MIRAN® SapphIRe Gas Analyzers for Anesthetic Agent Detection

ABSTRACT

Describes procedures for determining the concentration of several anesthetic gases in air, with other gases present, to ensure that concentration levels are kept within safe limits.

INTRODUCTION

Waste anesthetic gas exposure is f extreme importance for thise workin in operating rooms, dental offices, ans veterinary offices. It has also been reported that some of the bighest levels of waste anethetic gases have neen found in postoperative recovery rooms. This document highlights the conclusions of several studies in regard to the health effects of chronic exposure to anesthetic gases.

In addition to personnel monitoring, waste anesthetic gas is measured as part of Preventative Maintenance (PM) work. Service technicians can identify leaks on anesthetic delivery systems by using any of the MIRAN SapphIRe Ambient Air Analyzers.

Each of the portable gas analyzers can be easily configured to measure all the anethetic gases. Typically the detection level for these gases is in the 100 ppb range. Continuous monitors are also available for long term monitoring. These systems have the ability to monitor up to five compounds at up to 24 locations.

ANALYTICAL THEORY

Infrared spectroscopy provides the fingerprint of a molecule. The fingerprint consists of a unique series of energy absorbances across a wavelenght range of 2.5 to about 14 micrometers (µm). Qualitative analysis of a compound is accomplished by examining the entire series of peaks. Quantitative analysis is accomplished by examining one or more specific absorbance peaks, and determining the height of the peak.

The MIRAN infrared instruments are spectrophotometers that effectively measure the amount of energy (also referred to as the level of absorbance) received after passing the beam of infrared light through a gas sample. The greater the amount of light (energy) that is absorbed by the compound, the greater the concentration. The law that applies to infrared spectroscopy is Beer's Law, which states that:

$$A = kbC$$

where

A = Absorbance
k = Gas Specific Constant
b = Pathlength
C = Concentration

The Absorbance (A) is directly proportional to the concentration (C) when the gas specific constant (k) and pathlength (b) are both held constant.

All of the MIRAN Spectrophotometers are based on setting up a calibration curve. With the MIRAN SapphIRe analyzer, this calibration is represented mathematically in the form of the following equation.

$$C = PA + QA^2$$

where

C = Concentration
A = Absorbance
P = Linear Term
Q = Quadratic Term

The mathematics and coefficients for every compound calibrated in the standard and user library are stored in the software of the MIRAN SapphIRe analyzer. When the instrument detects an absorbance, it automatically performs the calculations and delivers a reading in ppm to the user.

HEALTH RISKS

A number of studies have been completed that describe the professionals at risk due to waste anesthetic gas exposure. That group includes 60,000 anesthesiologists, nurse anethetists and OR (Operating Room) nurses, 50,000 veternarians, and 250,000 dentists, hygenists, and assistants. The findings from a study sanctioned by an Ad Hoc Committee of the American Society of Anesthesiologists[1] found:

An increased risk of spontaneous abortions and congental abnormalities in children of women in the exposed group and of the offspring of the wives of male or personnel.

- A 1.3 to 2 times increase in the occurence of cancer in exposed females mainly from an increase in leukemia and lymphoma
- A statistically significant increase in hepatic disease for women anesthesiologists, women nurse anethetists, and male anethesiologists.
- A 1.2 to 1.4 times increase in renal disease in women but no increase in the men from the study group.

A separate study of dental assistants[2] showed that for each hour exposure to unscavenged nitrous oxide per week, there was a 6 percent reduction in the probability of becoming pregnant during each menstrual cycle.

Nitrous oxide is used by about 40% of all dentists in the United States. Unlike hospitals, however, dentists' offices typically do not use scavenging equipment. It has been reported that scavenging equipment can reduce the level of waste nitrous oxide by about 90%. For those offices using scavenging equipment, the levels of nitrous oxide are typically 100 ppm. However, where no scavenging equipment is used, levels typically reach values of 1000 ppm.

NIOSH APPROVED METHOD[3]

When monitoring for nitrous oxide, several techniques are typically employed, such as infrared spectroscopy using the MIRAN SapphIRe analyzer, or passive and active dosing badges.

The instantaneous response of the MIRAN SapphIRe analyzer, however, makes it a highly desirable method of performing on-th-spot analysis and long term testing.

The MIRAN SapphIRe analyzer meets all criteria set down by NIOSH for performing nitrous oxide tests. NIOSH Method 6600 identifies the sampling, measurement, accuracy, and equipment issues surrounding the choice of an approved instrument. Some of the requirements from the method are:

- Technique: Long-Pathlength Portable Infrared Spectrophotometer
- Pathlength: 0.5 to 40 meters
- Calibration: Closed loop dilution of nitrous oxide
- Wavelength: 4.48 micrometers

Method 6600 and any of the MIRAN SapphIRe ambient air analyzers are clearly ideal for measurement of nitrous oxide for personnel monitoring compliance.

PREVENTIVE MAINTENANCE

The MIRAN SapphIRe ambient air analyzers are used widely for the detection of leaks in anesthetic delivery systems. As part of the routine maintenance of equipment, an entire leak test of the system can be performed very easily with either of these instruments. Since many anethetic delivery systems come equipped for delivery of isoflurane, halothane, enflurane, or sevoflurane, it is important that a full leak check cover the detection of the halogenated gases may be possible, thereby saving valuable analytical time.

In addition to routine maintenance for leaks in systems, these analyzers can also detect leaks in the entire patient monitoring system during actual OR procedures.

In many cases, corrective actions have been immediately implemented to minimize the levels of nitrous oxide escaping to the atmosphere.

ANESTHETIC CART CALIBRATION

Anesthetic cards are typically calibrated by index of refraction instruments. However, because of the capabilities of Thermo's variable pathlength technology and the inherent advantages of infrared spectroscopy, it is possible to measure sub-ppm and percent concentrations of anethetic gases.

Anethetic delivery concentrations of some of the halogenerated agents typically are in the 5%-20% range. By recalibrating the MIRAN SapphIRe for different wavelengths, it is possible to use these instruments to calibrate anesthetic carts.

With delivery rates of anesthetic carts in the 5 liter per minute range, response time of the MIRAN SapphIRe analyzers is less than 2 minutes. Multiple challenge concentrations can be examined with the SapphIRe analyzer by increasing the delivery concentration. Utilizing the SapphIRe analyzer for calibration or performance verification of anesthetic carts significantly enhances the value of the SapphIRe analyzer for the entire hospital staff.

Analysis of cart performance is performed by placing the SapphIRe analyzer in the ANALYSIS mode and turing off the pump via the control key menu. The user then flows the gas through the instrument and records the concentration value.

To calibrate the SapphIRe analyzer for high concentration readings, the user can create the correct analytical parameters in the Custom Calibration menu by injecting high concentration standards into the Closed/Loop Calibration system. The chart below indicates approximate settings for the SapphIRe analyzer. Values specific to a particular analyzer should be installed for the greatest degree of accuracy.

Compound	Range	Pathlength (meters)	Wavelength (microns)
Isoflurane	0-6%	0.5	10.0
Halothane	0-6%	0.5	11.1
Desflurane	0-21%	0.5	14.0
Sevoflurane	0-6%	0.5	12.4

CHOOSING AN ANALYTICAL WAVELENGTH

Whenever single wavelength infrared technology is used, it is important to choose the correct wavelength to aviod interferences from other compounds. This phenomenon occurs when a secondary gas has an absorbance at about 9.6 micrometers (Figure 1) and isoflurane is also present (Figure 2), isoflurane will also be detected. In this case, the user should analyze sevoflurane at about 11 micrometers.

The way to overcome the issue of interference is to choose a wavelength that is unique to the gas in question. For example, it the user is trying to measure isoflurane and halothane is also present, the user should select a wavelength of 13.3 micrometers. Although isoflurane can be measured at this wavelenght, halothane has little or no absorbance at 13.3 micrometers.

The MIRAN SapphIRe-30E or SapphIRe-100E allow the user the ability to analyze a compund at one of several wavelengths. For instance, in the above case the user would go to the fixed library and choose ISOFLRANE. The menu would now prompt the user to choose the correct gas from the secondary name list. In this case, the user would choose the 13.3 selection. This indicates the wavelength being chosen is 13.3 microns, thereby "dodging" the interference.

Since these calibrations are embedded in the SapphIRe analyzer, the accuracy specifications are the same as for all other gases.

The other choice the user has is to measure isoflurance using the multicomponent calibration embedded in the system. Of course, this assumes that the multicomponent calibration has been installed. If the calibration is installed, the MIRAN SapphIRe analyzer measures halothane at one wavelength (probably 12.2 microns) and measures isoflurane at a second wavelength (probably) 8.2 microns) and then automatically inputs the absorbance values into the algorithum to subtract out halothane's contribution from the isoflurane absorbance reading. A compensated value for isoflurane is displayed (without the halothane contribution). Of course, the user has the option of displaying both values - compensated halothane and compensated isoflurane. The specific wavelengths used for the application depend on the requirements along with input from the Applications Laboratory.

SPECTRAL INFORMATION

Table 1 shows the detection levels achievable with various instruments. The spectral data is also present for identifying the best possible wavelength for analysis of each anesthetic agent.

Table 1. Detection Levels Achievable with Various Instruments

Compound	Range	Wavelength (micrometers)	Estimated Minimum Detectable Limits (ppm)
			SapphIRe
Nitrous Oxide	0-100	4.5	0.06
Halothane	0-10	8.4	0.15
Isoflurane	0-10	8.7	0.03
Enflurane	0-10	8.7	0.03
Desflurane	0-10	8.6	0.06
Metofane	0-10	9.2	0.07
Ethylene Oxide	0-10	3.3	0.4
Formaldehyde	0-40	3.5	0.4
Xylene	0-200	13.1	1.5

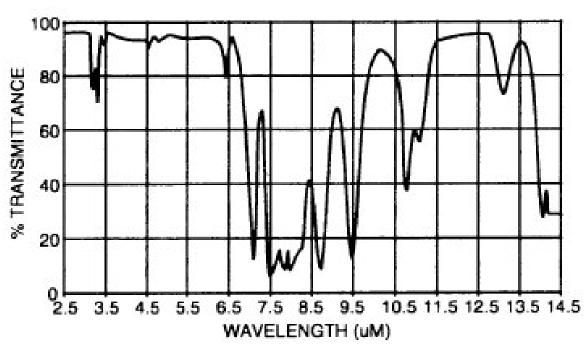

Figure 1. Infrared Spectrum of Sevoflurane

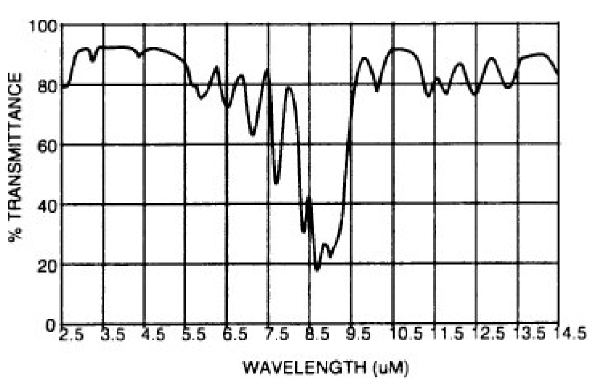

Figure 2. Infrared Spectrum of Isoflurane

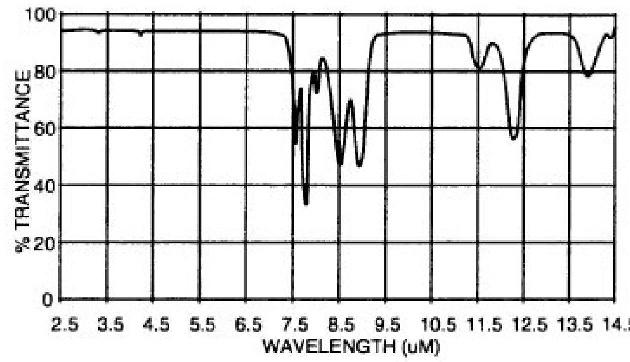

Figure 3. Infrared Spectrum of Halothane

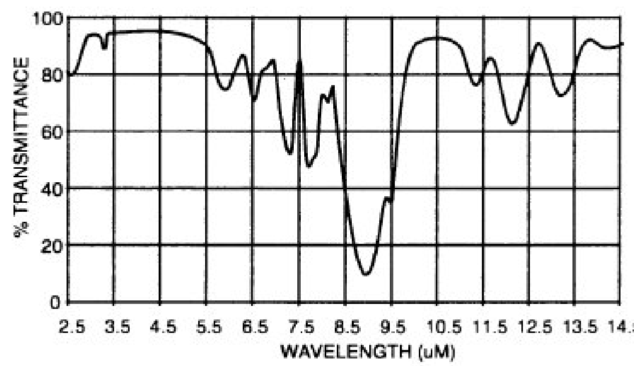

Figure 4. Infrared Spectrum of Enflurane

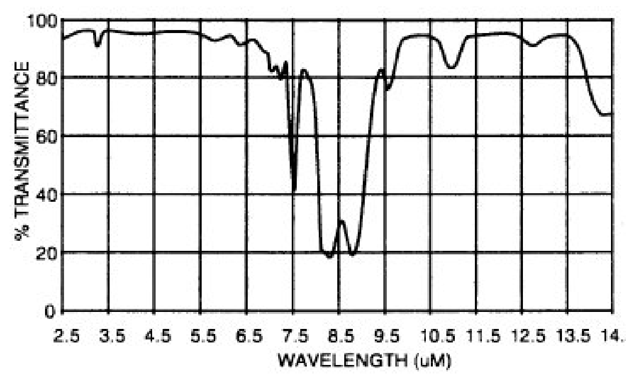

Figure 5. Infrared Spectrum of Desflurane

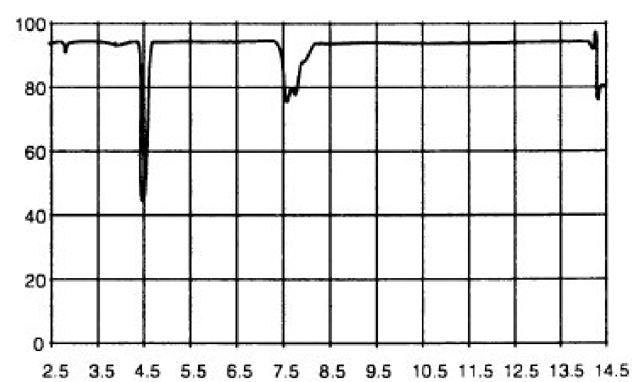

Figure 6. IR Spectrumof Nitrous Oxide

AVAILABLE INSTRUMENTATION

MIRAN SapphIRe-1
The MIRAN SapphIRe-1 is designed for the user with one specific measurement requirement. The SapphIRe-1 comes dedicated for the compound you choose. Because of the variable wavelength technology, virtually any anesthetic gas can be chosen.

MIRAN SapphIRe-5
The MIRAN SapphIRe-5 is designed for users who have one application to handle but there are mulitple compounds that need detection. Simultaneous measurement and display of up to 5 gases is accomplished by the wavelength switching capability of the SapphIRe-5. For greater flexibility, the SapphIRe-5 also has a user library that can store up to 10 single gas calibrations and up to 10 multicomponent applications.

MIRAN SapphIRe-30/SapphIRe-30E
The two units in the SapphIRe-30 series give the user even greater flexibility in addition to the multicomponent measurement and display. These units come calibrated for 30 single gases. The SapphIRe-30E has even greater flexibility, allowing the user to choose the measurement wavelength in order to "dodge" interference from other compounds.

MIRAN SapphIRe-100/SapphIRe-100E
These instruments are the next level up in the family. Instead of 30 single gas measurements, the user can choose from over 100 single gas measurements.

CONCLUSION

The MIRAN family of gas analyzers is an ideal choice and te industry standard for monitoring the presence of anesthetic agents. Because of their ability to measure low levels of anesthetic agents, they are great tools for personnel monitoring. WIth their ability to measure very high levels, they are also ideally suited for calibration of anesthetic carts and for preventative maintenance/leak detection work. Finally, the fact that they meet all the criteria of NIOSH Method 6600 practically mandates that they be used for personnel monitoring of nitrous oxide.

REFERENCES AND FOOTNOTES

1. Foley, Kevin, "AANA Journal Course: Update for nurse anesthetists - occupational exposure to trace anesthetics: Quantifying the risk," *Journal of the American Association of Nurse Anesthetists*, August 1993, Vol. 61, No.4
2. Rowland, Andrew et al, "Reduced Fertility among Women Employed as Dental Assistants Exposed to High Levels of Nitrous Oxide," *New England Journal of Medicine*, October 1992, Vol. 327, No. 14.
3. Burroughs, G.E. and Woebkenberg, M.L., National Institute of Safety and Health, Method 6600, February 1984.

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ELECTRON CORPORATION

Environmental Instruments
First Responder / Industrial Hygiene
27 Forge Parkway
Franklin, MA 02038