Operation Manual
QCL-MAN -CT4000-OEM-Module, Rev D
October 2015

CT4000 OEM Module

EMERSON
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Preface

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All possible care has been taken in the preparation of this publication, but Emerson Process Management and its agents and distributors accept no liability for any inaccuracies that may be found. This manual reflects the state of the product at the issue date below, but further enhancements, while in service, may mean that the manual does not reflect your particular system.

Emerson Process Management reserves the right to make changes without notice both to this publication and the products which it describes.

Revision D, September 2015

If you require technical assistance with this product that is not covered within this manual, then help can be requested from Cascade Technical Support (qcl.csc@emerson.com) or Cascade Technologies distribution partners.

NOTICE

Only for EC countries:

Do not dispose of measuring tools into household waste!

According to the European Guideline 2002/96/EC for Waste Electrical and Electronic Equipment and its implementation into national right, measuring tools that are no longer usable must be collected separately and disposed of in an environmentally correct manner.

Associated Publications

There are currently no associated publications for this manual.

Document Record

The list below gives, for each element of this manual, the latest Revision Number that has been incorporated and the date of that revision.

Publication Element	Revision No.	Revision Date
Front Cover	Revision D	September 2015
Preface	Revision D	September 2015
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Contents	Revision D	September 2015
Safety Precautions	Revision D	September 2015
List of Abbreviations	Revision D	September 2015
Glossary	Revision D	September 2015
Section 1 Introduction	Revision D	September 2015
Section 2 Description	Revision D	September 2015
Section 3 System Specification	Revision D	September 2015
Section 4 Operation	Revision D	September 2015
Section 5 Scheduled Maintenance	Revision D	September 2015
Section 6 Failure Diagnosis	Revision D	September 2015
Appendix A	Revision D	September 2015
Appendix B	Revision D	September 2015

Safety Precautions

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

⚠ WARNING

ELECTRIC SHOCK

The OEM module operates using mains voltage that is dangerous to life. Ensure that the OEM module is disconnected from the mains supply before removing any outer covers or performing any work inside the OEM module. This is particularly important when working at heights.

Death, personal injury and/or damage to persons and/or property may result if this is not observed.

Besides the danger from high voltages, the seals against water and dust can be damaged or impaired if the OEM module is closed or opened incorrectly.

⚠ WARNING

BURNS

Some parts of the OEM Module may be heated to 200 °C. To prevent burns, do not touch any of the hot parts. Always assume that all parts of an OEM module are hot unless it has been of switched off and allowed to cool down.

Before touching, handling, fitting, removing, or performing any maintenance on the OEM module, ensure that it has been switched off and allowed to cool for at least one hour. Before performing any maintenance on, or in the vicinity of, the analysis cell, allow the OEM module to cool for at least twelve hours, as the analysis cell is insulated against heat loss.

When handling the OEM module, always use suitable protective gloves.

Personal injury and/or damage to property may result if these safety precautions are not observed. These precautions are particularly important when working at heights. If a burn is received, seek medical treatment immediately.

⚠ DANGER

FLAMMA BLE SUBSTANCES

Some parts of the OEM module may reach temperatures of 200 °C and may present an ignition source. Exercise care when using oil, paint, cleaning rags, and other flammable substances near the OEM module. A fire may result if this precaution is not observed. Always assume that the interior of an OEM module is hot unless it has been switched off and allowed to cool down.

⚠ WARNING

LASER

The OEM module contains lasers. Opening up the OEM module and attempting to perform adjustments or procedures other than those specified in this manual may result in hazardous optical radiation exposure.

Classification

The classification of the system is Class 1. The lasers within the OEM module are Class 1:

The QCL lasers, which are activated when the system is operating, are Class 1. The emitted laser light is invisible (mid-infrared), and the combined laser powers are sufficiently low at the first accessible aperture that the unprotected eye will not be damaged. This class is eye safe under all operating conditions.

The characteristics of the lasers contained within the OEM Module are included in **Table1**.

Table1 Laser characteristics

Parameter	QCL laser	Comment
Operation mode	Pulsed	
Lasers per system	1 – 4	
Wavelength	4 – 10 µm	
Power	< 5 mW	Combined powers of QCL laser at first accessible aperture < 9.62 mW
Pulse duration	< 1 µs	
Pulse repetition frequency	< 100 kHz	
Duty cycle	< 5%	

Location of laser safety labels on the OEM module are specified in **Section 3.4**.

⚠ CAUTION

Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

⚠ WARNING

HAZARDOUS SUBSTANCES

The OEM module may contain hazardous substances. Always handle OEM Module assemblies and components with extreme caution.

Gas handling components within the OEM module may contain particulate matter residue from the sample gases. Over the life of the OEM module, the concentration of particulate matter may become enriched within the gas handling components. The particulate matter comprises carbon, ash, soluble organic fraction, and, depending upon the type of gases that are sampled, may include compounds derived from sulfur, which are acidic in nature and may cause respiratory problems. When performing repairs and maintenance on the OEM module:

- Handle used gas handling components with extreme caution;
- Avoid direct skin contact with used gas handling components;
- Smoking, drinking, and eating in the work area are prohibited;
- Goggles or eye shields are to be worn;
- A suitable face mask is to be worn to protect against inhalation of particulate matter;
- Keep food and beverages away from the OEM module;
- Do not wet fingers, eyes, or any exposed skin;
- Pack used gas handling components for disposal in sealed packaging and label it *Contaminated*;
- Dispose of contaminated items as hazardous material according to the applicable local, national or international health and safety regulations and pollution regulations.

⚠ WARNING

HEAVY ITEM

Handle the OEM module with caution during unpacking, installation, maintenance and transport to prevent crushing of hands, feet, or other body parts.

The OEM module weighs 13 kg and should always be lifted with caution. Wear suitable protective gloves and protective footwear. When preparing the OEM module for transport by air, road, or rail, safeguard the OEM module against movement or break-away during transport by securely strapping it in place.

⚠ WARNING

EQUIPMENT DAMAGE – PRE-SYSTEM STARTUP CHECKS

Do not power up or try to operate the OEM module unless it is physically secure and all connections to the OEM module and control PC are in place.

Before beginning the OEM module system start-up process, it is important to ensure that power, sample handling facilities and any calibration gases that are required are available at the installation site.

Abbreviations

The following abbreviations are used in this manual:

Table 2 Abbreviations

Abbreviation	Stands for
AC	Alternating current
ADC	Analog to digital converter
DC	Direct current
EMC	Electromagnetic compatibility
GB	Gigabyte
GHz	Gigahertz
Hz	Hertz
I.P.	Internet protocol
IPxx	Ingress protection (the xx are numbers that define the level of protection)
kHz	Kilo-hertz
L	Liter
L/min	Liters per minute
m	Meter
mm	Millimeter
mm^2	Square millimeter
µm	Micro-meter
mW	Milli-watt
Nm	Newton meter
No.	Number
OEM	Original equipment manufacturer
Para	Paragraph
PC	Personal computer
ppm	Parts per million
ppmC	Parts per million carbon
s/n	Signal to noise
TEC	Thermoelectric controller
UPS	Uninterruptable power supply
USB	Universal serial bus
V	Volt
W	Watt

Glossary

The following words, defined in the table below, are used in this manual.

Table 3 Glossary

Word	Definition
Danger	Signal word used to indicate an imminently hazardous situation, which, if not avoided, will result in death or injury.
Warning	The word *warning* has two meanings within this manual. Signal word used to indicate a potentially hazardous situation, which, if not avoided, could result in death or serious injury. This is the normal usage of the word *warning* within this manual. In the Troubleshooting and Diagnostics section of this manual, some of the on-screen error messages generated by the OEM module system include the word *warning* to indicate a minor fault.
Caution	Signal word used to indicate a potentially hazardous situation, which, if not avoided, could result in minor or moderate injury.
Background	A pulse recorded with no absorbing species at the wavelengths of the lasers present in the cell.
Detection limit	Although the gas detection range is given from zero, this is the lowest possible level of gas that the OEM module can detect.
Fit	In the repair procedures, *fit* means to place an assembly, sub-assembly, or component in its correct position.
Fitting	The technique used to analyze the recorded data to give a concentration.
Laser beam path length	The optical distance travelled by the laser through the gas being measured.
Measurement frequency	The frequency at which all output gas concentrations are updated.
Measurand	A quantity that is being determined by the measurement.
Purge	The use of high pressure gas to remove particulates that may have built up on the cell mirror surfaces.
Replace	In the repair procedures, *replace* means to remove and discard an unserviceable item and then fit a serviceable replacement item.
Sample flow rate	The rate at which sample gas flows through the cell.

Contents

List of Tables

List of Figures

1 Introduction

1.1 Introduction

The CT4000 OEM module is an electronic sensor that identifies and measures gas concentrations. The CT4000 is a configurable gas sensor designed to be integrated with the customer's sample handling system. The CT4000 is used with GasSensor-3 software, which may be supplied on a PC with the unit or as a software package to install on a customer owned PC. The software analyses the laser pulses and calculates and displays the gas concentrations detected.

This operation manual for the OEM module is intended for the person who installs and maintains the equipment.

1.2 Customer information

This manual contains all the information required to install, operate, and maintain the OEM module. Please read the manual carefully before you start work on the OEM Module, as it contains important information that must be followed to guarantee the correct operation of the system and the safety of personnel. The manual is divided into sections, which should allow users to rapidly find the information they need.

Emerson Process Management is committed to continuously improving its products and documentation. Every effort will be made to include any sensor modifications by the manufacturer in the documentation. However it should be noted that this document reflects the supplied OEM module as of the revision number and date on the front cover.

Should you require further information, or should particular problems arise that are not covered within this Operation Manual, then additional help can also be requested from Cascade Technical Support (qcl.csc@emerson.com) or Cascade Technologies distribution partners. Further contact details for Cascade Technologies can be found in the preliminary material of this manual.

1.3 Safety precautions

⚠ CAUTION
Before installing or performing any maintenance on the OEM module, read and understand the safety precautions given in the preliminary material of this manual.

The OEM module described in this manual has been quality control tested and left the manufacturer in pristine condition. To achieve the correct and safe operation of the product, it must be transported, installed, operated, and maintained as described by the manufacturer.

All lasers used within the Emission Sensor are of class 1. The emitted laser light is invisible (mid-infrared) and the pulse duration so short that the unprotected eye will not be damaged. The nature of the laser beam path and beam width further ensures that it should be impossible to cause any eye damage.

There is also a visible laser that may be installed in the OEM module for service and maintenance procedures. It is not installed at the point of shipment or in normal operation. This visible laser is of class 2. A class 2 laser is safe because the blink reflex will

limit the exposure to the beam to no more than 0.25 s. Intentional suppression of the blink reflex could lead to eye injury. The visible laser will be supplied with the relevant operational and safety instructions.

1.4 Qualified personnel

This manual provides maintenance personnel with the level of knowledge required to safely start, operate, switch off, install, maintain, and troubleshoot the OEM Module.

The installation, advanced operation, switching off, service, and troubleshooting of the OEM module must only be performed by technically qualified personnel in the field of instrumentation and control who are familiar with this manual and who have been specially trained on the OEM module. Only qualified and trained persons have the required specific knowledge to correctly interpret the general safety information, warnings and procedures given in this manual and apply them to this particular application. Please contact Emerson Process Management or their distribution partners for further information on training that is available.

Knowledge of the safety information within this manual and its technically correct implementation are prerequisites for danger-free operation, installation, and maintenance of the OEM module.

1.5 Software version

The OEM Module includes software that is used to control the operation of the sensor. This Manual describes software version 3.9.

2 Description

2.1 Equipment purpose and role

The CT4000 OEM module (**Figure 2-1**) is a gas sensor system that can be configured to measure the concentrations of multiple small molecules contained in the gas sample that is supplied to the OEM module via a sample line. The types of molecules that are measured depend on the system configuration.

Figure 2-1 CT4000 OEM module

The OEM Module is typically configured to detect and measure between one and eight components, depending on the combination of laser modules. These components may include, but are not limited to, a selection of the following gases:

Table 2-1 Gases

Name	Symbol
Nitric oxide	NO
Nitrogen dioxide	NO_2
Carbon monoxide	CO
Carbon dioxide	CO_2
Water	H_2O
Sulfur dioxide	SO_2
Methane	CH_4
Nitrous oxide	N_2O
Ammonia	NH_3

The configuration and performance of the OEM Module supplied with this manual can be found in Appendix A – System Configuration and Performance, located at the end of this manual.

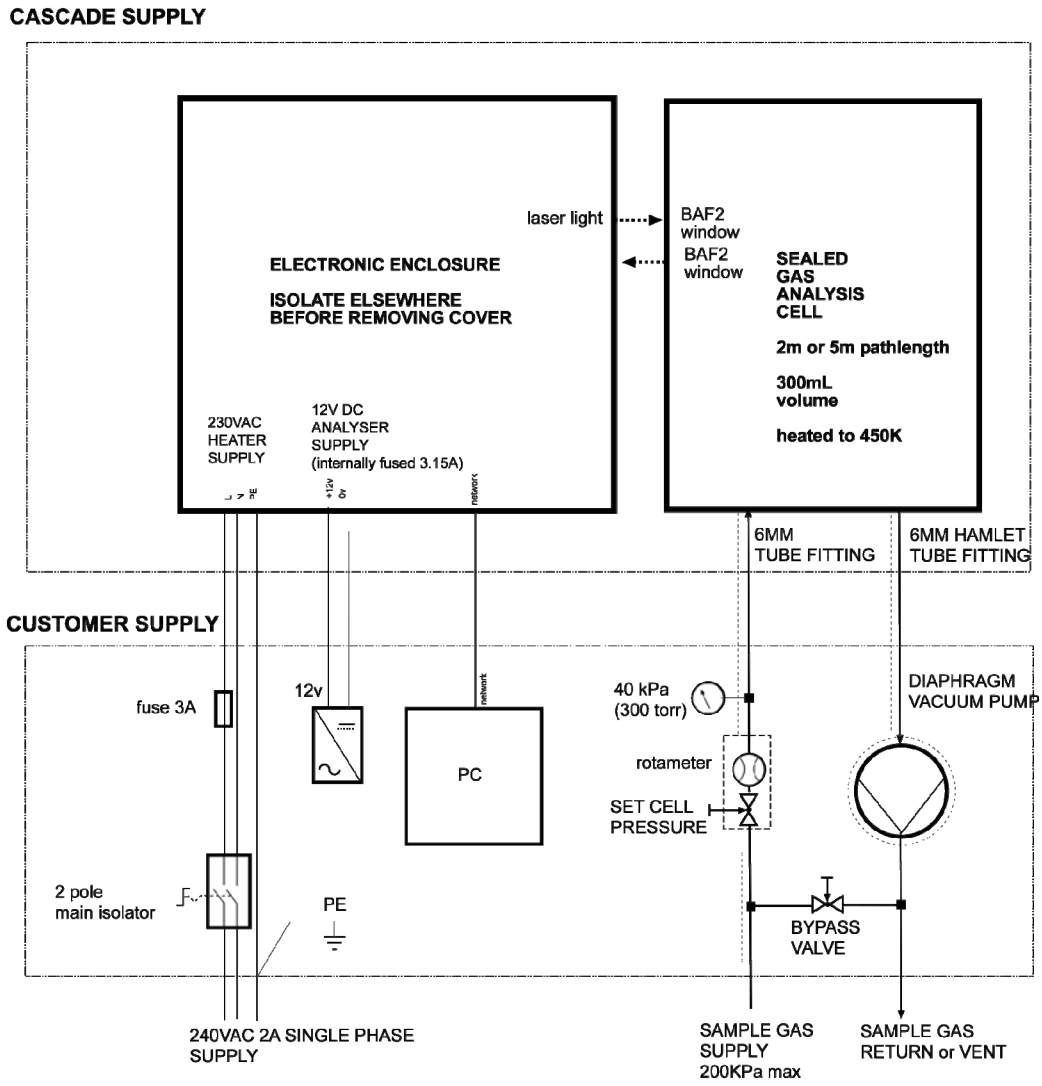
2.2 System overview

A compete OEM module gas analysis system consists of a gas handling system, the OEM module, and a control PC as shown in **Figure 2-2** below. The gas handling system is provided by the customer, the OEM module is supplied by Cascade Technologies Ltd, and the control PC is typically supplied by the customer, but may be supplied by Cascade Technologies depending on the customer requirement. **Figure 2-2** shows the typical scope of supply.

The OEM module enclosure contains an optical system with up to four lasers, a heated multi-pass sample cell, a series of optical components that direct the laser beams through the sample cell, sample and outlet ports that can be connected to a gas handling system, and control and analysis electronics. The whole system operates from a 12 V DC input and either a 110 or 240V AC supply, depending on system configuration. The exact configuration of the OEM Module supplied with this manual can be found in Appendix A - System Configuration and Performance.

Gas concentrations are measured using mid-infrared optical absorption spectroscopy. The light sources are quantum cascade lasers, which are operated to produce wavelength chirps that cover the absorption lines of the gases. The light from each laser is directed through the sample cell using a series of optical components. The sample gas is conditioned and drawn through the cell by external sample handling system. The light exits the multi-pass cell and is directed to the infrared detector in the OEM Module. The variation in the intensity of light in the vicinity of the absorption lines is measured, and the concentration is determined using a comprehensive spectral fitting routine.

Figure 2-2 Complete OEM module gas analysis system



There is no sample conditioning provided within the OEM module; the sample gas must be brought within the parameters shown in
Table 3-4 before entering the OEM module system. Detailed characteristics of the OEM module are also given in **Section 3**.

Table 2-2 Main items of the CT4000 OEM module

Item	Name or Description	Supplied by	Part number	Quantity	Notes
1	CT4000 OEM module	Emerson Process Management	CT4XXX-XXXXX	1	
2	Gassensor-3 software package, version 3.8.X or higher	Emerson Process Management	GS-3.8.X GS-3.9.X GS-3.10.X	1	Software version included in **Error! Not a**
3	110 or 240 V AC power cable to OEM module	Customer	Customer choice	1	AC power specification included in **Error! Not a valid**
4	12 V DC power cable combined with digital IO to OEM module	Customer	Customer choice	1	
5	Heated gas sample line hose	Customer	Customer choice	1	
6	Exhaust line hose (for sample gas)	Customer	Customer choice	1	
7	Compressed air supply (for purge gas line)	Customer	Customer choice	1	
8	Purge gas line hose	Customer	Customer choice	1	
9	Gas handling system	Customer	Customer choice	1	Including gas cylinders and vacuum pump as appropriate
10	Ethernet cable from OEM module to control PC	Customer	Customer choice	1	
11	Control PC	Customer or Emerson Process Management	TBA	1	Confirmed at time of order placement
12	Power cable to control PC	Customer	Customer choice	1	

2.3 Location of OEM module

The OEM module should be mounted in the vicinity of a gas handing system. Emerson Process Management recommends that:

1. The OEM Module is free from risk of direct liquid spillage and away from any hot air vent.

1. No more than 25 m of Ethernet cable run from the OEM module to the control PC.

2.3.1 System installation

The **inlet** and **exhaust** sample lines and the **DC** and **AC supply** cables can then be connected to the OEM Module as shown in **Figure 2-3** and **Figure 2-4**.

Electrical Power to operate the OEM Module must be provide by the customer. Two electrical supplies are required:

1. A +12 V DC supply to operate the control, analysis, and data communication electronics contained within the OEM module.

2. A 110 V or 240 V AC supply to power the heater that maintains the temperature of the sample cell at a constant temperature. The temperature set point of the sample cell is factory set and may be between 50 and 190 ˚C, depending on system configuration.

⚠ CAUTION
Many gases that the OEM Module can measure are highly poisonous even at low concentrations. Special care should therefore be taken to endure that the exhaust sample line discharges the sample gas to a location that will not cause inhalation injury to personnel.

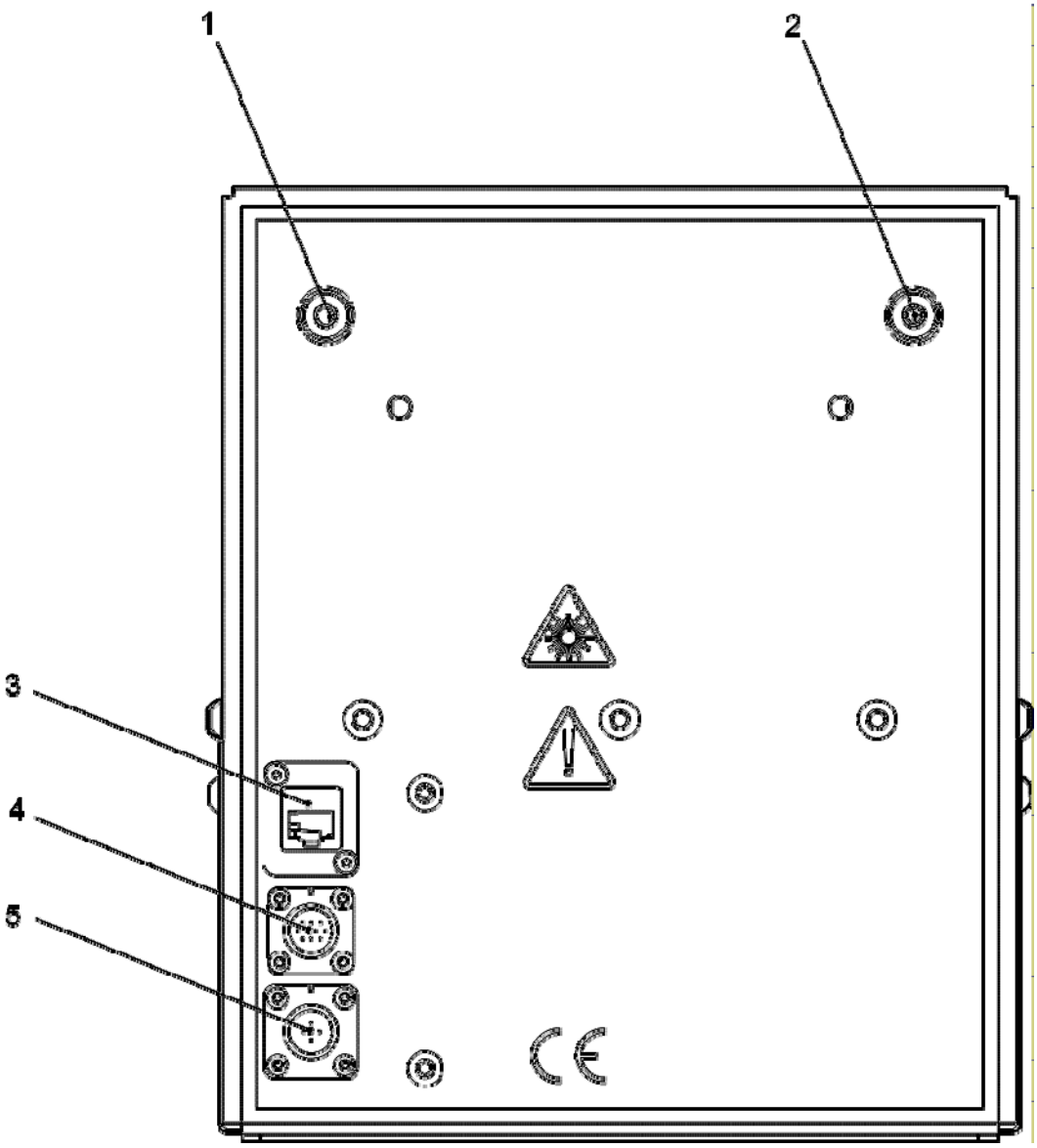
The sample line must be heated all the way to the **inlet** fitting on the OEM Module to prevent condensation forming at any point in the sample line. The sample line should be set to the same temperature as the OEM Module cell. The cell temperature can be found in the system configuration detailed in Appendix A.

The OEM module can then be connected to the control P.C. via the Ethernet port using a Cat 5 network cable.

2.3.2 Operation

Once the OEM module and control PC are powered on, the system is ready to use. Detailed instructions of how to operate the gas sensor software can be found in **Section 4 – Operation**.

Figure 2-3 Connection points



1. Gas outlet
2. Gas inlet
3. Ethernet connector
4. DC power in and Digital IO connection point
5. AC power in connection point

2.4 OEM module description

The OEM module system consists of the OEM module, a sample handling system and a control PC. **Figure 2-2** shows a complete OEM module system. **Table 2-2** lists all the main items of the OEM module system.

2.4.1 OEM module

The system contains between one and four lasers, which are mounted in the lower electronic tray. The control electronics are also located in this section. Light emitted from the lasers is directed using a series of optical components from the upper tray into the sample cell, where it may be partially absorbed by the gas present in the cell. The light that is transmitted from the cell is detected by a receiver in the upper electronic tray.

The variation in the intensity of the light in the vicinity of the absorption lines is measured, and as the path length and the absorption characteristics of the gas are known, the concentration may be determined using the Beer Lambert Law. The gas sensor software uses a comprehensive spectral fitting routine to match the recorded spectra to a theoretically generated spectrum, and uses this best fit to calculate the concentrations of the gases present.

2.4.2 Control PC

The control PC runs the gas sensor software, which controls the OEM module and calculates the gas concentrations from the data provided by the OEM module. The control PC displays and can be configured to store the calculated information. The type and size of the control PC depends on the particular application and regulatory requirements; so it could be a laptop in a protective housing, a nineteen inch rack mounted system, or a normal desktop computer. The measured data may also be transmitted from the control PC to a client. The control PC is usually provided by the customer but may be supplied by Cascade Technologies with the OEM module on request.

2.4.3 Sample handling system

The sample handling system controls the gas flow through the OEM module. It typically consists of the parts shown in **Figure 2-2**. A vacuum pump is used to draw the sample through the sample cell, and a series of valves control the flow rate and pressure in the sample cell. The cell pressure should be controlled to the set point given in **Table A-3** of

Appendix A. A heated line is recommended on the inlet side to condition the gas up to the same temperature as the sample cell before it enters the OEM Module. A heated line on the exhaust may be required to prevent condensates forming in the line.

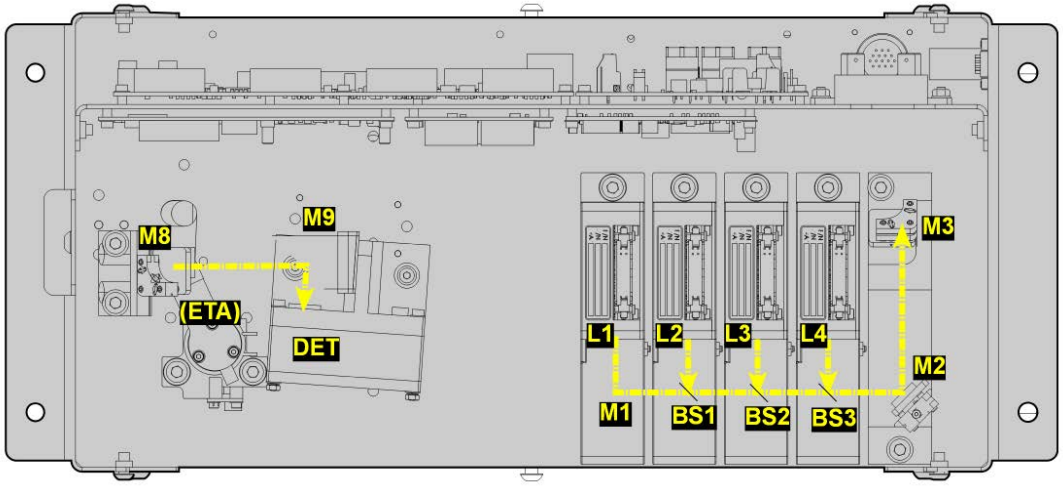
2.5 Optical description

The laser modules are located in the lower electronic tray of the OEM module. Each laser module produces a separate light beam, and these beams are combined linearly as the modules are aligned in the system. The combined beams are closely coupled, parallel, and coaxial about a virtual line. The laser light beams pass through the baseplate onto an optical steering assembly which directs the laser beams through the sample cell.

The sample cell contains a set of mirrors to create a path through the sample gas that is between 2m and 5m through multiple reflections along the length of the cell. The laser beams exit the cell at the opposite end to where they entered and are directed using a second optical block on to a receiver.

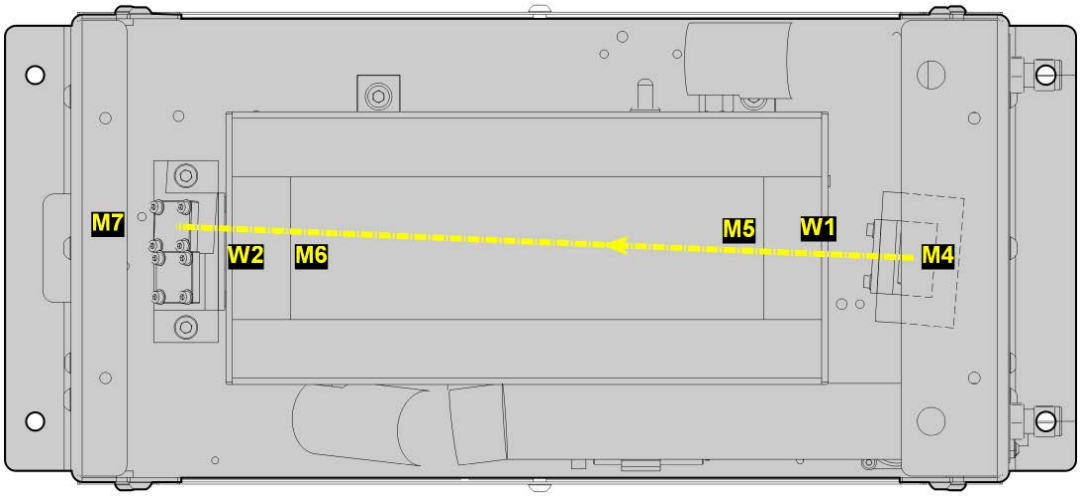
By measuring and analyzing the light detected by the receiver unit, it is possible to accurately determine the concentrations of the target molecules within the gas sample cell.

Figure 2-4 Optical path - electrical side



L1 to L4	Collimation lens 1 to 4	M7 and M8	Steering mirrors onto detector
M2 and M3	Steering mirrors to upper section	ETA	Etalon (optional)
BS1 to BS4	Beam splitters 1 to 4	DET	Detector

Figure 2-5 Optical path - cell side shown with insulation removed



M3	Steering mirror into cell	W1 and W2	Cell windows
M4 and M5	Internal Cell Mirrors	M6	Steering mirror to lower section

Refer to **Figure 2-4** and **Figure 2-5**. The light beams output from up to four lasers are collimated by lenses L1 to L4 in **Figure 2-4** and combined to a linear beam using four beam splitters (BS1 to BS4). The combined light beam is directed on to the upper section shown in **Figure 2-5** by a series of mirrors (M1 to M3) where it is directed through a multipath cell configured to a path length of either 2m or 5m depending on the specification. The sample cell has two internal mirrors (M4 and M5) and windows (W1 and W2) to create a sealed cell. The light exiting the cell is directed back to the lower section and onto a receiver (MCT detector) using two steering mirrors (M6 and M7) and an off-axis parabolic mirror (M8). There is an optional etalon which may be moved into the beam to allow calibration of the wavenumber output of the lasers using an interference fringe pattern that it produces. **Section 4.12** describes how the laser calibration is performed using the Gas Sensor software and the etalon.

3 System Specification

3.1 Gas detection

The CT4000 OEM Module is highly configurable in the gases that can be detected and their range of concentrations. A detailed specification including the gas measurement capability is therefore included in **Appendix A**.

3.2 Detailed system specification

Table 3-1 gives the physical characteristics of the OEM Module. Schematic diagrams of the sensor and mounting points are shown in to **Figure 3-1** to **Figure 3-3.**

Table 3-1 Physical characteristics

OEM module	Value	Units	Comment
CT4000 dimensions	498 x 218 x 260	mm	Depth x width x height.
CT4000 weight	13	kg	

Table 3-2 gives the general characteristics of the OEM Module.

Table 3-2 Performance characteristics

OEM module	Val	Units	Comment
Heater supply voltage	110 or 240	V	AC 50-60Hz (specify on order).
DC Supply Voltage	12	V	2 A
AC Peak Power Consumption	500	W	Max consumption per sensor.
Continuous steady-state AC Power Consumption	200	W	Once sensor has stabilized and the sample cell has reached the temperature set point.
Frame and structure material	-	-	Stainless Steel S304 and Electroless nickel coated aluminum.
Housing material	-	-	Powder coated aluminum.
Measurement Technique	-	-	Mid IR Absorption Spectroscopy.
Mid IR Source	-	-	Quantum Cascade laser
Laser classification	CLASS 1 (Mid IR)		BS EN 60825-1:2007 Safety of laser products. Equipment classification and requirements (identical to IEC 60825-1 2007).
Inlet gas port connector	6	mm	Swagelok type
Exhaust gas port connector	6	mm	Swagelok type
Purge air pressure	2	barg	Maximum purge pressure

Figure 3-1 OEM module dimensions - top view with fixing centers

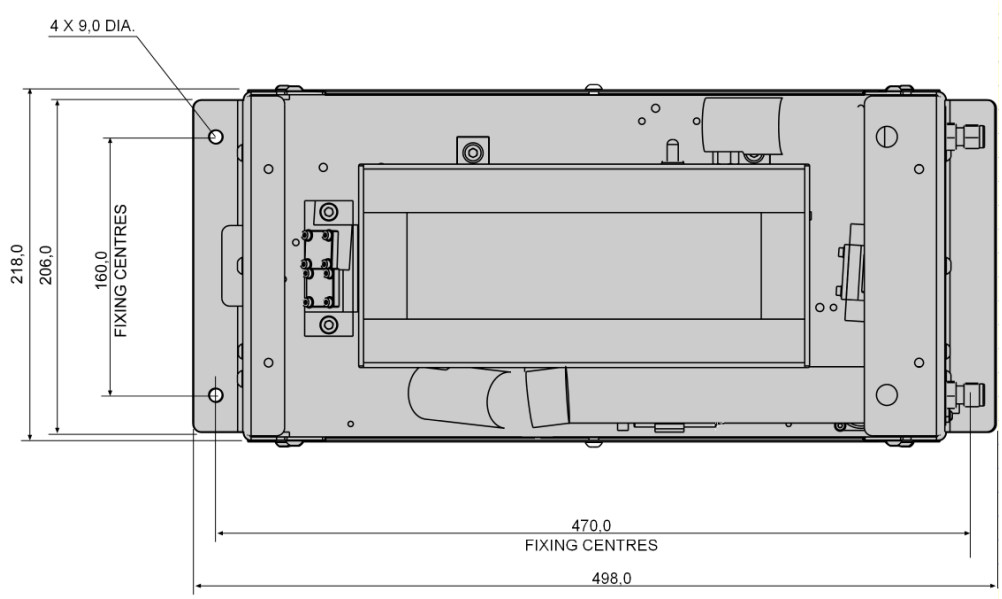


Figure 3-2 OEM module dimensions - end on view with connection points

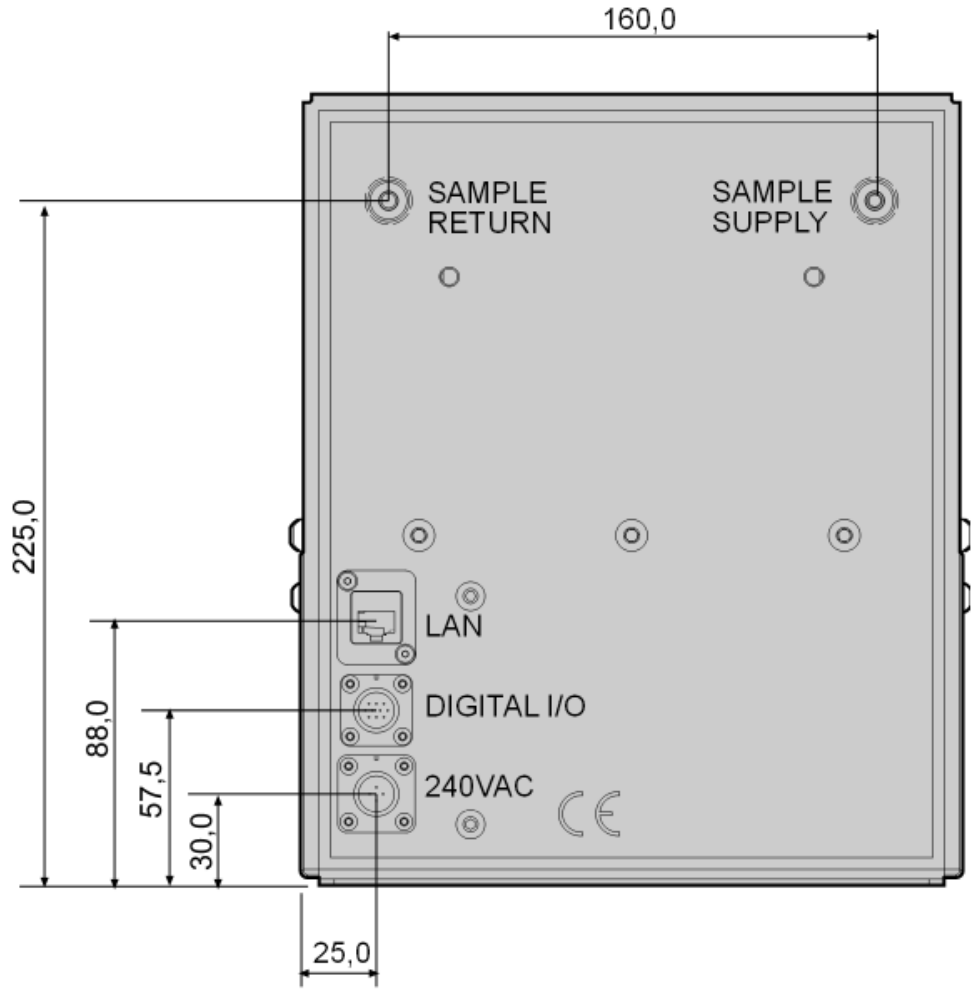


Figure 3-3 OEM module dimensions - side view

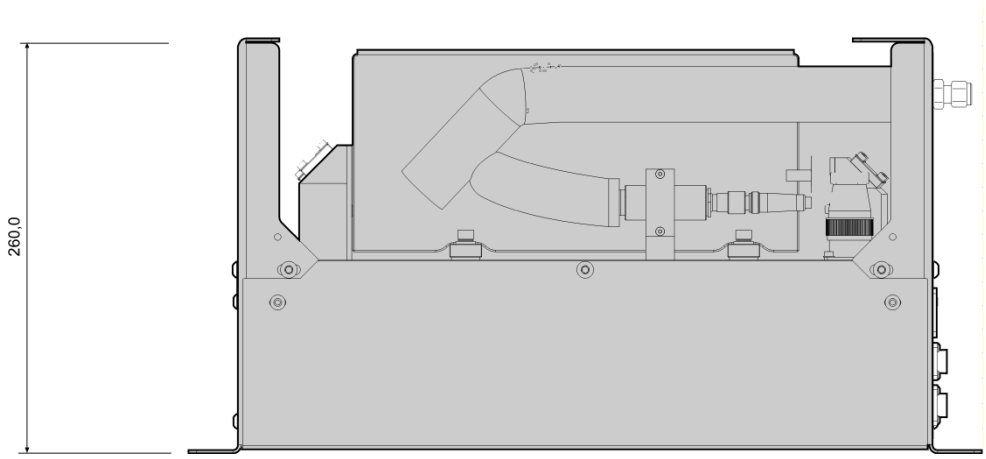


Table 3-3 gives right angled and straight coupled electrical connector options to connect to the OEM module.

Table 3-3 Electrical connector specifications

Connector	Manufacturer	Part number	Description
12 VDC Supply and Digital IO	Hirose*	HR34B-12WPB-10S	10 pole male straight solder bucket cable connector
12 VDC Supply and Digital IO	Hirose*	HR34B-12WPB-10S(71)	10 pole male right angle solder bucket cable connector.
AC Power Supply	Hirose*	HR34B-12WLPD-4S	4 pole male straight solder bucket cable connector
AC power supply	Hirose*	HR34B-12WPE-4S	4 pole male right angle solder bucket cable connector.
Ethernet	Various	CAT5e	n/a

** The Hirose connectors are available from RS Components, part numbers 715-3328 and 715-3356 for the straight and right angle 12 V DC Supply and Digital IO and 715-3338 and 715-3312 for the straight and right angle AC Power Supply connectors, correct at the revision date of this Operation Manual.*

Table 3-4 gives the environmental characteristics of the OEM module.

Table 3-4 Environmental characteristics

Environmental characteristic	Value	Units	Comment
CT4000 operating temperature range	-20 to +70	deg C	Ambient temperature.
Sample gas temperature range	+50 to +195	deg C	Factory set, specify on order
Sample gas moisture content	20	%	Maximum
Sample gas particulate density	5	Mg/m3	
Sample gas particulate size	10	µm	
CT4000 IP Code	30		Ingress Protection (IP) to IEC 60529
CT4000 Humidity Range	10 to 95	%	Relative humidity (Non-condensing) at 45 deg C.
Operating Altitude	0 to 2000	m	Indoor use

3.3 Control PC specification

The control PC is supplied by either the customer or Emerson Process Management. There are a number of PC types available. If a control PC has been supplied by Emerson Process Management with the OEM module, refer to

Appendix A for the specification. The two most commonly supplied types of control PC are a rugged laptop and a rack mounted PC that is compatible with a 19 inch rack. The minimum specifications for a control PC are given in **Table 3-5**.

Table 3-5 Control PC minimum specifications

Parameter	Value	Units	Comment
Processor	1.8	GHz	Intel(R) Atom™ D525
RAM memory	2	GB	
Hard disk	8	GB	SSD
Ethernet	100	MBit	
Operating system	12.04 LTS	Ubuntu	

3.4 System labels

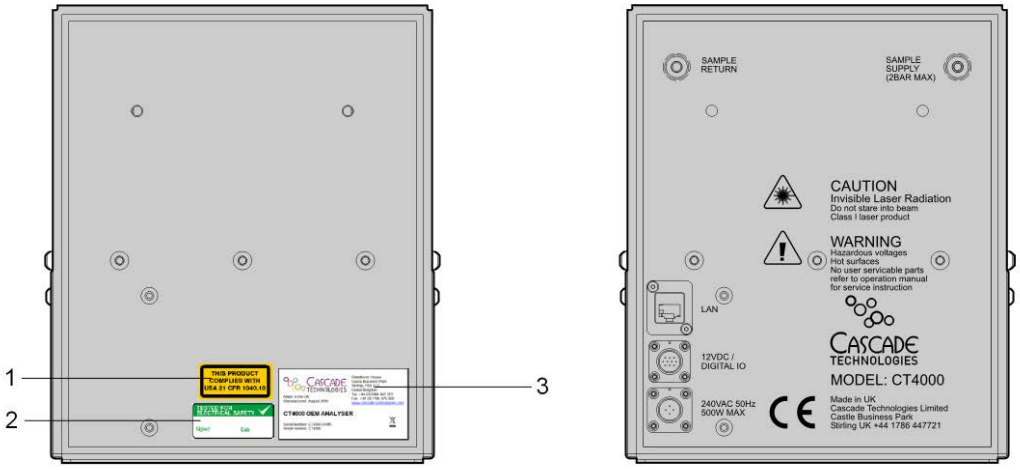
The labels applied to the OEM module are specified in **Table 3-6**. **Figure 3-7** shows the label locations on the external casing.

Table 3-6 System labels

Label type	Example	Location
Identification label		External end panel
Electrical safety label		External end panel
USA FDA Compliance Label (for systems shipping to USA)		External end panel
Caution – Hot label		On cell insulation
Warning – isolate electrical supply		Lower external cover
AC power supply voltage label		On cell insulation and in the lower section containing electronic PCAs
Laser radiation warning label		On baseplate next to Laser Modules

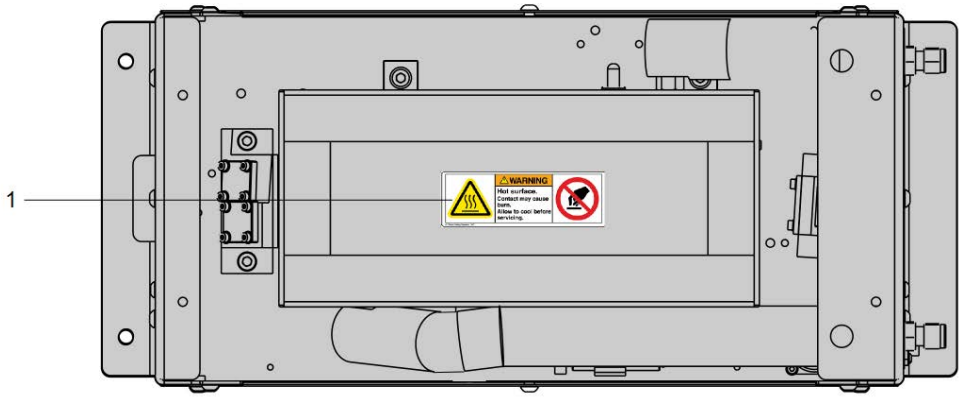
Label type	Example	Location
Laser module identification label		On laser module housing

Figure 3-4 Label locations - end panels



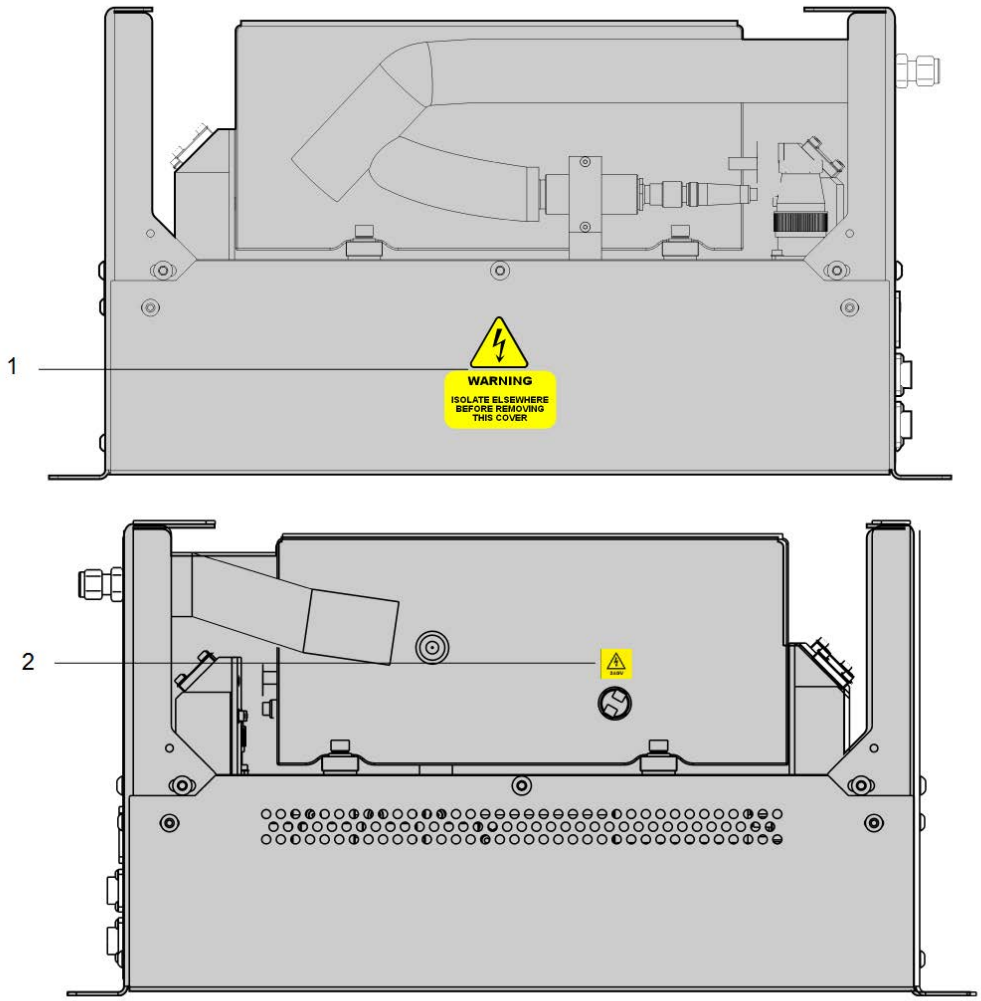
1. USA FDA Compliance label
2. Electrical safety label
3. Identification label

Figure 3-5 Label locations - top view



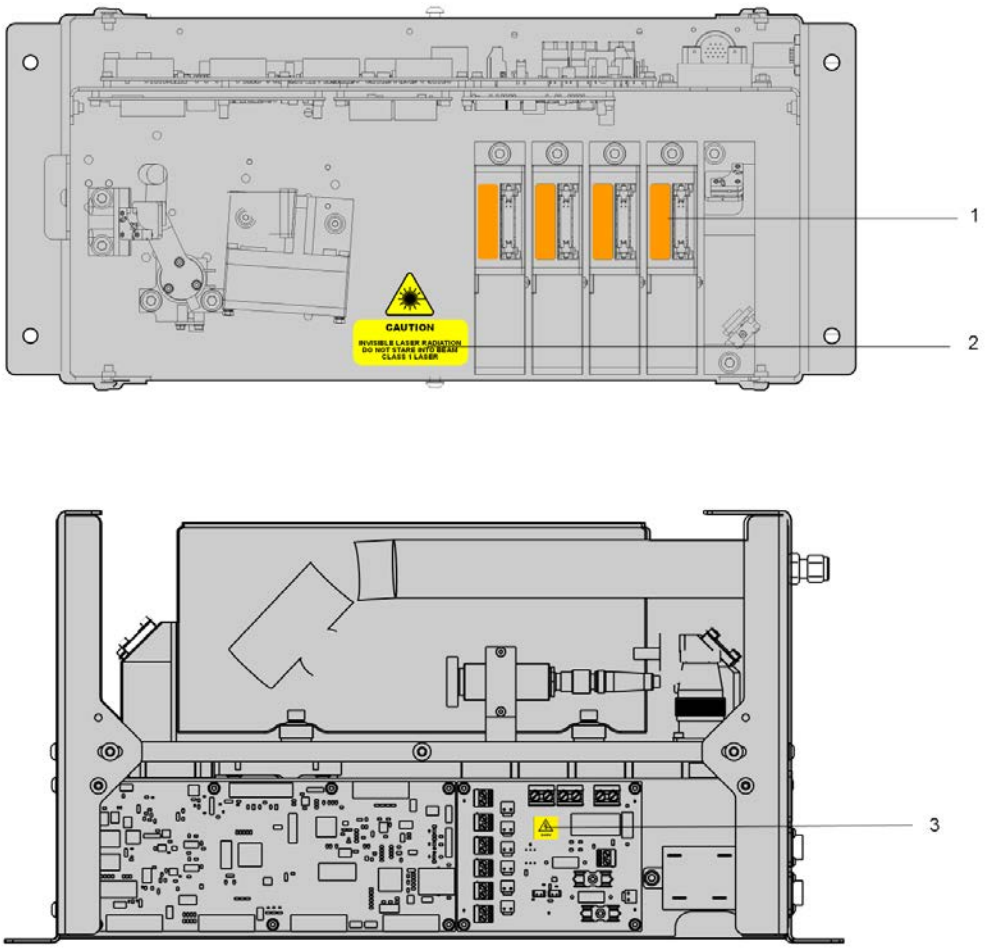
1. Caution – Hot label

Figure 3-6 Label locations - side panels



1. Warning – Isolate electrical supply
2. AC power supply voltage label

Figure 3-7 Labels visible with covers removed



1. Laser module Identification Label
2. Laser Radiation Warning Label
3. AC Power Supply Voltage Label

3.5 Compliance approvals

This product complies with USA 21 CFR 1040.10. It is also designed and manufactured under an approved quality management system to ISO 9001:2008.

3.6 CE marking

Emerson Process Management and the CT4000 OEM Module have satisfied the requirements for applying the CE marking to the system.

4 Operation

4.1 Introduction

This section describes how to start and perform normal operations using the CT4000 OEM module. Operation of the OEM Module is controlled through the software display on the control PC.

It should be noted that the gases shown in the following screenshots may be different from those shown in your particular OEM module system. They indicate the functionality of the software, which is the same regardless of the gases being measured.

NOTICE

This manual describes version 3.9 of the control software. The screenshots provided in this section show the software version as version 3.9.19, indicating that it is sub-version 19 of software version 3.9.

The OEM module requires a control PC to operate. This is usually provided by the Customer to the minimum specification given in **Table 3-5**. The control PC must have the gas sensor software package installed prior to operation of the OEM module. The gas sensor software package will be provided by Cascade Technologies with the OEM module. If you do not have a copy of the software installation package please contact Cascade Technologies or their distribution partners for assistance. **Section 4.2** provides instructions to install the gas sensor software.

In some cases the control PC is provided by Cascade Technologies with the OEM module. In this case, the control PC will be supplied ready to use. Please proceed to **Section 4.3** for further instructions on operation of the OEM module.

⚠ WARNING

BURNS

Some parts of the OEM Module are heated to 200 degrees C. To prevent burns do not touch any of the hot parts. Always assume that all parts of an OEM module are hot unless it has been switched off and allowed to cool down.

Before touching, handling, fitting, removing, or performing any maintenance on the OEM module, ensure that it has been switched off and allowed to cool for at least thirty minutes. Before performing any maintenance on, or in the vicinity of, the analysis cell, allow the OEM module to cool for at least twelve hours as the analysis cell is insulated against heat loss.

When handling the OEM module, always use suitable protective gloves.

Personal injury and/or damage to property may result if these safety precautions are not observed. If a burn is received, seek medical treatment immediately.

4.2 Software installation

The control PC should have the minimum specification given in **Table 3-5**. The operating system is Ubuntu, and the software package provided is for installation onto this software platform. The gas sensor software package is installed as follows:

1. Power on the control PC and log in to the *Administrator* account

2. Copy the software package to the **Home** folder. The software package will be named: *Cascade_GasSensor.sh* or similar.

3. Open a terminal window by going to *Applications* > *Accessories* > *Terminal*.

4. Type the following command into the **Terminal** window and press enter: *sudo /home/admin/Cascade_GasSensor.sh*

NOTICE
The name of the software package and location of the file may vary depending on the PC set up and application. Please amend the command above as appropriate for the installation.

5. You may be prompted for the Administrator password. Following installation of the package, the PC automatically restarts. On restart, the gas sensor software automatically opens.

6. A license file for the software may also be provided with the format Licence.conf. Copy this file to the following location on the control PC: */home/user/.Config/CascadeTechnologiesLtd/*

7. A configuration file will also be provided with the format *CT4XXX-0XXXX.cfg*. Copy this file to the home folder and refer to **Section 4.5** to set the preferences so that the configuration file automatically loads when the gas sensor software is started (recommended).

The gas sensor software package is now installed and ready to use.

4.3 Sensor states

The OEM module has three operating states: *WORK MODE*, *STANDBY MODE* and *OFF*.

1. As the OEM module is designed for long term continuous operation, the OEM module is usually in *WORK MODE*.

2. When not being used to calculate gas concentrations, it is recommended that the OEM module is placed in *STANDBY MODE*.

3. The OEM module is normally only placed in the *OFF* state for maintenance.

4. To start measuring gas concentrations using the OEM module system, it is necessary to perform the start-up procedure described below.

4.4 Preparation for use

The OEM module must be installed and fully commissioned prior to operation.

4.5 Startup procedure

To start measuring gas concentrations using the OEM module perform the following steps:

1. Connect power to the OEM module. The OEM module requires a 12 V DC supply and either 110 or 240 V AC. The AC voltage requirement is determined by the

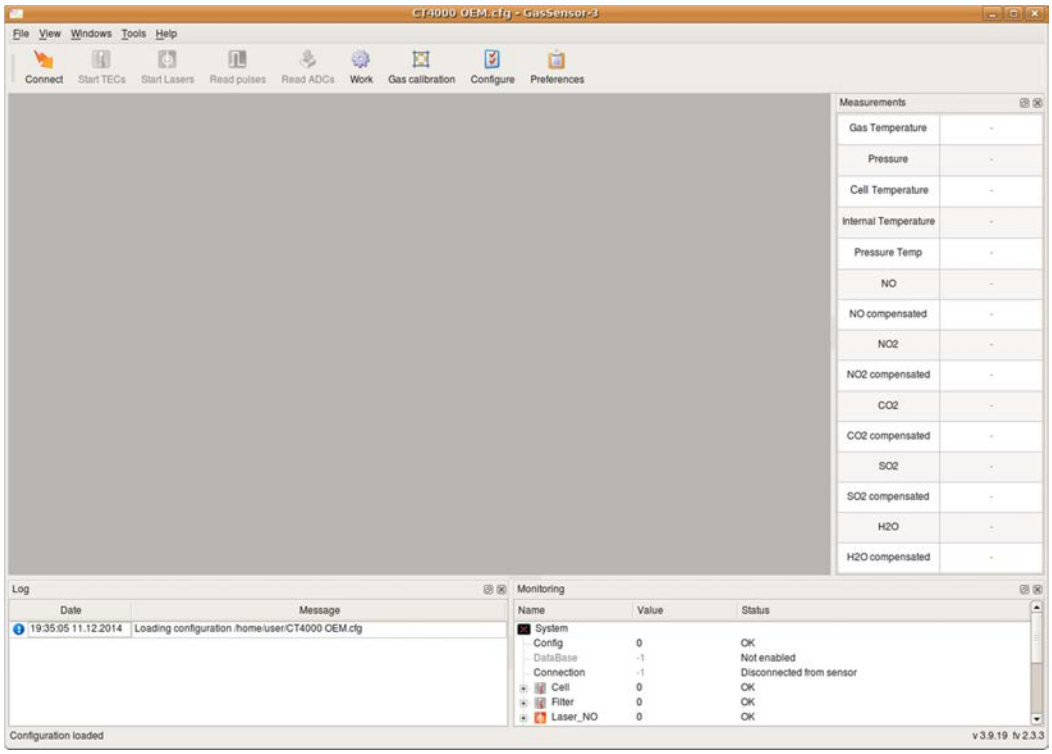
heater specification. Please refer to the warning labels on the OEM module case at the power connection points if unclear.

2. Connect the OEM module to the control PC, and power on the control PC.

3. The OEM module does not have a sample handling system. Connect the exhaust to a source of suction and a suitable gas ventilation system. Connect the Inlet to the gas supply to be analyzed.

4. The control PC may be configured to automatically load the gas sensor software and the configuration file for the OEM module it has been supplied with. On completion of the startup procedure, the screen will look similar to that shown in **Figure 4-1**.

Figure 4-1 Initial screen



4.5.1 Standby mode

Once the system is powered on and the control PC has loaded the gas sensor software, the system should be put into standby mode whilst the gas cell reaches the operational temperature. The operational temperature may vary from system to system; please refer to the system configuration.

1. Connect the sensor to the PC by clicking the *Connect* button.

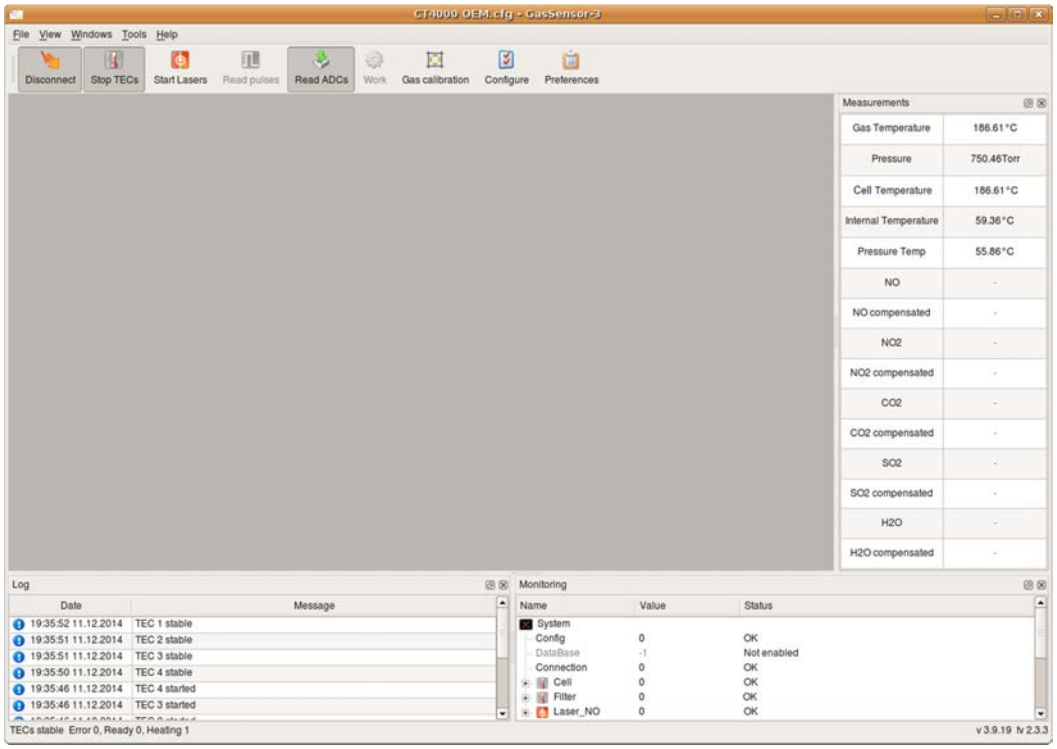
2. Start the laser thermoelectric coolers by clicking the *Start TECs* button.

3. Monitor the cell heaters by clicking the *Read ADCs* button.

4. Following activation of these three buttons, the OEM Module will be in *Standby Mode*, shown in **Figure 4-2**.

The OEM module should be left in *Standby Mode* when not in use. This will maintain the cell temperature to the set value, and the OEM module will remain ready to use at any time.

Figure 4-2 *Standby Mode* screen



4.5.2 Work Mode

Once the cell temperature has reached the target temperature, to start analyzing gas concentrations, the OEM module must be put into *Work Mode*.

1. Disconnect from the sensor by clicking the *Disconnect* button.

2. Click the *Work* button.

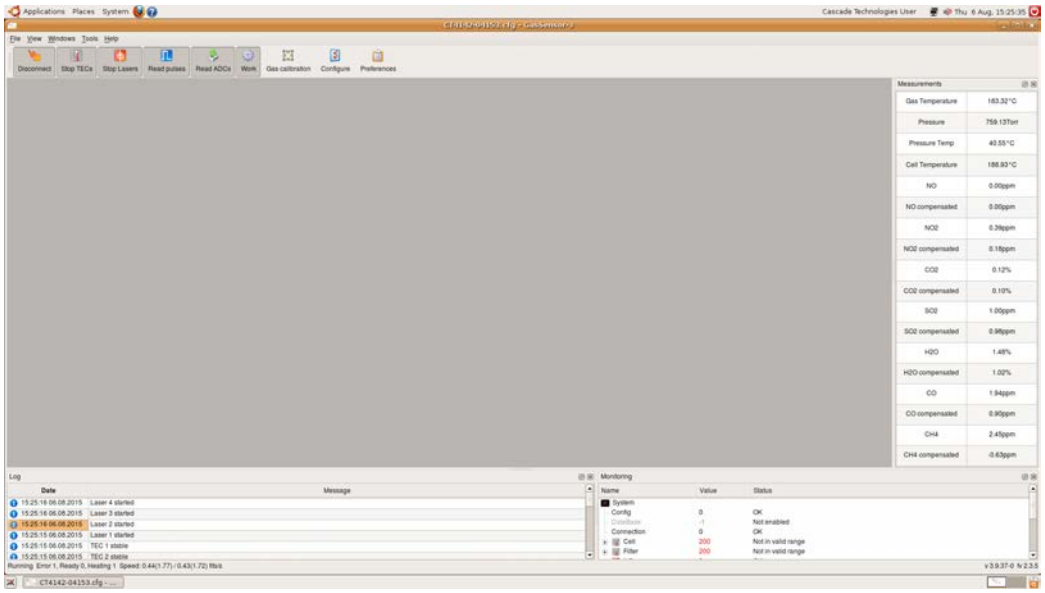
The gas concentration will update in the measurements plot, as shown in **Figure 4-3**. Operation of the gas sensor software package is described in more detail in **Section 4.8**.

To return the OEM module to Standby Mode, click the *Work* button and follow the procedure given in **Section 4.5.1**.

The CT4000 system can be left in either *Standby* or *Work* mode, as shown in the following sections, until routine servicing is required. Routine servicing is described in **Section 5:**

Scheduled Maintenance.

Figure 4-3 *Work Mode* screen



4.6 System shutdown

The gas sensor software can be stopped by clicking the *Work* button shown in

Figure 4-3, then choosing *Quit* from the **File** menu.

The PC can then be shut down by clicking the *power* button at the top right of the menu bar (see **Figure 4-4**).

Figure 4-4 Shutdown button

The OEM module can then be shut down by turning off the power supply.

4.7 Restarting gas sensor software following system shutdown

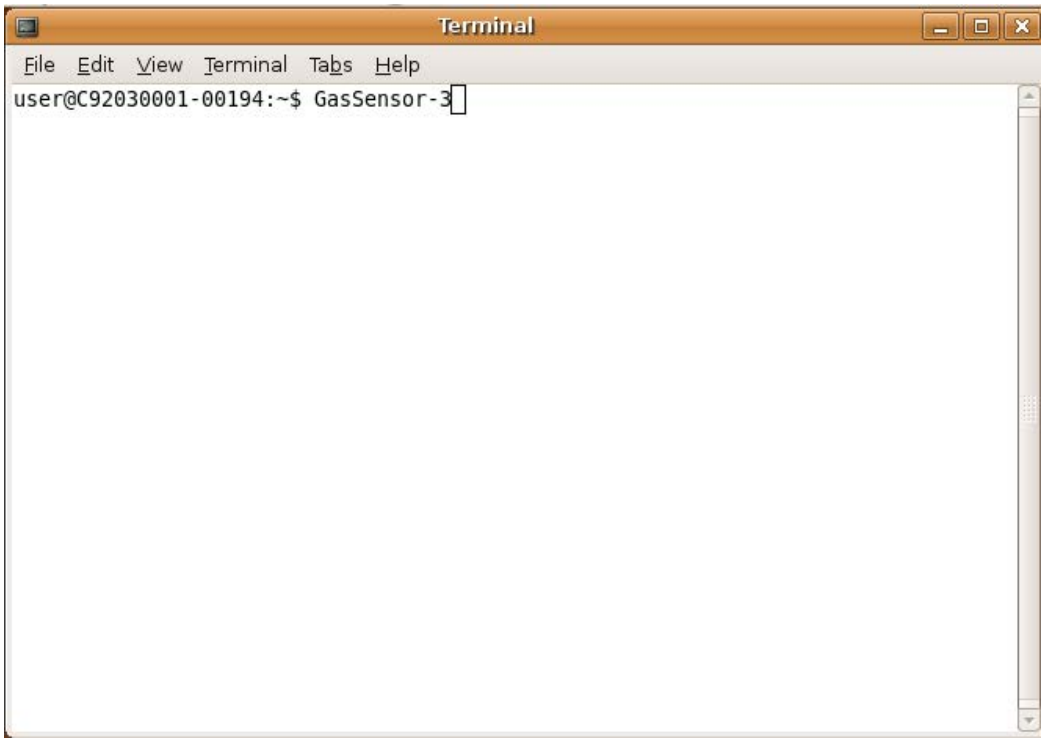
If the gas sensor software is closed down using the procedure described in **Section 4.6**, it may be restarted using the following procedure:

1. Open a terminal window, by selecting **Applications** > **Accessories** > *Terminal*.

2. A terminal window opens. Type *GasSensor-3* and press *Enter*, as shown in **Figure 4-1**.

3. The gas sensor software main screen will be displayed as shown in **Figure 4-1**.

Figure 4-5 Terminal startup

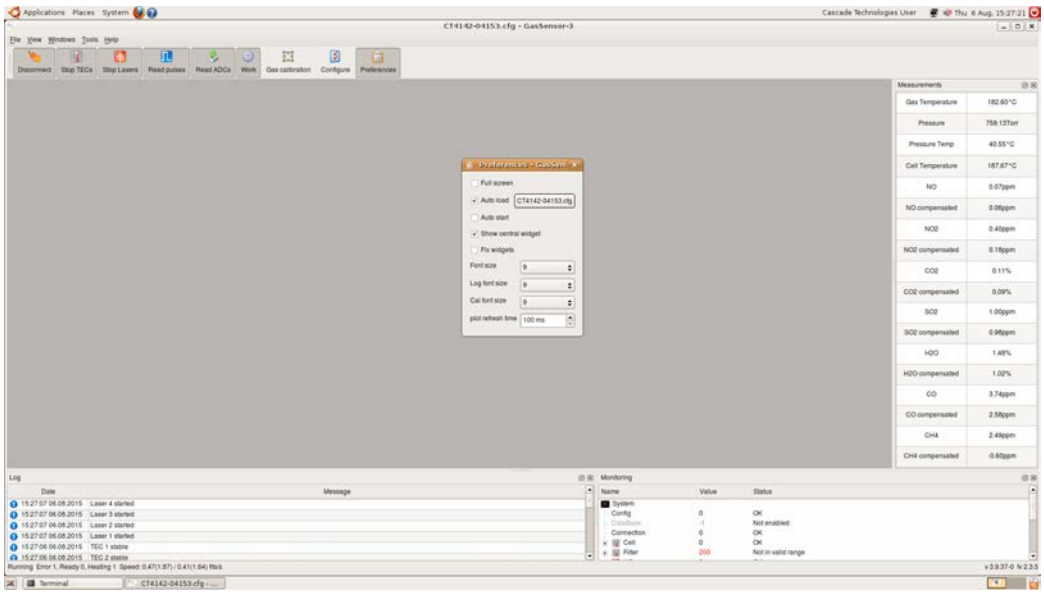


4.8 System preferences

The OEM module has a number of startup options that can be configured in the **Preferences** window, shown in **Figure 4-6**. The preferences are usually configured to automatically load the correct configuration file for the instrument and should be set up to do this:

1. Select Full screen to set the display to cover the entire PC screen.
2. The *Auto load* radio button should remain checked to automatically load the configuration file for the OEM module.
3. Select *Auto start* to automatically set the OEM module to operational mode on startup of the PC.
4. Select *Fix widgets* to fix the order of the icons on the top banner.
5. The font size and plot refresh time may also be configured. Note that decreasing the plot refresh time from 100 ms may slow down the update rate of the OEM module.

Figure 4-6 Preferences window



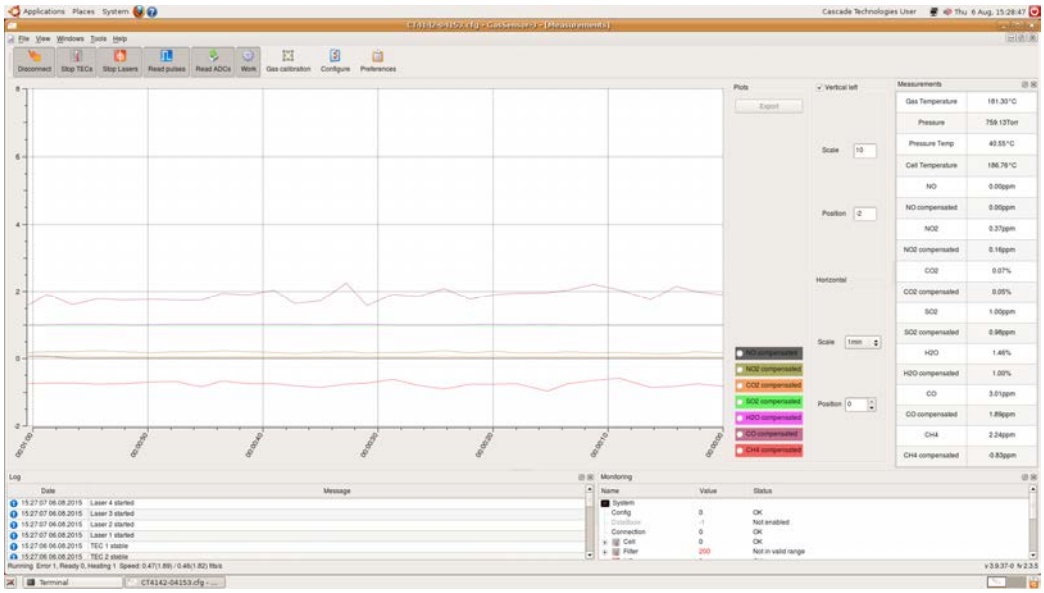
4.9 Gas sensor software package

Figure 4-7 shows the main screen displayed by the gas sensor software package. Each element in the window is described in the following paragraphs. The various sections of the gas sensor software main screen can be resized by clicking on their border and dragging with the mouse. The exact layout of your screen may consequently vary from that illustrated here.

The gas sensor software may be configured to start automatically when the PC is started, using the **Preferences** tab described in **Section 4.8**. If the gas sensor software does not start automatically, it can be started from a terminal window following the steps given in **Section 4.7** and put into *Work Mode* by following the steps in **Section 4.5.2**. Once in *Work Mode*, the display on the control PC will appear as shown in

Figure 4-3.

Figure 4-7 Gas sensor software screen



1. **Menu bar**
2. **Tool bar**
3. **Display area**
4. **Measurements display**
5. **Sensor measurements column**
6. **Software version**
7. **Monitoring window**
8. **Log window**
9. **Sensor status**
10. **System messages**

4.9.1 Measurements

As shown in **Figure 4-7**, the main screen of the gas sensor software package displays the gases being measured, the units of measurement, and the measurement readings obtained from the OEM module. In **Figure 4-7**, there are five gases being measured; NO, NO_2, CO_2, SO_2 and H_2O on a single path, with both the initial output and zero / span calibration (compensated) values being shown. There are ten gas concentrations in total. In each case, the last recorded measurement is displayed.

1. When the gas sensor is switched on, the measurements in the sensor measurements column (5) will initially appear as dashes (-) until the first readings are taken.

2. After a few seconds, the initial gas concentrations, and the OEM module system temperatures and pressures will be displayed in the sensor measurements column (5).

3. The **Pressure** reading is the pressure in Torr in the sample cell.

NOTICE

A Torr is a non-SI unit of pressure, defined as 1/760 of standard atmospheric pressure, and is equal to the fluid-pressure of 1 mm of mercury.

4. The **Internal Temperature** reading is the temperature in degrees C in those areas of the sensor that are not heated and not in direct contact with the gas. If the sensor is functioning correctly, the internal temperature reading should be between 20 degrees C and 65 degrees C.

5. The **Gas Temperature** reading is the temperature in degrees C of the sampled gas. If the Sensor is functioning correctly, the gas temperature reading should be the same as, or close to, the cell temperature reading.

6. The **Cell Temperature** reading is the temperature in degrees C of the sample cell.

7. The **Pressure Temperature** gives the temperature of the pressure sensor in degrees C, and is used to correct the thermal dependency of the pressure sensor.

8. The **Concentration** readings are the concentrations of each gas, calculated from the appropriate laser.

9. In the bottom right-hand corner (6) of the screen is the software version number and the fitting software version numbers.

10. In the bottom left-hand corner (9) of the screen is the sensor status. The information given consists of: the operating state of the Sensor; the number of concentration fits the software is performing per second; and the average number of concentration fits performed since the sensor was started.

⚠ CAUTION

If the gas sensor software display does not display measurements as shown in **Figure 4-7** or if the most recent (top) icon in the **Log** window (10) of the screen is not the blue circular icon shown, then refer to the Troubleshooting and System Diagnostics in **Section 0** of this manual for guidance.

4.9.2 Log Messages

Log messages (10) are displayed at the left of the screen as shown in **Figure 4-7**.

1. The first panel of the **Log** window gives the date and time that the message was generated and defines the message level, that is, the importance of the message, by means of the icon at the start of the message.

2. At the start of each Log message is a colored icon. The color of the icon indicates whether the CT4000 system is operating correctly (blue circular icon), there is a minor fault or indication of a service that cannot be completed due to the current status (yellow triangular icon), or a major fault (red square icon with a white cross inside).

3. The second panel of the Log window contains the text of the System Status message. **Figure 4-7** shows Information messages. A list of all system message levels with their definition can be found in **Section 6.7.1, System messages**.

4.9.3 Viewing data in graphs

The measured gas concentrations can be viewed in a graph. In GasSensor-3, click **Windows** in the top menu bar and then select *Show measurement plot* from the dropdown list that appears.

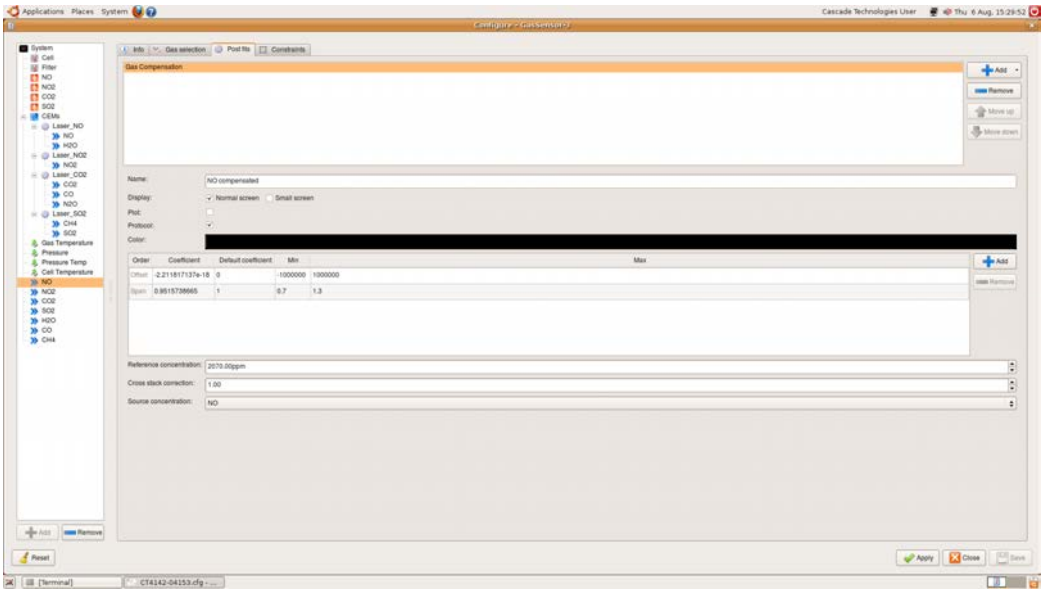
The plot is displayed in the central space and can be moved and stretched like a standard computer window. The **Measurements** plot is shown in

Figure 4-3. In this case it has been configured to show the compensated gas measurements.

1. By clicking the **Vertical left** box, the **Concentration** axis can be scaled to closely examine the measurements. **Scale** gives the vertical scale of the graph in the measurand units from top to bottom. **Position** gives the position of the bottom of the graph in the measurand units. Note that 1 % vol is equivalent to 10,000 ppm.

2. Similarly, the time axis can be rescaled by choosing a different scale from the dropdown list. The plot will display the last 600 readings, which is typically between one and ten minutes of data, but may vary depending on the update rate of the analyzer. These readings can be exported to a .csv format file by clicking the appropriate gas button to the right of the graph, then clicking the *Export* button.

Figure 4-8 Configuration window



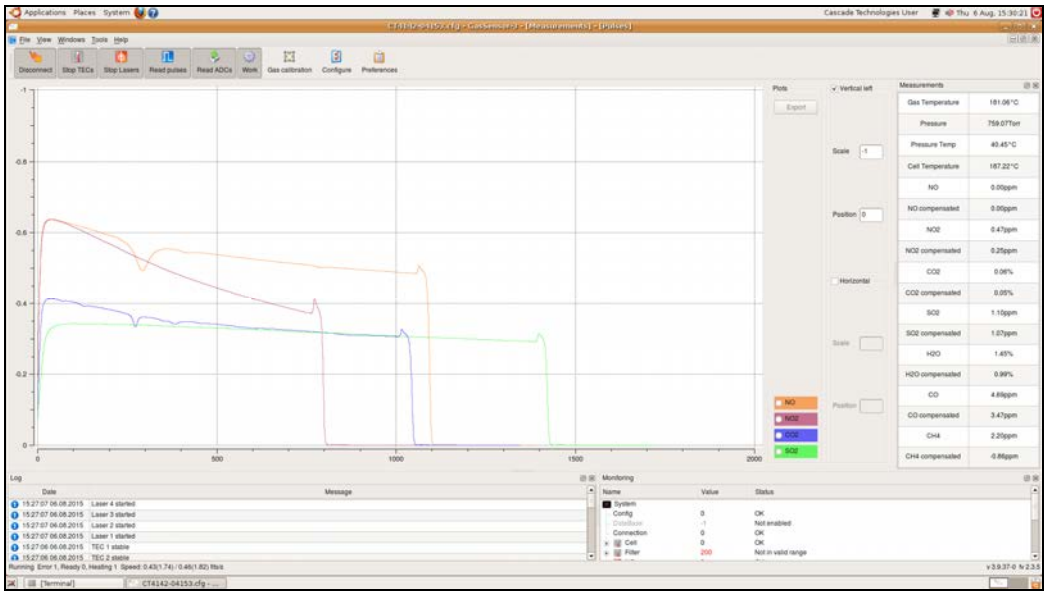
The gases which are displayed on the measurement plot can be selected by opening the configuration file. Click on the *Configure* button in the tool bar to open the file. The configuration window will appear as shown in **Figure 4-8**. Scroll down until the measurements are displayed, indicated by blue >>. Select the gas that is to be added to the measurement plot. In the **Info** tab, select the **Post Fits** plot and check that the name matches the name that is displayed on the measurements list. Select the *Plot* checkbox to add the measurement to the graph. **Figure 4-8** shows selecting *NO compensated* to be displayed on the plot.

4.9.4 Viewing the laser pulses plot

With the sensor running normally, the laser pulses can be viewed by selecting *Show pulses plot* from the **View** menu.

1. The laser pulses should look similar to those shown in **Figure 4-9**. There may be any number of pulses between 1 and 4, depending on your system specification. The flat line at the end of the pulses should be at 0, and the pulse intensity should be greater than -0.05. If the pulse intensity is less than -0.05, contact Emerson Process Management for assistance.

Figure 4-9 Laser pulses plot



2. If background division is used, the pulses displayed will be divided by a background and will look similar to **Figure 4-10**. Although this may look like a system error, if the vertical scale is changed, the pulses may be viewed more clearly as shown in **Figure 4-11**. The pulses should be centered around 1 and show the absorptions as decreasing features. The background function is described in **Section 4.10**.

Figure 4-10 Background Division plot

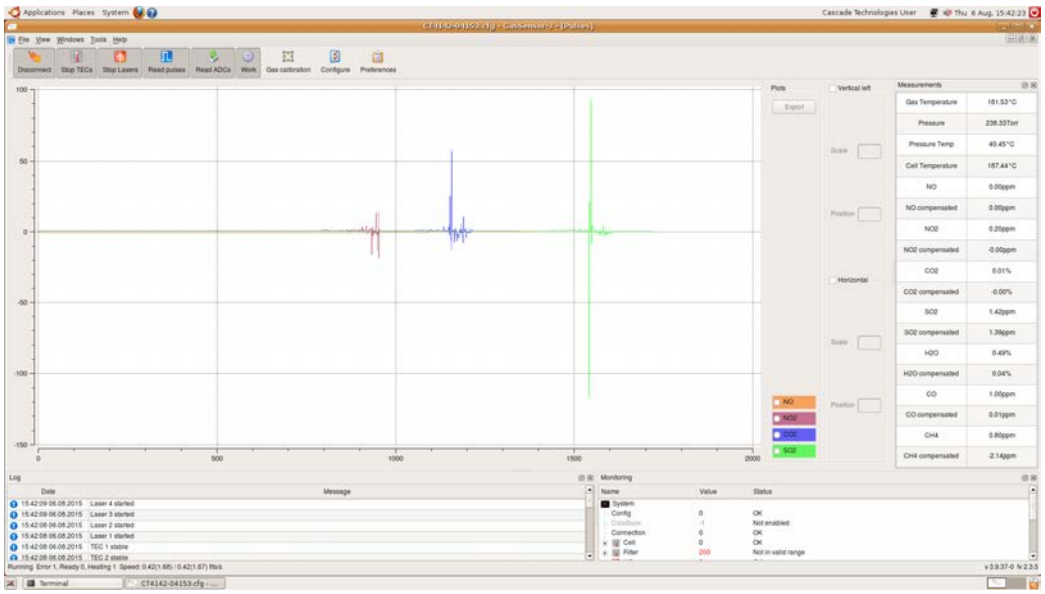
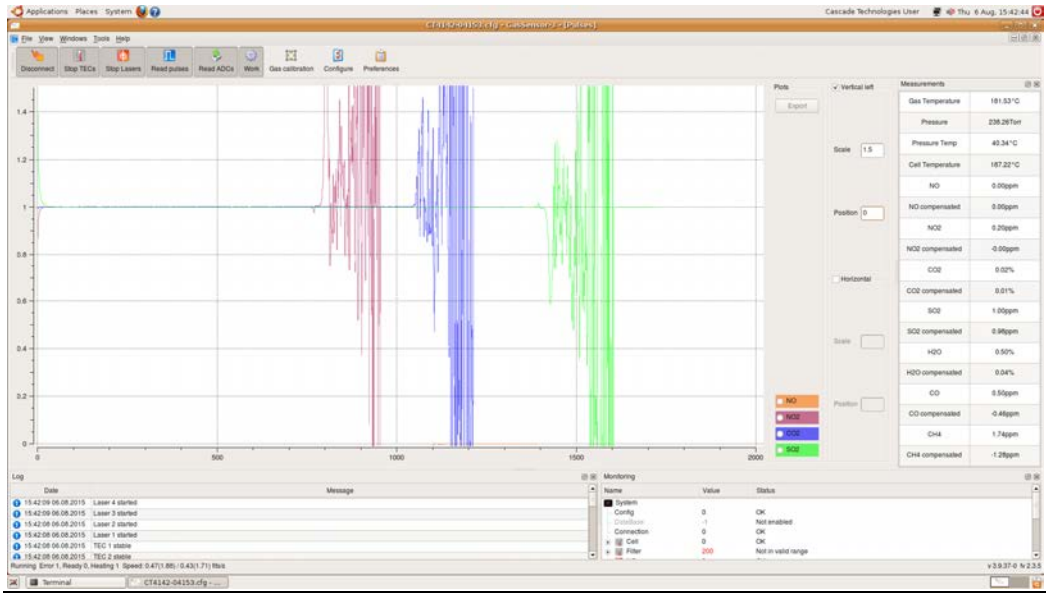


Figure 4-11 Background Division plot rescaled



4.10 Gas calibration procedure

The gas concentrations measured by the OEM module can be calibrated against a known sample gas by using the following procedures. The OEM Module configuration has to be preconfigured to allow zero and span calibration procedures to be used. If you are unable to complete the steps below, contact Emerson Process Management for further assistance.

4.10.1 Tools required

The calibration of the CT4000 requires the following items:

1. Suitable span calibration gases for each gas measured
2. Nitrogen gas of suitable purity for zero calibration gas.
3. Gas bottle pressure regulator.
4. Appropriate plumbing to connect gas bottle to the OEM module.

4.10.2 Schedule

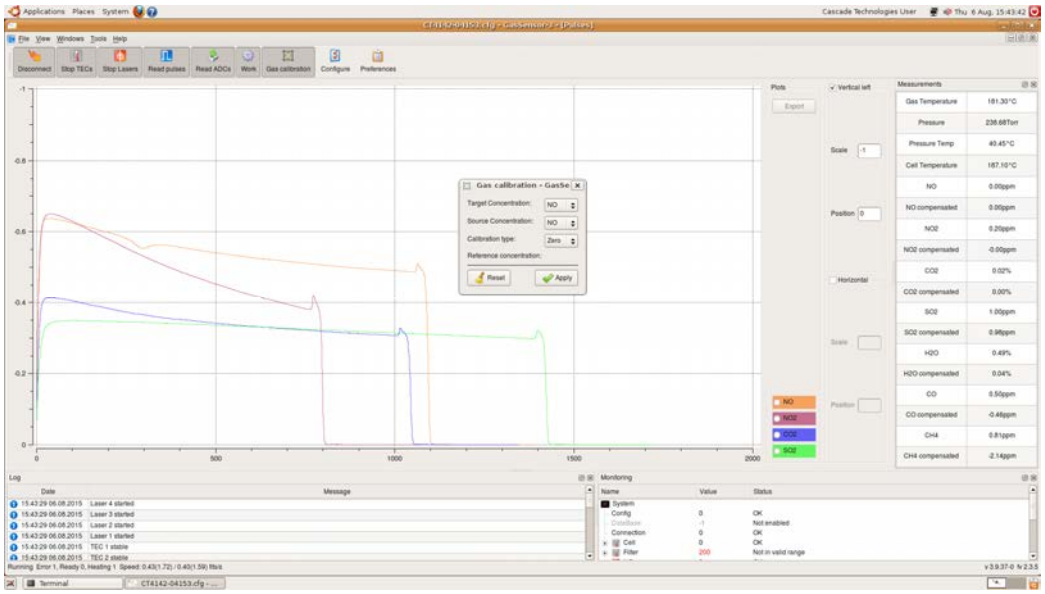
Zero and span calibration should be carried out at the user defined maintenance period. It is recommended that both zero and span calibration are carried out at the same time.

4.10.3 Zero calibration

The zero gas concentrations measured by the OEM module when no exhaust gas is flowing through the OEM module can be calibrated against a known sample gas by using the following procedure:

1. The analyzer must have been running at a stable temperature for at least thirty minutes prior to following this procedure.
2. Connect the tube from the calibration gas bottle regulator to the inlet gas port on the front of the CT4000, or through an external gas manifold.
3. Click *Gas calibration* at the top of the screen.
4. The Gas calibration window shown in **Figure 4-12** opens.

Figure 4-12 Zero calibration



5. Flow the zero gas from the cylinder into the analyzer.

6. Allow the concentrations to stabilize and wait for two minutes after stabilization.

7. Click the **Concentration** dropdown list and then click to select the gas you wish to calibrate.

8. Click *Apply*.

9. A system message should appear to indicate that the reference concentration has been successfully applied.

10. Stop the flow of calibration gas from the cylinder.

11. Close the **Gas Calibration** window by clicking on the cross at the top right hand side of the window.

12. Repeat steps 1-11 for the remaining gases as required.

4.10.4 Span calibration

The gas concentrations measured by the OEM Module can be calibrated against a known sample gas by using the following procedure:

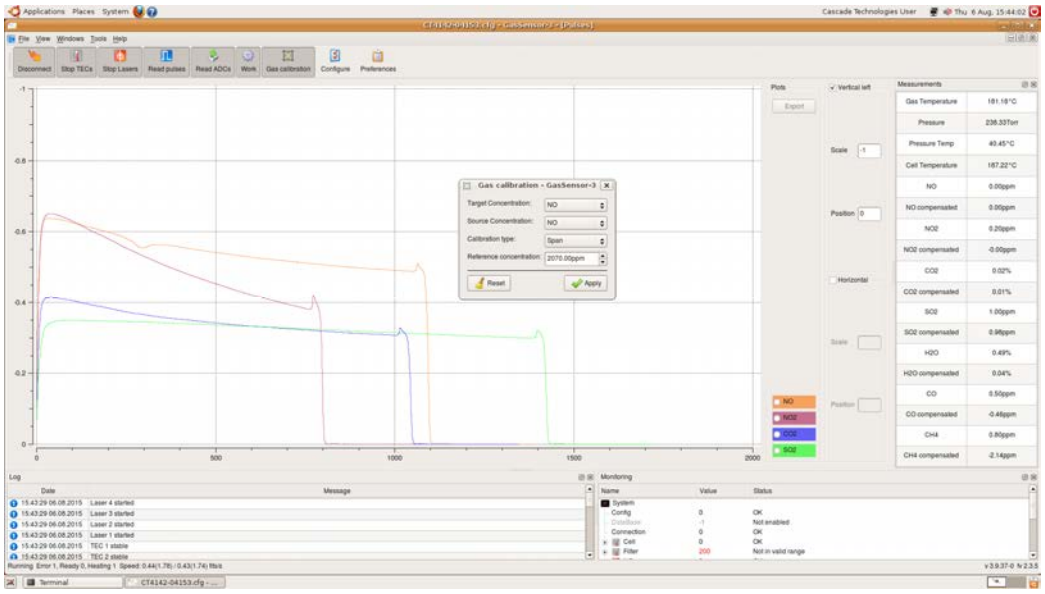
1. The analyzer must have been running at a stable temperature for at least thirty minutes prior to following this procedure.

2. Connect the tube from the calibration gas bottle regulator to the OEM module.

3. Click on Gas calibration at the top of the screen, as shown in the **Figure 4-12**.

4. The Gas calibration window shown in **Figure 4-13** opens.

Figure 4-13 Span calibration



5. Flow the span gas from the cylinder into the analyzer.

6. Allow the concentrations to stabilize and wait for two minutes after stabilization.

7. Click the **Concentration** dropdown list and then click to select the gas you wish to calibrate. Click the **Calibration type** dropdown list and select *span*.

8. Set the appropriate reference concentration using the up and down arrows by typing in the correct calibration gas value. Then click the *Apply* button; as shown in **Figure 4-14** below.

9. Clicking *Reset* changes the selected gas span calibration value back to its default setting.

10. A system message appears to indicate that the reference concentration has been successfully applied.

11. Stop the flow of calibration gas from the cylinder.

12. The **Gas Calibration** window can then be closed by clicking on the cross at the top right hand side of the window.

13. Repeat steps 1 to 12 for the remaining gases as required.

4.11 Background division

Background division can be used as a method of minimizing the noise on a laser pulse and enhancing the sensitivity of the instrument. It is recommended that you discuss your requirements with the Emerson Process Management technical team to determine whether background division is suitable for a particular application or gas. For example, background division of a laser that is monitoring water is challenging, as water may be present in the external light path, and it may be difficult to completely purge residual water from the system.

Background division can be activated in the following way:

1. While the system is in work mode, supply zero gas to the analyzer and wait for at least two minutes for any residual gas to purge from the system.

2. Select the Read Background icon from the top banner or from the Tools dropdown list.

3. After a short period, a message in log will confirm that a background has been selected for each laser and that normal working mode has resumed.

4. To renew a background, follow steps 1 to 3 above.

5. To cancel a background, click on the cancel background button on the top banner, or from the Tools dropdown list.

4.12 X-Shift adjustment

In order to maintain the laser wavelengths during long term operation, a periodic wavelength optimization is required, as described below.

1. With the sensor taking measurements of each gas, allow the gas concentration readings to come to a steady value.

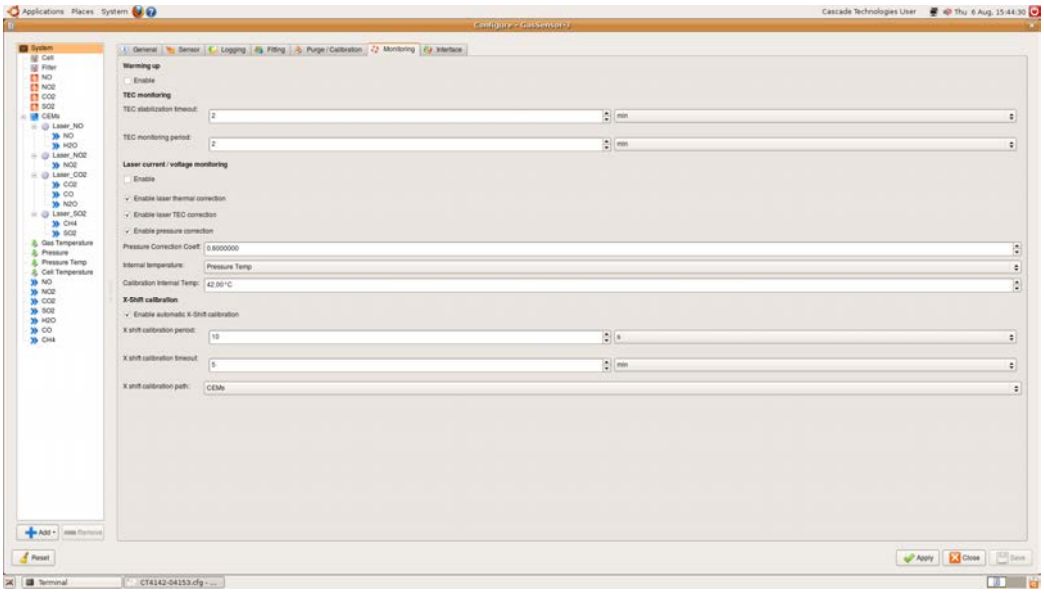
2. Click the **Tools** dropdown list and select *Configure*, or click the *Configure* icon on the top banner.

3. Click *System* in the explorer panel and click on the **Monitoring** tab, as shown in **Figure 4-14**.

4. Check the *Enable* box under the heading **Automatic Xshift calibration**.

5. Click *Apply*, *Save*, and *Close*.

Figure 4-14 X-Shift adjustment



6. If the **Log** window is not visible, select *Log* from the **View** dropdown list.

7. Note that the position of the **Log** window may vary depending on your system. If any of the laser wavelengths require optimization, a series of notices *X-Shift: TEC # temperature offset adjusted to xxxxx* appear at ten second intervals in the **Log** window. When the optimization is complete, *Path #, Laser #: X-Shift has come back into target range* appear. In the example below, Laser 2 is back in the target range, while Laser 1 is still undergoing optimization:

Figure 4-15 The Log window

13:54:20 08.07.2011	X-Shift: TEC 1 temperature offset adjusted to -0.875058
13:54:10 08.07.2011	X-Shift: TEC 1 temperature offset adjusted to -0.798664
13:54:00 08.07.2011	Path 1, Laser 2: X-Shift has come back into target range
13:54:00 08.07.2011	X-Shift: TEC 1 temperature offset adjusted to -0.706396
13:53:49 08.07.2011	X-Shift: TEC 2 temperature offset adjusted to -1.10745

8. When all necessary adjustments have completed, repeat steps 1 to 3, uncheck the *enable* box, and then repeat step 5.

9. Note that it is possible for all, none, or some of the lasers to require adjustment.

4.12.1 After X-shift adjustment

Once the X-shift adjustment has been completed, a zero calibration and a span gas calibration should be performed as described in **Section 4.10**, if this functionality of the software is regularly used to maintain the gas concentrations.

4.13 The laser calibration tool

This procedure describes the steps taken to perform the calibration of the lasers within a sensor using the calibration tool on gas sensor 3.

NOTICE
This procedure may only be carried out if an etalon is installed in the system. This is an optional component that may be specified on order. Contact Emerson Process Management if you are unsure of the configuration of your system.

This procedure is for use by Emerson Process Management personnel and qualified personnel who have received training on use of the tool only. For further assistance, please contact Emerson Process Management.

4.13.1 Required equipment

The following equipment is required:

1. A CT4000 OEM module
2. An etalon assembly for the CT4000
3. A control PC with a suitable version of gas sensor-3 software (version 3.8 or higher)
4. Calibration gas of a concentration of between 30 and 100% of range (refer to Appendix A of this manual for information on the concentration ranges for your system).
5. Sample handling system or pump.

NOTICE
If there is no etalon assembly installed in the CT4000 you are using, the following window will be displayed when the laser calibration tool is activated:

Figure 4-16 Laser calibration feature restriction message

4.13.2 Procedure

Calibrate each laser as follows:

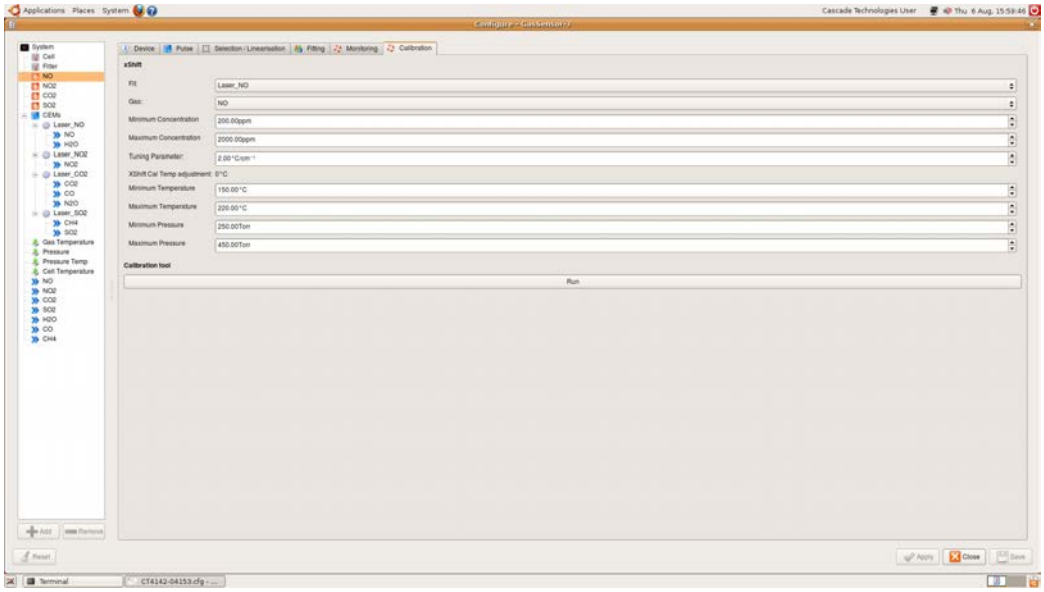
1. Ensure the sensor is powered on and in Work Mode, and that the unit has been powered on for sufficient time for the cell to reach a stable operational temperature for at least one hour.

2. Supply nitrogen or zero air to the OEM module, wait a few seconds and then press the *Configure* button.

3. Select the laser you wish to calibrate (NO is shown in the screenshots in this procedure) from the dropdown list on the left side.

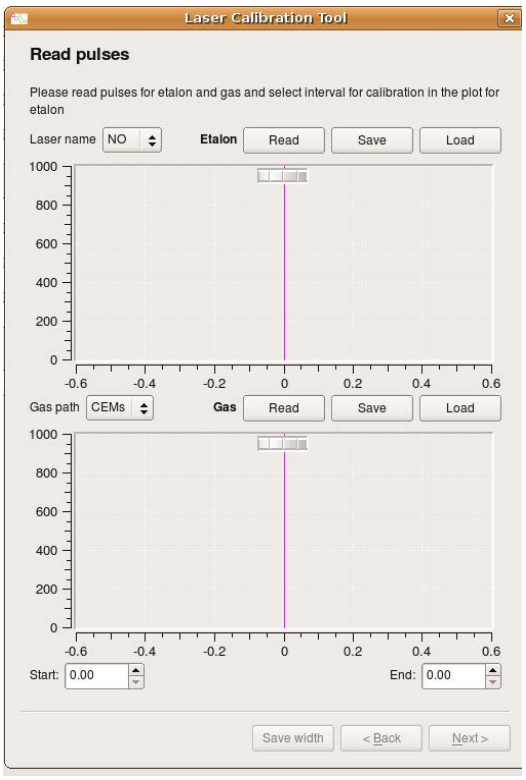
4. On the **Calibration** tab, go to the **Calibration tool** section and click the *Run* button. **Figure 4-17** shows the opening screen.

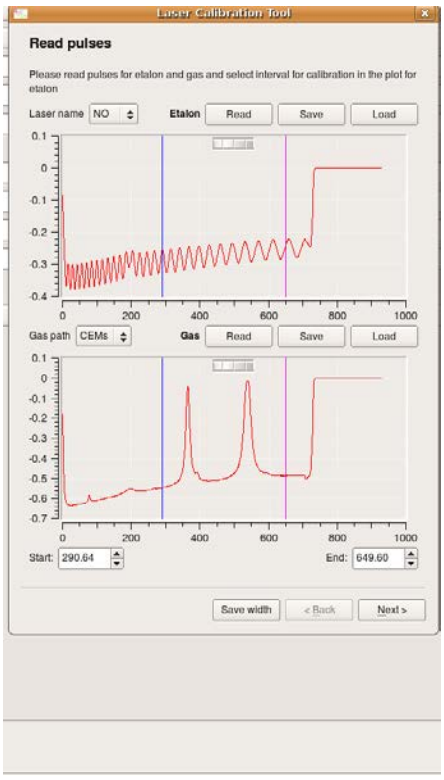
Figure 4-17 Selecting the laser and starting the calibration tool



5. On pressing the *Run* button, the screen in the left hand panel of **Figure 4-19** Etalon calibration will appear in a separate window.

Figure 4-18 Calibration tool screen





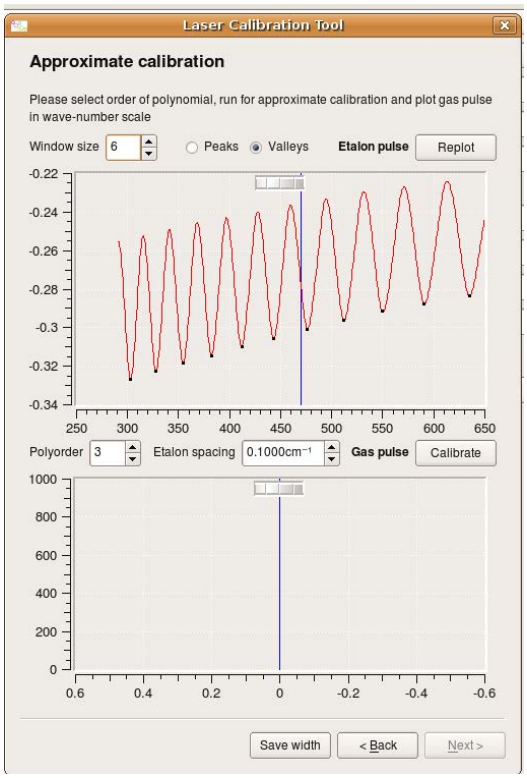
6. Ensure that there is no gas (except nitrogen or zero air) flowing to the sensor. Press the *Read* button for the **Etalon pulse**. This enables the etalon in the sensor, saves the pulse data from the relevant detector, and displays it. If the etalon fringes do not look well defined, press the *Read* button a second time.

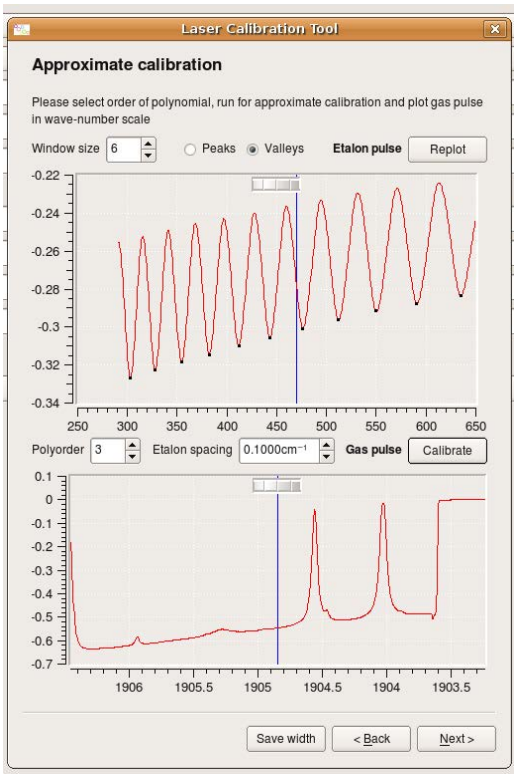
7. Now supply the target gas for the laser that is under calibration to the OEM module. Press the *Read* button for **Gas pulse**. The right hand panel of **Figure 4-19** shows how the etalon and the gas pulses might look for an NO laser.

8. Before moving to the next page, select the window that will be used in the calibration by dragging the blue and pink lines to the desired position on the etalon pulse. When moved on the etalon pulse, the lines will automatically move on the gas pulse. For example, for NO, both absorption lines should be included in the calibration and so the window selected should accommodate this. Take care not to leave either line on the edge of the pulse as this may affect the calibration. The lines have been correctly adjusted in the right hand panel of **Figure 4-19**.

9. Click *Next*. The etalon fringes should now be recognized by the software as shown in the left hand panel of **Figure 4-20**. Each *valley* (or trough) should be marked with a black point. The software defaults to *valleys* instead of *peaks*, but either can be used. If all of the valleys or peaks are not recognized by the software, change the value in the **Window size** box in increments of 1 and click *Replot*. Repeat this until all fringes are recognized.

Figure 4-19 Etalon calibration

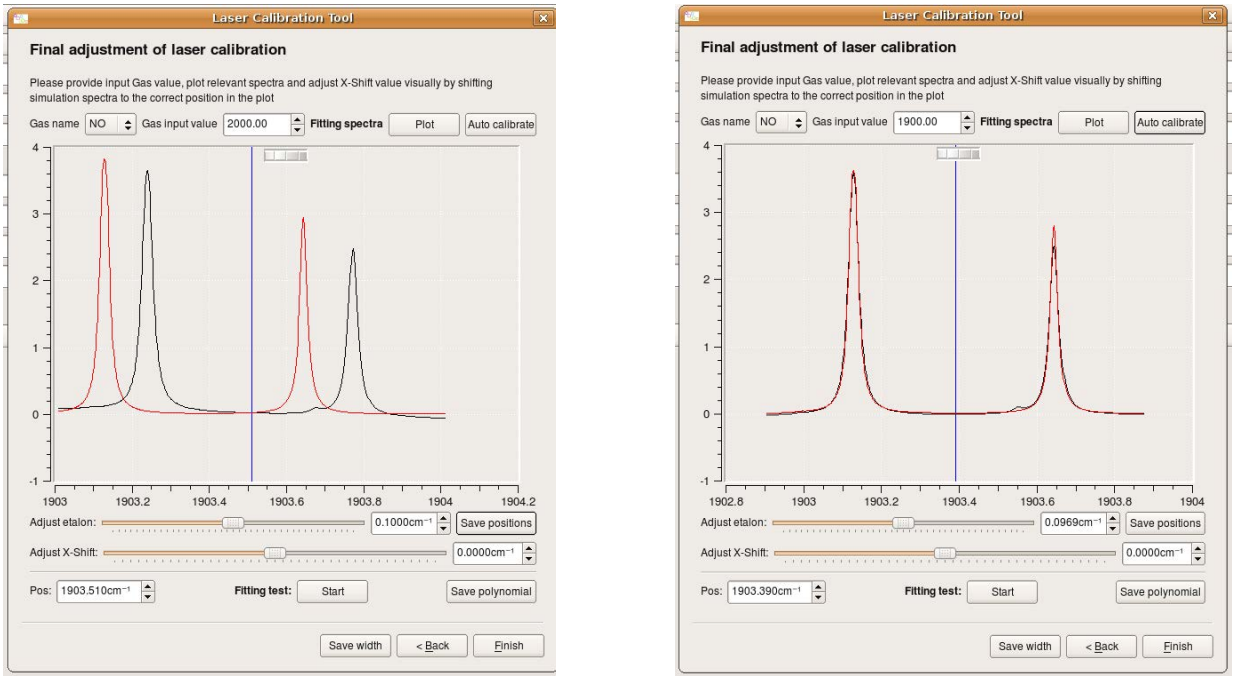




10. Click the *Calibrate* button in the middle of the screen. The software should show the gas pulse; see an example in the right hand panel of **Figure 4-20**.

11. Click *Next* for the final adjustment of the calibration. Enter the gas concentration and click *Plot*. Two sets of spectra should appear, the actual spectrum (black) and the simulated spectrum (red), as shown in the left hand panel of **Figure 4-20**.

Figure 4-20 Final adjustment of calibration



12. Click *Auto calibrate*. The software should try to match the two spectra to each other. However, the *Auto calibrate* feature may not match the spectra exactly.

13. For an accurate calibration, the two spectra are as closely matched as possible, so that they overlap completely. Further adjustment is normally required after the auto calibration. There are three parameters that may be adjusted:

    a. The **Gas Input value** (the concentration value in ppm) may be altered by typing in a new value or by using the up and down arrows. This is mainly useful for matching the heights of the absorption peaks on the spectra.

    b. The **X-Shift** value may be altered by using the slider, typing in a new value, or using the up and down arrows. This moves the position of the spectrum in the X-axis.

    c. The **Adjust etalon** feature may be altered by using the slider, typing in a new value, or using the up and down arrows. This is the fine adjustment of the wavelength tuning of the laser to achieve a closer fit.

These parameters can be adjusted several times in order to achieve the best fit. Press the *Save positions* button after any adjustment of the X-shift or etalon, especially if the up and down arrows are used for the adjustments, as *Save positions* activates the change. The right hand panel of **Figure 4-20** shows the final calibration for the NO laser described in this procedure.

NOTICE

The **Fitting Test** feature can be used for a preview of the fitting for the laser before the laser calibration factors are saved. To activate click the *Start* button next to **Fitting Test**.

14. Once a satisfactory calibration has been achieved, click *Save polynomial*, and this will write the new polynomial values for the fit to the laser module memory. Click *Finish*.

15. As a final check, the fitting for the laser should be viewed. First, click *Work* on GasSensor-3. Once the sensor has started properly, click *View* and then *Fittings*. Choose the appropriate path and laser to view the fit. The real data and the simulated data should be closely overlapped.

16. If the fit is satisfactory, the calibration for the laser is complete. Repeat the procedure for other lasers as appropriate.

5 Scheduled Maintenance

5.1 Maintenance

This Section describes the scheduled maintenance for the OEM module. Scheduled maintenance is also sometimes known as planned preventative maintenance.

5.2 Schedule

The following are maintenance activities and their suggested frequency. Variation in customer sites may require these activities to be performed more or less often than indicated; however, the time between checks should not be increased by more than 20%. Details of the actions to be performed are contained in subsequent paragraphs of this section, or in **Section 0** of this manual.

5.2.1 Weekly check

At least once per week, perform the following preventative maintenance action:

Check the zero and span calibration of the OEM module.

5.2.2 Monthly check

At planned monthly intervals, perform the following preventative maintenance actions:

1. Perform the weekly check detailed in **Section 5.2.1**.
2. Run an X-Shift calibration.
3. Purge the long path cell mirrors.

5.2.3 Biannual check

At planned biannual intervals, perform the following preventative maintenance actions:

1. Perform the monthly check detailed in **Section 5.2.2**.
2. Perform a laser wavelength calibration (if supported by the system configuration).

5.3 Maintenance activities

Maintenance activities are described in this section or referenced to the relevant part of this manual.

5.3.1 Zero calibration

Refer to **Section 4** for instructions on how to perform a zero calibration. This activity is performed using the GasSensor-3 software.

5.3.2 Span calibration

Refer to **Section 4** for instructions on how to perform a span calibration. This activity is performed using the GasSensor-3 software.

5.3.3 X-shift calibration

Refer to **Section 4** for instructions on how to perform an X-Shift calibration. This activity is performed using the GasSensor-3 software.

5.3.4 Sample cell mirror purge

The sample cell mirrors are purged using the inlet port connector on the OEM module, and either a high pressure dry nitrogen or high pressure dry zero air gas supply. The purge is intended to remove any particulate matter or dust that has adhered to the mirror surface while sampling gas.

The sensor should be powered off and allowed to cool for at least twelve hours prior to performing a mirror purge. This is to allow the system to cool and to prevent thermal shock when cold purge gas is applied to the mirror surface. If the system is purged when the gas cell is heated, the purge gas should also be heated to the same temperature as the gas cell prior to entering the OEM module purge port.

To purge the mirrors, connect the purge air gas supply to the inlet port. Disconnect the exhaust port connection to prevent pressure buildup within the cell. Set the supply pressure to one bar, and open the purge air supply. Apply the purge gas for two minutes. Turn off the air supply and disconnect the purge supply.

5.3.5 Laser wavelength calibration

Refer to **Section 4** for instructions on how to perform a laser wavelength calibration. This activity is performed using the GasSensor-3 software. An etalon assembly is required to perform a laser wavelength calibration, and this is an optional accessory depending on the system configuration. Contact Cascade Technologies if you are unsure of the suitability of your system to perform this maintenance activity.

6 Failure Diagnosis

6.1 Introduction

This section contains the failure diagnosis procedures for the OEM module.

⚠ WARNING

HEAVY ITEM

- Handle the OEM module with caution during unpacking, installation, maintenance, and transport to prevent crushing of hands, feet, or other body parts.
- The OEM module weighs 13 kg and should be lifted with caution. Wear suitable protective gloves and protective footwear. When preparing the OEM module for transport by air, road, or rail, safeguard the OEM module against movement or break-away during transport by securely strapping it in place.

6.2 Failure diagnosis principles

The failure diagnosis procedures described in this section makes the assumption that any host equipment is fully functional. Ensure that the host equipment is fully serviceable before performing failure diagnosis on the OEM module.

Electrical power to operate the OEM module is provided by the host equipment.

All controls and indicators are on the OEM module or control PC unless otherwise indicated.

Failure diagnosis of the OEM module comprises interpretation of the system messages displayed on the computer and visual examination.

6.3 Repairable faults

The following items in the cell assembly are repairable by maintenance personnel who have been trained and are authorized to carry out repairs on the OEM module. In all cases, the repair is by direct replacement of the faulty item with a known serviceable item:

- Cell heaters
- Cell thermistors
- Cell thermal cut out
- Pressure sensor
- The complete cell assembly

The following items in the Laser Module Side are repairable. In all cases the repair is by direct replacement of the faulty item with a known serviceable item:

- Detector
- Etalon assembly
- All four Laser Modules
- Digitizer PCA
- Peripheral PCA
- Power Distribution PCA
- Detector TEC PCA

The other items in the OEM module that are repairable are as follows. In all cases the repair is by direct replacement of the faulty item with a known serviceable item:

- The control PC (where supplied by Emerson Process Management)
- Ethernet connector
- DC voltage connector
- AC voltage connector
- 12 V ceramic fuse

6.4 Faults only repairable by Emerson Process Management

If any of the following items in the OEM Module are unserviceable, the complete OEM Module **must** be returned to Emerson Process Management for repair:

- The cell internal mirrors
- The cell windows
- The cell insulation and pipework
- The motherboard PCA
- Any other component not listed in the repairable parts

6.5 Tools and test equipment

The tools required to perform scheduled maintenance on the OEM Module are standard hand tools. The only test equipment required when repairing the OEM Module is a multi-meter that may be used to perform continuity checks on electrical wiring during an Inspection.

6.6 Wiring diagram

To assist with Failure Diagnosis, a layout and wiring diagram for the OEM module is shown in **Figure 6-1**. The Cable Assembly configurations are shown in **Figure 6-2** and **Figure 6-3**.

These diagrams may be used to locate the position of a wiring connector should it become disconnected.

⚠ WARNING

BURNS

Some parts of the OEM module are heated to 200 °C. To prevent burns do not touch any of the hot parts. Always assume that all parts of an OEM Module are hot unless it has been switched off and allowed to cool down.

Before touching, handling, fitting, removing, or performing any maintenance on the OEM module, ensure that it has been switched off and allowed to cool for at least sixty minutes. Before performing any maintenance on, or in the vicinity of, the analysis cell, allow the OEM module to cool for at least twelve hours as the analysis cell is insulated against heat loss.

When handling the OEM module always use suitable protective gloves.

Personal injury and/or damage to property may result if these safety precautions are not observed. If a burn is received seek medical treatment immediately.

Figure 6-1 CT 4000 OEM module wiring diagram

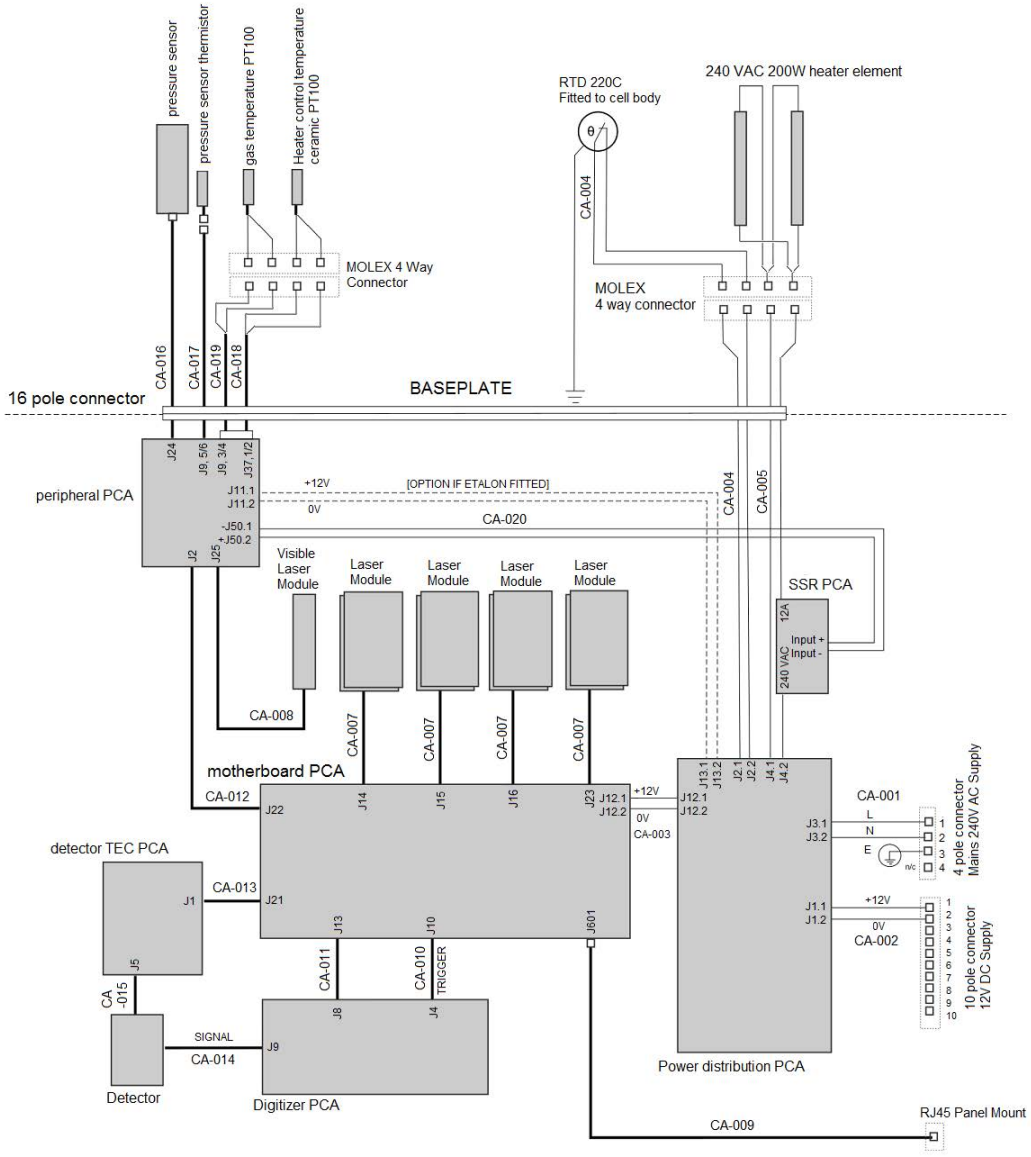


Figure 6-2 CT4000 OEM module cable assembly wiring detail

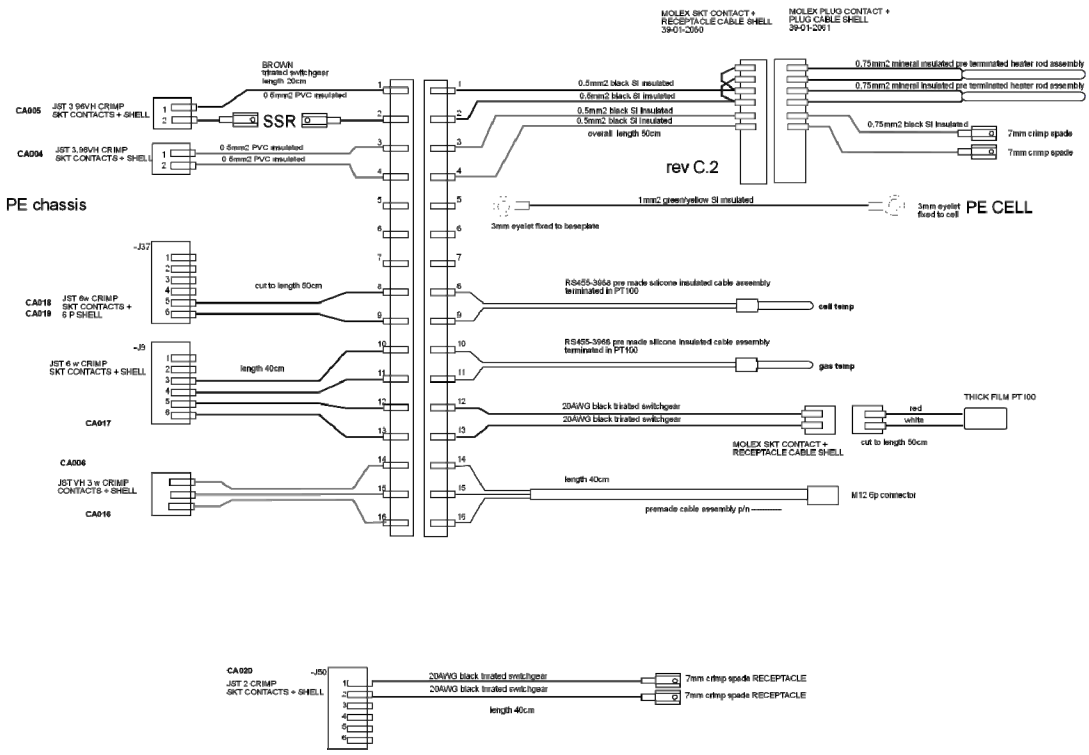
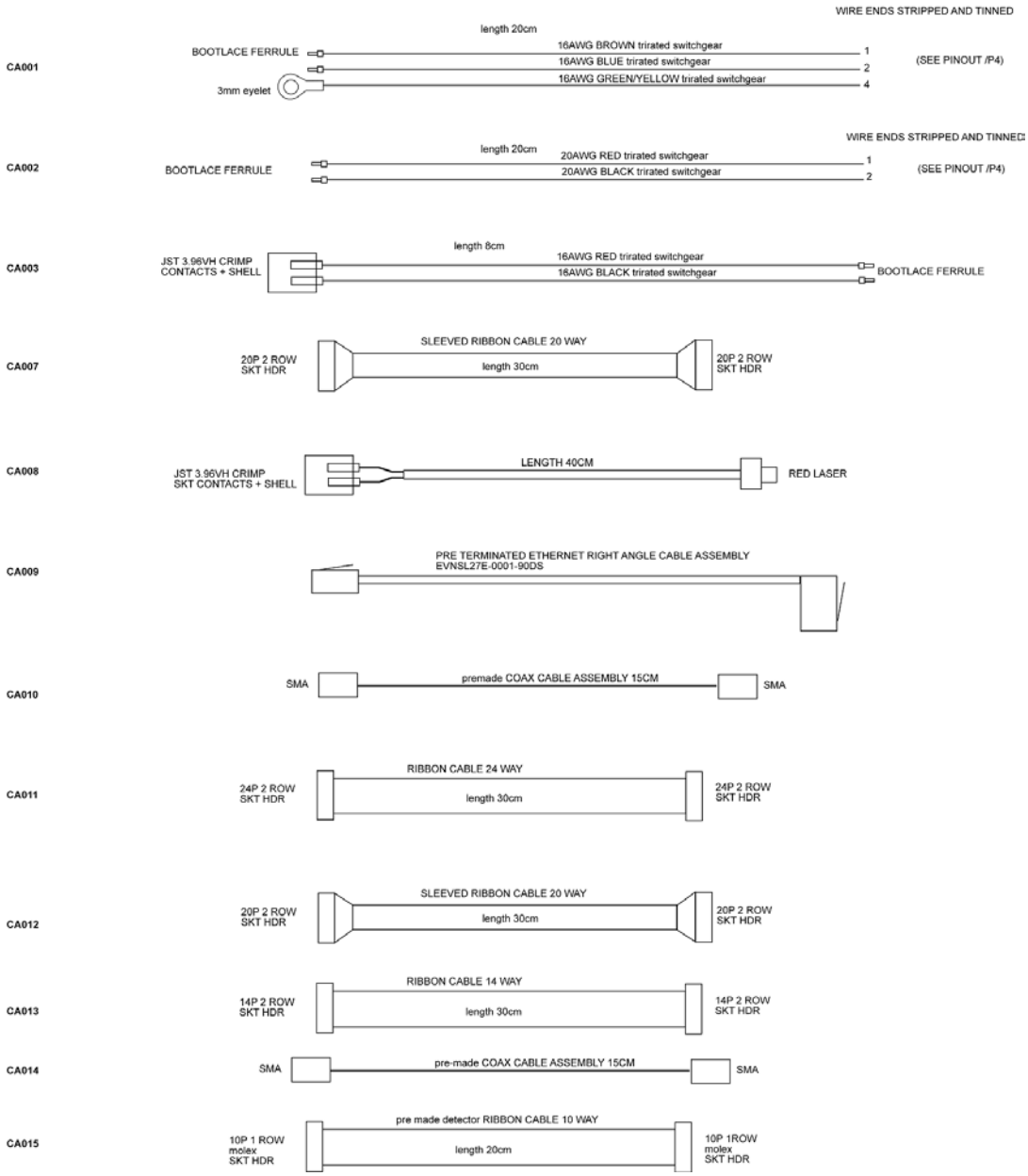


Figure 6-3 CT4000 OEM module cable assembly wiring detail continued



⚠ DANGER

FLAMMABLE SUBSTANCES

Some parts of the OEM module may reach temperatures of 200 °C and may present an ignition source. Exercise care when using oil, paint, cleaning rags, and other flammable substances near the OEM module. A fire may result if this precaution is not observed. Always assume that all parts of an OEM module are hot unless it has been switched off and allowed to cool down.

⚠ WARNING

ELECTRIC SHOCK

The OEM Module operates using mains voltage that is dangerous to life. Ensure that the OEM Module is disconnected from the mains supply before removing any outer covers or performing any work inside the OEM Module. This is particularly important when working at heights.

Death, personal injury, and/or damage to persons and/or property may result if this is not observed.

Besides the danger from high voltages, the seals against water and dust can be damaged or impaired if the OEM Module is closed or opened incorrectly.

⚠ WARNING

HAZARDOUS SUBSTANCES

The OEM module may contain hazardous substances. Always handle OEM module assemblies and components with extreme caution.

Gas handling components within the OEM module will contain particulate matter residue from the sample gases. Over the life of the OEM module, the concentration of particulate matter will become enriched within the gas handling components. The particulate matter comprises carbon, ash, soluble organic fraction, and, depending upon the type of fuel used, may include compounds derived from sulfur, which are acidic in nature and may cause respiratory problems. When performing repairs and maintenance on the OEM Module:

- Handle used gas handling components with extreme caution.
- Avoid direct skin contact with used gas handling components.
- Do not smoke, eat, or drink in the work area.
- Wear goggles or eye shields.
- Wear a suitable face mask to protect against inhalation of particulate matter.
- Keep food and beverages away from the OEM module.
- Do not wet fingers, eyes, or any exposed skin.
- Pack used gas handling components for disposal in sealed packaging and label it *Contaminated*.
- Dispose of contaminated items as hazardous material according to the applicable local, national, or international health and safety regulations and pollution regulations.

6.7 General troubleshooting and diagnostics information

The OEM module is specifically designed to run unattended indefinitely, to automatically resolve system issues, and to recover from power failures and return to a normal working state. This troubleshooting guide is intended to assist maintenance personnel, who have been trained to service the OEM module, when the OEM module has not appeared to be working normally for a period of more than five minutes. If the procedures given in this section fail to return the OEM module system to normal operation, notify your service agent for further assistance.

6.7.1 System messages

Table 6-1, **Table 6-2**, and **Table 6-3** all list system messages that can appear in the **System Messages** panel of the **Gas Sensor** software window and describe the meaning of each message. The system messages are divided into three types:

- Notices
- Warnings
- Errors

1. A system message that is a Notice is for information only and requires no action by the user.
2. A system message that is a warning indicates that a minor fault has occurred. The problem cannot be rectified by the user, but may be automatically rectified by the OEM module. A suitably qualified and trained engineer is required to rectify faults that are not automatically rectified.
3. A system message that is an Error indicates that a major fault has occurred. The problem cannot be rectified by the user or the OEM module. A suitably qualified and trained engineer is required to rectify the fault.

Table 6-1 System notice messages

Message and type	Meaning
NOTICE	No action required.
Sensor, communication recovered; Communication with the sensor recovered	The gas sensor software has reconnected via Ethernet to the exhaust analyzer.
Sensor {name}, initialized; Sensor initialized	The Sensor with {name} has been successfully initialized.
Sensor {name}, initialized; {system firmware}	The computer has successfully initialized the exhaust analyzer with {name} and {firmware version}.
Laser {number} started	The laser {identified by its number} has started and is operating normally.
TEC {number} started	The thermoelectric controller (TEC) {identified by its number} has started.
TEC {number} stable	The thermoelectric controller (TEC) {identified by its number} is operating normally.
Heater Cell started	The heater in the analysis unit has started and is operating normally.
Laser {Laser N}: X-Shift has come back into target range	The automatic X-Shift adjustment has changed the laser TEC temperature to within the normal range.

Table 6-2 System warning messages

Message and type	Meaning
WARNING	Repairs (if required) can only be performed by a suitably trained and qualified engineer.
GasSensor, log to file error; Error while logging to file; system error while writing logs	It has not been possible to write a Gas Sensor log file to the computer file system.
Laser, TEC warning; TEC {TEC N} not in +-5 deg C range of set point	The thermoelectric controller (TEC) identified as {TEC N} is outside the normal acceptable range.
Sensor, Unknown error received; network system error	A non-fatal error related to the Ethernet communications between the exhaust analyzer and the computer. Refer to **Section 6.7.3: Communication fault messages**.
SpecFit, fit error; Error returned by the fitting routine, pulse is flat line	The laser pulse has no shape and appears to be just a flat line.
SpecFit, fit error; Error returned by the fitting routine, tail of pulse is not just noise	The tail of the laser pulse is not shaped as expected.
SpecFit, fit error; Error returned by the fitting routine, pulse is too noisy {s/n}	The shape of the pulse contains too much noise for the fitting routine to calculate an accurate concentration.
Laser {Laser N}: X-Shift is {above/below} warning level	The automatic X-Shift adjustment has changed the laser TEC temperature to within the warning range.
X-Shift: TEC {TEC N} temperature offset adjusted to x.xxxxx	The automatic X-Shift adjustment has changed the laser TEC temperature to that shown.
Laser {Laser N}: X-Shift Concentration=xxxx.xx is {above/below} below the {maximum/minimum} level	The measured gas concentration is outside the limits that allow the automatic X-Shift adjustment of the laser TEC temperature to be adjusted.

Table 6-3 System error messages

Message and Type	Meaning
ERROR	**Repairs can only be performed by a suitably trained and qualified engineer.**
Laser, TEC error; TEC {TEC N} not in +-10 deg C range of set point	The thermoelectric controller (TEC) identified as {TEC N} is outside the warning acceptable range.
Sensor, communication failed; Communication with the sensor lost	Some communications via Ethernet between the computer and the exhaust analyzer have been lost. Refer to **Section 6.7.3:**
Sensor, communication lost; Communication with the sensor lost	Communications via Ethernet between the computer and the exhaust analyzer have been lost for greater than a set time-out period. Refer to **Section 6.7.3: Communication fault messages.**
Path {Path N}, Laser {Laser N}: X-Shift is {above/below} error level	The automatic X-Shift adjustment has changed the laser TEC temperature to above or below the error range.

6.7.2 Warning or error message significance

A warning or error message that is displayed again and again with new time stamps indicates that the gas concentrations being measured may be compromised. If the warning or error message does not reappear with a new time stamp after a period of several seconds, and there is no message stating “communication lost”, then this indicates that the problem has been resolved.

6.7.3 Communication fault messages

The one warning and two error messages related to communication failures between the control PC, the CT4000 OEM module, and an external data logger or reader are usually caused by:

- The Ethernet cable being disconnected.
- Power loss to the Sensor.
- Power loss to the Ethernet switches (if installed).

If these three communication fault messages are not followed by the recovery notice: “Sensor, communication recovered; Communication with the sensor recovered”, then stop the software and shut down the sensor as described above. If the problem persists when the sensor is restarted, contact Emerson Process Management for assistance.

6.7.4 Resolution of warning or error messages

For warning or error messages that are not resolved automatically by the CT4000 system, or if the Gas Sensor software seems to have frozen or is not behaving as described in this manual, then follow the system shutdown and system startup instructions in Sections **4.6**and **4.7** and re-start the whole OEM module. If the same faults reoccur, then follow the fault resolution procedures given below.

6.8 Simple fault resolution

The faults described below may be investigated and possibly rectified by a suitably trained and qualified engineer.

6.8.1 No gas measurement change

6.8.1.1 Symptom

Measurements do not change when measurement gas is supplied to the analyzer.

6.8.1.2 Possible cause

There is no flow through the measurement cell. The OEM module does not have an internal sample handling system, and it is the user's responsibility to flow gas through the measurement cell. Check the external pump and gas supply.

6.8.2 Gas temperature low

6.8.2.1 Symptom

The temperature of the sample cell is outside of specification.

6.8.2.2 Possible causes

6. The cell is heating up after startup; wait for the temperature to become stable and then monitor for at least ten minutes. If temperature is still too low, then consider the following other possible causes.

7. The AC voltage is disconnected; check that the AC voltage is connected and at the voltage specified in Appendix A.

8. The cell heaters are faulty; replace cell heaters. This is a specialist maintenance task; contact Emerson Process Management for parts and assistance.

6.8.3 Laser signal level low

6.8.3.1 Symptom

The size of the laser signal is low; the baseline to peak measurement is less than 0.05V.

6.8.3.2 Possible causes

9. The cell mirrors are contaminated; purge the sample cell mirrors as described in **Section 5.3.4**.

10. The sensor optics are misaligned; contact Emerson Process Management for instruction.

11. The cell window is contaminated; contact Emerson Process Management for instruction.

6.9 Visual examination of the OEM module

A visual examination of the OEM module is recommended as the next step in failure diagnosis after interpreting the system messages. The upper and lower sections of the OEM module should be assessed. The section components are illustrated in **Figure 6-5**,**Figure 6-6**, and **Figure 6-7**, and the inspection process is described below. If any components are found to be faulty, replacements may be purchased from Emerson Process Management and will be supplied with instructions for installation. If a component is found to be faulty and is not a repairable part, please contact Emerson Process Management for technical support.

⚠ WARNING

ELECTRIC SHOCK

The OEM Module operates using mains voltage that is dangerous to life. Ensure that the OEM Module is disconnected from the mains supply before removing any outer covers or performing any work inside the OEM Module. This is particularly important when working at heights.

Death, personal injury, and/or damage to persons and/or property may result if this is not observed.

Besides the danger from high voltages, the seals against water and dust can be damaged or impaired if the OEM module is closed or opened incorrectly.

6.9.1 Visual inspection of the CT4000

1. Visually examine the exterior of the OEM module for signs of damage.

2. Visually examine the upper section of the OEM Module around the cell assembly for signs of damage. Refer to **Figure 6-6** and **Figure 6-7**.

3. Remove the lower cover from the underside of the OEM module as described in **Section 6.9.2**.

4. Perform a visual inspection of the optical and electrical components in the lower section of the OEM module. Refer to **Figure 6-5**, **Figure 6-6**, and **Figure 6-7**.

5. Refit the lower cover using the reverse of the removal instructions in **Section 6.9.2**.

If any components are found to be faulty, and they are some of the repairable parts listed in **Section 6.3**, the parts may be replaced using spare parts and service procedures provided by Emerson Process Management or their distribution partners. If a component is found to be faulty and is not a repairable part, please contact Emerson Process Management for technical support.

If any loose connections are found in the lower electronic tray, refer to the layout and wiring diagrams shown in **Figure 6-2**, **Figure 6-3**, and **Figure 6-4** to identify the connection points and repair the connection.

6.9.2 Removing the lower cover

The lower cover on the underside of the CT4000 OEM module must be removed in order to perform repairs in this section. Refer to **Figure 6-4** below and remove the lower cover as follows:

1. Turn the OEM module upside down so it rests on the upper lips (1.)

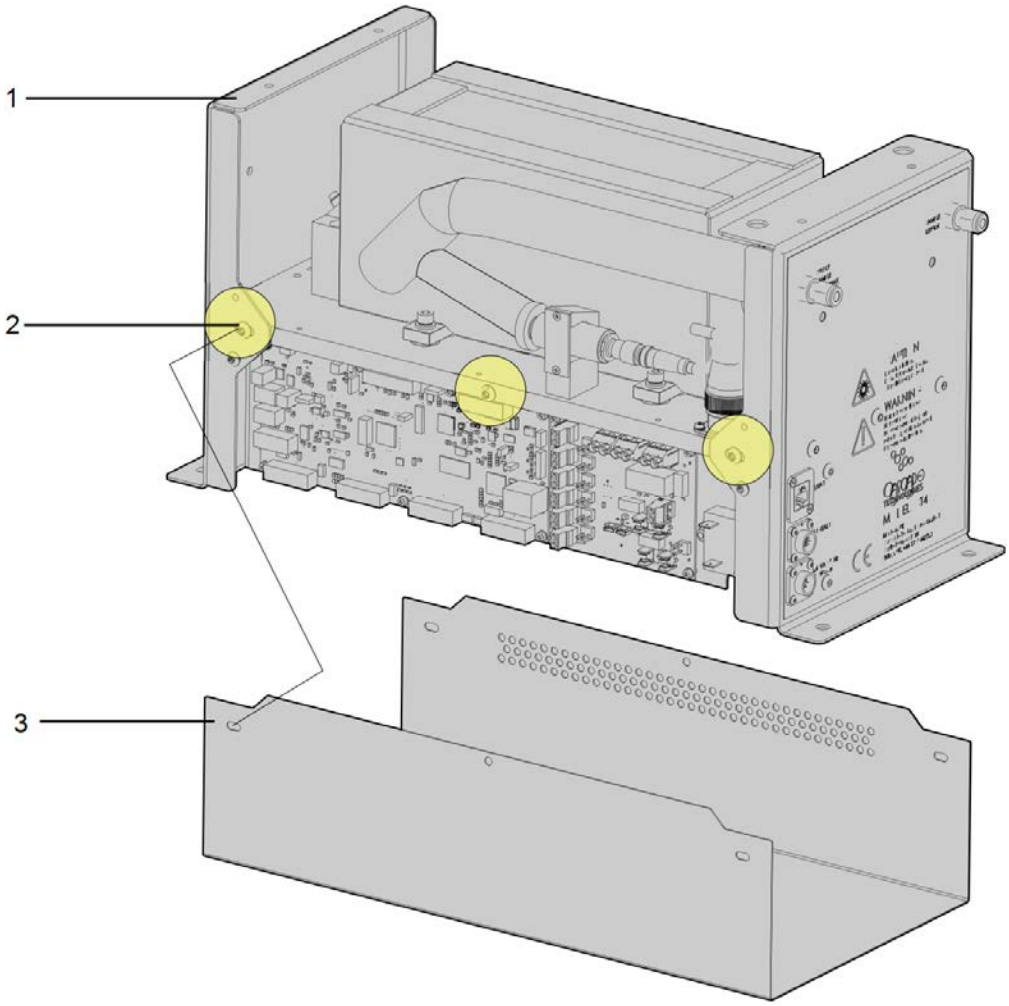
2. Remove and retain the six M6 by 6 screws and associated spring and plain washers (2).

3. Slide the lower cover (3) upwards and remove it from the OEM Module.

4. Examine the lower cover for signs of physical damage.

5. Perform a visual inspection of the CT4000 OEM module electronic and optical components. The components are identified in **Figure 6-5**, **Figure 6-6**, and **Figure 6-7**.

Figure 6-4 Removal of the lower cover



1. **Upper lips on OEM Module**
2. **M6 x 6 mm screw with washers**
3. **Lower cover**

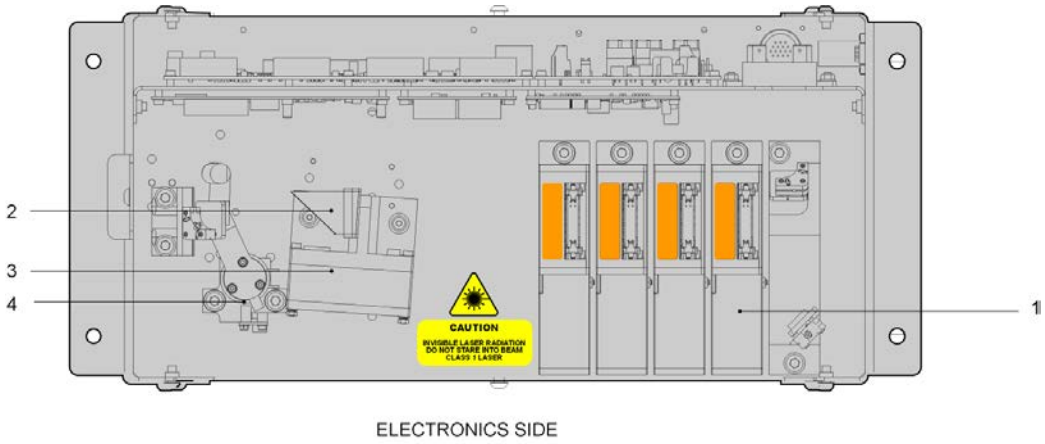
6.9.3 Replacing the lower cover

1. Slide the lower cover (3) downwards onto the OEM module.
2. Use the six M6 by 6 screws and the associated spring and plain washers to reattach the lower cover.
3. Turn the OEM module right side up.

6.9.4 Component identification

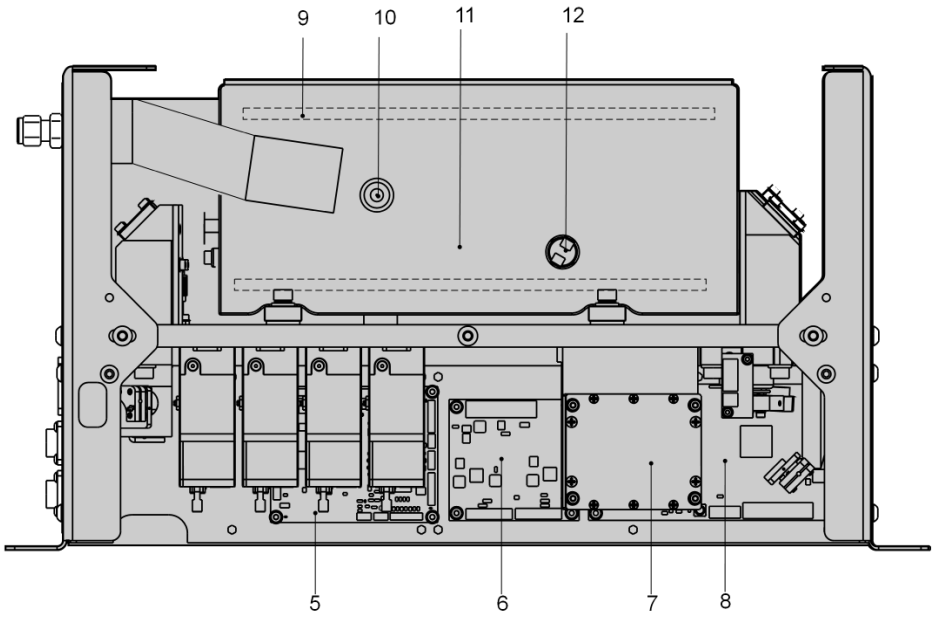
Figure 6-5 to **Figure 6-7** provide schematic diagrams of the CT4000 OEM module and are shown to aid component identification during a visual inspection. Refer to **Section 6.3** for a list of repairable items in each section of the OEM module.

Figure 6-5 Components in the electronic section



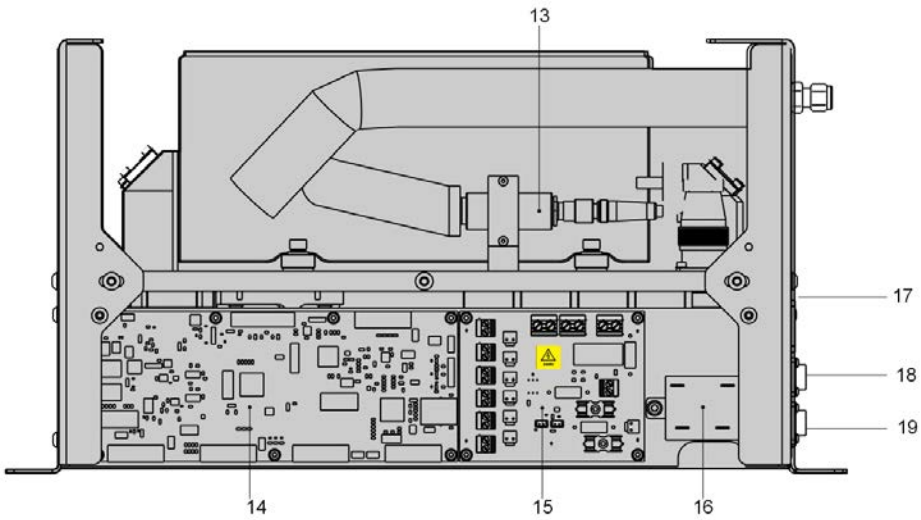
1. **Laser module**
2. **Off-axis parabolic mirror**
3. **Detector module**
4. **Etalon assembly (optional)**

Figure 6-6 Components in laser module side



5. **Peripheral PCA**
6. **Detector TEC PCA**
7. **Detector module**
8. **Digitizer PCA (behind detector)**
9. **Heater rods (inside cell body)**
10. **Gas temperature thermistor**
11. **Cell assembly**
12. **Thermal cut out**

Figure 6-7 Components in PCB side



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13. Pressure Sensor Assembly
14. Motherboard PCA
15. Power distribution PCA
16. Solid state relay PCA
17. Ethernet connector
18. DC voltage connector
19. AC voltage connector

Appendix A: Model CT4142

The system configuration and performance characteristics of the model CT4142 are specified in this appendix.

A.1 System specification

Basic performance characteristics of the OEM module supplied with this manual are given in **Table A-1**.

Table A-1 System Specification

		Path 1	
Attribute	**Gas**	**Value**	**Units**
Range	NO	2,000	ppm
	NO_2	500	ppm
	SO_2	2,000	ppm
	CO_2	15	%
	CO	3,000	ppm
	CH_4	3,000	ppm
	H_2O	20	%
Detection limit	NO	5	ppm
	NO_2	1	ppm
	SO_2	5	ppm
	CO	5	ppm
	CH_4	5	ppm
	CO_2	0.1	%
	H_2O	0.1	%
Zero noise	NO	< 5	ppm
	NO_2	< 1	ppm
	CO	< 5	ppm
	CH_4	< 5	ppm
	SO_2	< 5	ppm
	CO_2	< 0.1	%
	H_2O	< 0.1	%
Span noise	NO	< 40	ppm
	NO_2	<10	ppm
	CO	< 60	ppm
	CH_4	< 60	ppm

		Path 1	
Attribute	**Gas**	**Value**	**Units**
	SO_2	< 40	ppm
	CO_2	< 0.3	%
	H_2O	< 0.4	%
24 hour zero drift	NO	< 5	ppm
	NO_2	< 1	ppm
	CO	< 5	ppm
	CH_4	< 5	ppm
	SO_2	< 5	ppm
	CO_2	< 0.1	%
	H_2O	< 0.1	%

A.2 Cross-interference performance

The OEM module supplied with this manual is designed to be immune to the cross-interferent gases listed in **Table A-2**. The response of the analyzers will be < the detection limit when the cross-interferent is supplied at the listed concentration.

Table A-2 Cross-interference performance

Gas	Concentration	Units
Water (H_2O)	20	%
Nitric oxide (NO)	2,000	ppm
Nitrogen dioxide (NO_2)	500	ppm
Nitrous oxide (N_2O)	100	ppm
Methane (CH_4)	3,000	ppm
Carbon monoxide (CO)	3,000	ppm
Oxygen (O_2)	20	%

A.3 Linearity performance

The linearity performance of the OEM module supplied with this manual is given below.

- A linear fit to the data set will give a maximum error of < 2 % when analyzed to MCERTS standards.
- A linear fit to the data set will give an R^2 coefficient of > 0.999.
- Test data points are 0, 10, 30, 50, 70, 90 and 100% of the range.

A.4 Performance characteristics

Performance characteristics of the OEM Module supplied with this manual are given in **Table A-3**.

Table A-3 Performance characteristics

Attribute	Value	Units	Comments
Cell temperature	190	C	Factory set
Cell pressure	300 ± 50	Torr	Variation in concentration reading < 2% of reading per 10 Torr, test range 300 to 350 Torr
Path length	2	m	
Rise time (T_{10} to T_{90})	< 5	s	With a flow rate of > 5 L/min
Measurement frequency	>1	Hz	All measurements
Operational temperature	-20 – 70	degrees C	Variation in concentration reading < 2% of reading per 10 °C, test range 25 °C to 45 °C.
Storage temperature	-20 – 70	degrees C	Allow system to acclimatize in non-condensing environment
Warm up time	90	minutes	Temperature drift < 2% after 90 minutes
Vibration resistance	20 – 100 0.02	Hz G	Variation in concentration reading < 1% of full scale

A.5 Operational and physical characteristics

Operational and physical characteristics of the OEM module supplied with this manual are given in **Table A-4**.

Table A-4 Operational and physical characteristics

Attribute	Value	Units	Comments
Sensor supply voltage	+ 12	V	DC
Heater supply voltage	240	V	AC 50 – 60 Hz
Dimensions	498 x 218 x 260	mm	Depth x width x height
Weight	13	kg	
Control PC type	n/a		Supplied by customer
Control PC dimensions	n/a		Supplied by customer
Control PC weight	n/a		Supplied by customer

Appendix B: Model CT4125

The system configuration and performance characteristics of the model CT4125 are specified in this appendix.

B.1 System specification

Table B-1 System specification

		Path 1	
Attribute	**Gas**	**Value**	**Units**
Range	SO_2	100	ppm
	CO_2	15	%
Detection limit	SO_2	3	ppm
	CO_2	0.1	%
Zero noise	SO_2	< 3	ppm
	CO_2	< 0.1	%
Span noise	SO_2	< 2	ppm
	CO_2	< 0.3	%
24 hour zero drift	SO_2	< 3	ppm
	CO_2	< 0.1	%
24 hour span drift	SO_2	< 2	ppm
	CO_2	< 0.3	%

B.2 Cross-interference performance

The OEM module supplied with this manual is designed to be immune to the cross-interferent gases listed in **Table B-2**. The analyzer's response will be less than the detection limit when the cross-interferent is supplied at the listed concentration.

Table B-2 Cross-interference performance

Gas	Concentration	Units	Comments
Water (H_2O)	20	%	
Nitric oxide (NO)	1,000	ppm	
Nitrogen dioxide (NO_2)	200	ppm	
Nitrous oxide (N_2O)	100	ppm	
Methane (CH_4)	100	ppm	
Carbon monoxide (CO)	1,000	ppm	
Oxygen (O_2)	20	%	

B.3 Linearity performance

The linearity performance of the OEM module supplied with this manual is given below.

- A linear fit to the dataset gives a maximum error of < 2 % when analyzed to MCERTS standards.
- A linear fit to the dataset gives an R^2 coefficient of >0.999
- Test data points are 0, 10, 30, 50, 70, 90, and 100% of the range.

B.4 Performance characteristics

Performance characteristics of the OEM module suppled with this manual are given in **Table B-3.**

Table B-3 Performance characteristics

Attribute	Value	Units	Comments
Cell temperature	190	° C	Factory set
Cell pressure	300 ± 50	Torr	Variation in concentration reading < 2% of reading per 10 Torr, test range 300 to 500 Torr
Path length	5	m	
Rise time (T_{10} to T_{90})	< 5	s	With a flow rate of > 5 L/min
Measurement frequency	> 1	Hz	All measurements
Operational temperature	-20 – 70	° C	Variation in concentration reading < 2% of reading per 10 °C, test range 25 to 45 °C
Storage temperature	-2- - 70	° C	Allow system to acclimatize in non-condensing environment
Warm-up time	90	Minutes	Temperature drift < 2% after 90 minutes
Vibration resistance	20 – 100 0.02	Hz G	Variation in concentration reading < 1% of full scale

B.5 Operational and physical characteristics

Operational and physical characteristics of the OEM module supplied with this manual are given in **Table B-4**.

Table B-4 Operational and physical characteristics

Attribute	Value	Units	Comments
Sensor supply voltage	+ 12	V	DC
Heater supply voltage	240	V	AC 50 – 60 Hz
Dimensions	498 x 218 x 260	Mm	Depth x width x height
Weight	13	Kg	
Control PC type	N/A		Supplied by customer
Control PC dimensions	N/A		Supplied by customer
Control PC weight	N/A		Supplied by customer

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