

## Sales Quotation

Thermo Process Instruments, L.P.

Quote No.	Create Date	Exp. Delivery Time	Pages
4093-1-SP-07-10-1-RGW	August 11, 2010	14 weeks	36
Contact Info	Phone No.	Payment Terms	Valid To
Rebekah Derryberry	302 992 4191	30 days net	October 11, 2010
Sal Mengine	302 992 4620		
Inco 1	Inco 2	Shipping Method	
FCA	Port of Entry	Air Freight & Motor Freight	

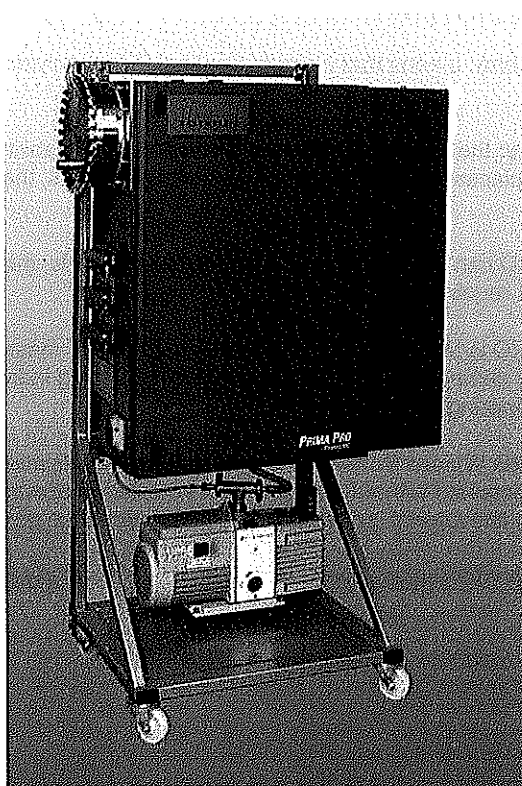
### Submitted To:

DuPont MST Engineering  
Wilmington DE

RE: Project C4887, Spec. 13I-7002

### Quotation For:

Thermo Scientific Sentinel PRO Environmental Mass Spectrometer



### Sales Manager:

Maggie Cline

### Prepared By:

Robert Wright

To place an order:

Call: 1-800-437-7979

Fax: 1-713-272-5331

Email: [unitprocessing.ps.sl@thermofisher.com](mailto:unitprocessing.ps.sl@thermofisher.com)

Additional instructions, terms and conditions apply.

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We are pleased to submit our proposal in response to your inquiry. This proposal includes the following sections within this document:

SECTION	PAGE NUMBER
<input type="checkbox"/> <b>COMMERCIAL SUMMARY</b>	3
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<input type="checkbox"/> <b>APPLICATION SUMMARY</b>	6
<input type="checkbox"/> <b>TECHNICAL DESCRIPTION</b>	9
<input type="checkbox"/> <b>SITE REQUIREMENTS</b>	26
<input type="checkbox"/> <b>TERMS AND CONDITIONS - GENERAL</b>	32

The Sentinel PRO is currently the world's leading environmental monitoring gas analysis mass spectrometer system with over 100 installed units worldwide. The system is designed for monitoring volatile compounds in ambient air and can monitor multiple sample points in the workplace, stack or perimeter fence. The Sentinel PRO allows species specific analysis down to concentration levels of parts per billion for a wide range of volatile organic compounds (VOCs). Many features of the Sentinel PRO make it the most powerful system available for multi-point, multi-component VOC monitoring applications.

- **Multi-stream sampling system:** means that a single Sentinel PRO analyzer can analyze multiple sample points.
- **Multi-component Capability:** the Sentinel PRO's multi-component capability, combined with multi-stream sampling system enables replacement of several conventional analyzers, therefore providing cost savings and reduced maintenance.
- **Sensitivity:** the Sentinel PRO can detect many VOCs to sub-ppm levels, therefore comfortably meeting today's health, safety and emissions requirements.
- **Specificity:** the Sentinel PRO is based on a powerful magnetic sector mass spectrometer analyzer. It can therefore positively identify a component in a complex mixture, enabling individual component levels to be reported accurately and minimizing false alarms.
- **GasWorks and Sentinel PRO Wizard Software:** Comprehensive applications software package that can be configured operated and maintained without any specialist knowledge of mass spectrometry. Sentinel PRO Wizard provides a unique on line tutorial, parts manual and maintenance guide.

We trust this proposal meets with your requirements. However, if you have any further questions then please do not hesitate to contact us.

## COMMERCIAL SUMMARY

Detail	Project Summary	Price
Page 3	<b>Tag No. 7040-8512 Sentinel Pro</b>	\$177,121
Page 4	<b>Tag No. 7040-8513 Sentinel Pro</b>	\$172,075
	<b>Two Day Factory Acceptance Testing at Winsford UK.</b> Does not include any special calibration gases, which if required would be charged at cost plus 10%	\$4,200
<b>TOTAL PROJECT</b>		<b>\$353,396</b>

**Note:**

Pricing includes crating and preparation for shipment. Thermo handles all customs clearance at port of entry and then forwards analyzer to job site via air ride suspension truck. We will notify DuPont when analyzers are shipping.

Quote detail follows:

Item	Configuration—TAG No. 7040-8512 (Mass Spec #1)	Price
1	Sentinel PRO Environmental Mass Spectrometer with temperature controlled 1kV ion source, scanning magnetic sector (scanning 0-1 Tesla) analyzer and configuration comprising: <ul style="list-style-type: none"> <li>GP air conditioned cabinet on a wall or floor-mountable frame</li> <li>Dual detector with double SEM / Thoria Filament</li> <li>Inlet Probe with Membrane Leak</li> <li>8 m3/hr Rotary Vacuum Pump</li> <li>TurboDrag Pump</li> <li>Standard side-channel blower sample pump for sample lines to 400m</li> <li>64-Port RMS with 1/4" Fittings and digital sample flow measurement</li> <li>Gasworks Software with Modbus and OPC Communications</li> <li>13 digital inputs, 13 digital outputs</li> <li>6 calibration ports</li> <li>Service Kit comprising ion source, vacuum gauge, leak, pressure/flow sensor board, membrane, seals kit, fuse kit and tools</li> <li>Prima Documentation Set (CD)</li> </ul>	\$149,033
2	5 day commissioning visit for start-up, testing and operator training. (Mandatory item.)	\$12,853
3	Conversion to 120V, 50/60 Hz	\$0
4	Sentinel PRO RMS sample genie filter	\$3,189
5	1 inch stainless steel sample tube kit (between RMS and sample pump)	\$2,613
6	Heat Shield	\$2,366
7	Kalrez 171mm o ring for RMS	\$1,076
8	Kalrez 4.1mm o ring for RMS	\$125
9	Spare Oil Ultra Grade 19 Edwards Rotary Pump (1.0 Litre)	\$61
10	Dell Computer For GasWorks With DVD Drive And 17" Monitor	\$1,500
11	PC Anywhere 32 Version Host + Remote	\$300
12	Stainless steel tag	\$478
13	Protocol converter Modbus to Profibus DP	\$3,527
<b>TOTAL Tag No. 7040-8512</b>		<b>\$177,121</b>

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Item	Basic Configuration—TAG No. 7040-8513 (Mass Spec #2)	Price
1	Sentinel PRO Environmental Mass Spectrometer with temperature controlled 1kV ion source, scanning magnetic sector (scanning 0-1 Tesla) analyzer and configuration comprising: <ul style="list-style-type: none"> <li>• GP air conditioned cabinet on a wall or floor-mountable frame</li> <li>• Dual detector with double SEM / Thoria Filament</li> <li>• Inlet Probe with Membrane Leak</li> <li>• 8 m3/hr Rotary Vacuum Pump</li> <li>• TurboDrag Pump</li> <li>• Standard side-channel blower sample pump for sample lines to 400m</li> <li>• 32-Port RMS with ¼" Fittings and digital sample flow measurement</li> <li>• Gasworks Software with Modbus and OPC Communications</li> <li>• 13 digital inputs, 13 digital outputs</li> <li>• 6 calibration ports</li> <li>• Service Kit comprising ion source, vacuum gauge, leak, pressure/flow sensor board, membrane, seals kit, fuse kit and tools</li> <li>• Prima Documentation Set (CD)</li> </ul>	\$143,987
2	5 day commissioning visit for start-up, testing and operator training. (Mandatory item.)	\$12,853
3	Conversion to 120V, 50/60 Hz	\$0
4	Sentinel PRO RMS sample genie filter	\$3,189
5	1 inch stainless steel sample tube kit (between RMS and sample pump)	\$2,613
6	Heat Shield	\$2,366
7	Kalrez 171mm o ring for RMS	\$1,076
8	Kalrez 4.1mm o ring for RMS	\$125
9	Spare Oil Ultra Grade 19 Edwards Rotary Pump (1.0 Litre)	\$61
10	Dell Computer For GasWorks With DVD Drive And 17" Monitor	\$1,500
11	PC Anywhere 32 Version Host + Remote	\$300
12	Stainless steel tag	\$478
13	Protocol converter Modbus to Profibus DP	\$3,527
<b>TOTAL Tag No. 7040-8513</b>		<b>\$172,075</b>

Item	Options	Price
14	Printer	\$305
15	Additional Instrument Documentation Set (printed)	\$311

## Notes and Exceptions

### RFX ES846705 ESP-XX-I-C4887 – Spec 7002 Mass Spectrometer

2.4, Freight Terms – The quoted equipment is manufactured in our Winsford, UK facility. The equipment is crated and shipped via air freight to the nearest port of entry. Thermo takes care of all import paperwork and customs clearance. Equipment will be shipped from nearest port of entry via air ride suspension motor freight to job site. DuPont to designate the carrier and freight terms will be collect.

2.5, Delivery date is 14 weeks, after acceptance of order. Approval drawings will be provided two weeks after order acceptance. Final drawings will be provided four weeks after receipt of approval drawings. The quoted equipment ships from Winsford, UK.

2.8 No detailed information concerning cost factors used to arrive at pricing will be provided. Thermo considers this information to be proprietary.

3.0, Terms and Conditions—Thermo proposes to use the previously negotiated Terms and Conditions between DuPont and Thermo for like equipment.

3.2, Payment Terms – Thermo standard payment terms are net 30 days. As an accommodation to DuPont, we believe that extended payment terms have been negotiated. Thermo will amend our standard payment terms to net 45 days for a purchase order arising from this quotation.

3.3 No, Thermo does not agree to the Terms and Conditions listed in Sections 3.1 and 3.2. See item 3.0.

4.0, Long Term Storage—Thermo agrees with these requirements.

### Equipment Specification 13I-7002

#### Engineering Notes

6. No Certificate of Conformance to Material Specifications for wetted surfaces is available.

#### Vendor Document Requirements

No parts list or bill of materials is provided. Thermo considers that information to be proprietary. Manuals for components such as the turbomolecular pump, sample pump, rotary pump, etc. will be provided.

There are no recommended spare parts. The Sentinel PRO analyzer is shipped with a maintenance kit that includes all items that would be necessary for maintenance of the system.

There is no spare parts list available. See note above concerning maintenance kit.

Specification "Mass Spectrometer DMAC in IR Analyzers", page 6 of 12

#### 2.0 Scope of Work

2.3, Training – Training classes are comprised of classroom time as well as a significant amount of "hands-on" training. Typically, during the start up service, the technician will conduct the classroom portion of the training on the day before he leaves site, after the analyzer has been commissioned. This classroom portion of the training typically lasts ½ day and the second half of the day is spent in "hands on" operational/maintenance training. It is practical to accommodate no more than 6 persons so that all participants get a chance to work with the machine. This basic familiarization training will ensure that plant personnel are conversant with the analyzer and capable of operating it. Thermo offers factory-based training classes that are more in-depth. The Sentinel PRO maintenance/operating course is one week long and takes place at either our Sugarland, Texas facility or at our location in Winsford, UK. Pricing is available if DuPont has interest. Please contact Maggie Cline at 979 345 5470 for more information.

2.4, Maintenance Support Contract – The quoted equipment is shipped with a maintenance kit that allows for the complete replacement of the inlet assembly, the ion source and the penning gauge. The anticipated maintenance

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interval is every 2-3 years. The turbomolecular pump located inside the analyzer is maintenance free for a period of three years. Maintenance contracts are available, but the analyzers quoted are warranted for three years. It is Thermo's recommendation that no maintenance support contract be purchased at this time.

3.0, System Description—No printers have been quoted. All spares are readily available in the USA with standard delivery times and no special costs or orders.

7.0 Tagging – Analyzers quoted will be provided with stainless steel tags as specified. Tagging requirements listed are not applicable to Thermo's scope of supply with the exception of item 1.

## TERMS AND CONDITIONS - SENTINEL PRO

<b>Prices</b>	Ex Works (packers Manchester) excluding local duty and taxes.
<b>Delivery</b>	Delivery times are currently 14 weeks for Sentinel PRO from acceptance of your order. This is our best estimate at the time of quoting and is subject to revision at the time of order placement.
<b>Standard Warranty</b>	12 months from date of commissioning or 18 months from date of shipment, whichever is the sooner. The warranty covers defects in goods and faulty workmanship but excludes consumable items such as filaments, filters etc.
<b>Enhanced Warranty</b>	All RMS mechanical components (excluding consumables) are covered by a 3-year parts warranty (36 months from shipment), subject to installation and operation in accordance with the instrument site guide and manual. All Thermo Scientific electronics are covered by a 3-year parts warranty (36 months from shipment), subject to commissioning and operation in accordance with the instrument site guide and manual. This is also subject to the instrument being maintained in accordance with the prevailing maintenance schedule by either Thermo Scientific employees or Thermo Scientific trained engineers and records of the maintenance kept in the GasWorks Instrument Log. Failure to comply with any aspect of the enhanced warranty terms results in the basic warranty terms prevailing.
<b>Commissioning date</b>	To be agreed with Thermo Scientific with at least 4 weeks notice and to be within 6 months of date of shipment unless agreed at time of order. Note that changing commissioning dates with less than 4 weeks notice may not be possible owing to other pre-arranged commissioning visits. Thermo Scientific will give dates at the earliest opportunity in keeping with Thermo Scientific commissioning plan. Commissioning can only be carried out by a trained Thermo Scientific engineer.
<b>Prepared site</b>	It is essential that the customer has a prepared site, with the necessary facilities to allow efficient commissioning of the Sentinel PRO system. A site readiness form will be issued prior to commissioning for completion and return to the installing Thermo Scientific office. Failure to comply with the site requirements (as enclosed) resulting in extended commissioning days or an additional visit will allow Thermo Scientific the right to charge at standard daily rate, plus expenses, for each additional day incurred.
<b>Training</b>	Initial operator training is provided during commissioning. Additional training (maintenance and application) can be arranged at site or our factory (at extra cost). Please contact us for details.
<b>Calibration Gases</b>	These are not supplied as standard, but mixtures will be recommended, as appropriate to the application. Acceptance on site is against measurement of an agreed set of calibration gas bottles supplied by the customer. Failure to have acceptance gases available at commissioning may result in additional commissioning costs, which will be charged at standard Thermo Scientific daily rate, plus expenses.
<b>Drawings &amp; Manuals</b>	One set of drawings and manuals are supplied with any system ordered, but will not be issued before an order is placed. Extra sets can be purchased. Modification to standard drawings or production of additional drawings will be charged at the appropriate rate.
<b>Testing</b>	Testing is performed to Thermo Scientific standard test specification. Special testing to specific customer requirements will be charged as appropriate for additional work and/or equipment/gases required.

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<b>Factory Acceptance</b>	Should this (extra cost) option be taken this will be performed at Thermo Scientific Winsford facility prior to shipment, tested on Air. See note above regarding special testing.
<b>Validity</b>	Until October 30, 2010.
<b>Order Placement</b>	All orders should be sent to: Thermo Process Instruments 1410 Gillingham Lane Sugar Land TX 77478
<b>Remit to</b>	<b>Thermo Process Instruments LP</b> P. O. Box 711998 Cincinnati OH 45271-1998
<b>Payment Terms</b>	100% on delivery at 30 days net.

## APPLICATION SUMMARY

## PERFORMANCE SPECIFICATION

Component	Detection limit	Measurement Range	Accuracy of analysis
Dimethylacetamide	< 0.1 ppm	0.1-100 ppm	< 0.05 ppm or 10% relative, whichever is larger

Dimethylacetamide will be monitored by measuring the molecular ion peak height at mass 87 and normalizing relative to the oxygen isotope peak of air at mass 34 ( $^{16}\text{O}^{18}\text{O}$ ).

Total analysis and settling time would be approximately 20 seconds per inlet.

Therefore for 20 sample points, the cycle time for measurement update on all 20 sample points is 400 seconds.

During commissioning, as a demonstration of performance, following calibration, 10 ppm of Dimethylacetamide will be monitored over 24 hours, and all readings shall be observed to remain within the range of 9.0 ppm and 11.0 ppm.

## CALIBRATION

The required calibration gases are the following:-

	Calibration Gas 1	Calibration Gas 2
Dimethylacetamide	10ppm	
Toluene	10ppm	
Oxygen	21%	21%
Nitrogen	Balance	Balance

Calibration gas 1 contains toluene as well as the measurement component Dimethylacetamide. The toluene is added in order to provide a reference, in the case of any degradation in the concentration of Dimethylacetamide. Normally the relative response of Dimethylacetamide/Toluene should remain within 10% relative.

Calibration gas 2 is recommended for use as a 'zero' gas, for calibrating the background and should contain less than 10 ppb of hydrocarbons.

Calibration gases should be contained in "A" size cylinders. Cylinder pressures should be the maximum obtainable up to 2500 psi, consistent with the components in them being non-condensing. Double stage regulators with 0-30 psi(g) output stages should be used in conjunction with the calibration gas cylinders to set the output pressure to the mass spectrometer calibration panel to ~15 psi to produce the correct flow rate during calibration. **It is the responsibility of others** to provide calibration gas cylinders, regulators and pipe-work leading from each cylinder to the calibration panel. It is recommended that electro-polished 316 stainless steel tubing be used for connecting the calibration cylinders to the calibration panel.

As an alternative to calibration gas 1 above, a Kin-Tek Permeation Gas Standard Generator can be used. This can either be ordered as an extra option, or be supplied by the customer. This will require a supply of instrument air at a pressure of 0-40 psig. Instrument air will be continuously consumed at 4 l/min.

## SAMPLE CONDITIONING REQUIRED

The Sentinel PRO requires sample line flow of 4 to 8 l/min. To maintain sample flow the system is supplied with a sample pump to create a vacuum inside the RMS of typically 200 - 250 mbar.

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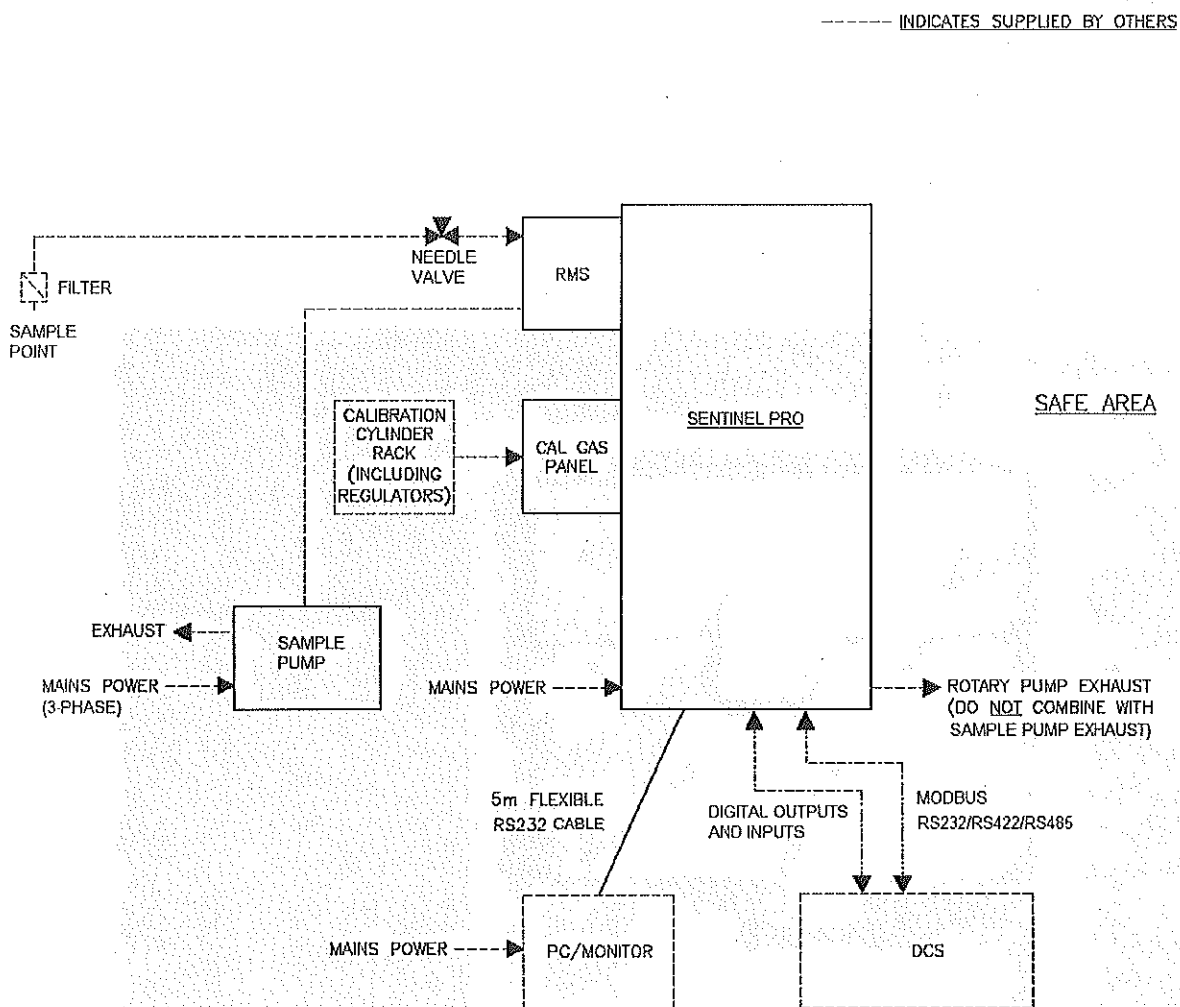
Field sample line material should be PTFE, FEP or PFA of between 4mm to 8mm I.D. The following is a guide to tube diameters required for different line lengths:-

	internal diameter tube of 4mm (5/32")	internal diameter tube of 6mm (1/4")	internal diameter tube of 8mm (5/16")
Up to 150 feet	Suitable	Suitable	Suitable
Between 150 feet and 800 feet		Suitable	Suitable
Between 800 feet and 1600 feet			Suitable

To protect the Sentinel PRO against dirt ingress and dust we recommend that a filter be fitted to each sample line pickup point. A typical filter could be the *Parker 9933-05-BQ* filter.

**It is the responsibility of the customer to supply all sample lines and filters.**

## INSTALLATION ARRANGEMENT

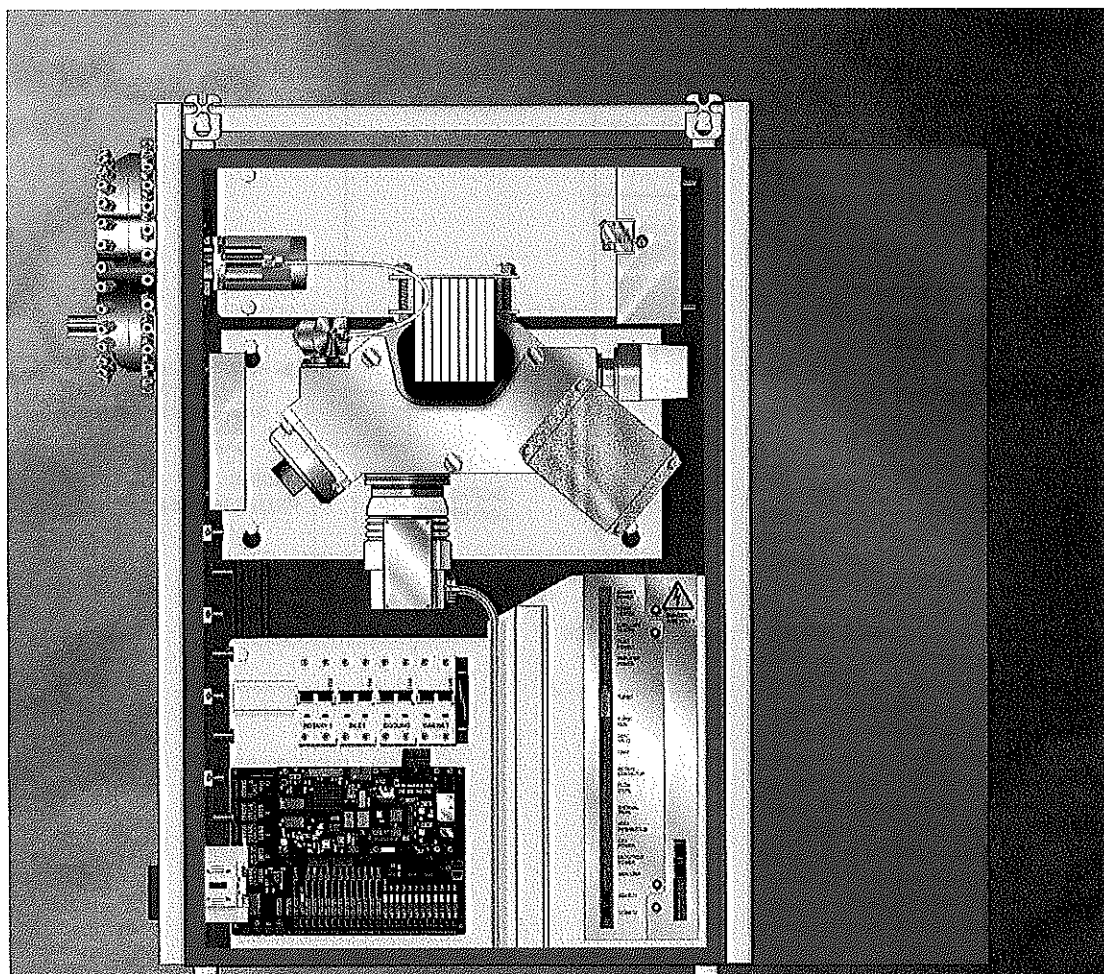


## TECHNICAL DESCRIPTION

### Introduction

The Sentinel PRO is a high performance gas analyzer based on a powerful and flexible scanning magnetic-sector mass spectrometer. The system has been designed to deliver superior analytical performance with high reliability and minimum maintenance.

The Sentinel PRO is a rugged, compact process monitoring system designed and built to ISO 9001 standards. The instrument is designed for continuous unattended operation in the most demanding process environments. It has been designed for ease of maintenance and simplicity of operation and to meet the most stringent electrical codes. The Sentinel PRO system conforms to EMC directives and meets the requirements for both radiated and conducted emissions.



### Principle of Operation

The sample gas is introduced via a stream selector and a pressure reduction system comprising a membrane inlet to introduce sample gas into the ion source under vacuum. Using an electron emitting filament, the ionization chamber converts the sample molecules into ions which are positively charged molecules or parts of molecules. These ions are then separated according to their mass by a variable magnetic field. The different mass ions are then quantified by the detector in accordance with the abundance of the signals at these masses.

## Main components

### **Analyzer:**

At the heart of the Sentinel PRO is a patented magnetic sector analyzer which offers unrivalled precision and accuracy. Thermo Scientific manufactures *both* quadrupole and magnetic sector mass spectrometers. Over nearly three decades of industrial experience has shown that magnetic sector based analyzers offer the best performance for industrial on line gas analysis.

Key advantages of magnetic sector analyzers include improved precision, accuracy, long intervals between calibrations and resistance to contamination. Typically, analytical precision is between 2 and 10 times better than a quadrupole analyzer, depending on the gases analyzed and complexity of the mixture.

A unique feature of the Sentinel PRO magnet is that it is laminated. This means that the Sentinel PRO magnetic analyzer can scan at speeds equivalent to that of quadrupole analyzers, therefore offering the unique combination of rapid analysis and high stability. The variable magnetic field is provided by a patented electromagnet with a laminated core, allowing the rapid and extremely stable analysis of a number of user-defined gases. The scanning magnetic sector is controlled with 24-bit precision using patented magnetic flux measuring technology for extremely stable mass alignment.

The ion source is an enclosed type for high sensitivity, minimum background interference and maximum contamination resistance. This is a high-energy (1000 eV) analyzer that offers extremely rugged performance in the presence of gases and vapors that have the potential for contaminating the internal vacuum components.

The ion optics is under full computer control, removing the need for manual tuning of the analyzer. Options are available for both single and dual detector ion sources. Temperature control to 0.1 degree C is a standard feature of the ion source, providing maximum stability and faster response to polar compounds.

Ion detection and amplification is encoded and transmitted to the local Processor using fiber-optic cable for maximum noise immunity. With the continually updated zero reading minor components can be measured more reliably in complex mixtures.

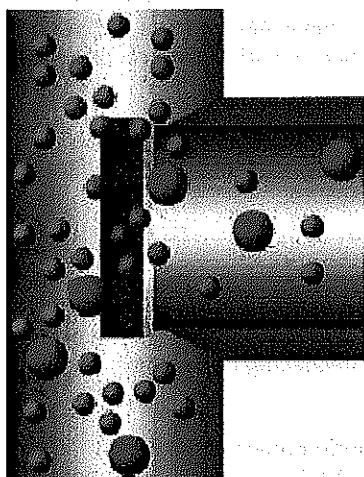
### **Inlet System:**

The unique RMS sample selection system sets new standards for multi-stream sampling, offering an unmatched combination of sampling speed and reliability, which allow selection of the gas sample from 1 of 32 or 1 of 64 streams. Stream settling times are application dependent and completely user configurable. The RMS includes digital sample flow recording for every selected stream. This can be used to trigger an alarm in case of fall off in sample flow, for example due to a blocked filter in the sample line.

This unit includes inlet control electronics, which provides electronic control of the stepper motor, calibration panel and RMS temperature (up to 120 deg. C). The position of the stream selector is optically encoded for reliable, computer controlled stream selection. The temperature and position control signals are communicated via the VG/ network, which will accommodate multiple inlet systems on a single analyzer.

**Membrane Inlet**

A key feature of the Sentinel PRO is its membrane inlet. This acts as a real time enrichment device for Volatile Organics, offering detection limits that are orders of magnitude lower than a conventional capillary inlet for VOCs.



Volatile Organic



Air gas

**Calibration Panel Options:**

A calibration panel is required when any of the RMS options is chosen since this type of inlet is a stream selector rather than a rotary valve. It has been designed to ensure that all sample streams flow continuously thereby eliminating transport lag and minimizing cycle time. It is necessary therefore to provide a control panel to ensure that calibration gas streams are only opened during calibration. The calibration valves are available in blocks of 6 up to a maximum of 4 panels (giving up to 24 calibration valves total) and come mounted to the side of the Sentinel PRO cabinet with a single tube connected to the appropriate port of the RMS. When the RMS is mounted through the analyzer shelter wall (so that no gas connections are made inside the shelter for enhanced safety) then the calibration panels are mounted outside on the same panel as the remote RMS.

**Electronics****Mass Spectrometer Power Supplies:**

Power supply and distribution has been engineered to ensure minimum power consumption and maximum reliability with extensive system monitoring at all points around the network. The principles of fault-tolerant design have been implemented throughout.

**Local Computer:**

The local processor provides embedded processing power for true, stand-alone control of all mass spectrometer functions. A local network provides control of all ancillary equipment. A serial port is provided for connection to a PC and an additional three configurable serial ports are provided for remote communication. As standard Modbus protocol communications are supplied (RTU or ASCII, both data logging and external control).

**Serviceability:**

The Sentinel PRO provides full maintenance access from the front of the unit via a hinged door.

The system analyzer monitors approximately 60 analyzer parameters (configuration dependent) continually, which ensures that any problems are easily detected and diagnosed.

**The Vacuum System:**

This includes the external rotary pump that provides backing vacuum for the high-performance combination turbomolecular pump and an active cold-cathode vacuum gauge for interlock protection of the ion source filaments.

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Space is available adjacent to the standard rotary for installation of the side-channel blower sample pump that is used to monitor atmospheric pressure samples.

### **Cooling:**

The cabinet is cooled by a side mounted air conditioner that stabilizes the temperature within the cabinet to within  $\pm 0.5$  deg C.

### **Wheels:**

The cabinet frame includes wheels for convenience when moving the system. Once the Sentinel PRO is in place the wheels can be removed if required.

### **Hazardous Area Operation:**

The Sentinel PRO can also be configured for installation in hazardous areas. In these situations a purged and pressurized enclosure is provided with the necessary controls to meet Class 1 Division 1 (X-purge), Class 1 Division 2 (Z-Purge) or ATEX zone 1. The hazardous area Sentinel PRO includes the appropriate motor for the external rotary pump.

**THERMO SCIENTIFIC SENTINEL PRO ENVIRONMENTAL MONITORING MASS SPECTROMETER SPECIFICATIONS**

Ion Source	Enclosed Electron Impact with Dual Filaments, temperature controlled (settable over range 100-200 degrees C, to $\pm 0.1$ degrees C)
Analyzer Type	Scanning Laminated Electromagnet, 6 cm radius, 80 degrees deflection
Mass Range	Adjustable, default is 1-150 amu at 1000 eV ion acceleration voltage, (at 500 eV ion acceleration voltage, mass range is 1-300 amu)
Resolution	Switchable between two collector resolving slits having resolving powers of 140 (0.36 mm) and 85 (0.69 mm)
Mass scale stability	Measured at mass 28 < 0.013 amu over 24 hours
Detector	Faraday/twin MCP-SEM dual detector
Inlet Type	Membrane leak
Sample Flow	Digitally measured and recorded for each stream for any instrument with RMS option
Vacuum System	Turbomolecular Pump and Rotary Pump
Precision	At 10 ppm concentration, readings vary by less than $\pm 0.5$ ppm over 24 hours and less than $\pm 1$ ppm over 1 month (typical, application dependent)
Linearity	<5% relative over decade change in concentration (typical, application dependent)
Dynamic range	10 ppb – 100 ppm or 100 ppb – 1000 ppm (typical, application dependent)

**COMMUNICATION OPTIONS****Serial Communications**

The Sentinel PRO supports many communication protocols on its serial ports (both RS-232C and RS-422 or RS-485). These may be used for both data logging and instrument control and may be intermixed as required. Connections may be made using either 7 or 8 data bits with one stop bit and parity may be set to None, Odd or Even. The baud rate may be chosen from the following list: 300, 1200, 2400, 4800, 9600, 19200 and 38400.

The supported protocols are:

VGCP  
Simple ASCII  
Siemens 3964  
Modbus  
OPC

The protocols are implemented in various flavours and the facilities they each support depend on the chosen style. Only one style for each protocol may be implemented in a single instrument. I.e. while it is reasonable to have both a PVGCP Slave and a Modbus ASCII Master, it is not possible to have both a Modbus ASCII Master and a Modbus RTU Master within a single instrument.

**VGCP** is available in these styles:

***VGCP Master (Data Logger)***

In this style, the only function available is transmission of Analysis results after each sample is completed. The message includes time-stamped instrument status and derived values as well as the Analysis concentrations.

***PVGCP Master (Data Logger)***

This adds checksumming and retries to the basic VGCP Master but no further features.

***VGCP Slave***

As a slave, VGCP requires the connected host to poll for Analysis results. The slave may also be commanded to control instrument functions such as: Enable Stream, Disable Stream, Start Scheduling, Start Calibration and Stop Activity.

***PVGCP Slave***

This adds checksumming and retries to the VGCP slave to provide a secure protected link to external gateways such as the X-Link.

A test program, written to operate on a PC under Windows, is included on the GasWorks distribution CD so that all four styles can be fully exercised on site. Xon/Xoff flow control (Software flow control) is supported in all styles.

**Simple ASCII**

Simple ASCII is available only as data logging, un-pollled connection, which transmits Analysis results after each sample is completed. Its format is suitable for connection to simple programs or even direct to a printer. There is no checksumming or retrying and Xon/Xoff flow control is supported.

**Siemens 3964**

Siemens 3964 is available in these styles:

***3964***

In this style, the format conveys Analysis results after each sample is completed. The message can include instrument status and derived values as well as the Analysis concentrations.

***3964R***

This style adds a checksum to the transmissions and expects the responses from the host to be similarly enhanced.

No flow control is supported for these styles.

**Modbus** is available in these styles:

**Modbus ASCII Master**

In this style, Analysis results are transmitted as scaled integers. The register map is user-definable and may be to more than one slave (RTU). Transmitted registers may contain values for time stamps, instrument status, Analysis concentrations and derived values.

**Modbus RTU Master**

This style transmits the above register data in the more common 8-bit RTU format.

**Modbus ASCII Slave**

As a full slave, the instrument may be commanded to control instrument functions such as: Enable Stream, Disable Stream, Start Scheduling, Start Calibration and Stop Activity. The host may also read all measured concentrations and derived values as well as the time stamps, stream alarm states and instrument hardware condition from a user-defined register map. The slave can be configured as any unit in the range 1 to 255.

**Modbus RTU Slave**

This style supports the above functions in the more common 8-bit RTU format.

Xon/Xoff flow control is supported for the ASCII Master and Slave styles only.

**Protocol Converter Hardware**

Multi-protocol gateways are available that can operate over RS232, RS485, Ethernet, and many proprietary networks and highways. Configuration and on-line diagnostics may be carried out with the unit in operation using a portable PC via an auxiliary port. This unit can also be operated in either data logging or remote control mode. Effectively this unit extends the range of communication options to include the following DCS communication standards: -

- Allen-Bradley Data Highway
- Allen-Bradley Data Highway Plus
- Allen-Bradley DH485 Allen-Bradley
- Allen-Bradley 1771 Remote I/O (scanner mode)
- Allen-Bradley 1771 Remote I/O (adapter mode)
- Allen-Bradley DF-1
- Allen-Bradley Ethernet
- Daniel Daniel Modbus RS 232 or 485
- Echelon Lonworks
- GE Fanuc Genius
- Magnetek MicroTrac Arcnet
- Modicon Modbus RS 232 or 485
- Modicon Remote I/O
- Modicon Modbus Plus
- Phoenix Contact Interbus-S (master only)
- Profibus Profibus-DP (master / slave)
- Reliance AutoMate Remote I/O
- Reliance AutoMate R-NET

**OPC**

We offer two options for OPC (OLE for Process Control or Open Process Control): -

**GasWorks OPC Data Logger (via GasWorks)**

This allows simple read-only OPC access to instrument statuses and stream analysis data (alarm indications, concentration values and derived values) via the GasWorks application. These OPC items are only available when the PC running the GasWorks workstation software is connected to the instrument.

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### **GasWorks OPC Server (via a dedicated MODBUS connection)**

As well as access to instrument statuses, stream analysis data (alarm indications, concentration values and derived values), this provides the ability to control the instrument - to start/stop analyses, enable/disable streams etc. It provides a direct connection to the instrument at all times and hence doesn't rely upon the PC running the GasWorks workstation software being connected to the instrument.

This functionality is provided by a separate application that can run on any PC having a dedicated serial link to the instrument (this link is in addition to any serial connection used to connect the GasWorks workstation to the instrument).

### **Analog and Digital I/O**

The I/O system is based around the OPTO22 OPTOMUX system and is typically located in a wall-mounted base unit enclosure along with the appropriate Brain Boards, power supplies, mains filters, cables and connectors. Communication with the Sentinel PRO is made over an RS-422 serial link composed of a dual twisted pair line, or optionally via fiber optics and RS232-RS422 converter for remote operation.

#### **Analog I/O**

Analog input and output modules are available in various types, namely 4-20 mA output, 4-20 mA input, 0-10V output and 0-10V input. Outputs can represent both gas concentrations and derived values. Examples of derived values are calculations (e.g. calorific value and Wobbe index) and system parameters (e.g. cabinet temperature and filament current).

#### **Binary 'stream ident' output**

Up to six digital output modules provide a binary representation of the inlet number to which the last set of analog outputs apply. A further output module provides a data valid flag which will be high when both the inlet number and analog data are valid.

#### **Digital external control**

The function of the inputs is to allow the user to perform a number of tasks without operating via the PC. These are used in either of two ways:

As a set of four modules to...

- Enable External Control
- Start Scheduled (multi-point) Analysis
- Start Calibration
- Go To Standby

Or as a set of two modules to...

- Start or Stop Schedule
- Run Calibration Now

#### **Instrument activity outputs**

The function of these outputs is to indicate the status of the analyzer: -

- External Control Active
- Running Scheduled Analysis
- Calibrating
- In Stand-by

#### **Stream inhibit digital inputs**

The function of this series of digital inputs is to allow the user to enable or disable any of the sample streams, which have been previously enabled for multi-point Analysis in the software. This function allows the user to effectively change the multi-point sequence without interrupting the Analysis; indeed it permits changes in the multi-point sequence to be made without making any operation on the PC or with the PC disconnected (i.e. in the stand-alone state).

#### **Component alarm outputs**

The I/O system may be configured to provide component alarm outputs on any or all sample streams; these may be associated with up to 10 different response categories (e.g. H2 20 mole % may be a response 1 category, N2 <

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30% may be a response 2 category, Wobbe < 2 may be a response 8 category). Each response category utilized requires a separate output module. Also, if the alarm is to be stream specific, each specified stream uses a separate output module.

### Hardware alarm outputs

The I/O system may be configured to provide hardware alarm outputs for up to 10 different response categories, each representing one or more hardware alarm states. For example: -

Hardware Alarm (user configurable)	Response Category (user configurable)
Vacuum failure	Response 1
Emission (filament) failure	Response 2
Ion Energy low	Response 3
Cabinet temperature high	Response 4
Source Pressure $3.9 \times 10^{-5}$ mbar	Response 4
Source temperature not at set-point	Response 5

### Note on Digital Inputs

Digital input modules can be configured to switch on with either high or low signals. The high signal voltage is in the range of 10 - 32 volts.

### Notes on Digital Outputs

Digital outputs provide voltage free contacts that can be configured either open or closed contact for any particular function. Digital outputs can be configured as either static or pulsed (selectable as either 0.5 or 1.0 seconds).

### Hazardous Area

There are two options for I/O systems for a Sentinel PRO installed in a hazardous area: either the I/O enclosure is placed in a safe area and communication is made using either fiber optics or explosion proof RS422, or the I/O is placed local to the Sentinel PRO inside an explosion proof enclosure (EXD IO).

**ANALYSIS BY SENTINEL PRO: ACCURACY AND DETECTION LIMIT CONSIDERATIONS**

Environmental gas monitoring by mass spectrometry is performed by continuously introducing the sample gas via a membrane into an ion source, where an electron beam interacts with the sample gas, causing a proportion of the sample molecules, as they pass through, to become ionized as various molecular, fragment and atomic ions. The resultant ion beam is accelerated and extracted by an electric field and then subjected to mass separation. The resultant separated component ion beams of different mass-to-charge ratio ( $m/z$ ) are recorded by the ion detector as a series of peaks. Characteristic peak signal strengths are (within limits) linearly proportional to concentrations. However, the results are subjected to a normalization process, in order to correct for the following effects:-

- Pressure and temperature effects in sample
- Detector response variation with time

Normalization is carried out as follows:-

Non-normalized Concentration (that is concentration prior to normalisation) is calculated  

$$= (\text{Measured Intensity} - \text{Background Intensity}) / \text{Sensitivity}$$

Normalized Concentration = Non-normalized Concentration  $\times 100 / [\text{Sum of Non-normalized Concentrations}]$

This assumes that all significant components in the gas sample are being accounted for in the analysis method. Therefore some components may be measured which are not of interest to the user, but are required in order to normalize the results. Frequently water is not included in the analysis, so that the normalized results have to be considered to be on a dry basis. For environmental gas monitoring with the Sentinel PRO, the significant components other than the target compound being monitored, are air components and it is convenient to measure them as a single component, i.e. 'air'. Air is monitored by using a minor peak,  $m/z$  34, which corresponds to the isotopic form of oxygen  $O^{16}O^{18}$  which is present in air at a concentration of ~850 ppm. This peak is chosen in preference to the more abundant air peaks in order not to saturate the sensitive SEM detector which is used for monitoring the component(s) of interest.

It is sometimes the case, that the peaks being measured are 'overlapped' or composite with contributions from more than one component. A de-convoluting data reduction technique is involved in deducing the component contributions to the peaks. On the Sentinel PRO this is performed automatically by an embedded processor in the mass spectrometer. An important assumption is made (and is generally obeyed) that the overlapping peaks, when combined, obey the principle of linear peak superposition. The principle of linear peak superposition is that the composite peak height at a particular mass is simply equal to the sum of the peak heights which correspond linearly to the individual concentrations of the contributing components in the complex mixture. This may be represented as follows:-

$$i_1 = s_1 f_{11} C_1 + s_2 f_{21} C_2 + s_3 f_{31} C_3 + \dots s_n f_{n1} C_n$$

where  $i$  is a composite peak height, and for 1 to  $n$  components contributing to this peak,  $s$  is the base peak sensitivity,  $f$  is its cracking pattern and  $c$  is its concentration. Values of  $s$  and  $f$  are determined for each component during calibration. During analysis the peak heights ( $i$ ) are measured for 1 to  $n$  (or  $>n$ ) masses so that there are at least  $n$  simultaneous equations to determine the  $n$  unknown values of  $c$ . Matrix inversion is used to solve these sets of simultaneous equations. These calculations are executed by the instrument computer to generate the concentration results. Some components may be measured which are not of interest to the user, but are required in order to deconvolute these interferences. A published mass spectral library (e.g. NIST) can be checked to see if there are interferences from other components possibly present.

There can be variations in the values of  $s$  and  $c$  caused by changes in the detector response: these may change by up to 5% relative. The extent of change in these values can be minimized by running a calibration gas mixture at regular intervals to decide when re-calibration is necessary. This is most easily accomplished by scheduling an automatic calibration which a pre-check with appropriately set tolerances on the calibration gas, for example on a daily basis. If the check analysis of the calibration gas in the pre-check falls outside any of the tolerances, a complete calibration is performed

As a 'rule of thumb' the uncertainty due to interference of measurement of particular component A using a particular peak intensity will be equal to  $0.05 \times (\text{intensity due to overlapping components}) / \text{sensitivity of A}$

This can be expressed as:-

$$0.05 \times (\Sigma \text{concentration} \times \text{sensitivity of overlapping component}) / \text{sensitivity of A}$$

This effect of overlapping peaks will particularly influence the accuracy of measurement and even the ability to detect a component in the presence of interfering components. The lower the sensitivity of the component being measured relative to the overlapping component, the worse the effect. The sensitivity depends not only on the ionization efficiency and mass spectrometer analyzer transmission efficiency, but also the permeability of the component to the silicone membrane inlet.

Consideration should also be paid to possible errors due to errors in the concentrations of the calibration gases themselves.

Another limitation to the detection of a component is the background. Generally a component can be detected down to a concentration for which the peak intensity is  $1/10^{\text{th}}$  of the background peak intensity. Typically background levels are equivalent to the range of 0.1 ppm to 1 ppm for a 'low' sensitivity component such as VCM. Note for a higher sensitivity component such as benzene which has a sensitivity typically 20x greater than that of VCM, the backgrounds are accordingly less significant by a factor of 20 (in the range of 0.005 ppm – 0.05 ppm). For an even higher sensitivity component such as styrene which has a sensitivity typically 200x greater than that of VCM, the backgrounds are accordingly even less significant by a factor of 200 (in the range of 0.0005 ppm – 0.005 ppm). It is seen that the significance of the background depends very much on the sensitivity of the component of interest.

Lastly, a further limitation on detection is the noise of the detector. The noise of the detector depends on the integration time, being inversely proportional to the square root of the integration time. The SEM detector uses a  $1 \times 10^9$  ohm amplifier feedback resistor and is operated with a gain of typically 10,000 (twin MCPs) but might be somewhat less depending on the upper detection limit required. The maximum voltage that can be measured with the detector amplifier is 10 volts, corresponding to  $1 \times 10^{-8}$  amps. The detector electron output noise due to the amplifier is typically  $\sim 2 \times 10^{-14}$  amps (expressed as the standard deviation of the baseline) for a 1 second integration time. This is equivalent to  $2 \times 10^{-18}$  amps ion current at 10,000 gain. However there is another significant contribution to noise on the SEM besides the amplifier. This is statistical noise. Statistical noise arises from the fact that the ion current is a beam of discrete charged particles and therefore each particle has a certain probability it will reach the detector within a certain measurement window (during the integrated measurement). The standard deviation of the ion current due to statistical noise is given by:-

$$\text{St Dev} = n^{1/2} / n \times \text{ion current}$$

where n is number of ions measured during the integration time

$$\text{for a 1 second integration time } n = \text{ion current} / 1.6 \times 10^{-19}$$

since  $1.6 \times 10^{-19}$  is the charge in coulombs on each singly charged ion and amps = coulombs per second.

$$\text{Therefore St Dev} = (\text{ion current} \times 1.6 \times 10^{-19})^{1/2} \text{ amps}$$

**GASWORKS SOFTWARE FOR WINDOWS 2000, XP AND VISTA****Introduction**

GasWorks has been designed to ensure that the Thermo Scientific gas analysis mass spectrometers can be easily configured, operated and maintained without specialist knowledge of mass spectrometry. The system is based on our extensive experience of the needs of process users and, as such, includes industry standard communication protocols, multilevel security, event logging, automatic calibration and tuning, diagnostics and on-line help. The software suite also benefits from an extensive array of data presentation forms that can be configured to meet the needs of a variety of control-room or laboratory situations. This document provides only a brief overview of what can only be described as the most comprehensive software package provided by any analyzer manufacturer in the world.

**System Architecture**

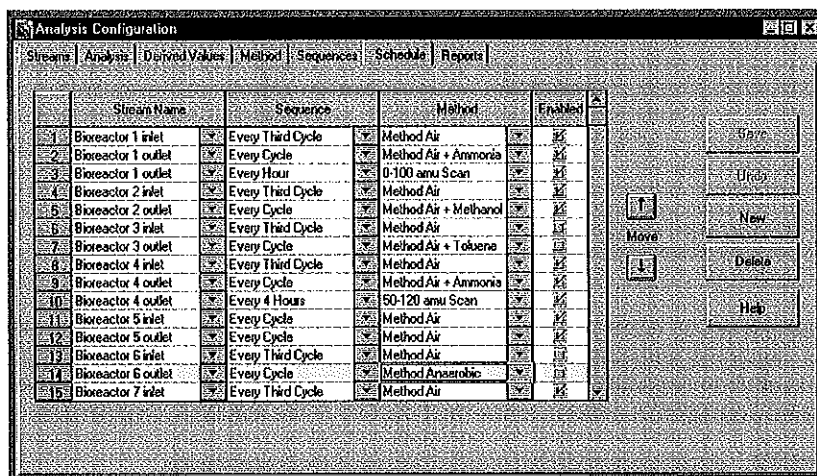
GasWorks is a two-processor system. The primary machine is the control engine built into the instrument. It provides a fully multitasking 32-bit real time control system which manages all aspects of instrument control. It contains a database of all instrument configuration and operational details and retains this through power fail thus allowing restart without user intervention. Since this database contains all data needed for instrument operation, the analyzer can be configured and then left to run through its scheduled processes with no further intervention, simply sending its results to the DCS and calibrating itself when necessary. The instrument controller needs no installation since its program is burned-in and its data is loaded from the host GasWorks machine.

The host GasWorks machine is a PC operating under Windows 2000, XP and Vista. It provides a convenient graphical user interface for configuring analysis methods, derived value calculations, calibration routines, communication protocols, I/O, alarm levels, etc. The host GasWorks machine also provides real-time analysis numeric and trend displays, together with various mass spectral scan modes, data logging in csv spreadsheet format and DDE for presentation of the data over a network. Also provided are comprehensive data review programs for numeric and trend displays and statistical calculations of stored data.

The primary machine can operate in stand-alone mode: i.e. analyse, auto-calibrate and provide data without connection of the host GasWorks machine.

**Analysis Configuration**

The analysis configuration for an application is normally pre-programmed by Thermo Scientific application engineers. Components can however, be simply added or removed from the analysis by the user should this be desired. GasWorks is tailored to treat sample streams differently if the application demands, with the user having full control over the analysis performed, alarm levels and actions, auxiliary inputs and outputs, data logging and report generation.



The screenshot shows the 'Analysis Configuration' window with tabs for Streams, Analysis, Derived Values, Method, Sequences, Schedule, and Reports. The 'Streams' tab is active, displaying a table with 15 rows of stream configurations. To the right of the table are buttons for 'Move', 'New', 'Delete', and 'Help'.

	Stream Name	Sequence	Method	Enabled
1	Bioreactor 1 inlet	Every Third Cycle	Method Air	<input checked="" type="checkbox"/>
2	Bioreactor 1 outlet	Every Cycle	Method Air + Ammonia	<input checked="" type="checkbox"/>
3	Bioreactor 1 outlet	Every Hour	0-100 amu Scan	<input checked="" type="checkbox"/>
4	Bioreactor 2 inlet	Every Third Cycle	Method Air	<input checked="" type="checkbox"/>
5	Bioreactor 2 outlet	Every Cycle	Method Air + Methanol	<input checked="" type="checkbox"/>
6	Bioreactor 3 inlet	Every Third Cycle	Method Air	<input checked="" type="checkbox"/>
7	Bioreactor 3 outlet	Every Cycle	Method Air + Toluene	<input checked="" type="checkbox"/>
8	Bioreactor 4 inlet	Every Third Cycle	Method Air	<input checked="" type="checkbox"/>
9	Bioreactor 4 outlet	Every Cycle	Method Air + Ammonia	<input checked="" type="checkbox"/>
10	Bioreactor 4 outlet	Every 4 Hours	50-120 amu Scan	<input checked="" type="checkbox"/>
11	Bioreactor 5 inlet	Every Cycle	Method Air	<input checked="" type="checkbox"/>
12	Bioreactor 5 outlet	Every Cycle	Method Air	<input checked="" type="checkbox"/>
13	Bioreactor 6 inlet	Every Third Cycle	Method Air	<input checked="" type="checkbox"/>
14	Bioreactor 6 outlet	Every Cycle	Method Anaerobic	<input checked="" type="checkbox"/>
15	Bioreactor 7 inlet	Every Third Cycle	Method Air	<input checked="" type="checkbox"/>

**Data Presentation**

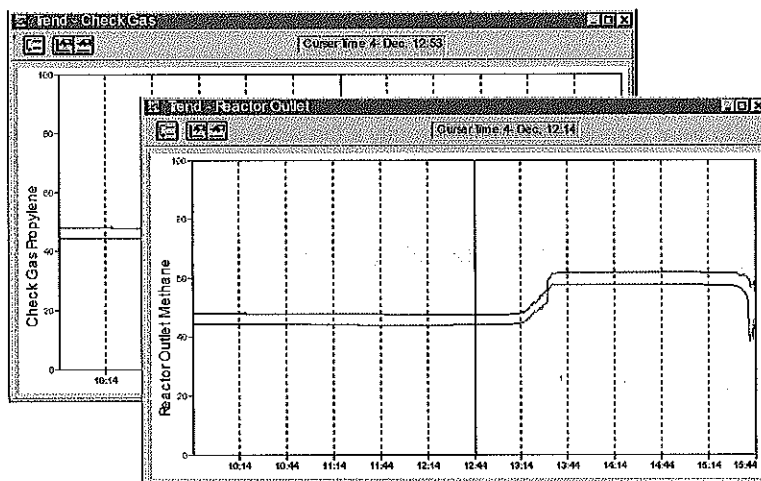
The "Numeric" screen provides a spreadsheet view of the data as it is generated by the mass spectrometer. The user can manually scroll through the data to view recently generated data on any of the enabled sample streams or this form can be configured to auto-scroll so that the most recent data is always presented.

Received Results Data From - 8 Sample Line 16-Nov-00 13:11:36.42					
Stream	5 Sample Line 16-Nov-00 13:11:10.29	6 Sample Line 16-Nov-00 13:11:17.76	7 Sample Line 16-Nov-00 13:11:26.42	8 Sample Line 16-Nov-00 13:11:36.42	
Analyte					
Air	100.00 %	100.00 %	100.00 %	100.00 %	
Dichloroethane	0.37 ppm	0.36 ppm	0.31 ppm	0.25 ppm	
Vinyl Chloride	0.00 ppm	0.00 ppm	0.00 ppm	0.00 ppm	

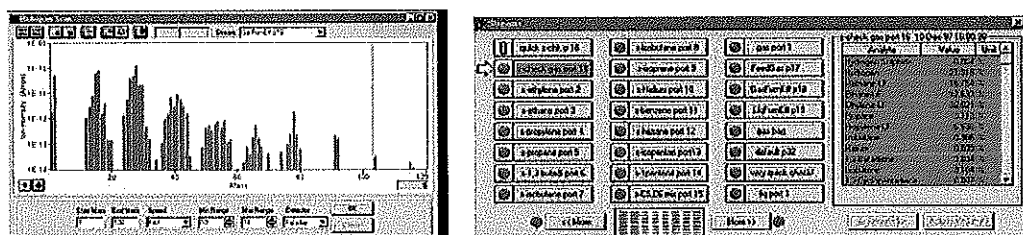
☐ Manual Scroll    ☒ Automatic Scroll

No limits on the number of components are imposed by the software, which can present raw mass spec data, on-line calculations (derived values) system parameters and external analog signals in addition to the calculated gas concentrations as shown above.

Multiple trend screens can also be provided for graphical presentation of data. This is of particular importance where the mass spectrometer is used to monitor a number of independent processes. Where this is the case, each process would have its own trend form, which is made available for display by selection from a drop-down list.



Each new trend form is configured using a set-up wizard which provides easy analyte and stream selection, axis configuration (log mode, linear mode, manual & automatic dynamic range, time, etc.) and trace color. Where a complex set of axes is required to present both logarithmic and linear plots on a single form then multiple y-axes are supported. Each form can be positioned and sized in order to make the best use of the available display area.



Many other data display forms are included in the standard GasWorks package including the "Scan" and "Streams View" forms shown above. The Streams View is particularly useful when the analyzer is used for environmental monitoring. Each sample stream is provided with a green/red LED style indicator and a button that is used to display the gas concentrations in the stream window. If a gas concentration goes above its alarm set-point, then the operator simply clicks on the button with the red alarm indicator and he will see the offending component hi-lighted in red. This display also indicates the currently selected stream -- a feature that allows the operator to judge when the next measurement will be made on any given sample port.

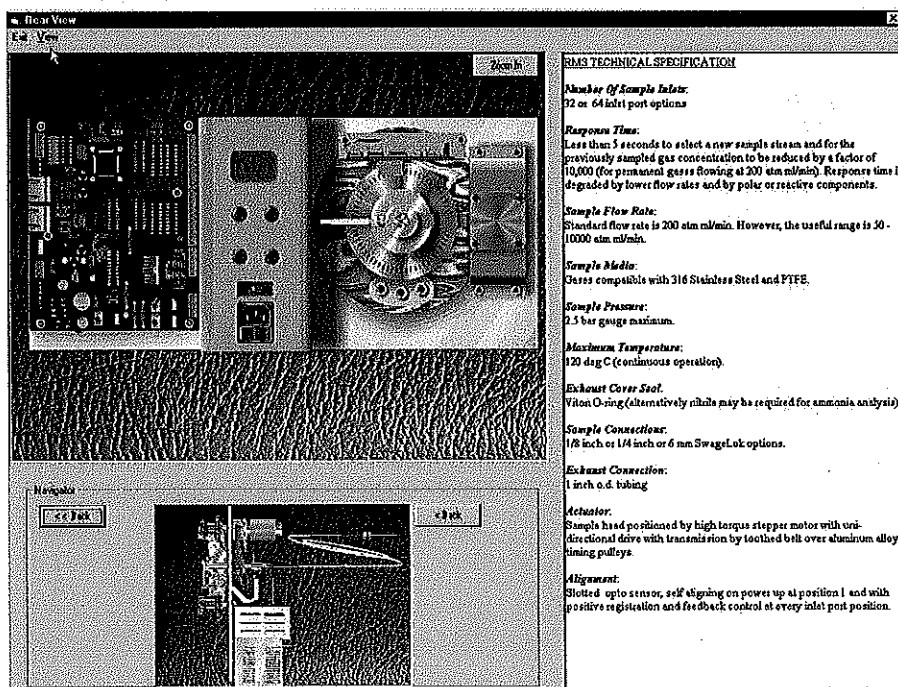


### System Security

GasWorks incorporates full multi-layered and user-definable security mechanisms. Before the operator can do anything, it is necessary for him to log in to gain operational authority. Password checking is performed before he is granted access to any system functions

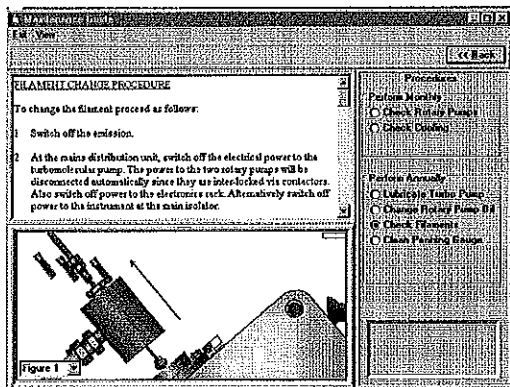
### Sentinel PRO Wizard: Expert System Software

This software package is an extensive knowledge base for the mass spectrometer system that is provided in order that the user has all the information that he needs to operate and maintain the analyzer right where he needs it - at the mass spectrometer. The software is easily navigated using command buttons and pull down menus with each subassembly having a number of "views" that can be selected in order to display the information being sought. These views include tutorial, parts manual, assembly dimensions, animations, electronic schematics, electrical connections and component options. Sentinel PRO Wizard includes application information such as recommended calibration methods, sample conditioning suggestions and typical plant data.

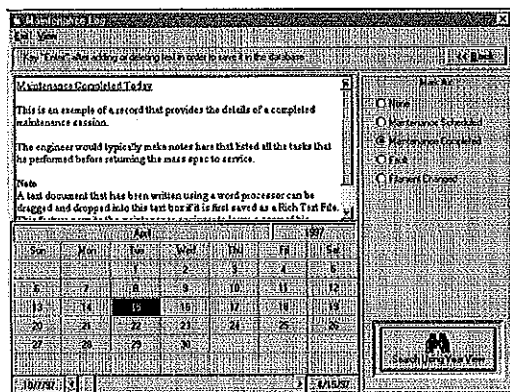


**Maintenance and Troubleshooting**

Preventative maintenance procedures are presented with clear and concise illustrated text to help guide the maintenance technician through the recommended routines. The troubleshooting section guides the user through a logical sequence of tests that will first localize the root-cause of a problem and then describe the solution. Maintenance and troubleshooting procedures are supplemented by a Maintenance Log that records maintenance history throughout the life of the analyzer.

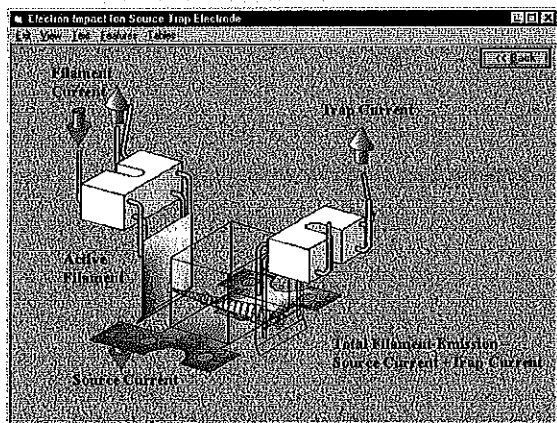


**The Maintenance Log** has a year view that can be used to locate a color-coded event such as a completed maintenance procedure or a reported fault. The selected record can be edited to include all the necessary information that might be useful for future reference.



**Tutorials**

Since the user is more likely to get maximum benefit from the mass spectrometer data if he understands the underlying concepts of the technology, we have included a series of tutorials that explain the fundamental operating principles of the Sentinel PRO. The illustrations, text and animations are used extensively during operator training at the time of installation and are often reused when in-house training is required at a later date.



**NOTE ON INSTRUMENT PACKING AND TRANSPORTATION**

*The instrument is packed using a wooden crate in which it is sealed in foil with desiccant. Although it is secured within the wooden crate, the instrument assembly itself is susceptible to possible misalignment or even damage by excessive vibrations or shocks. Accordingly the crate is fitted with 'shock-watch' and 'tilt-watch' indicators. We recommend that any transportation by road should be by vehicle fitted with air ride suspension to minimize vibration and shock transmission and a tail lift capable of handling at least 500 kg.*

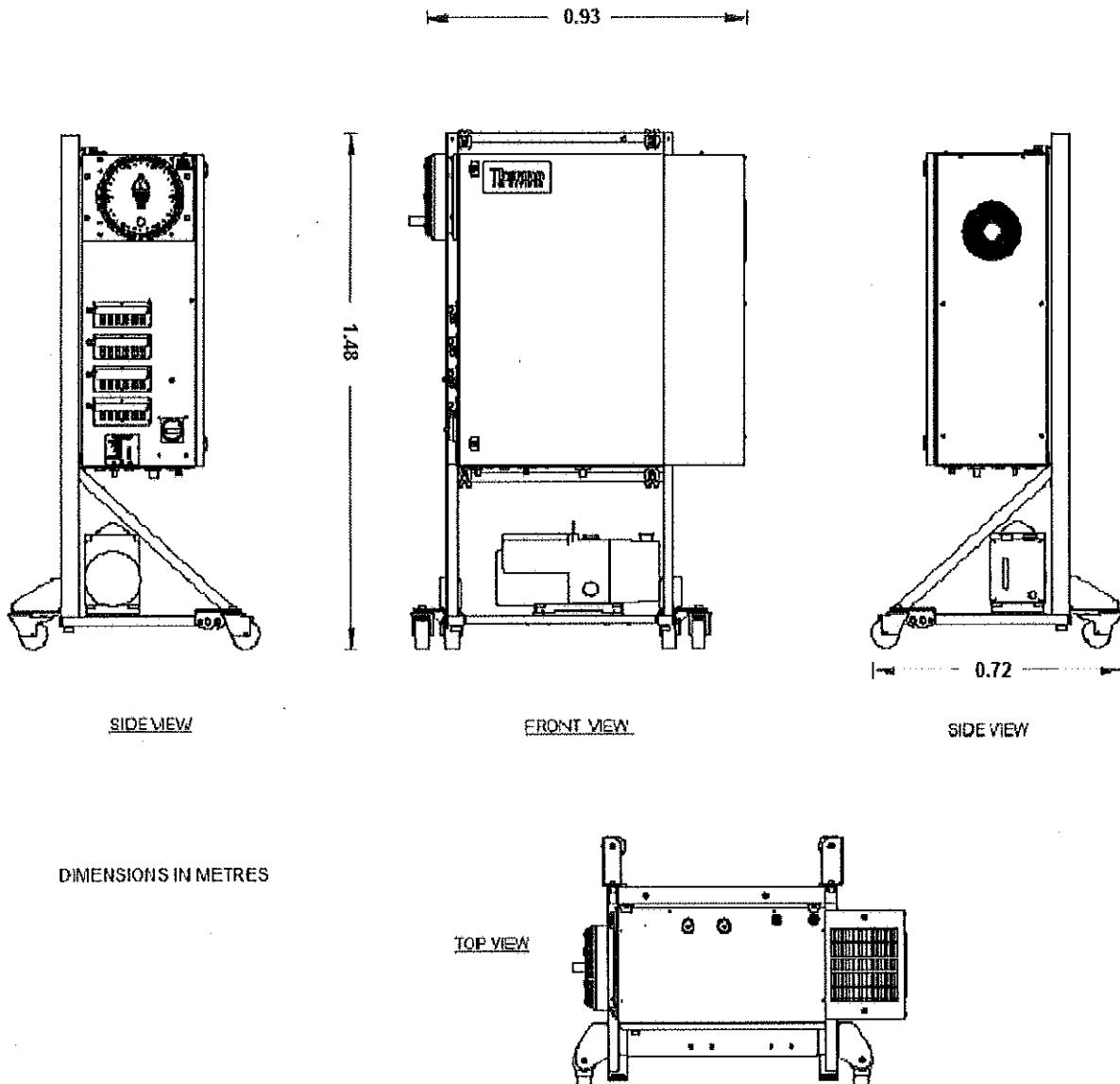
**NOTE ON INSTRUMENT STORAGE**

*Whether for an extended period or simply prior to installation the instrument should be stored in the following manner:*

- *In a secure location*
- *Upright*
- *Dry (protected from standing and falling water etc.)*
- *Between 5 degC and 40 degC (40 degF and 105 degF)*
- *90% Maximum humidity – Non condensing*
- *All packages together*

## SITE REQUIREMENTS

## System Dimensions



DIMENSIONS IN METRES

TOP VIEW

**Cable Entries - General Requirements**

A blank gland plate is supplied in the enclosure base. This is the only place where drilling the enclosure for user cable entries as allowed.

**Prima Pro / Sentinel PRO**

Any cable glands compatible with the cable/conduit type being used are acceptable.

**Computer and Communications**

The PC system typically comprises computer, monitor and printer. A detailed specification for the PC is available separately. The PC is connected to the instrument enclosure by means of a serial link.

Serial link connections to the instrument are made directly in the case of a general purpose (GP – safe area) system. Connection to the labelled terminals on the User I/O PCB in the bottom of the instrument enclosure is made via the gland plate. Other serial connections (e.g. link to DCS) are also made here. However in the case of an Ex

system, connections are made either using fiber optics or via the EXD isolation unit. The EXD isolation unit is a flameproof enclosure mounted on top of the instrument frame and connected to the instrument via flameproof conduit and providing isolation from all incoming signals when the instrument is switched off.

A number of different formats for the serial links are possible.

- a) RS232. Simple 3 wire link, transmission distance 5 metres. May be extended by the use of good quality screened cable.
- b) RS422. 4 wire link, extended transmission distances.
- c) RS485. 2 wire link, extended transmission distances (not available for host PC communication).
- d) Fiber optic RS232 - transmission distance up to 1000 metres. One pair of standard fiber optic modems is supplied for a Ex system not using an EXD isolation unit, with one modem being located in the instrument enclosure and one modem being located at the PC). The interconnecting fiber optic cables (a pair of fiber cores) are customer supplied and must have the following properties:

- ST termination
- Support multimode operation
- Compatible with LED drivers.

Typically a 62.5  $\mu\text{m}$  glass fiber is used. However, any size or material of fiber compatible with the requirements above may be used, although the transmission distance may be impaired. The individual fiber cores should be fitted with ST connectors on suitable length tails (all connections are to points inside the enclosure). It should be noted that installation and termination of the fiber optic cable is a customer responsibility.

Additional fiber optic pairs may be required for additional communications (e.g. link to DCS). In general it is recommended that a minimum of 6 or 8 core cable, is installed to allow for future expansion.

#### **Instrument Location**

##### **Temperature**

The ambient temperature should be between 12°C and 40°C.

##### **Humidity**

90% maximum, non-condensing.

##### **Vibration**

The instrument should be isolated from vibration sources. The vibration amplitude should be less than 1 mm in the frequency range of 0.1 Hz to 500 Hz.

##### **Particulate Contamination**

The instrument should ideally be positioned in an environment free of particulate contamination of greater than 50 $\mu\text{m}$ . If used in a dusty environment then it can be helpful to have a 'dry' gas cylinder (e.g. nitrogen or argon) available, to provide a clean gas blanket if the vacuum system needs to be opened up for servicing (typically once or twice a year).

##### **Inlet Gas Connections**

Calibration and sample gases connect to the multi-point RMS inlet by means of standard compression fittings (1/8" or 1/4" or 6mm depending on the customer's preference which is defined in the order). All fittings are supplied with PTFE blanks fitted (ferrules packed separately), primarily to provide a seal during transit. These may be used to blank unused ports, but for long term use, particularly at elevated temperatures, stainless steel blanks should be substituted.

##### **Calibration Gases**

Calibration panels (each having six gas channels) are used to control calibration gas flow. Each channel is supplied with an actuated valve - the valve is only opened when required, so that the (expensive) calibration gas is only allowed to flow when required and consumption of the gas is therefore minimized. The line pressure is adjusted to give the correct flow of calibration gas during calibration: typically 100 - 200  $\text{cm}^3\text{min}^{-1}$  of gas (5 l  $\text{min}^{-1}$  for Sentinel PRO) is allowed to flow over a 1-2 minute period). The flow rate is displayed by the GasWorks software in the status window.

The calibration gases connect to the inlet of the calibration panel via standard 1/8" or 1/4" or 6mm compression fittings. There is a single outlet for each calibration panel connecting to a port on the RMS inlet - the default is for the

calibration panel to be mounted on the side of the enclosure, in which case this connection is already made. For remote mounting calibration panels, it is a customer responsibility to supply and install the extended gas lines (1/8" compression fittings) and electrical / pneumatic valve drive lines. The line length should be minimized in order to give reasonable response times (<5 metres).

The calibration gases required are generally specified in writing to the customer shortly after receipt of the order and some time prior to the intended installation - this enables ordering and delivery of these frequently long-lead items. The calibration gases should be of the highest quality with a certificate of analysis from the manufacturer giving a concentration tolerance for each component. Helium gas (for instrument background measurement) should be at least 99.995% pure.

**The quality and stability of the calibration gases is important since the accuracy of the data given by the instrument is directly related to the accuracy of the certified levels of calibration gases.** Attention needs to be given to the possible effects of temperature (e.g. causing condensation). Advice can be sought from the gas supplier.

Double stage regulators with 0-2 bar(g) output stages should be used in conjunction with the calibration gas cylinders. It is the customer's responsibility to provide calibration gas cylinders, regulators and pipework leading from each cylinder to the calibration panel.

#### **Sample Gases**

It is the customer's responsibility to install sample lines up to the inlet. The lines can be stainless steel, PTFE or nylon but must be compatible with the gas flowing and the operating temperature.

**Each stream requires conditioning with, as a minimum, a filter to prevent particulate contamination and a flowmeter to verify flow.** The flowmeter should typically be 1.0 l min<sup>-1</sup> full scale (10 l min<sup>-1</sup> full scale for Sentinel PRO), but note that flows in the range 0.1 - 10.0 l min<sup>-1</sup> range (4 - 10 l min<sup>-1</sup> range for Sentinel PRO) may be acceptable - consult factory/manuals for further details.

Generally a 2 µm particulate filtering device is recommended. It is also necessary to prevent the introduction of liquid droplets into the RMS inlet system by use of suitable liquid traps or by using heated lines, with care to avoid cold spots. The RMS can be heated to any temperature from ambient up to 120°C, depending on the application.

For some applications, spare ports on the RMS can be used to admit a purge or diluting gas. This may be to dilute a corrosive, reactive, condensable, or hazardous (e.g. explosive) gas mixture to a safer concentration (in some cases, such gas mixtures may be formed by mixing of different incoming process gases streams in the common RMS exhaust). This action can reduce the requirement for special materials and heat tracing of the exhaust line. The purge flow will require regulation and monitoring, but the exact requirements will be application specific - consult the factory for advice.

#### **Exhaust Gas Connections**

There are two outlets, which should be exhausted to the outside or into a vent, i.e. not into the work area. These are:

- (i) Rotary pump exhaust (1/2" OD outlet tube).
- (ii) RMS inlet exhaust (1.0" outlet tube) or solenoid inlet exhaust (1/4 inch compression fitting). This exhaust line may need to be heated to avoid condensation problems.

*Sentinel PRO Sample pump exhaust (1.25 inch hose connection). **Note, Sample exhaust temperature can reach 100 deg centigrade, Therefore heat resistant hose must be used.***

**Please note that interconnection of these two exhausts MUST be avoided.** This is because the rotary pump exhaust contains an oil mist which could cause very serious contamination problems if allowed to enter the RMS inlet (and hence the capillary the mass spectrometer). If interconnection is unavoidable, it should take place several metres downstream, and a positive flow on the RMS exhaust guaranteed, to reduce the chances of back flow.

The possibility of any condensation in either exhaust back draining to the instrument should be avoided by either ensuring a continuous downward gradient on the line, or fitting of suitable traps. It is the customer responsibility to supply all the necessary pipework to connect the two exhaust outlets to a suitable location.

## Sales Quotation

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### Power Requirements

#### Power Supply Requirements

A single phase, power supply is required 115VAC ( $\pm 5$ VAC) 60Hz.

The normal 'running' average power consumption and start-up current are listed below (the latter is higher due to the "cold start" of the rotary pump, and is drawn for approximately 5 seconds falling quickly to the normal 'running' average).

	single rotary pump	two rotary pumps
Running power	1.6kVA	1.9kVA
Startup (115V/230V)	40A/20A	70A/35A

The instrument must be earthed.

### Power Connection

#### Sentinel PRO

Power is connected through the gland plate in the bottom of the enclosure to the terminals of the main breaker (labelled power). The earth (ground) connection is to the earth stud adjacent to this breaker.

#### Sentinel PRO Sample Pump Power Connection – Safe Area

A 3 Phase supply is required to drive the sample pump motor rated at 1 kW and 1.3 kW for the standard and higher capacity sample pumps respectively. The customer is required to make connection to the motor terminal box. Details for connection can be found inside the terminal cover box lid. The customer is also required to install suitable motor protection to meet local factory requirements.

For 220 - 240 volt systems a 400 volt 3 - phase  $\pm 10\%$  supply is required.

For 110 - 120 volt systems a 460 volt 3 - phase  $\pm 10\%$  supply is required.

#### Purge Requirement - Sentinel PRO

Since the instrument enclosure is sealed, the possibility exists of a minor internal leak of sample gas building up to high concentration levels. This is of concern if the gas is flammable or toxic. A purge port exists on the enclosure to enable continuous or pre-servicing (as required) purging with instrument air - the air supply must be clean and dry. Connection is to a 1/4" compression fitting in the instrument cabinet.

It is a customer responsibility to determine the purge flow rate and maintain its operation.

#### External I/O Unit

The External I/O unit is a wall mounting box of the following dimensions in the case of a safe area unit: height 0.6 metres, width 0.6 metres, depth 0.21 metres, approximate mass 40 kg.

The I/O unit must be located in a safe area, unless an EXD I/O has been supplied.

The EXD I/O unit is a wall mounted flameproof enclosure connected to the instrument via flameproof conduit and providing isolation from all incoming signals when the instrument is switched off.

The connection to the main instrument enclosure is RS422 or fiber optic RS232.

The unit has a blank gland plate in the bottom to enable drilling for user cable/conduit entries. Any cable glands compatible with the cable/conduit type being used are acceptable.

## Sales Quotation

Thermo Process Instruments, L.P.

### GasWorks PC Specification

If a PC is not purchased with the instrument, then a PC of the following specification needs to be supplied for installation of the GasWorks software:-

Some of the PC requirements vary greatly depending on the operating system chosen and so the recommendations have been shown for Windows 2000, Windows XP and Windows Vista (Business edition).

	<b>Windows 2000/XP</b>	<b>Windows Vista (Business)</b>
Processor	400 MHz (min)	1 GHz (min) 32 bit processor
System Memory	128 MB (min)	1 GB (min)
Hard Drive	20GB (min)	40GB (min)

The following GasWorks requirements are common to any of the above listed operating systems.

Display	17" (1024 x 768) Colour
Mouse	Any Windows supported mouse
Keyboard	Any Windows supported keyboard
Communication Port (GasWorks)	A 9-pin serial port or a USB-RS232 converter
Optical media	DVD-ROM or DVD-RW

The following optional items are common to any of the above listed operating systems.

Printer (optional)	Any Windows supported printer
Modem (optional)	Any Windows supported Internal or external modem

Note that for the option of single line printing of alarms it is necessary to have a non-page feed printer, that is, a continuous feed printer such as an Epson LQ-300+II.

The GasWorks PC may be networked. However, note that Network DDE is no longer supported under Windows Vista. Refer to the GasWorks Software Release Notes for further information.

GasWorks has been developed exclusively on Dell Optiplex PCs and is fully tested on those. It has also been successfully installed on HP Vectra, Digital and Compaq desktop PCs as well as Dell, Digital and Texas laptops. The usability of GasWorks improves with increasing PC performance. However, this has insignificant effect on the analytical speed of the instrument as all measurement and calculation is performed within the instrument.

GasWorks software is only supplied on DVD-ROM. It is possible to transfer installation files from the GasWorks DVD onto CD-ROM or USB media if required.

**TERMS AND CONDITIONS**

Terms and Conditions of Sale shall be as previously negotiated and documents entitled 2009 Final Dually Signed Contract and DuPont Master Agreement LSQ406-0001 Executed shall apply.