26/01	BP04	7:46	19:06	11.5 (1 x 1 hr and 2 x 15 min)	0	0	no	BDL	
Nurse 5	7/26/01	BP05	20:04	7:16	12	1	1	no	5.5	Delivery 2
Nurse 6	7/26/01	BP06	20:04	7:13	12	1	1	no	6	
Nurse 7	7/26/01	BP07	20:06	7:13	12	2	2	yes	4.2	Delivery 1 badge fell out of holder and hit floor (didn't break)
Nurse 8	7/26/01	BP08	20:07	7:14	12	0	0	yes	1.1	badge fell out of holder and hit floor (didn't break)
Blank	7/26/01	BP09	N/A	N/A	N/A	N/A	N/A	no	BDL	N/A
Nurse 9	7/27/01	BP10	7:49	19:42	12	1	1	yes	6.3	Delivery 3 badge fell out of holder and hit floor (didn't break)
Nurse 10	7/27/01	BP11	7:55	15:19	8	1	0	no	4.1	
Nurse 11	7/27/01	BP12	7:54	19:31	12	1	0	no	BDL	

Nurse's Name	Date	Field Sample Number	Start Time	Stop Time	Length of shift (show length of breaks)	# deliveries in shift	# N2O deliveries in shift	Badge problems? Yes/no	Results (ppm)	Comments
Nurse 12	7/30/01	BP13	7:30	19:22	12	2	1	no	1.3	Delivery 5
Nurse 10	7/30/01	BP14	7:46	19:24	12	1	1	no	6.7	Delivery 4
Nurse 13	7/30/01	BP15	7:47	19:19	12	1	0	no	1.2	
Nurse 12	7/31/01	BP16	7:45	18:33	12	1	0	no	BDL	
Nurse 10	7/31/01	BP17	7:47	15:21	8	0	0	no	BDL	
Nurse 14	7/31/01	BP18	7:48	13:57	12 (sent home)	0	0	no	BDL	
Nurse 15	7/31/01	BP19	19:35	7:29	12	1	1	no	15.1	Delivery 6
Nurse 13	7/31/01	BP20	19:38	7:13	12	0	0	no	0.9	
Nurse 16	7/31/01	BP21	19:41	7:28	12	1	1	no	8.1	Delivery 7
Nurse 11	8/1/01	BP22	7:36	19:20	12	1	1	no	9.9	Delivery 7
Nurse 17	8/1/01	BP23	7:40	19:41	12	1	1	no	4.8	
Nurse 12	8/1/01	BP24	7:43	19"46	12	1	0	no	not available	
Unexposed Office	8/1/01	BP25	8:43	21:05	N/A	N/A	N/A	N/A	BDL	Badge in Frances' office to determine background levels
Nurse 18	8/1/01	BP26	19:47	19:48	12	1	0	no	1.1	

Nurse's Name	Date	Field Sample Number	Start Time	Stop Time	Length of shift (show length of breaks)	# deliveries in shift	# N2O deliveries in shift	Badge problems? Yes/no	Results (ppm)	Comments
Nurse 16	8/1/01	BP27	19:44	7:00	12	0	0	no	BDL	
Nurse 1	8/1/01	BP28	N/A	N/A	N/A	N/A	N/A	N/A	BDL	
Blank	8/2/01	BP29	N/A	N/A	N/A	N/A	N/A	N/A	BDL	
Nurse 19	8/2/01	BP30	7:52	19:32	12	1	1	yes	2.1	Delivery 9 Patient used N2O for a short period of time - badge fell out of holder and hit floor (didn't break)
Nurse 20	8/2/01	BP31	7:51	19:27	12	0	0	yes	1.2	badge fell out of holder and hit floor (didn't break)
* Assay Technology N2O Badges; Lot # 2D01-4; Exp. 2/28/02; Item # N575AT										

APPENDIX 6

NITROUS OXIDE
MIRAN GRAPHS


Miran Delivery 1
N2O Concentration (ppm)
350
300
250
200
150
100
50
0
21:10:48
21:16:28
21:22:08
21:27:48
21:33:28
21:39:08
21:44:48
21:50:28
21:56:08
22:01:48
22:07:28
22:13:08
22:18:48
22:24:28
22:30:08
22:35:48
22:41:28
22:47:08
22:52:48
22:58:28
23:04:08
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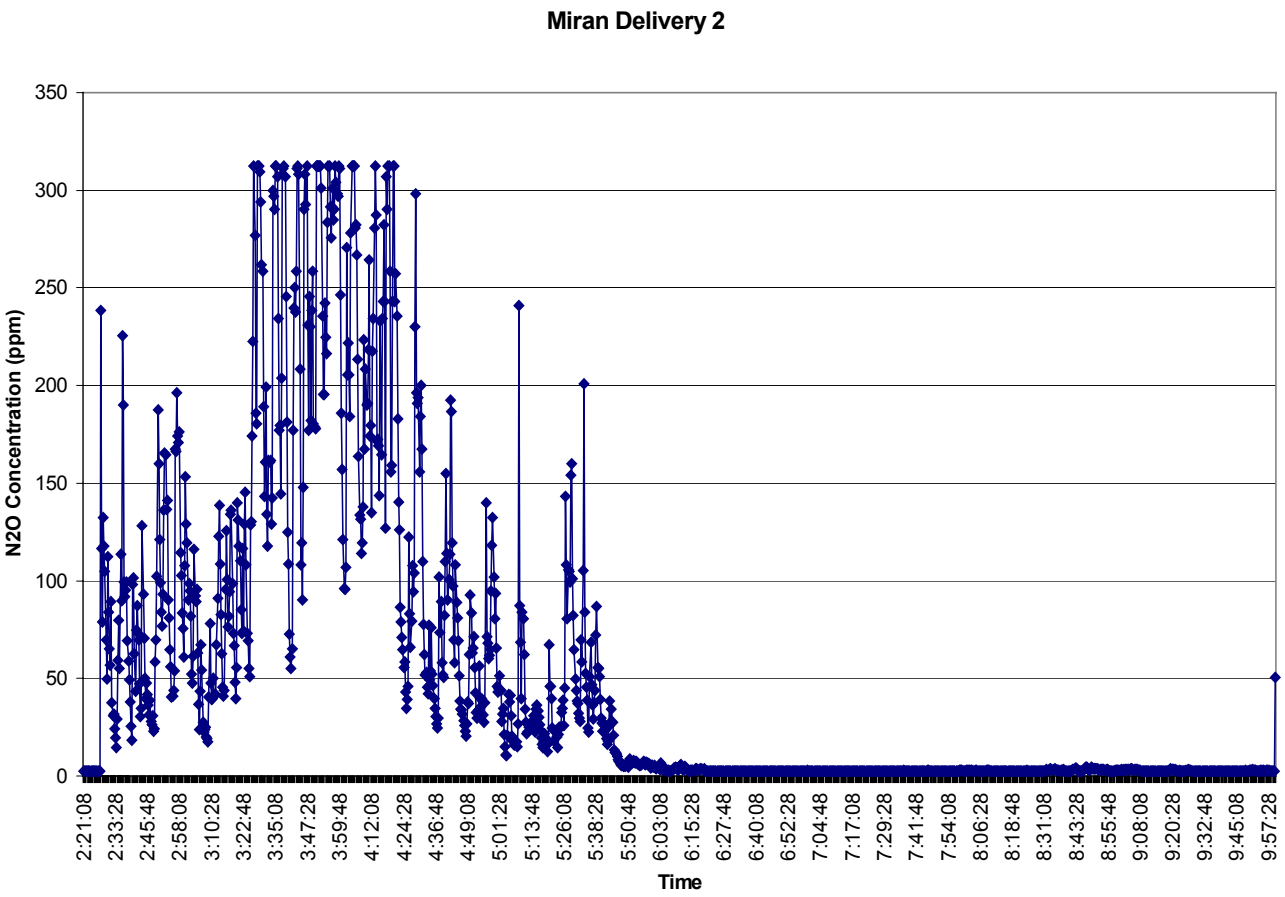
23:55:08
0:00:48
0:06:28
0:12:08
0:17:48
0:23:28
0:29:08
0:34:48
Time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8:18:48
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9:20:28
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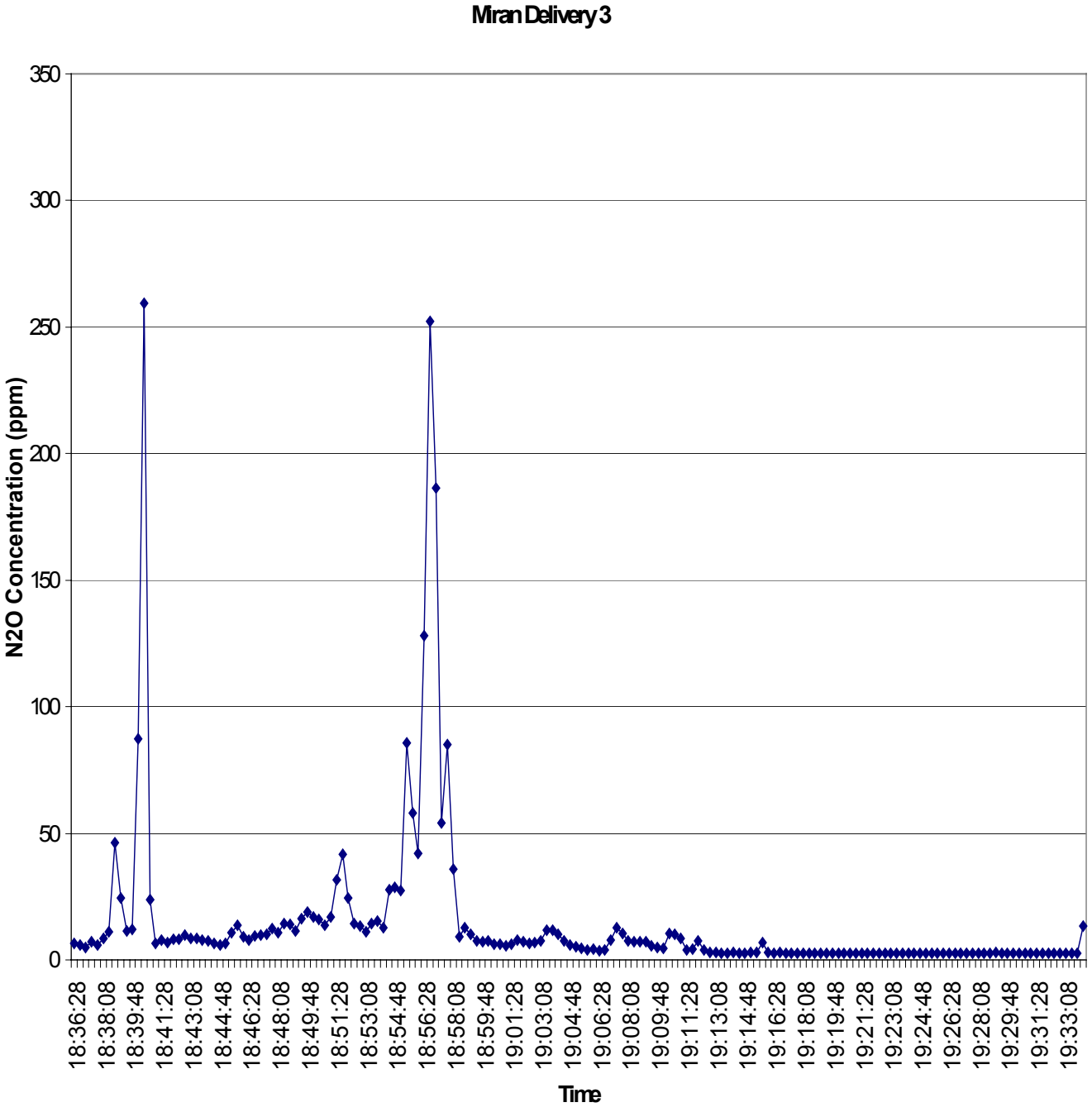
Time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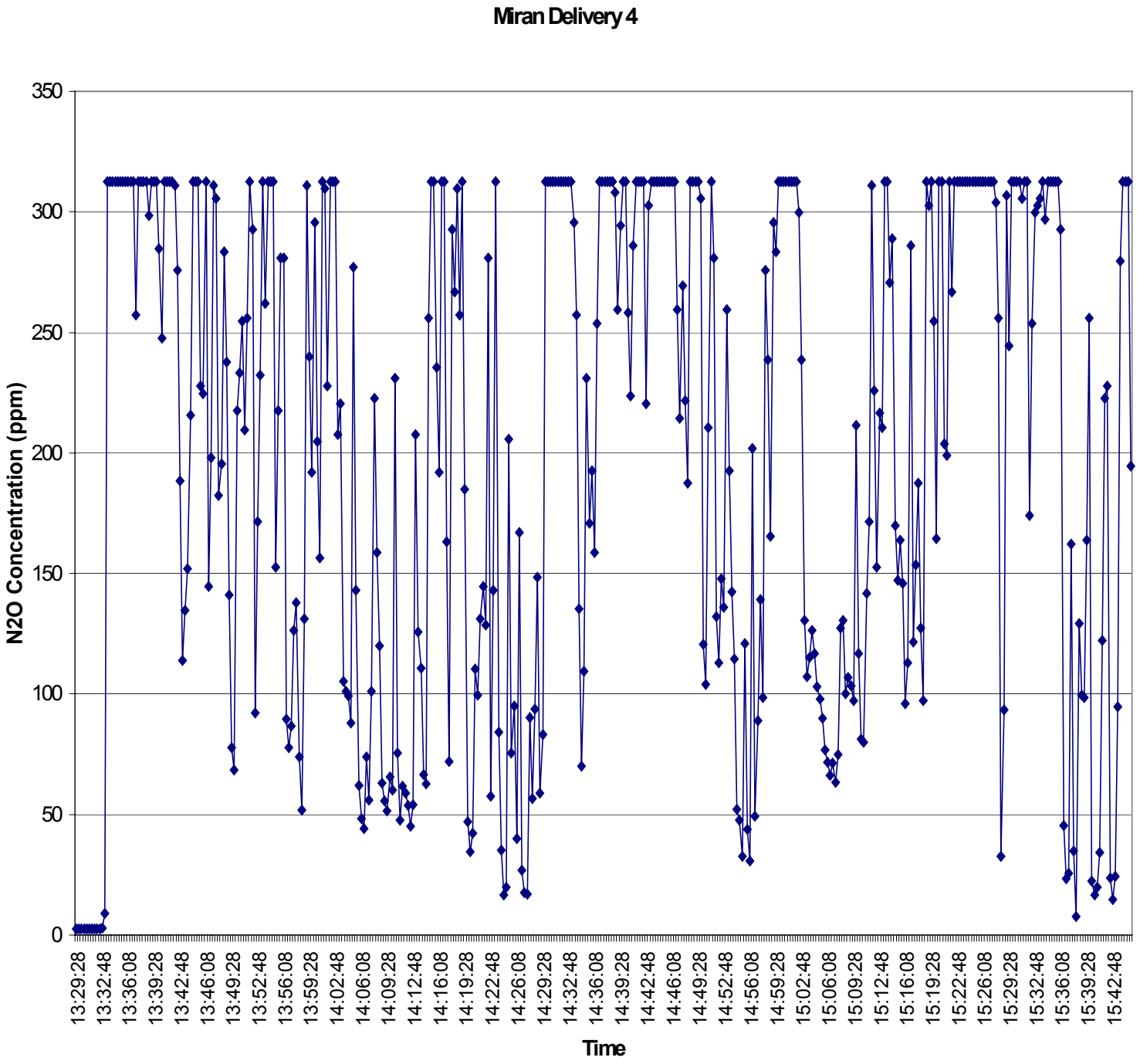
Time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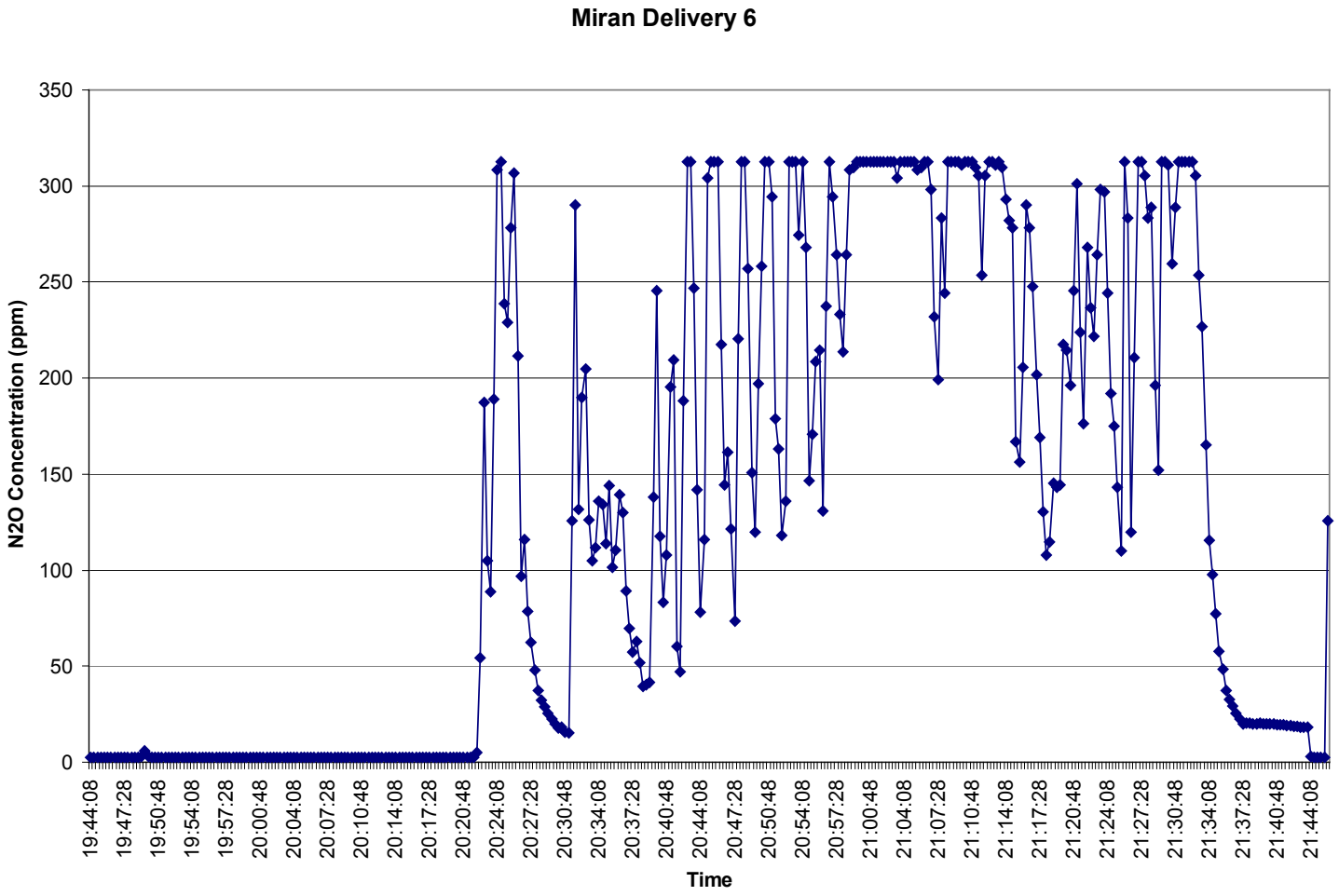
Time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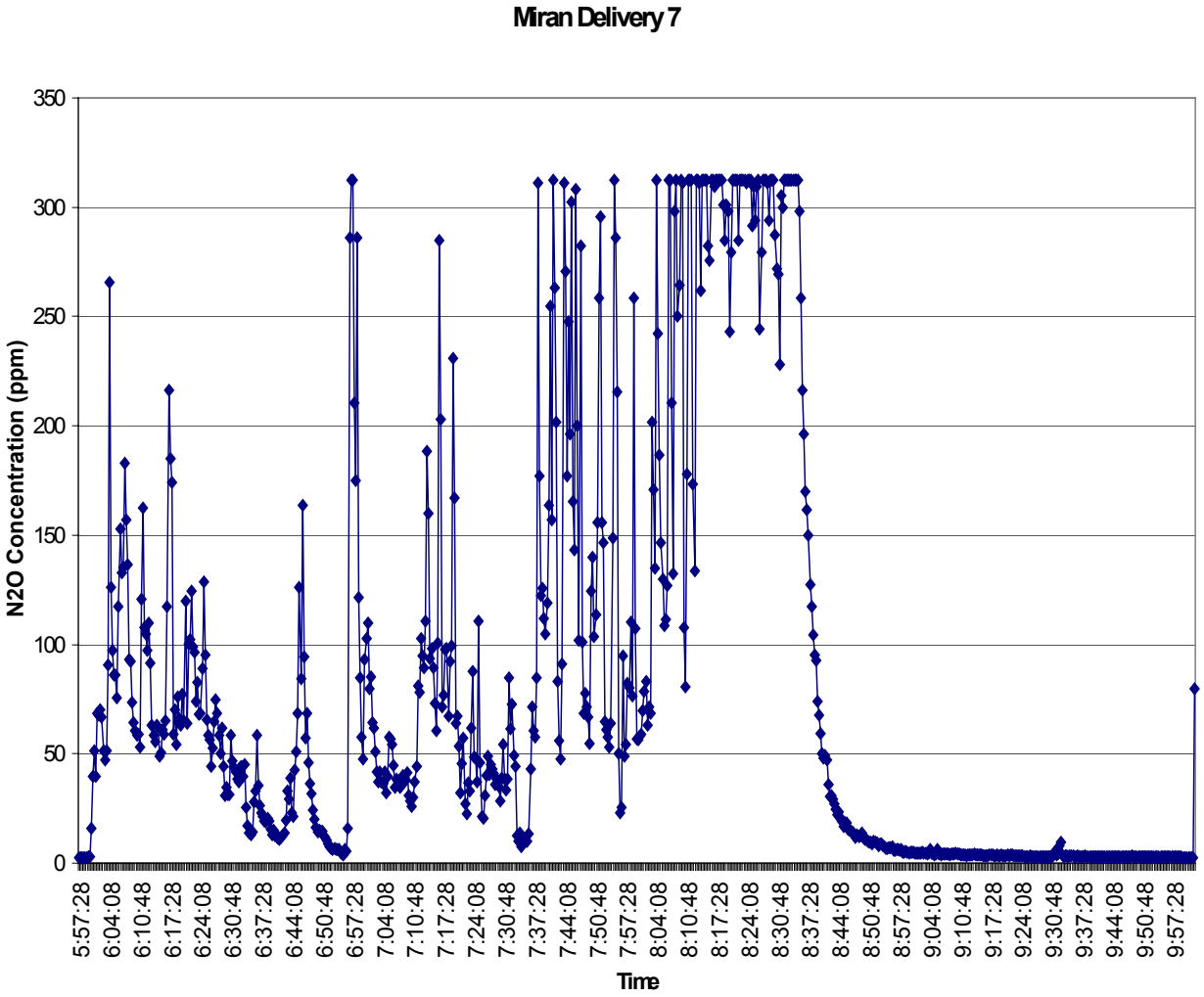
Time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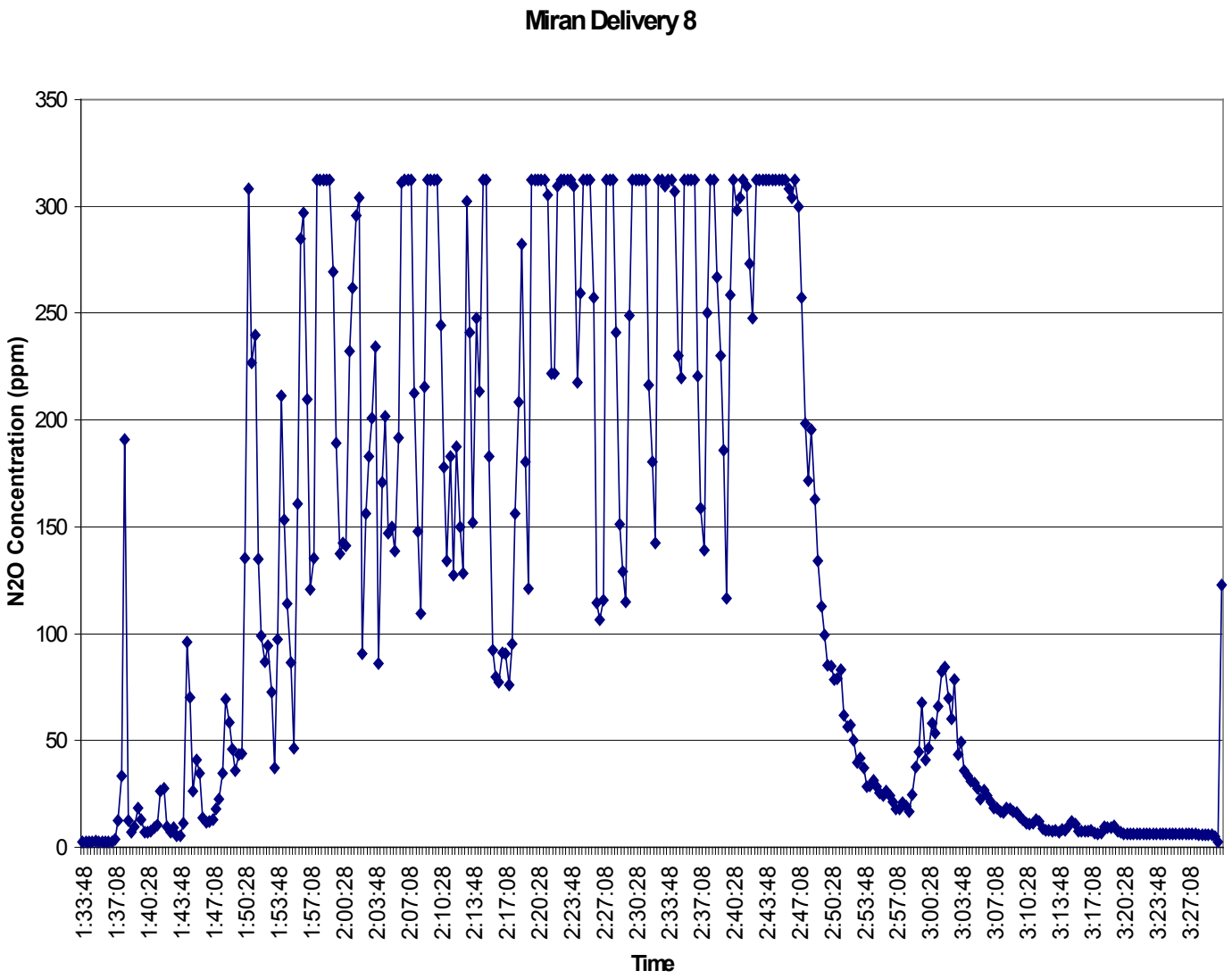
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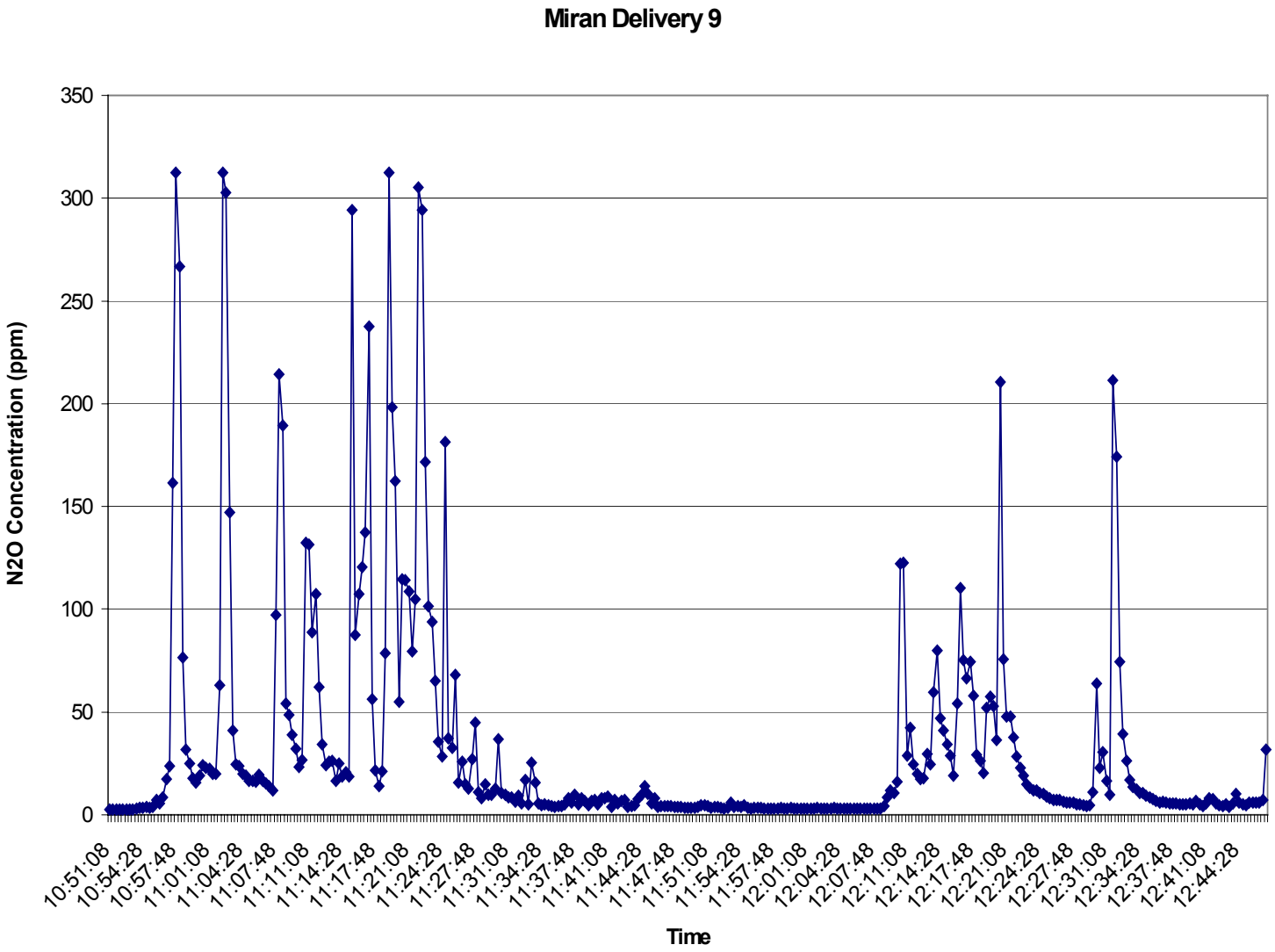
3:27:08
Time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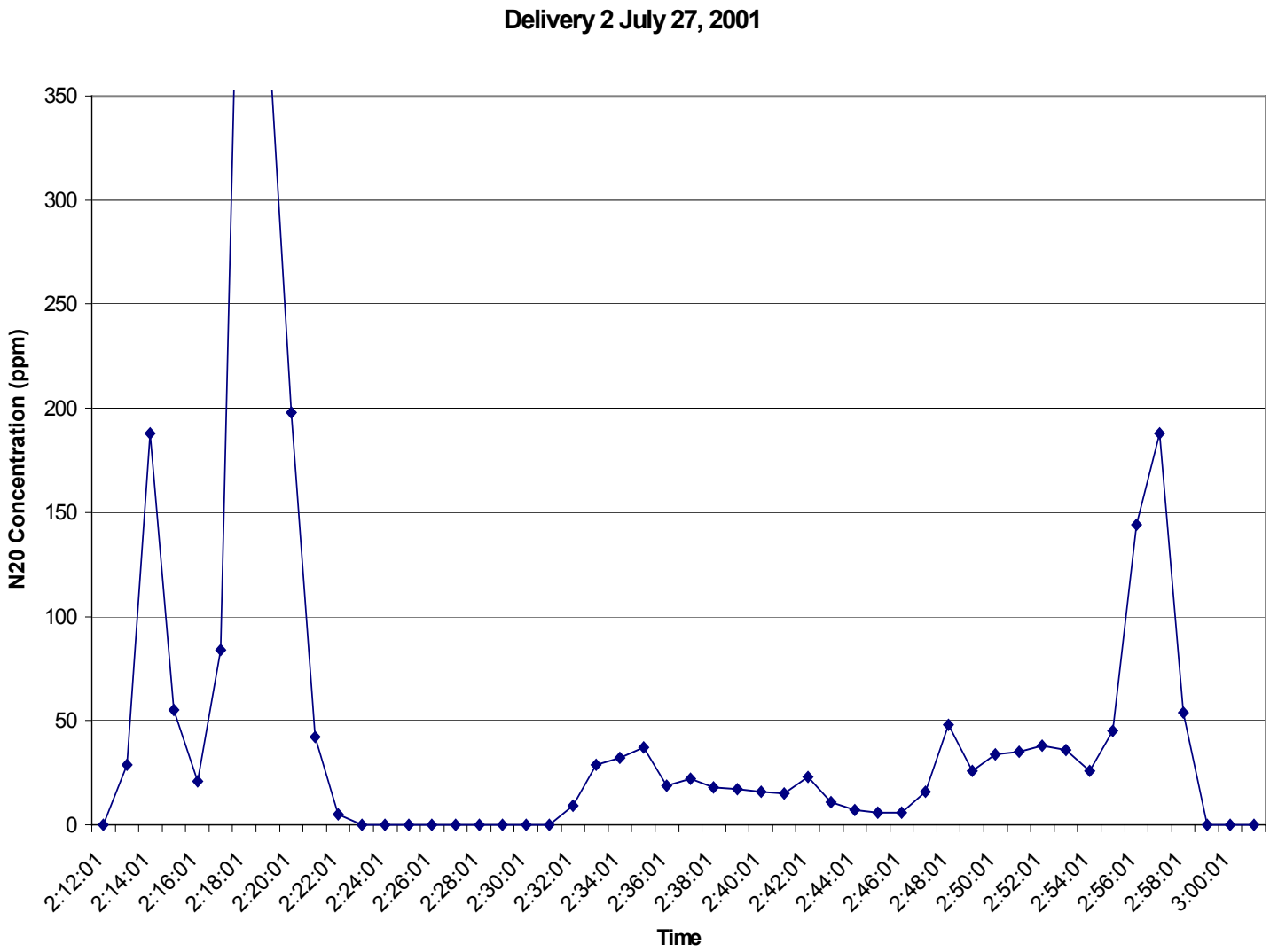
Time

APPENDIX 7

NITROUS OXIDE
MEDIGAS 3010 GRAPHS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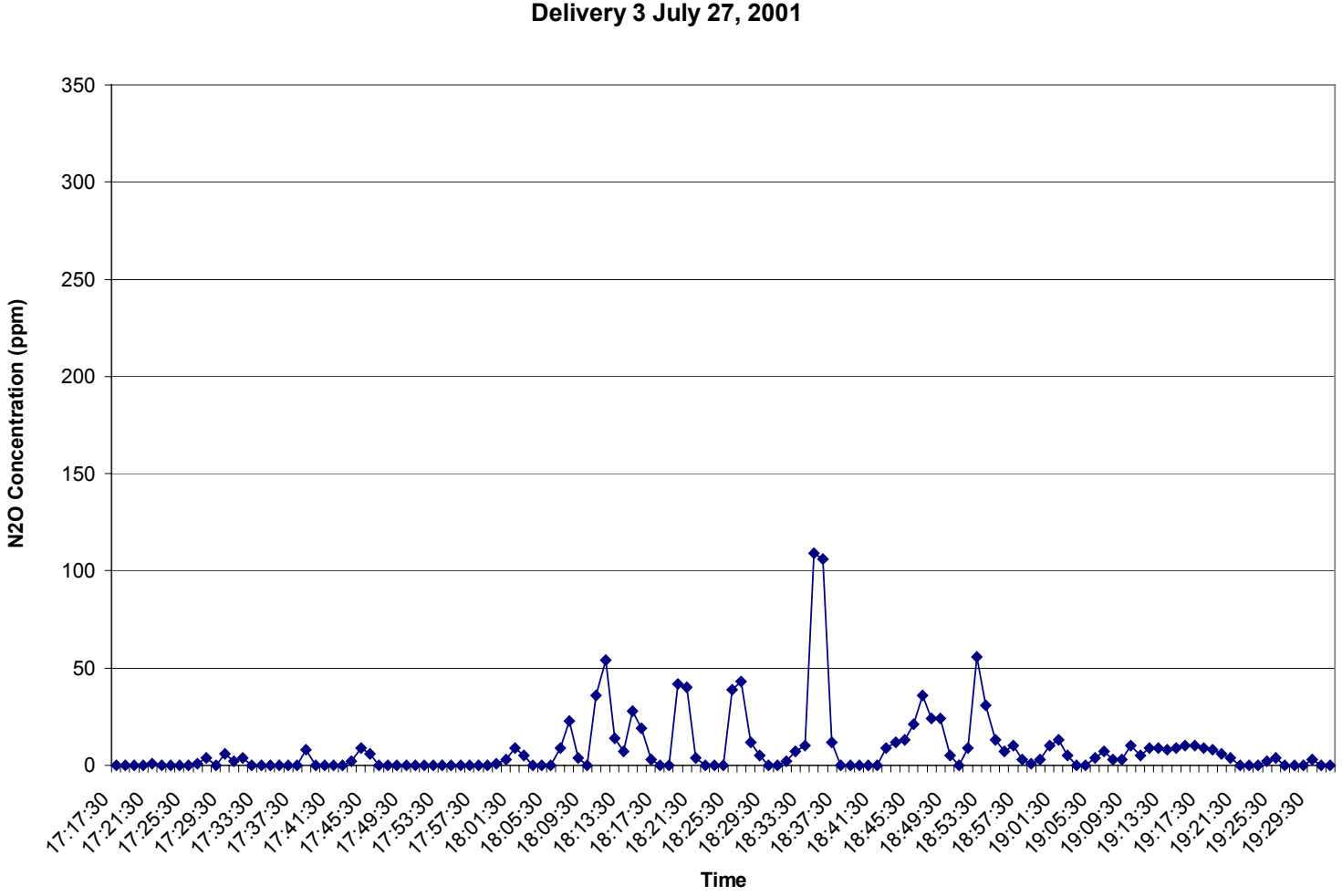
3:00:01
Time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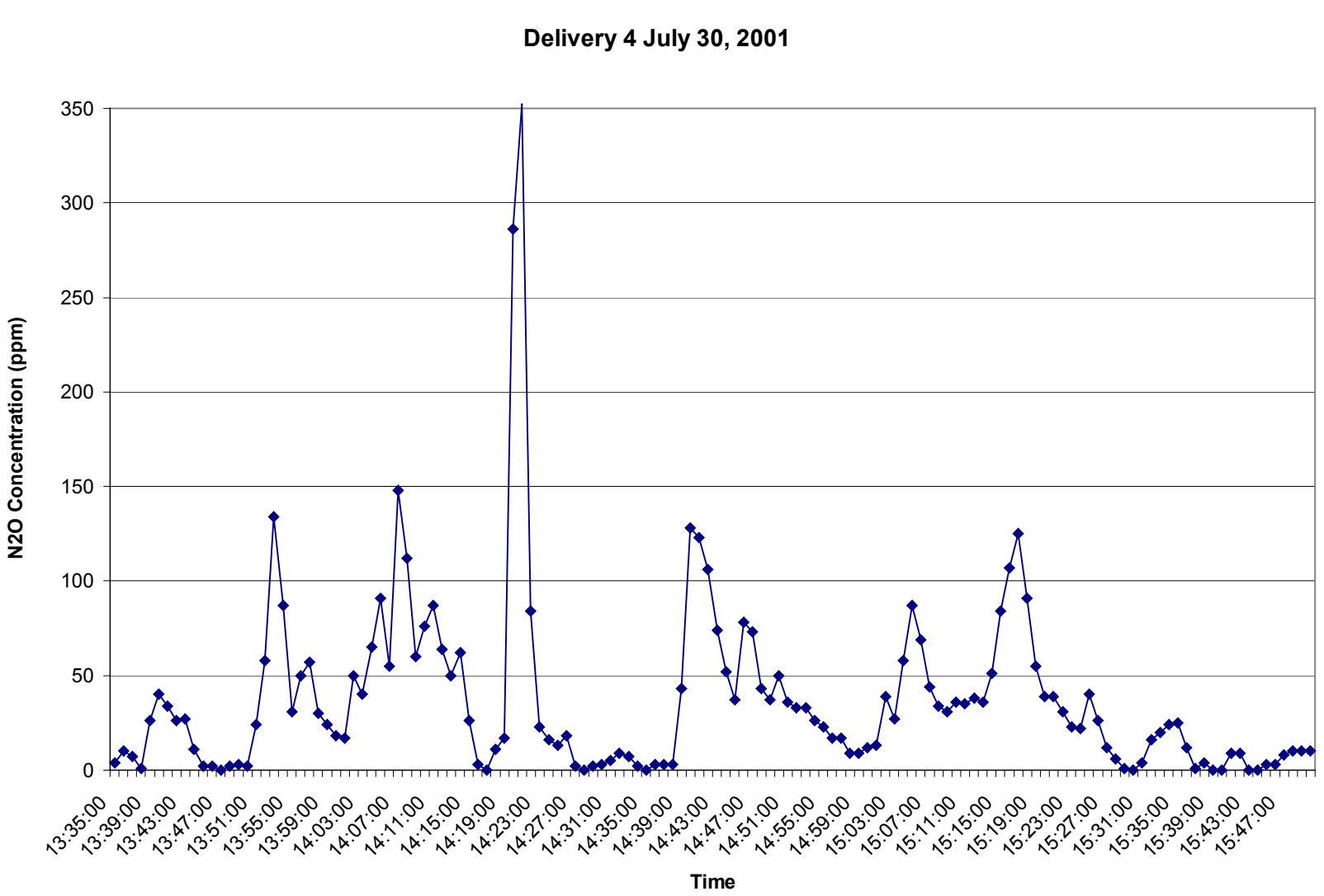
Time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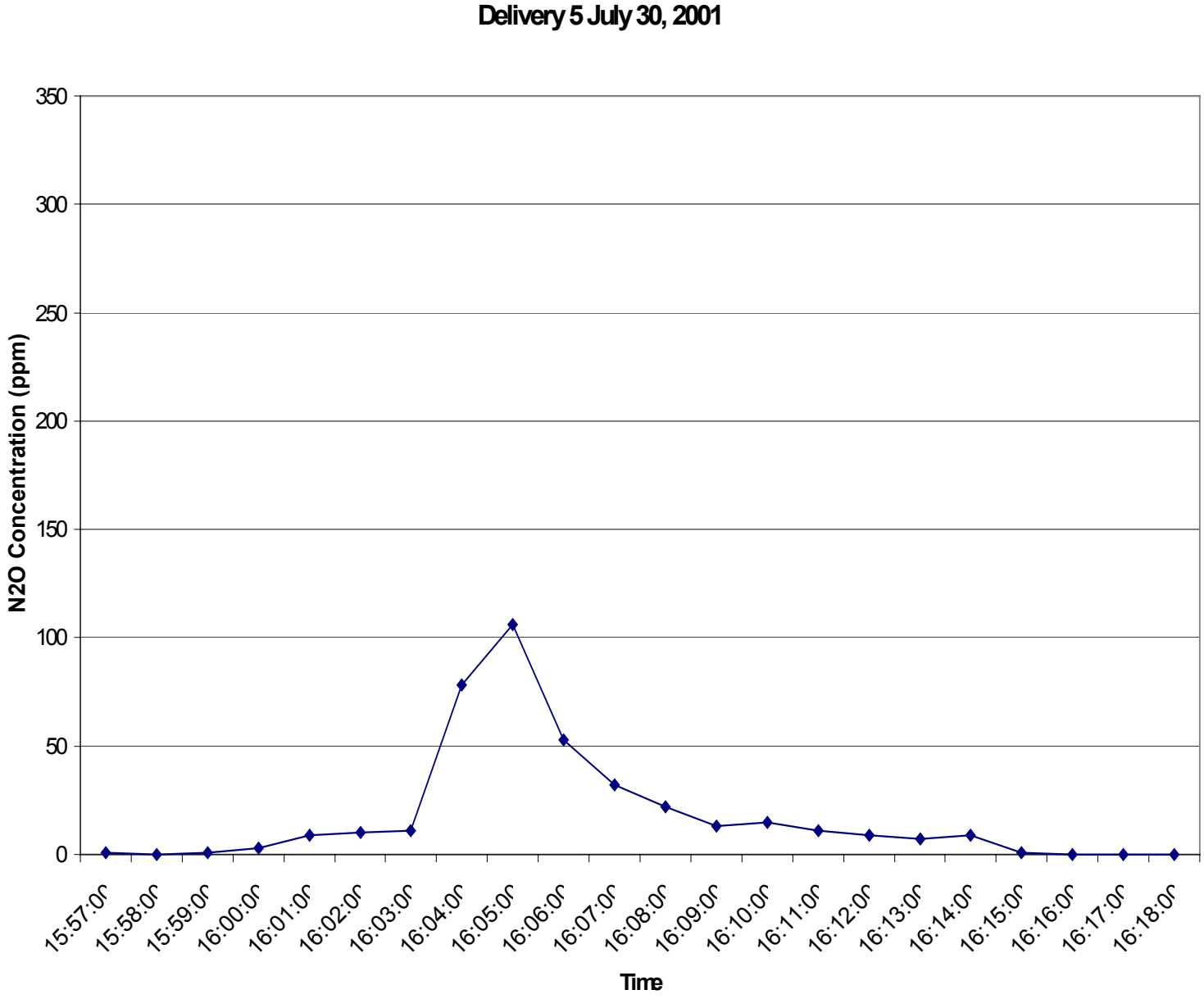
Time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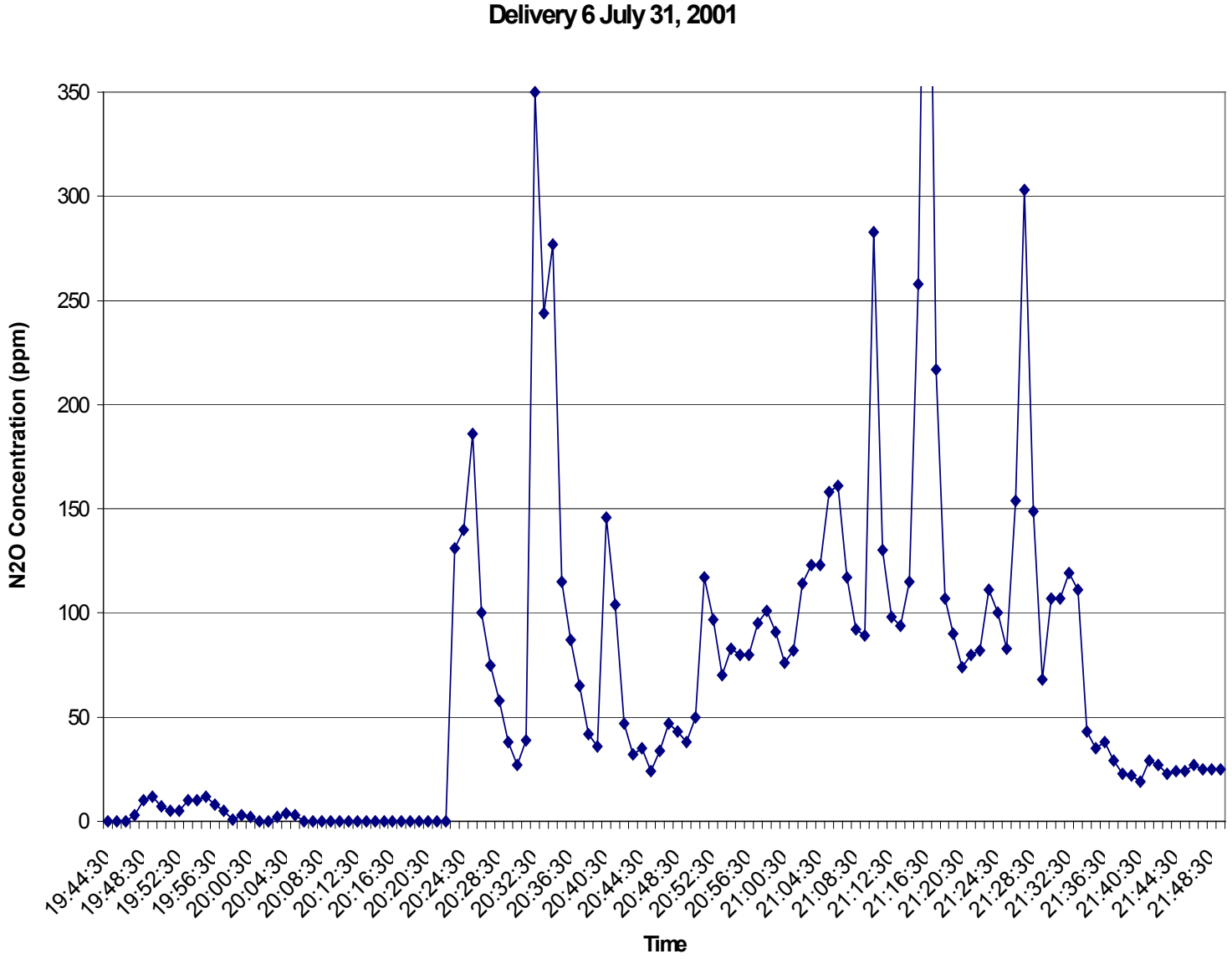
Time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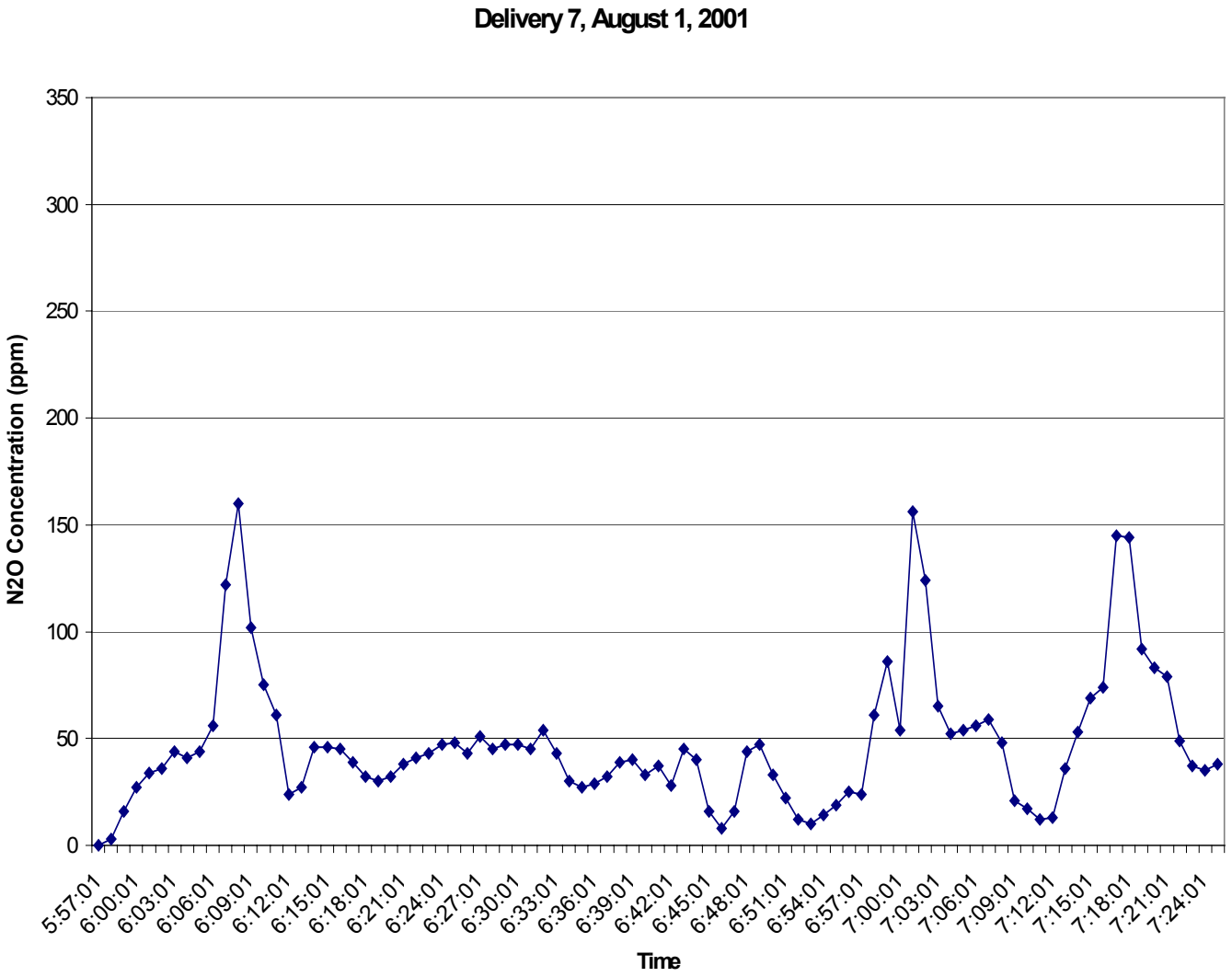
Time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7:03:01
7:06:01
7:09:01
7:12:01
7:15:01
7:18:01
7:21:01
7:24:01
Time

APPENDIX 8

PATIENT CONSENT FORM

Patient Consent Form for study: Nurses' Exposure to Nitrous Oxide

Langley Memorial Hospital, the Workers' Compensation Board of BC and McGill University are doing a research project concerning nurses' exposure to nitrous oxide (laughing gas) during labour and delivery.

Signing of this from acts as consent for Charlotte Ferguson, McGill Masters Student, to monitor the nurses during your delivery (only during nitrous oxide use). Your privacy will be respected at all times.

Please consider being part of this study if you chose to use nitrous oxide

during your delivery.

Your participation in the study is voluntary and will be kept confidential. If at any time you would like Charlotte to leave the delivery room – please say so and she will leave immediately.

If you have any questions about the study please feel free to ask Charlotte at any time.

Date: _____

Name: _____

Signature: _____

APPENDIX 9

PASSIVE DOSIMETER PRODUCT INFORMATION

E. Complete *Lab Request* or other *Chain of Custody* Form

1. Check that Sampler ID Number printed on back of Sampler matches that written on *Lab Request*.

2. Complete all information requested on *Lab Request*.

3. Keep a copy of *Lab Request* for your records.

F. Return Sampler to Analytical Laboratory

1. Place Sampler in Return Container (Fig. 6) and close securely.

2. Enclose Return Container and *Lab Request* in Return Mailer.

3. Refer to your Laboratory for allowable Holding Time between sampling and laboratory analysis and other technical questions.

4. Return Mailers may be used with any delivery service; affix proper postage before sending. For fastest turn-around-time, an Air Express Service is recommended. When returning several Samplers, send them in one box rather than using individual mailers.

5. For analysis, return Samplers to your Analytical Laboratory.

For Technical Support, call TOLL FREE NUMBER on Badge Holder.

WARRANTY

Products and services provided are subject to regular quality control programs backed by validation studies carried out under controlled conditions. While we pledge to work with each customer to establish field procedures which produce acceptable results, performance under field conditions which differ from the conditions of our testing is not guaranteed. **As our sole warranty, we guarantee to repair or replace any product or repeat any service found defective prior to its expiration date or within one year of sale for non-dated items.**

9161 6/99

Personal Monitoring System

ChemDisk™ Personal Sampler

with Laboratory Analysis Sold Separately

INSTRUCTIONS FOR USE

DESCRIPTION

ChemDisk™ Personal Sampler is designed to measure exposure to chemicals in order to demonstrate workplace compliance with Permissible Exposure Limits (PELs) and Short Term Exposure Limits (STELs) defined by the Occupational Safety and Health Act of 1970. After use the Sampler is returned to a Laboratory for analysis. Contact your AIHA-accredited laboratory for further technical information regarding this product.

The ChemDisk™ Personal Sampler Pack contains:

- Samplers (sealed in foil pouches)
- Holders (with clip for attachment)
- Return Containers (round plastic container)
- Return Mailers (foil-lined envelope)
- Instructions for Use (this text)

ChemDisk™ Monitor

IMPORTANT

- Read *Instructions for Use* and *Technical Insert* prior to use
- Do not use after Expiration Date printed on package.
- Store as directed on package.
- Do not open foil pouch until ready to use.
- Record Sampler ID Number for your records.
- When not in use, store Sampler away from chemicals.

A. Identify Components and Assign Samplers

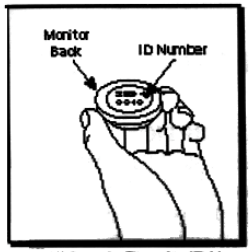
1. Choose a Sampler (in foil pouch) and Badge Holder for each person to be Samplered.

2. Enter Name of Person/Location to be Samplered on *Lab Request* or other *Chain of Custody* document.

3. Tear open Foil Pouch and remove Sampler. Discard pouch and any product conditioners found therein.

4. Use two line Sampler ID Number printed directly on back of Sampler (Fig. 1) for sample documentation.

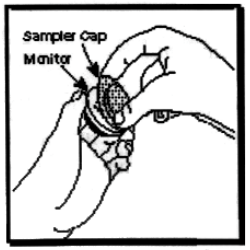
5. If sampling does not begin immediately, store Sampler in closed Return Container for up to one hour.



(Fig. 1) Locate Sampler ID No. on back of Sampler

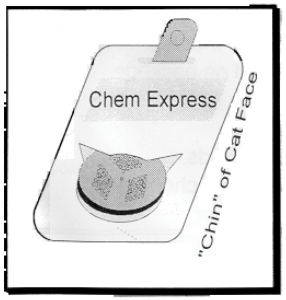
B. Assemble Sampler for Sampling

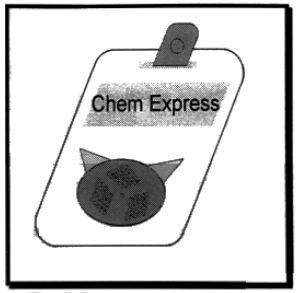
1. While holding the Sampler at its edge, remove Sampler Cap from Sampler (Fig. 2). **DO NOT REMOVE CLEAR BACK printed with Sampler ID No.** Save Sampler Cap for later use by placing in Return Container.



(Fig. 2) Remove Sampler Cap from Sampler

2. While holding Sampler with holes looking through the Holder's "cat face" cut-out, slide Sampler down and in until the Sampler's front rim rests in the "chin" of the "cat face". (Fig. 3)





(Fig. 4) Sampler "Locked" in Place

3. With sampling holes still facing forward, snap the flexible Holder over the Sampler's top front rim until it locks in place (Fig. 4) so that the Holder's front rim is "locked" in place in the Holder.

C. Begin Sampling

1. Document Sampling Date and Start Time for the Lab and for your records.

2. Attach Sampler to person to be monitored by clipping to outer clothing near breathing zone (Fig 5).

3. Refer to your Laboratory for recommended Sampling Times.


(Fig. 5) Wear Sampler

D. End Sampling

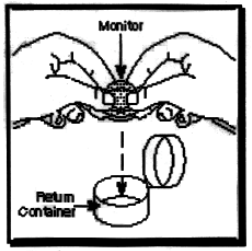
1. At end of Sampling Time, remove Holder with Sampler.

2. Remove Sampler from Holder.

3. **Immediately** snap Sampler Cap back onto Sampler to stop sampling and place in Return Container. (Figs. 2 and 6)

4. Record Stop Time (and Date, if applicable) for the Lab and for your records.

5. Total Sampling Time (in minutes) may be recorded in place of Start and Stop Times.



(Fig. 6) Replace Sampler Cap for return to Lab

APPENDIX 10

FORMALDEHYDE AND NITROUS OXIDE MSDS

Material Safety Data Sheet

Anachemia

255 Norman.
Lachine (Montreal), Que
H8R 1A3

EMERGENCY NUMBERS:

(USA) CHEMTREC : 1(800) 424-9300 (24hrs)
(CAN) CANUTEC : 1(613) 996-6666 (24hrs)
(USA) Anachemia : 1(518) 297-4444
(CAN) Anachemia : 1(514) 489-5711

WHMIS	Protective Clothing	TDG Road/Rail
WHMIS CLASS: D-1A D-2A		Not controlled under TDG (Canada). PIN: Not applicable. PG: Not applicable.
		

Section I. Product Identification and Uses

Product name	**FORMALIN SOLUTION 10%**
Chemical formula	Not applicable.
Synonyms	Formaldehyde buffered 10%, R-240010, 41915
Supplier	Anachemia Canada. 255 Norman. Lachine (Montreal), Que H8R 1A3
Material uses	For laboratory use only.

CI#	Not available.
CAS#	50-00-0
Code	R-240010
Formula weight	Not applicable.
Supersedes	

Section II. Ingredients

Name	CAS #	%	TLV
1) FORMALDEHYDE	50-00-0	3-4	Exposure limits: ACGIH Ceiling limit 0.3 ppm (0.37 mg/m3):
2) METHANOL	67-56-1	0.5-1.5	Exposure limits: ACGIH TWA 200 ppm (262 mg/m3) (skin); STEL 250 ppm (328 mg/m3) (skin)
3) SODIUM HYDROXIDE	1310-73-2	0.1-0.6	Exposure limits: ACGIH Ceiling limit 2 mg/m3
4) PHOSPHORIC ACID	7664-38-2	0.1-0.6	Exposure limits: ACGIH TWA 1 mg/m3; STEL 3 mg/m3
5) WATER	7732-18-5	Balance	Not established by ACGIH

Toxicity values of the hazardous ingredients

FORMALDEHYDE:
ORAL (LD50): Acute: 100 mg/kg (Rat). 42 mg/kg (Mouse). 260 mg/kg (Guinea pig).
ORAL (LDLo): Acute: 108 mg/kg (Woman).
DERMAL (LD50): Acute: 270 ul/kg (Rabbit).
VAPOR (LC50): Acute: 203 mg/m3 (Rat). 92 mg/m3 (Mammal). 454 mg/m3 (Mouse) (4 hour(s)).
METHANOL:
ORAL (LD50): Acute: 5628 mg/kg (Rat). 7300 mg/kg (Mouse). 14200 mg/kg (Rabbit).
DERMAL (LD50): Acute: 15800 mg/kg (Rabbit).
VAPOR (LC50): Acute: 64000 ppm (Rat) (4 hour(s)).

Section III. Physical Data

Physical state and appearance / Odor	Clear, colorless liquid with formaldehyde odor.
pH (1% soln/water)	Not available.
Odor threshold	Not available.
Percent volatile	>90% (V/V)
Freezing point	Not available.
Boiling point	Not available.
Specific gravity	Not available.
Vapor density	Not available.
Vapor pressure	Not available.
Water/oil dist. coeff.	Not available.
Evaporation rate	Not available.
Solubility	Miscible in water.

Section IV. Fire and Explosion Data

Flash point	CLOSED CUP: Higher than 93°C.
Flammable limits	LOWER: 7% (FORMALDEHYDE). UPPER: 73% (FORMALDEHYDE).
Auto-ignition temperature	299°C (Formaldehyde).
Fire degradation products	Oxides of carbon (CO, CO2).
Fire extinguishing procedures	Use DRY chemical, carbon dioxide, alcohol-resistant foam or water spray. Wear adequate personal protection to prevent contact with material or its combustion products. Self contained breathing apparatus with a full facepiece operated in a pressure demand or other positive pressure mode. Cool containing vessels with flooding quantities of water until well after fire is out.
Fire and Explosion Hazards	When heated, flammable and toxic vapors emitted. Contact with oxidizers may cause fire and/or explosion. Emits toxic fumes under fire conditions.

Section V. Toxicological Properties

Routes of entry	Inhalation and ingestion. Eye contact. Skin contact. Skin absorption.
Effects of Acute Exposure	May be fatal by ingestion, inhalation, or by skin absorption. Lachrymator. Target organs: central nervous system, liver, kidneys, spleen, eyes, skin, gastrointestinal system, respiratory system, lungs, reproductive system, peripheral nervous system, pancreas.
Eye	Vapors causes tearing and severe irritation. Liquid causes severe burns. Eye contact can result in corneal damage or blindness. IRRITATION: EYE-RABBIT 750 ug/24H SEVERE (FORMALDEHYDE).
Skin	Contact with liquid causes irritaion, drying, scaling, and cracking. Prolonged and repeated contact causes hardening or tanning effect. May cause allergic dermatitis. Liquid can be absorbed in toxic amounts through intact skin (massive skin contact can cause visual impairment and death). IRRITATION: SKIN-RABBIT 2 mg/24H SEVERE (FORMALDEHYDE).
Inhalation	Toxic. Vapors and mists are extremely irritating to the nose, throat, lungs and mucous membranes. Bronchitis, bronchopneumonia, pulmonary edema and chemical pneumonitis may occur. Prolonged exposure may result in more severe irritation and tissue damage. Methanol can cause central nervous system depression (signs and symptoms may include headache, dizziness, nausea, vomiting, drowsiness and incoordination), coughing, chest pain and dyspnea. Can affect the optic nerve resulting in blindness.
Ingestion	Toxic. Vapors, mists, and liquid are extremely irritating to the mouth and throat and stomach. Swallowing the liquid inflames the tissues, causes severe abdominal pain, nausea, vomiting, hematuria, proteinuria, anuria, acidosis, and possible loss of consciousness. Methanol can affect the optic nerve resulting in blindness.

Section V. Toxicological Properties

Effects of Chronic Overexposure	Repeated or prolonged exposure to spray mist may produce respiratory tract irritation leading to frequent attacks of bronchial infection. Repeated exposure to an highly toxic material may produce general deterioration of health by an accumulation in one or many human organs. Rats chronically exposed to 14 ppm formaldehyde contracted nasal cancers. Based on animal data and limited epidemiological evidence, NTP, IARC and OSHA have listed formaldehyde as a probable human carcinogen. Possible reproductive disorders from prolonged exposure (embryotoxic). Mutagen. Passes through the placental barrier in animal. May cause sensitization by inhalation (asthma) and skin contact (dermatitis). Can cause central nervous system depression. May cause damage to the central nervous system, repiratory system, lungs, eyes, skin, gastrointestinal tract, liver, spleen, and kidneys. Repeated or prolonged exposure to the substance can produce target organs damage.

Section VI. First Aid Measures

Eye contact	Immediate first aid is needed to prevent eye damage. IMMEDIATELY flush eyes with copious quantities of water for at least 20 minutes holding lids apart to ensure flushing of the entire surface. Seek immediate medical attention. DO NOT use an eye ointment.
Skin contact	Immediate first aid is needed to prevent skin damage. Immediately flush skin with plenty of water for at least 20 minutes while removing contaminated clothing and shoes. Seek immediate medical attention. Wash contaminated clothing before reusing.
Inhalation	Remove patient to fresh air. Administer approved oxygen supply if breathing is difficult. Administer artificial respiration or CPR if breathing has ceased. Seek immediate medical attention.
Ingestion	If conscious, wash out mouth with water. DO NOT induce vomiting. Seek immediate medical attention. Never give anything by mouth to an unconscious or convulsing person. If spontaneous vomiting occurs, have victim lean forward with head down to avoid breathing in of vomitus.

Section VII. Reactivity Data

Stability	Stable. Conditions to avoid: heat, sparks and flame, temperatures below 20°C.
Hazardous decomp. products	Not available.
Incompatibility	May react violently with: acids, alkalis, anhydrides, isocyanates, urea, phenol, oxidizing agents, oxides, organic oxides, reducing agents, ammonia, aniline, magnesium carbonate, performic acid, alkali metals, amines, hydrogen peroxide, nitromethane, nitrogen dioxide, perchloric acid, bases, monomers, water reactive materials, magnesium carbonate hydroxide.
Reaction Products	Reaction with hydrochloric acid may form bis-chloromethyl ether which is a confirmed human carcinogen according to ACGIH and carcinogenic to humans according to IARC. Hazardous polymerization will not occur.

Section VIII. Preventive Measures

Protective Clothing in case of spill and leak	Wear self-contained breathing apparatus, rubber boots and heavy rubber gloves. Full suit.
Spill and leak	Evacuate and ventilate the area. Stay upwind: Keep out of low areas. Eliminate all sources of ignition. Absorb on sand or vermiculite and place in a closed container for disposal. Use non-sparking tools. Transport outdoors. Wash spill site after material pick up is complete. DO NOT empty into drains. DO NOT touch damaged container or spilled material.
Waste disposal	According to all applicable regulations. Harmful to aquatic life at low concentrations. Can be dangerous if allowed to enter drinking water intakes. Do not contaminate domestic or irrigation water supplies, lakes, streams, ponds, or rivers.
Storage and Handling	Store in a cool place away from heated areas, sparks, and flame. Store in a well ventilated area. Store away from incompatible materials. Do not add any other material to the container. Do not wash down the drain. Do not breathe gas/fumes/vapor/spray. In case of insufficient ventilation, wear suitable respiratory equipment. Keep container tightly closed. Manipulate under an adequate fume hood. Do not use pressure to dispense. Storage temperature depends on methanol content and should be controlled to avoid precipitation or vaporization. Low temperature storage results in formation of paraformaldehyde, while high temperature storage produces formic acid. Keep away from direct sunlight or strong incandescent light. Empty containers may contain a hazardous residue. Handle and open container with care. Take off immediately all contaminated clothing. This product must be manipulated by qualified personnel. Do not get in eyes, on skin, or on clothing. Wash well after use. In accordance with good storage and handling practices. Do not allow smoking and food consumption while handling.

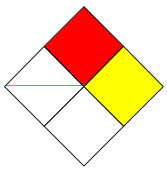
Section IX. Protective Measures

Protective clothing	Splash goggles. Impervious gloves, apron, coveralls, and/or other resistant protective clothing. Sufficient to protect skin. A OSHA/MSHA jointly approved respirator is advised in the absence of proper environmental controls. If more than TLV, do not breathe vapor. Wear self-contained breathing apparatus. Do not wear contact lenses. Make eye bath and emergency shower available. Have available and use as appropriate: face shields, rubber suits, aprons, and boots. Ensure that eyewash station and safety shower is proximal to the work-station location.
Engineering controls	Use only in a chemical fume hood to keep airborne levels below recommended exposure limits. Use explosion-proof ventilation equipment. Do not use in unventilated spaces.

Section X. Other Information

Special Precautions or comments

Highly toxic! Carcinogen! Mutagen! Sensitizer! Embryotoxic! Lachrymator. Irritant! Possible risks of irreversible effects. Readily absorbed through skin. Do not breathe vapor. Avoid all contact with the product. Avoid prolonged or repeated exposure. Use only in a chemical fume hood. Keep away from heat, sparks and flame. Handle and open container with care. Container should be opened only by a technically qualified person.
Synergistic materials: Alcohols may interact synergistically with chlorinated solvents (example: carbon tetrachloride, chloroform, bromotrichloromethane), dithiocarbamates (example: disulfiram), dimethylnitrosamine and thioacetamide. Formaldehyde: Ethyl acetate.
RTECS NO: LP8925000.



NFPA

Prepared by MSDS Department/Département de F.S..

Validated 28-Mar-2001

Telephone# (514) 489-5711

APPENDIX 11

MEDIGAS 3010 PRODUCT INFORMATION

BACHARACH®
The Measurable Difference

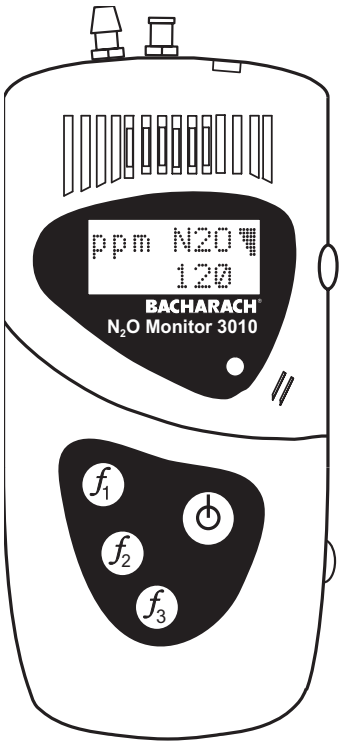
Instruction 19-9208

N_2O Monitor Model 3010

P/N 19-7109

Operation & Maintenance

Rev. 5 – December 2001



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Contents

SPECIFICATIONS

Range & Resolution ..... 0 to 1,000 ppm N_2O; 5 ppm resolution

Battery Life ..... Up to 9 hours on one charge

Battery Recharge Time .... Approx. 2 hours

Sensor ..... Dual wavelength IR cell

Operating Temperature ... 59 to 77 °F (15 to 25 °C)

Zero Drift ..... Typically <20 ppm over an 8 hour period with fully charged batteries and at a constant temperature (zero drift in auto-stablization mode)

Relative Humidity ..... 0–99% R.H., non-condensing

Dimensions ..... 5.5"L x 2.6"W x 0.8"H
(140 x 66 x 20 mm)

Weight ..... 8 oz (230 grams)

Construction ..... High Impact ABS Case

Case Seal ..... NEMA 12 (IP65)
(Dust and water resistant)

1.0 INTRODUCTION

1.1 General

The Bacharach N_2O Monitor 3010 is easy to use, but it is essential that this instruction manual be read and understood by all operators and maintenance personnel prior to using or servicing the monitor.

The 3010 is a compact and lightweight N_2O monitor that displays the current level of N_2O gas in either the range of 0 to 1,000 ppm, or a Time Weighted Average (TWA) ppm value.

The monitor is based on the infrared-absorption principle using a low volume, dual wavelength infrared cell to detect the presence of N_2O. The 3010 draws in a gas sample using its internal pump, which can be turned ON/OFF by pressing the f_3 button. The monitor automatically stores gas readings in memory at predetermined intervals. The stored data can be later downloaded to a personal computer via its integral IrDA communications link and optional BACH-COM software.

The monitor can be operated in the following three modes: 1) normal (real-time) ppm readings, 2) auto-stabilization for increased stability during long term TWA measurements, and 3) leak detection.

1.2 Main Features

- Displays either ppm N_2O or TWA
- Sampling modes: normal, automatic stablization, and leak detection
- TWA alarm
- Internal pump
- Battery capacity display
- Continuous data logging of readings with time and date stamp
- Memory capacity for approximately 800 sets of automatically logged readings
- Automatic compensation for elevation and changes in barometric pressure
- IrDA link for downloading stored data to a personal computer
- Easy calibration in fresh air
- Run-while-charging capability

1.3 Units of Measurement

The monitor's LCD shows N_2O concentrations expressed as either a current (real time) ppm reading, or a time-weighted-average (TWA) ppm value.

Note that the TWA ppm value is calculated using either the total elapsed-time period that the monitor was switched ON, or over a set 8-hour period. The method used to calculate TWA is set in software, and cannot be changed using the monitor's front panel pushbuttons. Refer to Sections 2.5, 2.6, and 2.7 for additional TWA information.

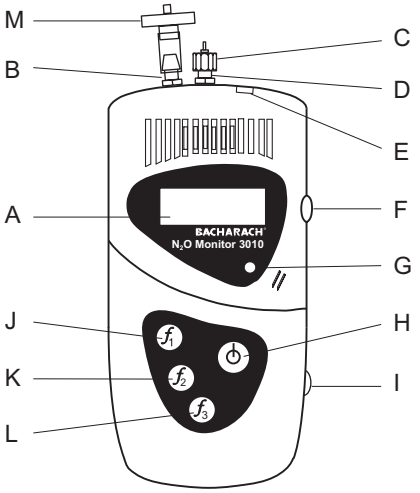
2.0 OPERATION

2.1 Important Note

Always ensure that the monitor's gas inlet connector (Figure 1, Item B) and outlet (Figure 1, Item D) are unobstructed and open to the atmosphere. Be careful not to breath directly on the monitor while taking a measurement; otherwise, inaccurate N_2O readings will result.

2.2 Switching the Monitor ON/OFF

Switch ON the monitor by momentarily pressing the ⏻ button. Switch the monitor OFF by pressing the ⏻ button for at least 3 seconds, or until the display goes blank. When first switched ON, there is a 30 minute warm-up period before the N_2O level is displayed.

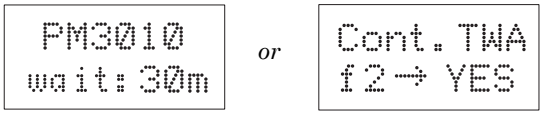


A – Digital display
B – Gas inlet
C – Restrictor
D – Gas outlet
E – TWA alarm light
F – IrDA link
G – Pump ON light
H – ON/OFF button
I – Battery charging socket
J – Toggle display between TWA and ppm (*f1*)
K – Calibration / Leak detection mode (*f2*)
L – Pump ON/OFF (*f3*)
M – Particulate Filter

Figure 1. Components of the 3010 N_2O Monitor

2.3 Start-Up Display

The display that appears when the monitor is first turned ON depends on what TWA format the monitor is currently in, and how long the monitor has been OFF. (Refer to Section *2.5 Time Weighted Average (TWA) Mode* for a detailed description of the monitor's two TWA formats.)



If the monitor is in its 8-hour 'TWA' mode and was OFF for *more* than 8 hours, then the first display appears at turn-on, which identifies the monitor and shows the countdown of the monitor's 30 minute warm-up period. After the warm-up period expires, the monitor automatically starts a new TWA reading. But if the monitor was OFF for *less* than 8 hours, then the second display appears, which gives an operator the option of continuing the previous TWA reading by pressing the *f2* button.

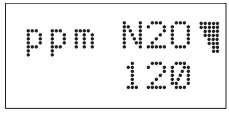
If the monitor is in its continuous 'twa' mode, then the second display always appears at turn-on, again giving the operator the option of continuing the previous TWA reading.

If *f2* is pressed, then the monitor continues operation with the previous TWA. But if *f2* is not pressed during warm-up, or if one of the other function buttons is pressed, then the monitor automatically starts a new TWA reading. At this time the monitor reverts to the first display for the remainder of the warm-up period.

2.4 Normal ppm Mode

The monitor's display is toggled between its TWA and normal display modes by pressing the *f1* button.

In this mode the gas level shown on the display is the current (real time) gas level being detected by the monitor. For example, the following display shows an N_2O level of 120 ppm.



Note that if a flashing "0" reading appears, this is an indication that negative drift has occured, and that the monitor needs to be re-zeroed per Section *3.8 Zero Calibration*.

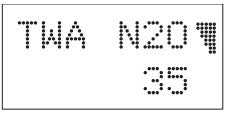
2.5 Time Weighted Average (TWA) Mode

The monitor's display is toggled between its normal and TWA display modes by pressing the *f1* button.

It is important to know that the time weighted average reading is available in two formats. This is designed to provide operators with the most appropriate data on their average ppm N_2O exposure in the working environment. The two formats are identified by the appearance of the letters "TWA" or "twa" in the display. Note that the TWA calculation gains more significance the longer the monitor is operating. This applies to both formats.

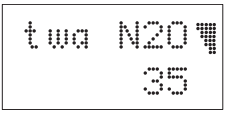
> **Note:** *The TWA/twa format is a factory setting, but it can be changed by using the optional BACH-COM software.*

- **TWA** (in upper case) is being calculated over a set 8-hour period. This format is designed to show the user's average ppm N_2O exposure level during a typical work day.



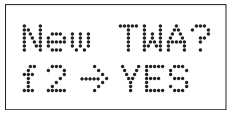
  If the monitor is switched OFF and then back ON before 8 hours has elapsed, then the operator has the option of continuing the current TWA reading by pressing the *f2* button as described in Section *2.3 Start-Up Display*. This is intended for instances such as lunch breaks where the unit is switched OFF for a short time, but the total TWA is required. Note that during the time the monitor is OFF, the gas reading will be assumed to be zero and will be added into the TWA if the previous TWA is continued when the monitor is switched back ON.

- **twa** (in lower case) is being calculated over a continuous time period. A new TWA is started by pressing the *f1* button as described below.



  If the monitor is switched OFF and then back ON, then the operator has the option of continuing the current TWA reading by pressing the *f2* button as described in Section *2.3 Start-Up Display*. Note that during the time the monitor is OFF, the gas reading will be assumed to be zero and will be added into the TWA if the previous TWA is continued when the monitor is switched back ON.

To start a new TWA reading after the monitor has been turned ON, press and hold down the *f1* button for 3 seconds or more until the following display appears:



Confirm that a new TWA is reading is desired by pressing and holding down the *f2* button for 3 seconds or more. The message "New TWA Started" will appear while the *f2* button is held down. Otherwise, press the *f1* button to cancel this operation and return to the existing TWA.

2.6 TWA Alarm

The 3010 Monitor has a built-in TWA alarm whose trip-point is based upon the selected TWA format (either 8 hours or continuous). The alarm level, however, is supplied from the factory preset to zero (no alarm), but can be activated by using the optional BACH-COM software. When the alarm is tripped, the monitor emits a beeping tone that remains on until the TWA level falls below its trip point. The alarm can be manually turned OFF by pressing the *f2* button which starts a new TWA reading, or the alarm can be turned OFF by simply switching OFF the monitor.

2.7 Auto-Stablization Mode

This mode automatically corrects for any drift when taking TWA readings. Auto-stabilization will effectively remove any effect of drift over periods of many days.

Before entering the auto-stablization mode, first zero the monitor per Section *3.8 Zero Calibration*, and, if necessary, select the TWA mode by pressing the *f1* button.

Enter the auto-stabilization mode by simply attaching the supplied restrictor (Figure 1, Item C) to the monitor's gas outlet (Figure 1, Item D), and then turning ON the pump by pressing the *f3* button. The monitor will automatically detect the presence of the restrictor and enter the auto-stablization mode.

> **Important!** *Use only the supplied restrictor, which has been specially calibrated to work with the monitor.*

Note: *Only TWA values are displayed while in the auto-stablization mode—normal ppm readings are not available.*

While in the auto-stablization mode, and with a non-changing level of N_2O being dectected, the monitor automatically cycles the pump ON and OFF for one minute intervals. Measurements taken during this time allow the monitor to automatically correct the readings for any drift.

When a change in the N_2O gas level is detected, the monitor interrupts the cycle of turning the pump ON and OFF and keeps the pump ON. Once the gas level stablizes, the process of cycling the pump ON and OFF resumes.

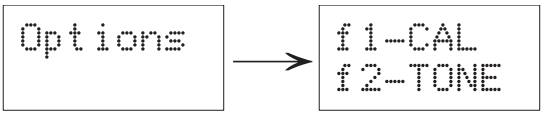
Important! *Do not attempt to turn the pump ON or OFF while in the auto-stablization mode.*

To exit the auto-stablization mode, remove the restrictor from the gas outlet and switch the pump ON (or OFF and then ON if it is already ON). The monitor will detect that the restrictor has been removed and revert back to its normal mode of operation after a short time.

2.8 Leak Detection Mode

This mode is intended for the detection of leaks from pipes or equipment containing N_2O gas. While in the leak detection mode, the monitor emits a beep with a repetition rate that is proportional to the concentration of gas—the higher the gas level, the faster the beep. The monitor can thus be used to detect gas leaks without the operator having to view the display.

Activate the leak detection mode by pressing and holding down the *f2* button until the following displays appear:



Momentarily pressing the *f2* button will activate this mode, or turn it OFF if already active.

2.9 Pump Operation (ppm Mode only)

> **Important!** *The restrictor (Figure 1, Item C)* ***must*** *be removed for the pump to operate in the ppm mode; otherwise, the monitor will automatically enter the auto-stablization mode as described in Section 2.7.*

With the monitor already switched ON, momentarily pressing the *f3* button turns the internal pump ON. Pressing *f3* again turns the pump OFF. We recommend attaching the supplied particulate filter (Figure 1, Item M) to the gas inlet connector whenever the pump is used. A customer supplied 3/16" I.D. sampling tube (not exceed 6 feet [1.8 m] in length) can be connected to the top of the particulate filter for drawing in gas samples from hard-to-reach locations.

> **Note:** *When switching the pump ON/OFF, a zero reading may offset from 5–10 ppm, but will stabilize after a couple of minutes.*

Note that the internal pump is intended for use only at normal atmospheric pressure, and is not designed to draw in gas samples against a vacuum or an obstruction such as a kinked sampling hose. The pump is capable, however, of pulling a gas sample against a restriction such as a dryer filter. If an obstruction or negative-pressure gradient is present, then gas *will not* be drawn into the monitor. Please consult the factory for applications where longer sampling lengths are required, or where it is necessary to draw against a vacuum.

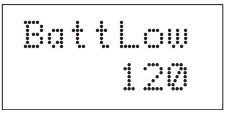
2.10 Datalogging

The monitor automatically stores data in both the normal and TWA modes at preset intervals. Although the time interval can be changed using the optional BACH-COM software, we recommend that the logging interval be kept at its factory setting for effective TWA calculations. The monitor is capable of storing approximately 800 readings.

While in its datalogging mode, the monitor will continue to add readings into memory at preset intervals. Each stored reading is the average reading during that period—not a 'snapshot' at the end of the interval. This ensures that no peaks in concentrations are lost, even if they occur between storage periods. When the memory is full the oldest data will be overwritten, so in normal use there is no need to clear the memory. If desired, memory can be cleared using the optional BACH-COM software.

2.11 Battery Low Display

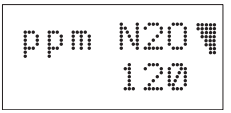
When the battery voltage falls below a pre-determined level, the display will alternate between its normal or TWA display and the following BattLow display:



In addition, the monitor's beeper will emit three rapid notes every 30 seconds. At this time the monitor should be given a full charge per Section *3.1 Battery Charging* as soon as possible.

2.12 Battery Charge Indicator

An indication of the battery's charge state is shown as a bar graph on the right-hand side of the display. As the charge reduces, the bar graph decreases in size. Typically 9 hours of operating time is available from one charge.



= represents full charge

= represents low charge

2.13 Fault Condition Warning

The monitor is capable of alerting the operator of an internal fault condition (i.e., a sensor failure or blockage in the infrared path). If a fault occurs, the monitor's beeper will sound continuously, and the following message is displayed until the monitor is switched OFF.

If the fault warning is displayed at any time, then the monitor must be returned to Bacharach for servicing.

2.14 Flow Fail Warning

When the pump is ON, a flow detector within the monitor will indicate when there is insufficient air flow, probably due to a blocked gas inlet or outlet. If a blockage occurs: the pump is automatically turned OFF, the monitor emits a beeping tone, and the following message flashes on the display.

At this time the cause of the blockage should be removed before the pump is restarted.

2.15 Powering Monitor from Charger

The monitor can be continuously powered by the charger as follows:

1. *Without* the charger attached, turn ON the monitor.

   Note: *Connecting the charger to a monitor that is OFF causes the monitor to enter its charging mode, which in turn prevents the monitor from being switched ON.*

2. Plug the charger into an appropriate AC wall outlet (or 12 VDC when using the optional in-car charger). Then plug the charger's output connector in the monitor's charging socket (Figure 1, Item I).

To turn OFF the monitor, first unplug the charger—the monitor will not turn OFF with the charger attached.

2.16 Cross Sensitivity

The monitor will exhibit some residual cross sensitivity to Carbon Dioxide (CO_2). This will be in the order of 5–10 ppm for a 1000 ppm concentration of CO_2.

3.0 MAINTENANCE

3.1 Battery Charging

When the "BattLow" message is displayed (refer to Section 2.11), the monitor must be recharged using the supplied battery charger.

> **Important!** *The battery has a long shelf life, but it is recommended that the battery be recharged once a month if left unused. Batteries that have not been charged for several months should be given at least two charge/discharge cycles before using the monitor.*

As with all rechargeable batteries, there are guidelines that should be observed: The battery should normally be charged at room temperature. Charging at temperatures below 54 °F (12 °C) should be avoided since this may cause a false indication of when the battery is charged, and could also damage the battery.

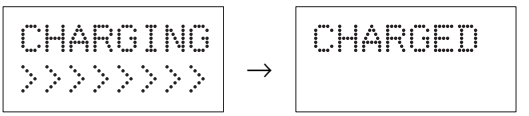
Before beginning the charging process, first ensure that the monitor is switched OFF. Next, plug the supplied charger into an appropriate AC wall socket (an optional 12 VDC in-car charger is also available). Then plug the charger's output connector into the monitor's charging socket (Figure 1, Item I).

The word "CHARGING" appears while the battery is being charged. Charging time is approximately 2 hours.

> **Note:** *If the battery is deeply discharged, the display will remain blank for a few minutes before the battery begins charging.*

Once the battery is fully recharged, the monitor will emit a beeping tone for 30 seconds and display the word "CHARGED." At this time, unplug the charger and remove its output connector from the monitor.

> **Important!** *After charging, you **must** wait at least 30 minutes before using the monitor to ensure best accuracy.*



3.2 Cleaning

Keep the monitor clean by wiping it with a soft cloth dampened with a mild detergent solution. The monitor can be sterilized by using isopropyl wipes. ***Do not*** immerse the unit in any sterilization agent.

3.3 Sunlight

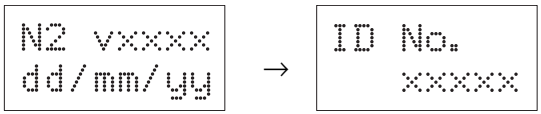
The unit should not be left out in direct sunlight, or in other areas where excessive heat exists, for long periods since component damage due to overheating may result.

3.4 Servicing

There are no user-serviceable parts inside the monitor. Unauthorized disassembly of the unit will invalidate its warranty.

3.5 Software Version / Serial Number

With the monitor switched OFF, and while holding down the *f*1 button, switch ON the monitor to display its software version and issue date. Releasing the *f*1 button displays the monitor's ID number for 5 seconds.



3.6 Factory Settings

> **Important!** *The monitor should be returned to its factory settings only when advised by a Bacharach Service Center.*

With the monitor switched OFF, and while holding down the *f*2 button, switch ON the monitor. The display will show

Keep the *f*2 button depressed until the display shows

WARNING! *After resetting the monitor to its factory settings, a zero calibration* ***must*** *now be performed per Section 3.8 before the unit is used.*

3.7 Response Check

To ensure that the monitor is operating correctly, it is recommended that it be periodically exposed to N_2O check gas as follows:

1. First perform a zero calibration per Section 3.8.
2. Connect a customer supplied cylinder of N_2O check gas to a Bacharach regulator and hose as shown in Figure 2.
3. Set up the monitor in its normal ppm mode per Section 2.4; then with the monitor's pump turned OFF, open the regulator and allow gas to flow until the monitor's reading stabilizes (approx. 3 minutes). *If the monitor does not respond to the gas, then return the unit to a Bacharach Service Center for evaluation.*
4. After completing the response check, shut OFF the regulator and remove the test equipment. Then turn ON the pump by pressing the *f3* button to flush the monitor with fresh air.

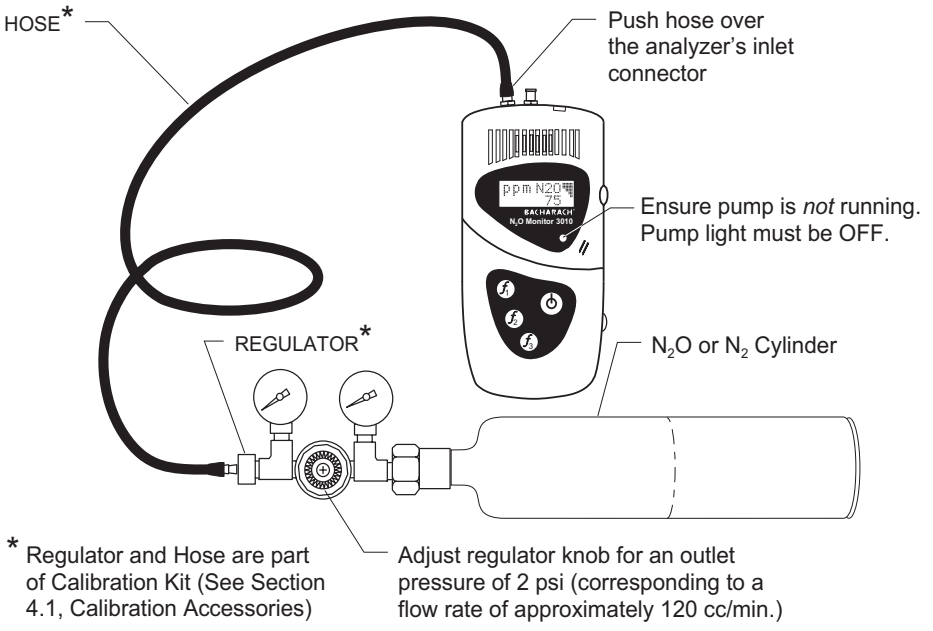


Figure 2. Applying Gas using Bacharach's Calibration Kit

3.8 Zero Calibration

There are two methods available to perform a zero calibration:

- Fresh Air
- Nitrogen

Note that a span gas is ***not*** required. The monitor is digitally calibrated and has a linear curve relationship between 0 and 1,000 ppm N_2O. Therefore a zero in fresh air or with Nitrogen will adjust the curve across its full reading range.

Follow these guidlines when calibrating:

- A calibration can be performed after the monitor's initial 30 minute warm-up period has expired. A calibration should ***not*** be performed immediately after the measurement of a high concentration of gas.

- A calibration should ***only*** be done in clean air prior to the monitor's initial use for the day, or ***after*** the unit has been switched OFF/ON. If clean air is not available, zero the unit using Nitrogen.

  WARNING! ***Never*** *attempt a zero in the actual testing environment.* ***Zeroing in a contaminated environment can cause erroneous gas readings.***

  WARNING! *Do not perform a zero calibration if the air temperature is below 60 °F (15 °C).* ***Zeroing in cold air can cause erroneous gas readings.***

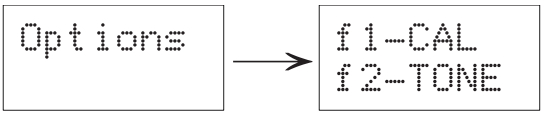
  WARNING! *Do not immediately perform a zero calibration when the instrument has just been brought in from a cold environment, such as a cold vehicle in the Winter. First allow the instrument to warm up to the temperature at which measurements are to be made before zeroing.*

When using the monitor for . . .

- TWA readings – zero before starting each 8 hour measurement period.
- leak measurements – zero daily before initial use.
- background monitoring – zero when moving from place to place.

3.8.1 Air Calibration

1. If not already done, switch ON the monitor per Section 2.2.
2. Press the *f3* button to turn ON the pump.
3. Allow the pump to run at least 2 minutes to purge the monitor of all possible contamination. Make sure that the display reading is *stable* before continuing with Step 4.
4. Press and hold down the *f2* button until the following displays appear:



5. Press the *f1* button to zero the monitor using fresh ambient air. If the calibration procedure was successful, the display will show:

If the procedure was unsuccessful, the message

will be displayed. If this happens, retry this procedure, ensuring that the monitor is only exposed to fresh air. If the procedure is still unsuccessful, then the monitor must be returned to a Bacharach Service Center for evaluation.

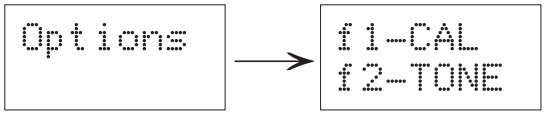
3.8.2 Nitrogen Calibration

WARNING! *This procedure assumes the use of a Bacharach Calibration Kit as listed in Section 4.1. If a non-Bacharach gas regulator is used, then an in-line flowmeter must also be used to ensure that the gas flow into the monitor is approximately 100 cc/minute.* ***Improper flow can cause erroneous gas readings.***

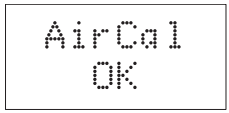
1. If not already done, switch ON the monitor per Section 2.2.

2. Using the Bacharach Calibration Kit with an N_2 cylinder attached as shown in Figure 2, adjust the regulator for an outlet pressure of 2 psi (equivalent to a flow rate of approximately 120 cc/min.). Flow Nitrogen through the monitor for 2 minutes with the pump OFF before proceeding to Step 3.

3. Press and hold down the *f2* button until the following displays appear:



4. Press the *f1* button to zero the monitor using Nitrogen. If the calibration procedure was successful, the display will show:



   If the procedure was unsuccessful, the message

   will be displayed. If this happens, retry this procedure. If the procedure is still unsuccessful, then return the monitor to a Bacharach Service Center for evaluation.

5. This completes the zero procedure. Shut OFF gas flow and remove equipment from monitor.

4.0 PARTS & SERVICE

4.1 Replacement Parts and Accessories

Replacement Parts

110/240 VAC USA & European Plug Charger 19-3312
Particulate Filter 54-0548

Accessories

12 VDC In-Car Charger 19-3302
Carrying Case (large) 19-3311
Carrying Case (small) 19-3337
IrDA Interface Kit & BACH-COM Software 19-3301
Protective Boot 19-3304
Table Top Stand 19-3307

Calibration Accessories

Air Calibration Check Gas, 100% N_2, 17 liter tank 23-4003
Calibration Kit (w/ carrying case, regulator and tubing) 19-8027
Pressure Regulator from Calibration Kit 24-0191
Rubber Hose from Calibration Kit (2 ft) 03-6351

4.2 Bacharach Sales/Service Centers

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