

The RAM 2000™ *Commercial* Remote Air Monitoring System



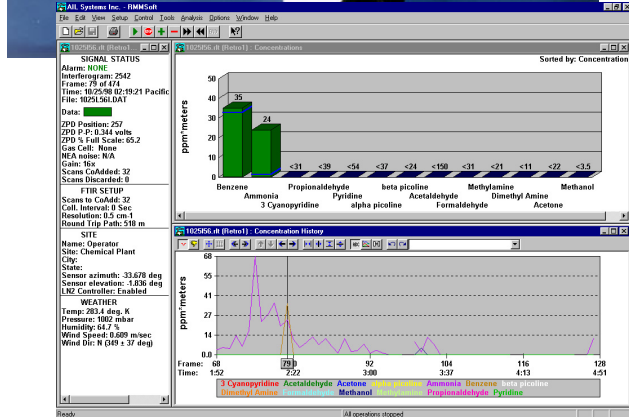
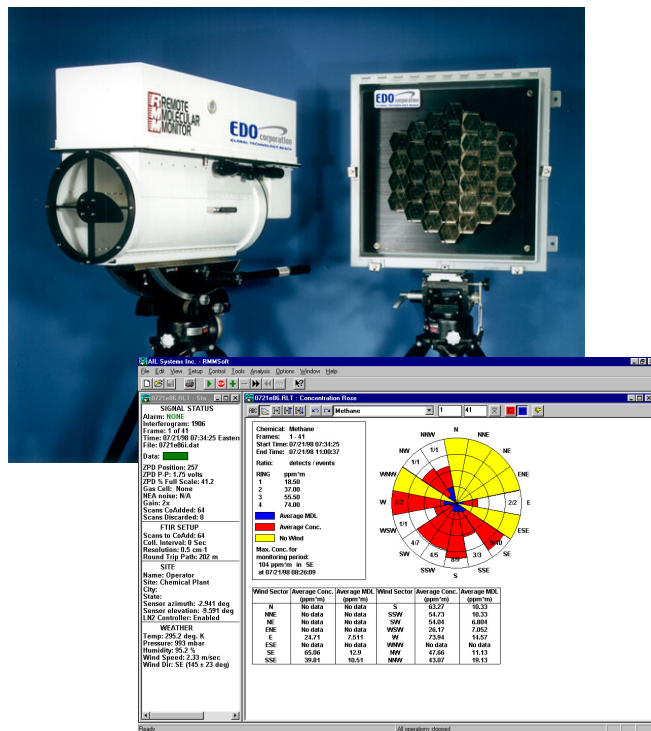
THE RAM 2000™ (Commercial)

Remote Air Monitoring System: Detects, identifies, and measures a wide range of hazardous compounds in real-time, around-the-clock, faster and more accurately than current conventional methods.

The system remotely monitors air quality by identifying and measuring the concentration of unwanted, dangerous or life-threatening gases in the atmosphere. RAM 2000™ can monitor air quality up to a 1.5 km distance.

The instrument is able to detect hundreds of gases and is designed to continuously operate unattended, over long periods, under a wide range of climatic conditions.

The RAM 2000™ has flexible, user-friendly, Windows-based software, and a display that can provide multiple levels of data. This allows the RAM 2000™ to be operated by non-technical and technical personnel.



The instrument is also available with an autopositioner configuration, which can be operated with the meteorological station and the automatic LN₂ refill system.

The autopositioner feature allows a single RAM 2000™ system to monitor multiple fence lines and internal paths to processing facilities.

The meteorological data is integrated with the FTIR data, thereby facilitating the use of a plume dispersion model, as well as creating a valuable historical record.

More than 30,000 hours of operational field data has been collected on the autopositioner configuration. Based on this field data, our initial prediction of a 10,000 hour mean time between failures (MTBF) for the RAM 2000™ Open-Path Remote FTIR Autopositioner System has been validated. For the fixed configuration, an estimate of 20,000 hours MTBF would not be unreasonable to assume.

FEATURES

- Rugged design for continuous operation
- Field-proven reliability that sets the industry standard
- Advanced signal processing produces minimum detection limits
- Alignment of telescope and retroreflector is quick and easy
- Single autopositioner unit monitors multiple fencelines
- Power needed only at end of fenceline
- Fencelines can be easily moved or reoriented
- Unit can be mounted in a light vehicle for mobile applications
- LN₂ refill system allows up to 60 days of unattended use
- Can be operated with Local Area Network (LAN) or Distributed Control System (DCS)
- Award-Winning Windows-based RMMsoft™ software

WINDOWS-BASED RMMsoft™

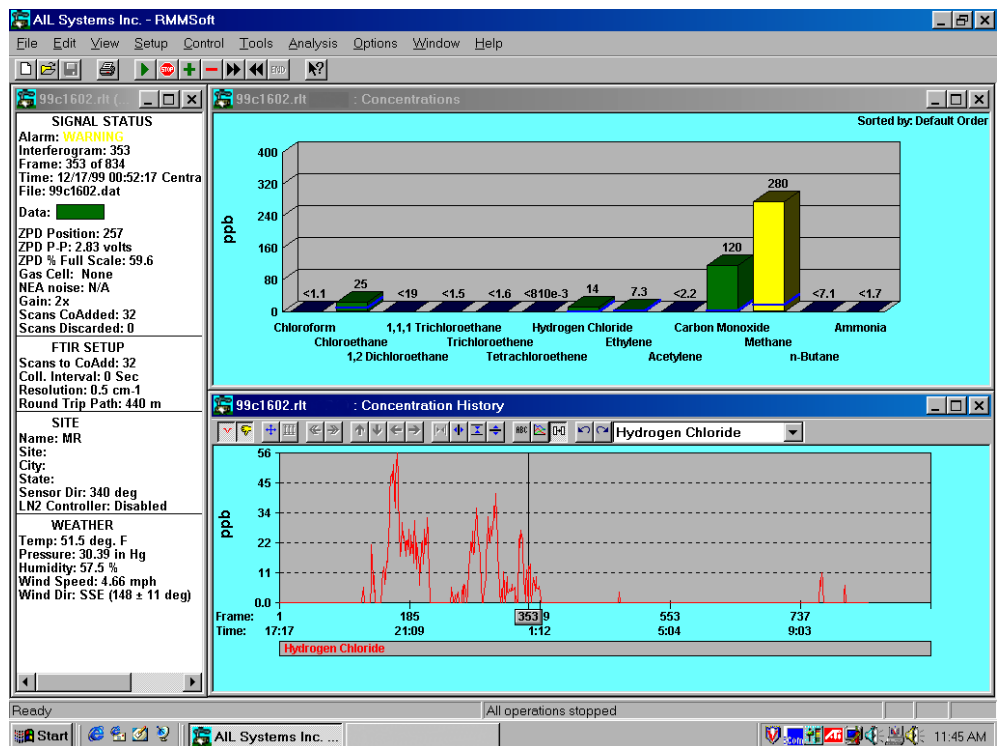
*Facilitates EASY-TO-USE OPERATION BY NON-TECHNICAL PERSONNEL
While providing DETAILED SPECTROSCOPIC ANALYSIS*

DISPLAY CHOICES

- 3-D BAR GRAPH (As Shown)
- 2-D BAR GRAPH
- LINE VALUES WITH ERROR-BAR LIMITS
- SUBSYSTEM STATUS

STATUS COLUMN SHOWS

- SYSTEM STATUS
- FTIR SETUP
- SITE INFORMATION
- WEATHER
- USER-DEFINED



BASIC SPECIFICATIONS

OVERVIEW

The RAM 2000™ system uses an infrared source which is modulated by a Michelson interferometer and then transmitted by a single transmitter/receiver telescope, through the atmosphere of interest, to a retroreflector. The retroreflector returns the beam to the transmitter/receiver telescope where a beamsplitter directs the beam to a sensitive, cryogenically-cooled, infrared detector. The modulated signal (interferogram) is converted to a signal spectrum by the Fourier transform. Portions of the infrared spectrum have been attenuated due to absorption by the gaseous chemicals in the beam. The frequency spectrum is converted to an absorbance spectrum which has a linear relationship to the concentration of the chemical times the beam pathlength. The concentration-pathlengths of the chemicals are determined from a regression analysis of the absorbance spectrum.

CONFIGURATION

Monostatic FTIR spectrometer for fence-line, open-path and remediation applications

INTERFEROMETER

Continuous Scan Michelson interferometer
Dual porch swing mirror suspension
Manually-adjustable fixed mirrors
HeNe laser frequency calibration

RANGE

Up to 1.5 km distance, spectrometer to retroreflector

SPECTRAL RANGE

700 to 4,000 cm^{-1}

RESOLUTION

0.5 cm^{-1} maximum

MINIMUM DETECT LEVELS (MDL)

Detection limits for chemicals measured by open-path FTIR systems will vary depending on the chemical, atmospheric conditions (humidity and temperature) and whether interfering chemicals may be present. The range of detection limits for a 100 meter separation between the transmitter/receiver telescope and the retroreflector is from 0.1 to 15 ppb for most infrared-active chemicals.

DETECTOR

Mercury cadmium telluride (MCT) detector element
Liquid nitrogen cooled for minimal noise contribution
Vacuum Dewar with 24-hour refill cycle
LN₂ automatic Dewar refill system, 60-day unattended operation, depending on supply Dewar size

QA CELL

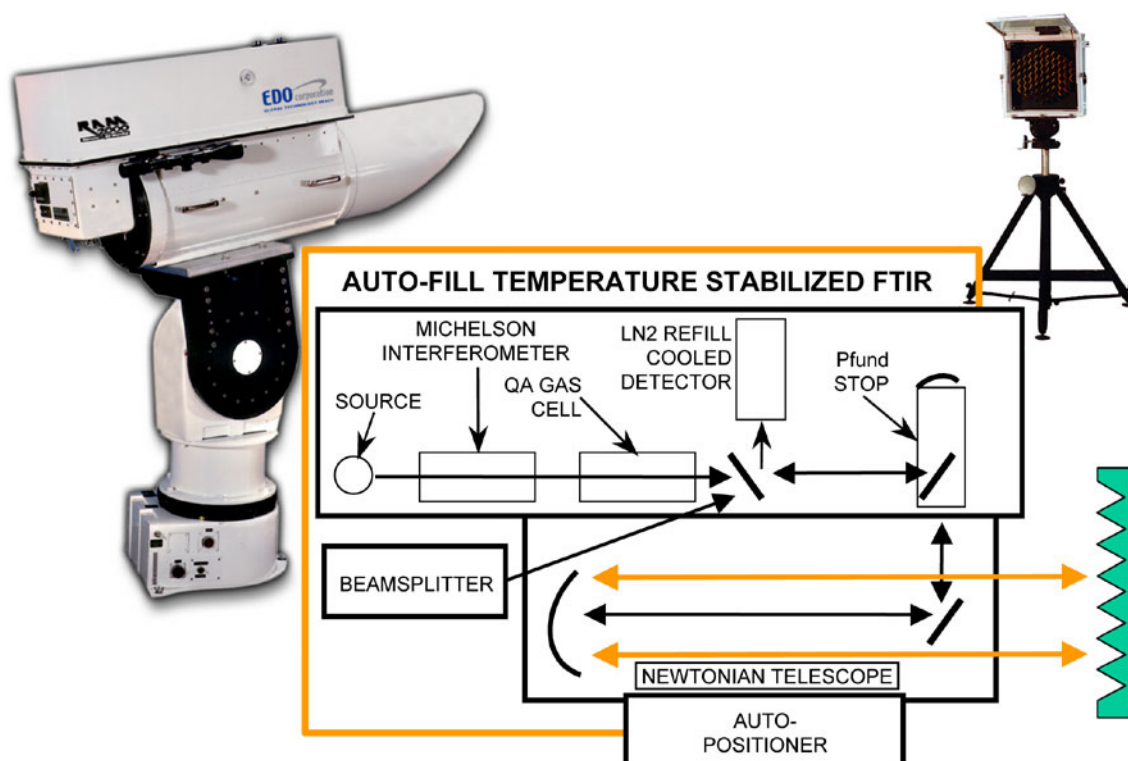
Integrated 15-cm gas cell with ZnSe windows for Quality Assurance. The cell has stainless steel quick disconnect fittings and a safety pressure relief valve.

DETAILED DATA ATTACHED

DETAILED INFORMATION

1. Scientific Principle Used for Detection and Identification of Target Analytes

EDO's Remote Air Monitoring System, RAM 2000™, is an active Open-Path FTIR system operating in a monostatic configuration. A single telescope is used to transmit and receive an eyesafe infrared beam through the local atmosphere to detect, identify, and quantify toxic and other unwanted chemical species. Infrared light from a silicon carbide glower is modulated by a Michelson interferometer and then transmitted by a 10-inch Newtonian telescope, through the atmospheric path being measured, to a retroreflector consisting of an array of hollow cube corners. The infrared beam is then reflected back to a cryogenically-cooled mercury cadmium telluride (MCT) detector. The detector

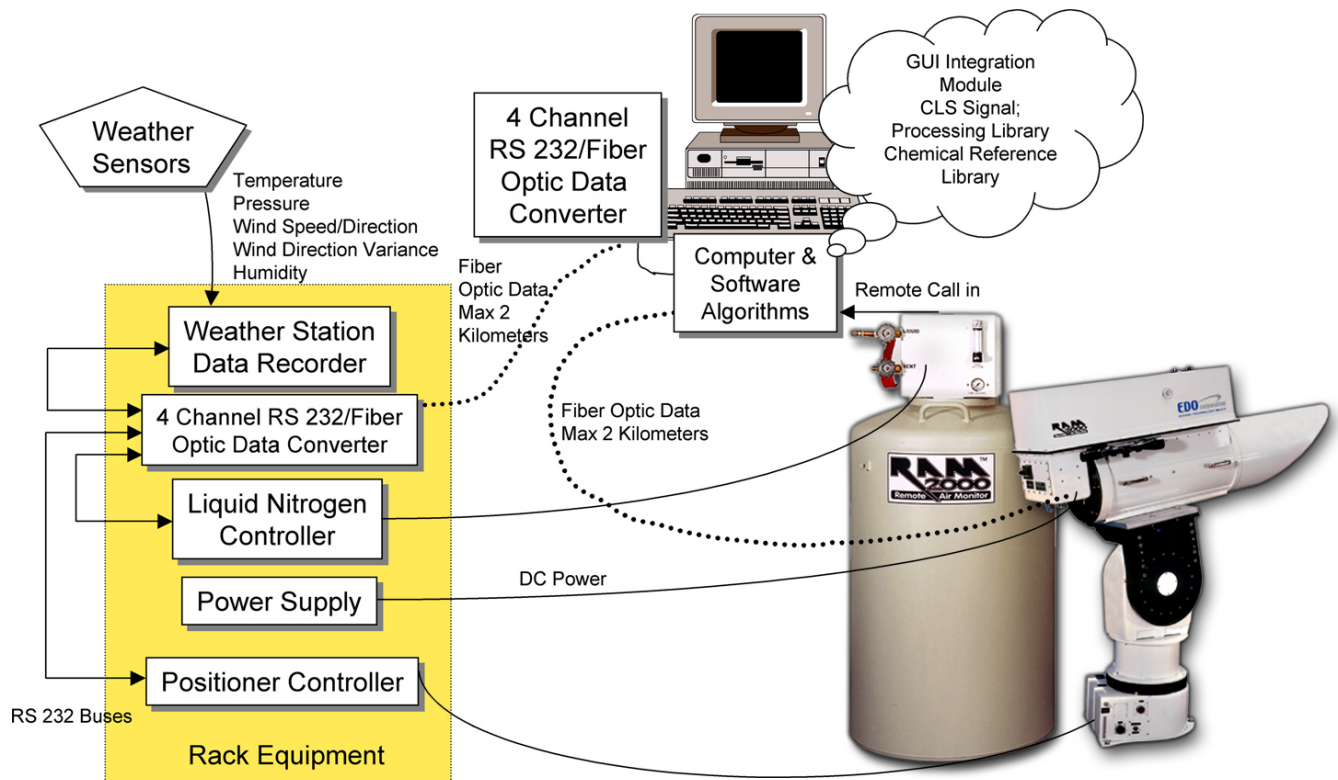


signal is the modulated beam with portions of the infrared spectrum attenuated due to absorption by gases and vapors present in the local atmosphere within the beampath. The modulated signal, referred to as an interferogram, is a time history of the infrared light received by the detector during a scan of the moving mirror in the Michelson interferometer. A Fourier transform converts the interferogram into a single beam spectrum, which is essentially a frequency spectrum of the detector signal. A background spectrum, I_0 (a spectrum made when the chemical species to be measured were not present), is used to convert the signal spectrum, I , to an absorbance spectrum, A , using the relation $A = -\log(I/I_0)$. The absorbance due to each chemical specie or target analyte is proportional to the concentration of the chemical, times the pathlength of the infrared beam through the chemical plume. Multicomponent regression techniques, which fit the absorbance spectrum (measured in the field) to reference spectra of the absorbing chemicals, are used to determine the concentrations of the individual absorbing chemical species even when present in a mixture of many different chemicals.

2. Configuration of the RAM 2000™ System

EDO's RAM 2000™ employs active Open-Path FTIR technology utilizing light from a silicon carbide glower within the RAM 2000™ instrument to project an eyesafe modulated infrared light beam to a retroreflector. The retroreflector directs the modulated beam back to a mercury cadmium telluride detector within the RAM 2000™ instrument. Modulation of the projected infrared beam is produced by a Michelson interferometer. This allows the detection electronics to be ac-coupled and insensitive to dc-contributions from any stray background source of infrared light. The return signal is analyzed for absorbed frequencies that act as fingerprints for any chemical specie present.

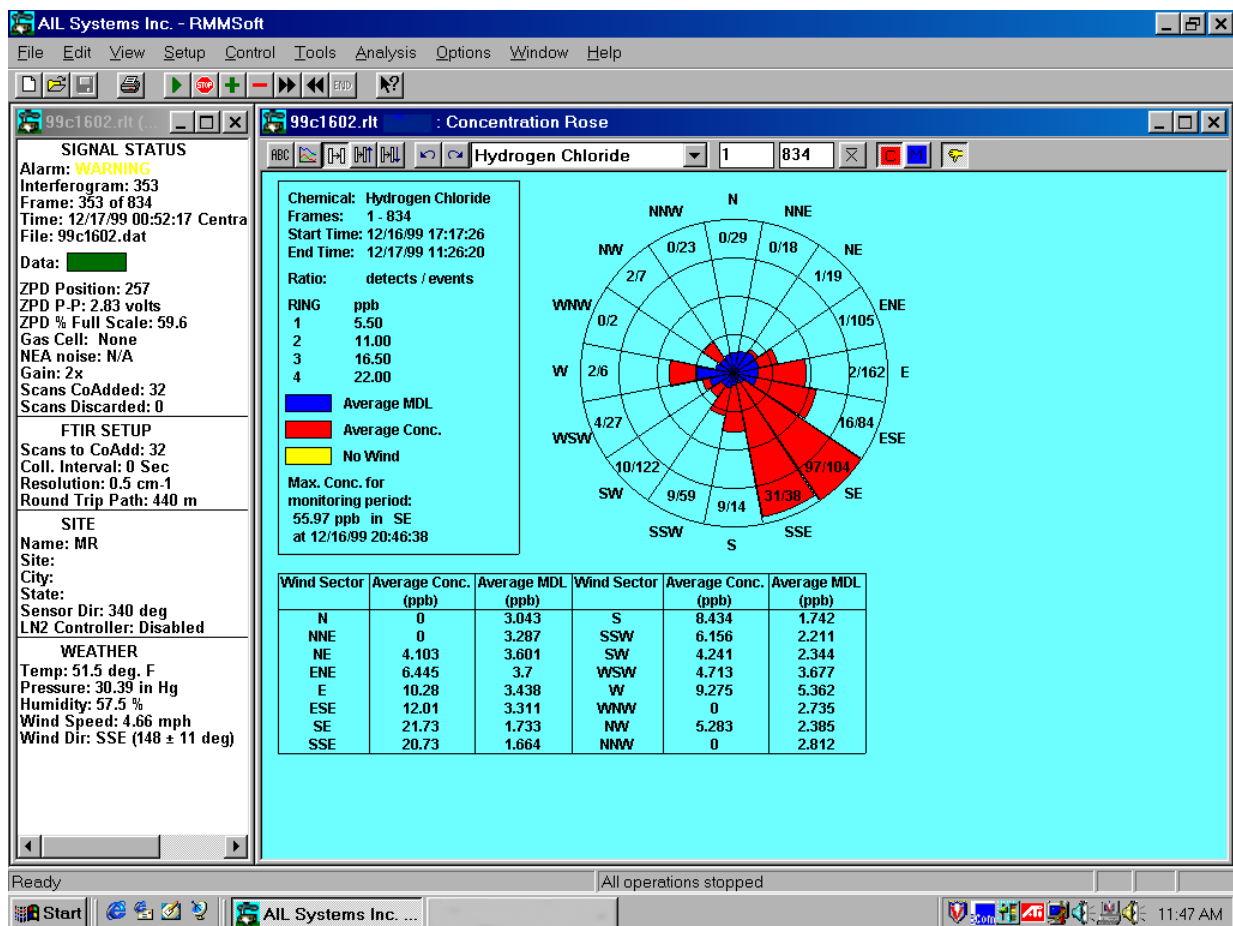
The basic system consists of a RAM 2000™ monitor/analyzer instrument and one retroreflector for each desired beampath. For continuous around-the-clock protection of a facility both the RAM 2000™ instrument and the retroreflector are securely and permanently mounted within enclosures that provide weather protection. For temporary field work both the RAM 2000™ instrument and the retroreflector are tripod mounted. When more than one beampath is monitored, a separate retroreflector is provided for each line-of-sight. Several accessories are also available. A meteorological station is usually included to provide information on the direction of flow and dispersion of the measured chemical plumes.



Note: FTIR requires 110 Vac in addition to dc power (Heat Stabilization and Laser Supply)

An accessory autopositioner enables a single RAM 2000™ instrument to address multiple beampaths and provide protection over a broad area of many acres. EDO's autopositioner is programmed to repetitively return to each selected beampath where it collects the user-selected number of co-added scans.

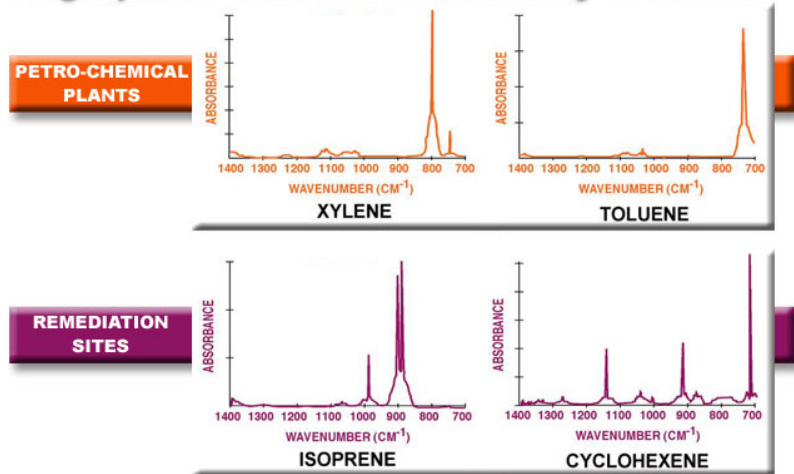
An accessory meteorological station is integrated with the RAM 2000™ system to supply weather data to facilitate identification of the source of the target analytes and enable modeling to project downwind concentrations at receptor sites. Recording of all weather parameters is synchronized with spectral data taking and archived together in a common file that retains all of the conditions under which the data was taken. Computer displays of concentrations and concentration histories, wind speed and wind direction trend charts and concentration or toxic chemical wind roses help to identify emission sources for each target analyte.



Windows™-based software enables easy-to-use operation. The RAM 2000™ system operation and display components may be located in a facility control room and integrated with a facility's network. The built-in analytical software includes multi-component regression algorithms that automatically identify and quantify the individual components in complex chemical mixture without any operator intervention. Each target analyte's concentration is displayed in a bar graph with individual user-set warning and trigger levels that are color coded for display and may also activate facility-desired responses or alarms. The software performs data quality checks on each data set. The software also simplifies report generation by computing concentration averages in addition to keeping track of maximum values and the time of their occurrence.

The RAM 2000™ will detect, volatile organic compounds (VOC's), more than 110 Hazardous Air Pollutants (HAP's) and many Toxic Industrial Chemicals BTEX family, alcohols and virtually all gases and vapors that have absorption spectra in the 2 to 14 μm (provided at the end of this document) lists many of these compounds. In addition, the RAM 2000™ will measure and display the concentration of each chemical specie present in ppm*meter or ppb*meter or as path averaged concentrations in ppm, ppb, mgram/m³ or μgram/m³.

Harmful Air Emissions Have Unique Spectral Fingerprints That Are Detected By RAM 2000™



The RAM 2000™ quantifies its detection of each target analyte. Not only does the RAM 2000™ specify a concentration for each target analyte detected, it also calculates a ± value within which there is a 99.4% probability that the actual RAM 2000™ concentration of the target analyte lies.

The RAM 2000™ has been tested using mixtures. RAM 2000™ systems have been in continuous round-the-clock operation at chemical plants in Elgin, SC and Harriman, NY for three years. The NIPA Hardwicke facility in Elgin, SC monitors 28 different chemical species simultaneously. The Nepera chemical facility in Harriman, NY monitors 17 different chemical species simultaneously. The RAM 2000™ system was set up by the user to simultaneously display the measurement results for 32 different chemical species upon completion of each data analysis. Thirty-two chemicals is not a hard limit, but was done for convenience and manageability of the bar graph display. If simultaneous analysis for more than 32 chemicals is desired, the graphical user interface could be changed to accommodate the number desired.

RAM 2000™ Provides Community Assurance Protection For a Pyridine Speciality Chemical Company Close by Elementary and High Schools



The RAM 2000™ system has performed detection and identification out to 1.5-kilometer ranges. The longer ranges require larger corner-cube retroreflector arrays.

4. Response Times

When the RAM 2000™ system is warmed up, it can take and analyze a data collection in 2 seconds. An individual FTIR scan takes 1.7 seconds and is the shortest data collection sample.

Usually FTIR scans are coadded (signal-averaged) to improve sensitivity. The number of coadds or sample data collection time is user selectable as is the time between data collection samples. Often a 1-minute data collection (32 coadds) is chosen by the user. Sensitivity improves as the square root of the data collection time so that a 1-minute data collection would have a sensitivity 5.66 times that of a single scan. The trade-off is rapid response for sensitivity. Thus the cycle time of the RAM 2000™ system is 2 seconds and the RAM 2000™ is ready to make another detection/identification 2 seconds after reporting the previous detection/identification event.

The setup time for the RAM 2000™ system from transportation container to ready-to-apply power to the system is 30 minutes. Warm-up time is 30 minutes. The system is ready to detect/identify target analytes within 30-minutes. Its sensitivity continues to improve for another 60 minutes.

5. Interfaces/Integration

Integration with the meteorological station enables synchronization of all weather parameters with the spectral data taking. Computer displays of concentration or toxic chemical wind roses help to identify emission sources for each target analyte. Both the meteorological and spectroscopic data are archived in a common file that retains all of the conditions under which the data was taken. The software also simplifies report generation by computing concentration averages in addition to keeping track of maximum values and the time of their occurrence.

The RAM 2000™ system is extremely user friendly. A great deal of effort has been directed to the development of a graphical user interface that would enable operation by personnel with minimal technical training; for example, in a guard shack of a chemical facility. Each target analyte concentration is displayed in a bar graph with individual user-selected warning and trigger levels that are color coded for display and may also activate facility-desired responses or alarms. The bar graph shows the results of the most recent data collection. A time history graph is usually displayed at the same time to show concentration trends of the target analytes. The software has been developed in a layered fashion. Qualified personnel with analytical chemistry and spectroscopic skills can follow the details of the analysis by examining the interferogram, single beam or absorption spectra, etc. Qualified personnel may add or subtract target analytes, or fine tune the analysis to better account for interference from other target analytes or other atmospheric constituents.



6. Consumables/Reliability

In addition to electrical power, the only consumable presently required by the RAM 2000™ is liquid nitrogen to cool the HgCdTe detector. The detector Dewar has approximately a 24-hour hold capability. With a 240-liter supply Dewar, the system will last 45 to 60 days before a refill or replacement of the supply Dewar is required. An automatic liquid nitrogen refill accessory is available from EDO which will refill the detector Dewar from the supply Dewar when the liquid nitrogen level in the Dewar level has dropped to a user-adjustable level. This allows the RAM 2000™ system to operate continuously for 45 to 60 days without operator attention. For permanent facility installation the automatic liquid nitrogen refill system has provided around-the-clock operation with minimal attention. EDO is presently developing a model of the RAM 2000™ system in which the liquid nitrogen Dewar is replaced with a long-life cryocooler with a 20,000-hour life for mobile applications.

The only component in the RAM 2000™ that needs to be replaced on a regular-interval basis is the HeNe laser. The beam from this low-power 1 mW laser is entirely contained within the RAM 2000™ instrument. Its function is to measure the distance the moving mirror in the Michelson interferometer has moved and provide a command when the next interferogram data point is to be taken. The lifetime of the HeNe laser is 5 years.

The RAM 2000™ system has operated in all weather conditions frigid, tropical, in rain, snow, etc. The optical train is thermal stabilized to maintain a constant 45°C temperature which allows the RAM 2000™ operate in all weather conditions from -10°C to 50°C without a performance degradation.

The RAM 2000™ has been hardened for field use. EDO has participated in many field programs and demonstrations including: the waste treatment facility at Tinker Air Force Base, OK; effluent monitoring at the 250-ft Idaho Chemical Processing Plant at the Idaho National Electronics Laboratory; remediation at the Number 1 site on the National Priority (Superfund) List, the Lipari Landfill in Pitman, NJ as well as the Fresh Kills Landfill in Staten Island, NY; and the American Petroleum Institute tests at the Phillips refinery in Sweeny, TX. For most projects the RAM 2000™ equipment is air shipped to a nearby airport and trucked to the site where the equipment has always arrived aligned and ready to operate.

7. Physical Characteristics

The dimensions and weights of the components of the RAM 2000™ system are:

RAM 2000™ monitor/analyzer	25.25" H x 15" W x 33" L	107 lb
Control rack mount	5.25" H x 19" W x 21" D	25 lb
Retroreflector	24" H x 24" W x 8" D	50 lb

When tripods are used to mount the RAM 2000™ instrument and the retroreflector, each tripod is 45" high and 12" x 12" when shipped folded. When the tripods are opened to mount the instrument and the retroreflector, their footprint expands to 45" by 45". Power requirements for the entire system can be accommodated by a single 15 A 120 v circuit. No hazardous materials are used in the RAM 2000™.

Table 1. Chemical Species which can be Detected, Identified and Measured by the RAM 2000™

Acetaldehyde	Chloroethane
Acetic acid	Chloroform
Acetone	Chloromethane
Acetonitrile	Chloromethyl methyl ether
Acetophenone	Chloropentafluoroethane
Acetyl Chloride	Chlorotetrafluoroethane
Acetylene	2-Chlorotoluene
Acrolein	4-Chlorotoluene
Acrylic acid	Chlorotrifluoroethylene
Acrylonitrile	Chlorotrifluoromethane
Allyl alcohol	m-Cresol
Allyl chloride	o-Cresol
Ammonia	p-Cresol
Arsine	Crotonaldehyde
Benzaldehyde	Cyclohexane
Benzene	Cyclohexene
Benzotrichloride	Cyclopentene
Benzyl alcohol	Cyclopropane
Benzyl chloride	1,2-Dibromo-3-chloropropane
Boron trichloride	1,2 Dibromoethane
Bromobenzene	Dibromomethane
Bromochloromethane	Dibutyl,monobutyl phosphate
Bromoform	m-Dichlorobenzene
Bromomethane	o-Dichlorobenzene
Bromotrifluoromethane	p-Dichlorobenzene
1,3 Butadiene	Dichlorodifluoromethane
Butane	1,1 Dichloroethane
2-Butanone	1,2 Dichloroethane
1-Butene	cis-1,2 Dichloroethene
cis-2-Butene	Dichloro-1-fluoroethane
trans-2-Butene	Dichloromethane
n-Butyl acetate	1,2-Dichloropropane
n-Butyl alcohol	1,3-Dichloropropane
n-Butyl aldehyde	1,3-Dichloropropene
Carbon dioxide	1,2-Dichlorotetrafluoroethane
Carbon disulfide	Dichlorotrifluoroethane
Carbon monoxide	Diethyl amine
Carbon tetrachloride	Diethyl ether
Carbonyl fluoride	Diethyl ketone
Carbonyl sulfide	Diethyl sulfate
Chloroacetic acid	Difluoroethane
Chlorobenzene	Di-isopropyl ether
2-Chloro-1,3-butadiene	Dimethyl ether
1-Chloro-1,1-difluoroethane	N,N-Dimethyl formamide
Chlorodifluoromethane	1,1 Dimethyl hydrazine

Table 1. Chemical Species which can be Detected, Identified and Measured by the RAM 2000™ (Cont.)

Dimethyl sulfate	Methyl amine
Dimethyl sulfide	2-Methyl butane
Dinitrogen pentoxide	2-Methyl-2-butene
Dinitrogen tetroxide	3-Methyl-1-butene
Ethane	Methyl formate
Ethanol	Methyl hydrazine
Ethyl acetate	Methyl isobutyl ketone
Ethyl acrylate	Methyl mercaptan
Ethyl benzene	Methyl methacrylate
Ethyl butyrate	Methyl nitrite
Ethyl formate	2-Methyl pentane
Ethylene	3-Methyl pentane
Ethylene oxide	2-Methyl-1 pentene
Ethyl vinyl ether	2-Methyl-2-pentene
Fluorobenzene	4-Methyl-2-pentene
Formaldehyde	Methyl tert-butyl ether
Formic acid	Methyl vinyl ether
Furan	Methyl vinyl ketone
Glyceryl trinitrate	Naphthalene
n-Heptane	Nitric acid
Hexachloro-1,3-butadiene	Nitric Oxide
Hexachlorocyclobutadiene	Nitro benzene
Hexachloroethane	Nitro ethane
Hexamethyl phosphoramidate	Nitrogen dioxide
n-Hexane	Nitroso benzene
2-Hexanone	Nitro methane
Hydrazine	Nitrous acid
Hydrogen bromide	Nitrous oxide
Hydrogen chloride	n-Octane
Hydrogen fluoride	Ozone
Hydrogen iodide	n-Pentane
Hydrogen peroxide	1-Pentene
Iodomethane	2-Pentene
Iso-butane	Pentafluoroethane
Iso-butanol	Perfluorobutane
Iso-butylene	Peroxy acetyl nitrate
Iso-cyanic acid	α -Picoline
Iso-phorone	β -Picoline
Isoprene	α -Pinene
Iso-propanol	β -Pinene
Iso-propylbenzene	Phenol
Mesitylene	Phosphine
Methane	Phosphorus trichloride
Methanol	Propane
Methyl acetate	n-Propanol
Methyl acrylate	

Table 1. Chemical Species which can be Detected, Identified and Measured by the RAM 2000™ (Cont.)

b-Propiolactone	Thionyl chloride
Propionaldehyde	Thiophene
Propionic acid	Toluene
n-propyl acetate	2,4-Toluene diisocyanate
n-propyl benzene	o-Toluidene
Propylene	Tributyl phosphate
Propylene glycol methyl ether acetate	1,2,4-Trichlorobenzene
Propylene imine	1,1,1 Trichloroethane
Propylene oxide	1,1,2 Trichloroethane
n-Propyl nitrate	Trichloroethylene
3 Cyanopyridine	Trichlorofluoromethane
Quinoline	2,4,5-Trichlorophenol
Silane	2,4,6-Trichlorophenol
Pyridine	1,2,3-Trichloropropane
Silicon tetrafluoride	Trichlorotrifluoroethane
Styrene	Triethylamine
Styrene oxide	Trifluoroethane
Sulfur dioxide	1,2,4-Trimethyl benzene
Sulfur hexafluoride	2,2,4-Trimethylpentane
Sulfur monochloride	Vinyl acetate
Tertiary-butyl benzene	Vinyl bromide
1,1,1,2 Tetrachloroethane	Vinyl chloride
1,1,2,2-Tetrachloroethane	Vinylidene chloride
Tetrachloroethylene	Water Vapor
1,1,1,2 Tetrafluoroethane	m-Xylene
Tetrafluoromethane	o-Xylene
Tetrahydrofuran	p-Xylene
Tetrahydrothiophene	