

PULSI 200LR
Optical Head Unit
Operating Manual

PROCAL

Procal Analytics Limited

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1 Introduction

About this manual

This manual is intended to assist the user in the safe and efficient installation, operation and maintenance of the PULSI 200LR series of optical head units. It has been written in accordance with the requirements of British Standard BS4884 *Technical manuals* Part 1: 1992.

It is split into a number of sections. *Introduction* (this section) gives a brief overview of both this manual and the systems which it describes, together with sources of further information and product support. *Installation* gives pre-installation information and goes on to describe how a PULSI 200LR system is installed. *Operation* gives information necessary to operate the head unit. *Technical description* gives the background to the principles behind the operation of the analyser and describes the system, but is not required reading for a routine operator. *Maintenance* lists and describes routine maintenance tasks, and provides fault-finding information down to the level of user-replaceable parts. Calibration instructions are given, together with spares lists. *Disposal instructions* details how the analyser and peripherals may be disposed of safely and without environmental damage. *Order-specific information* gives additional information specific to the instrument you have purchased. *Appendix B* gives details of the Auxiliary Output Unit, and *Appendix C* details the Auto Calibration Unit. *Appendix D* describes the optional In-Situ Heater and how it should be installed. *Appendix E* describes the optional Optical Head Cooler and how it should be installed. *Appendix F* covers issues involved with US EPA compliance.

About the PULSI 200LR series

The PULSI 200LR series is a range of high-performance infra-red gas process/emission analyser systems. These systems are intended to be used for measuring gas concentrations, particularly in continuous industrial processes and flue stacks.

Principles behind the system are described in the section entitled *Technical description*, together with descriptions of the different component parts that make up the system. Every system including a PULSI 200LR Optical Head Unit also incorporates an Analyser Control Unit and an Auto-zero/Auto-purge Unit. An In-Situ Heater is available as an option, as are an Optical Head Cooler, an Auto Calibration Unit, an Auxiliary Output Unit (AOU) and an Auxiliary Input Unit (AIU).

The Analyser Control Unit, which can control up to four Optical Head Units, is supplied with its own *Operating Manual*. Information relating to additional equipment that can be used in the system is given in this manual and in the Analyser Control Unit manual. Similarly, the Analyser Control Unit for Windows (ACW), which can control up to eight optical head units, is supplied with its own *Operating Manual*.

PULSI 200LR - an overview

Within the PULSI 200LR, up to six gases may be measured on up to six channels. The second digit of the model number indicates the number of measuring channels. For example, the 230LR has three measuring channels.

An optical diagram of the PULSI 200LR system is shown in Figure 1-1 below. Filtered IR radiation passes from the Optical Head Unit into the sample cell, which is fitted into the process duct. This sample cell has sintered panels, so allowing the gas under study to permeate through the sample cell. IR radiation passes through the sample gas, is reflected by a retro-reflector, and passes through the sample gas once more back to the Optical Head Unit. A Pt100 platinum resistance thermometer is situated in the sample cell. This provides temperature information to the Analyser Control Unit, which acts as the basis for the temperature compensation.

Purging of the sample is via the port on the Optical Head Unit flange, and may be carried out either manually, or automatically from the Auto-zero/Auto-purge Unit.

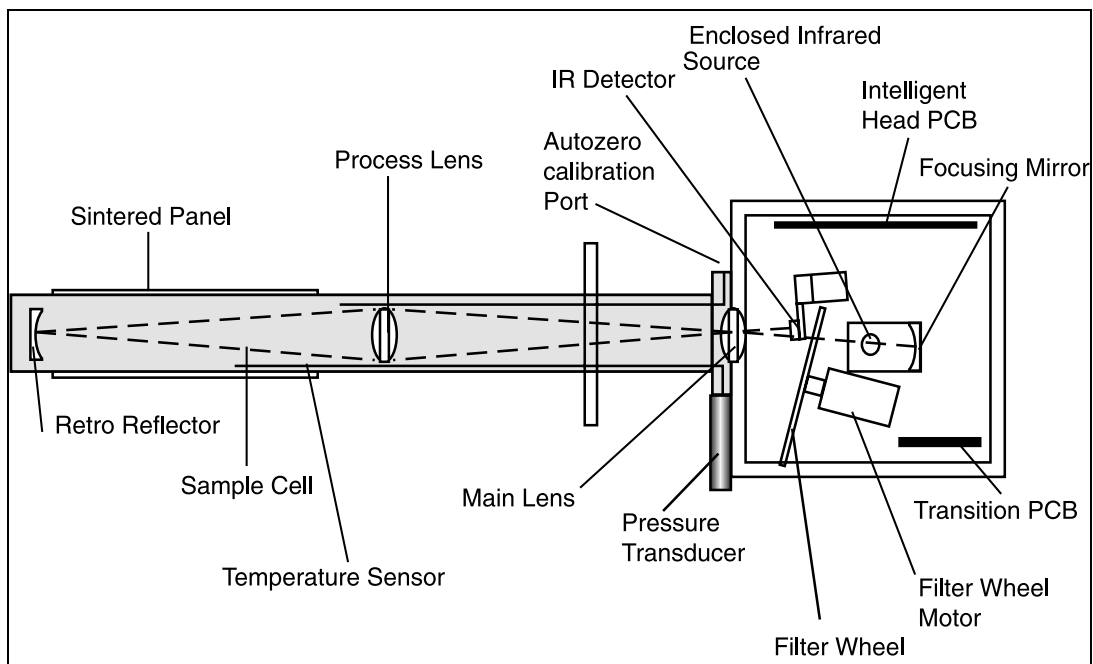


Figure 1-1 PULSI 200LR optical diagram

A schematic diagram of the PULSI 200LR system appears as Figure 1-2 opposite. This shows the various interconnections between different parts of the system, and some of the external devices that may be connected to the Analyser Control Unit.

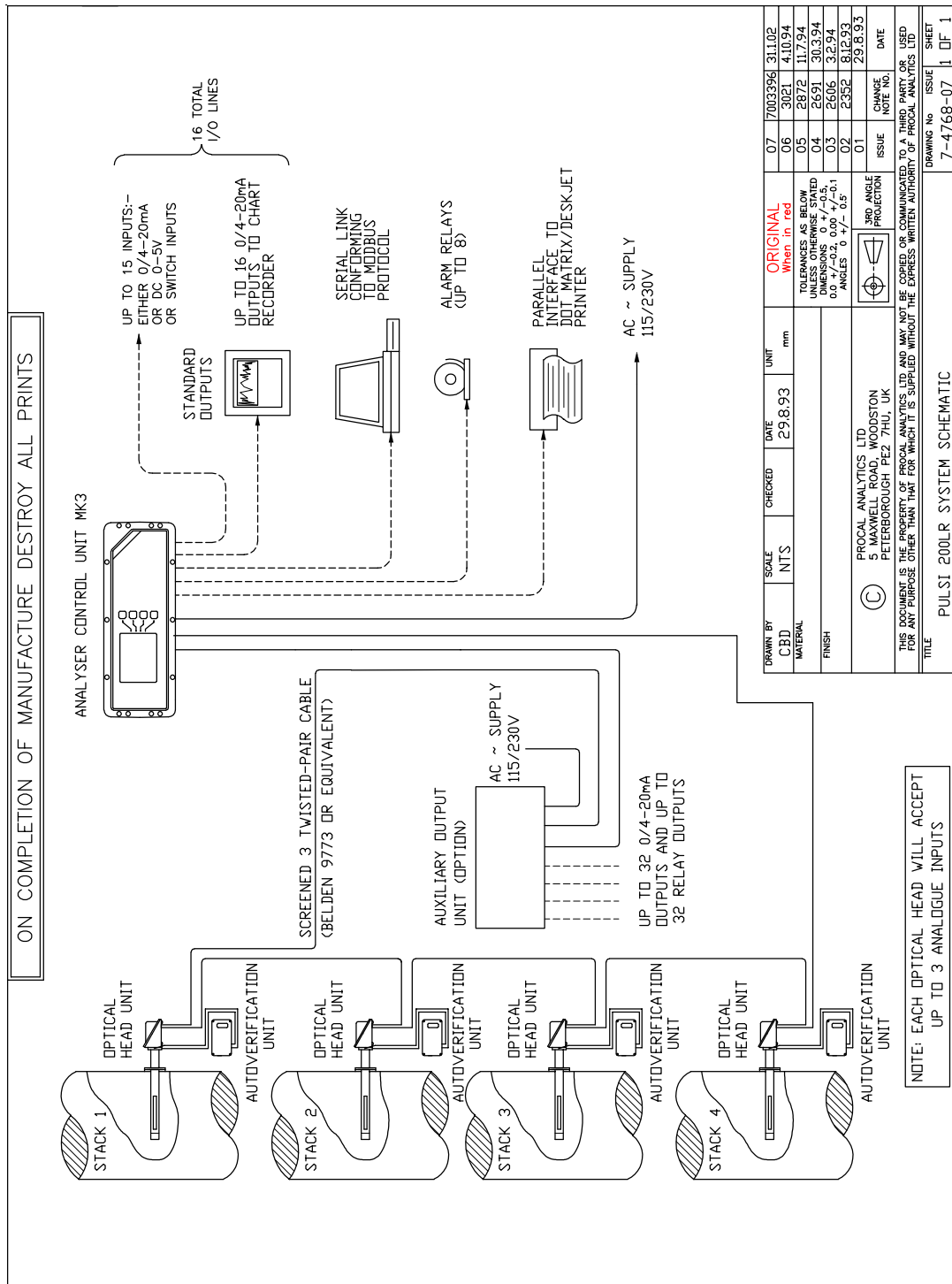


Figure 1-2 PULSI 200LR system schematic

Documentation conventions

Abbreviations

Within this manual, the following abbreviations are used:

■	ACU	Analyser Control Unit
■	AOU	Auxiliary Output Unit
■	AVU	Auto Calibration Unit
■	AZU	Auto-zero/Auto-purge Unit
■	IR	Infra-red
■	ISH	In-Situ Heater
■	LCD	Liquid Crystal Display (also referred to as the screen)
■	OHC	Optical Head Cooler
■	OHU	Optical Head Unit

Lists

Often in this manual, instructions or information are presented in list form. Use of black squares ■■■ indicates that there is no special order to the instructions or information. However, when instructions are numbered, it is important that the individual instructions or points are followed sequentially.

Figures

Figures in the text are always numbered in the form *Figure X-Y*, where *X* is the section number, and *Y* is the sequential figure number within that section. For example, *Figure 3-2* is the second figure in section 3. When a figure reference is in brackets (*Figure 9-4*), this refers you to that figure, usually to confirm the location of a component, control or indicator.

LCD screen displays

Screen displays on the ACU are presented in this manual as approximations. When values are shown on screens, it should be remembered that these appear by way of example only. It is highly unlikely that the values displayed on your screen will be the same as in this manual.

Some systems will have different screens because of custom modifications. If so, this will be highlighted in the section of this manual entitled *Order-specific information*.

Screen messages, prompts or options are repeated in text in a different typeface to the main text, for example: `Auto-zero NOW`.

Italics

Paragraphs in italics usually indicate background information which may be of benefit to the reader. Groups of words in italics are usually cross-referring the reader to a section or sub-section by name.

Dimensions

All dimensions in this *Operating Manual* are in mm (millimetres) unless otherwise indicated.

Further information

This *Operating Manual*, when used in conjunction with the *Operating Manual* for the ACU, should give you all the information you require to install, operate and dispose of your PULSI 200LR system. If you require any further information regarding the system or its use, you should contact Procal Analytics Ltd., or your Procal distributor or agent as shown in the panel below:

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internet: www.procalanalytics.com

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2 Installation

Introduction

This section describes how to install the standard PULSI 200LR Optical Head Unit and the Auto-zero/Auto-purge Unit.

WARNINGS

YOU MUST NOT ATTEMPT TO INSTALL THIS SYSTEM UNLESS YOU ARE QUALIFIED, COMPETENT AND AUTHORIZED TO WORK ON ELECTRICAL EQUIPMENT OPERATING AT YOUR LOCAL MAINS ELECTRICAL SUPPLY VOLTAGE.

READ THIS SECTION IN ITS ENTIRETY BEFORE ATTEMPTING TO INSTALL ANY PART OF THE SYSTEM. IF THERE IS ANYTHING YOU DO NOT UNDERSTAND, OR YOU DO NOT FEEL CONFIDENT OF YOUR ABILITY TO FOLLOW THE INSTALLATION INSTRUCTIONS, DO NOT PROCEED. CONTACT PROCAL ANALYTICS OR YOUR PROCAL-AUTHORISED DISTRIBUTOR.

ALWAYS ENSURE THAT YOU HAVE A VALID *PERMIT TO WORK* ON THE PIPEWORK OR DUCTING TO WHICH THE PULSI 200LR OPTICAL HEAD UNIT IS TO BE FITTED.

ALWAYS ENSURE THAT YOU COMPLY WITH LOCAL SAFETY REGULATIONS AND PROCEDURES.

Caution

The PULSI 200LR Optical Head Unit contains factory-set optical components. No alignment or focusing of these components is required during installation or operation. Adjustment of any mirrors, lenses or filters may invalidate the warranty and will almost certainly prevent the system from functioning properly.

Unpacking the system components

If this has not already been done, unpack the system components and check that they correspond to the units ordered and listed on the accompanying packing note. If there is any discrepancy, or any damage is apparent, do not attempt to install the system. Contact Procal Analytics, or your Procal distributor or agent.

Pre-installation information

Before installing the system, you must confirm that:

- suitable locations are available for all components of the system to be installed
- a suitably fused, switched, mains electrical power is available at 110 V / 230 V single-phase 50-60 Hz 600 W, adjacent to where the OHU will be fitted (only if an optional ISH is to be fitted)
- sufficient working space for two people to work is available around the point at which each Optical Head Unit is to be fitted. The working platform should be adequately fenced
- clean and dry instrument air at up to 10 l/min (intermittent) and 5.0 barG is available adjacent to where the Optical Head Unit and Auto-zero/Auto-purge Unit will be fitted
- the cable route from Optical Head Unit to ACU is not more than 150 m (greater distances may be possible: please consult Procal)
- all the interconnecting cables specified in this installation procedure are available.

In the section of this manual entitled *Order-specific information*, you will find PROCAL installation drawings which may be useful during installation. The precise nature of these drawings will vary, depending on the PULSI 200LR model, the mains electrical voltage, the options supplied and the configuration.

An optimum flange installation into a process duct is shown in Figure 2-1 below.

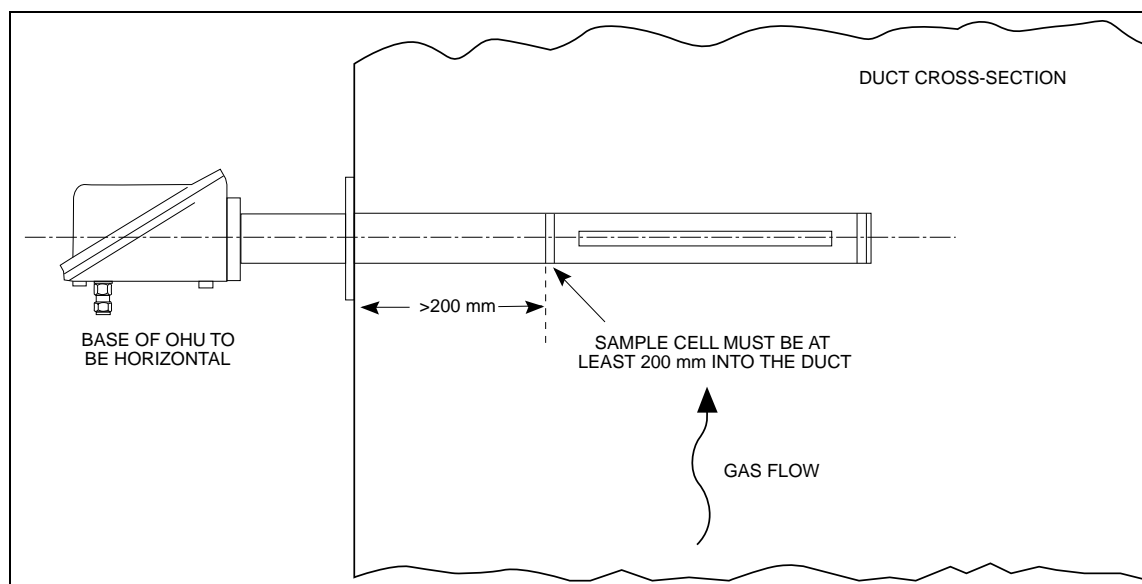


Figure 2-1 Optimum flange installation of the OHU into a process duct

Preparing the process gas duct

A special flange must be welded directly to the process duct to form a gas-tight entry exactly as shown in Figure 2-2. This flange may be manufactured from a 3 inch, 150 lb ANSI flange. This item is available from Procal, part number 4-1114

The mating surface of the process duct flange must be of a quality that will allow a gas-tight joint to be made when a gasket is used between the flange and the Optical Head Unit (or In-Situ Heater if fitted). The use of a flange and stub arrangement should be avoided unless absolutely necessary, since this could lead to acidic condensation forming. Figure 2-2 below gives mounting details for the flange.

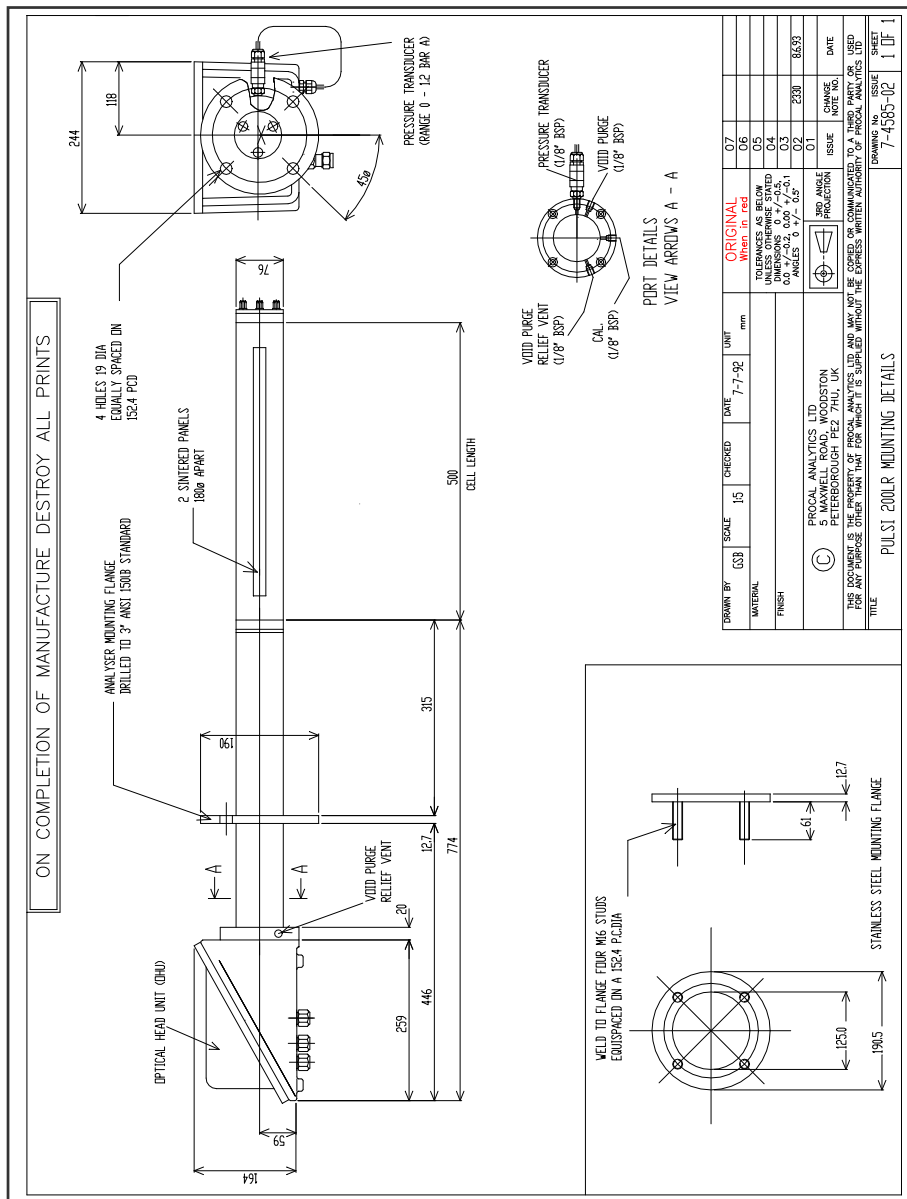


Figure 2-2 Flange mounting details

Preparing the Optical Head Unit

During preparation of the Optical Head Unit, you may need to refer to the relevant installation drawing in the *Order-specific information* section of this manual, particularly if you will be making up your own interconnecting cables.

- 1 Place the Optical Head Unit (OHU) carefully on the ground or workbench, such that it is stable and horizontal.
- 2 Remove and retain the eight 5 mm socket head screws securing the cover of the OHU to the OHU case.
- 3 Lift the cover clear and place to one side.
- 4 You will see the inside of the OHU as shown in Figure 2-3.

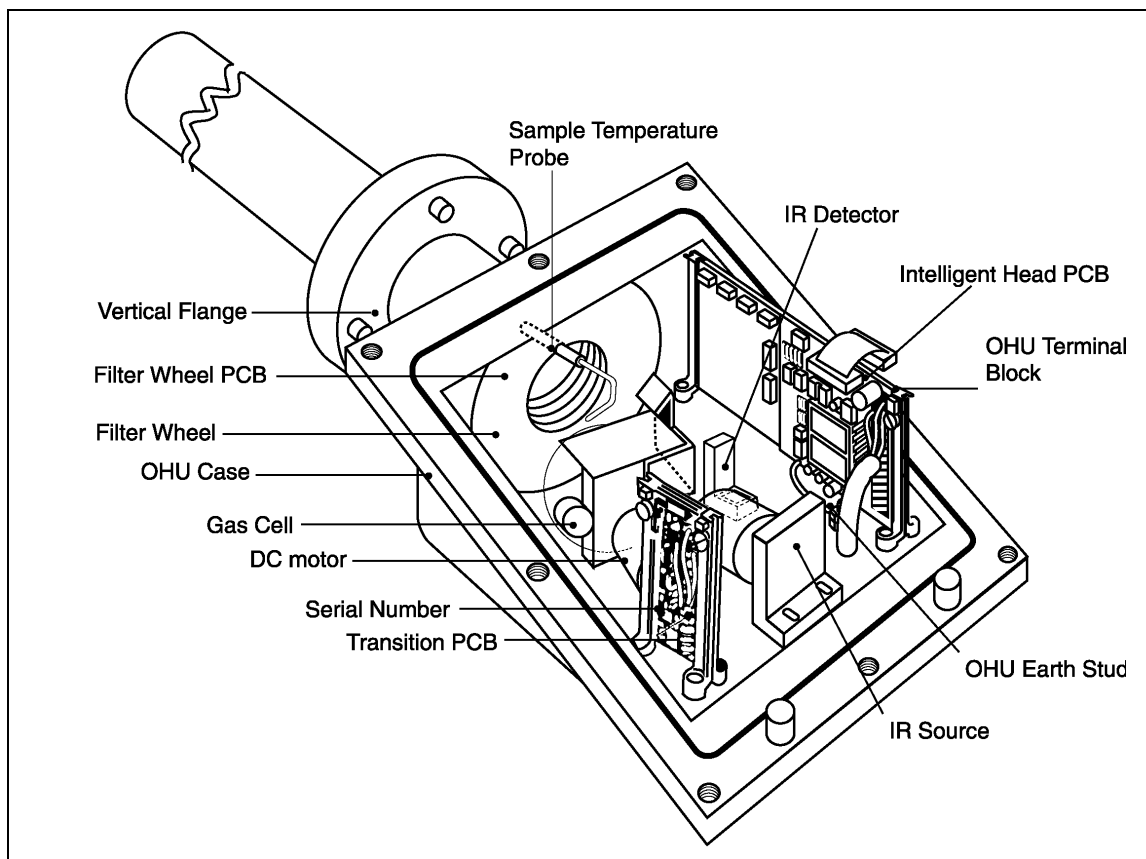


Figure 2-3 PULSI 200LR Optical Head Unit with cover removed

- 5 Locate the OHU-ACU interconnecting cable, which contains three twisted pairs. If supplied by Procal, this will have part number 5-8264-03 the end to be fitted to the OHU is prepared with 100 mm individual wires suitably terminated. If customer-supplied, this cable must be of suitable length with sufficient outer sheathing stripped at both ends, and all wires suitably terminated.
- 6 Gently feed this end of the cable through the cable gland underneath the OHU case. You should leave a 'loop' in the cable so that the OHU can be withdrawn from the process duct without disconnecting the cable.

- 7 The wiring of terminals 7 to 12 depends on the position of the OHU in the chain.
- 7(a) If the OHU is not the last in the chain, then identical cables are used to achieve the 'daisy chaining'. Connect the terminals as follows:

First OHU	Second OHU
Terminal 7	Terminal 1
Terminal 8	Terminal 2
Terminal 9	Terminal 3
Terminal 10	Terminal 4
Terminal 11	Terminal 5
Terminal 12	Terminal 6

- 7(b) If the OHU is the last in the chain or is the only OHU connected to the ACU, then a data termination is required. This is achieved by connecting a 120 ohm, 0.25 watt resistor between terminal 9 and terminal 10 on the OHU. The OHU to ACU return wire may also be connected. This is required if the length of cable between the ACU and the last OHU is greater than 50 metres. If supplied by Procal, this will have the part number 5-8430-02 (1.5 mm² cross section/18 AWG). The connection details are as follows:

OHU terminal number	to	ACU terminal SK3/TS3
11		7
12		8

- 8 Connect the external earth stud on the underside of the OHU to any convenient earth or ground point. IT IS VITAL THAT A GOOD EARTH (GROUND) CONNECTION IS MADE.
- 9 Run the cables, where appropriate, to the next OHU. Note that the total cable length between the ACU and all OHUs should not exceed 200 m (660 ft). If possible, the OHUs should be evenly spaced.

Since the AVU will be fitted later, it may be convenient to run the OHU - AVU cable at the same time. If this cable is not Procal-supplied, it will need to be prepared.

Installing the Auto-Verify Unit

All PULSI 200LR systems have an Auto Calibration Unit (AVU) fitted adjacent to the Optical Head Unit which may be used also as an Auto Zero Unit (AZU). The AVU is described in *Appendix C*.

The AVU has three main functions. Firstly, it provides totally automatic zeroing of the system. Secondly, it acts as a purging system to prevent condensation forming in the sample cell of the OHU under unusual operating conditions. Thirdly, it controls up to two Calibration Gas Bottles for automatic span correction of the system.

A schematic diagram of the AVU is shown in Figure 2-4.

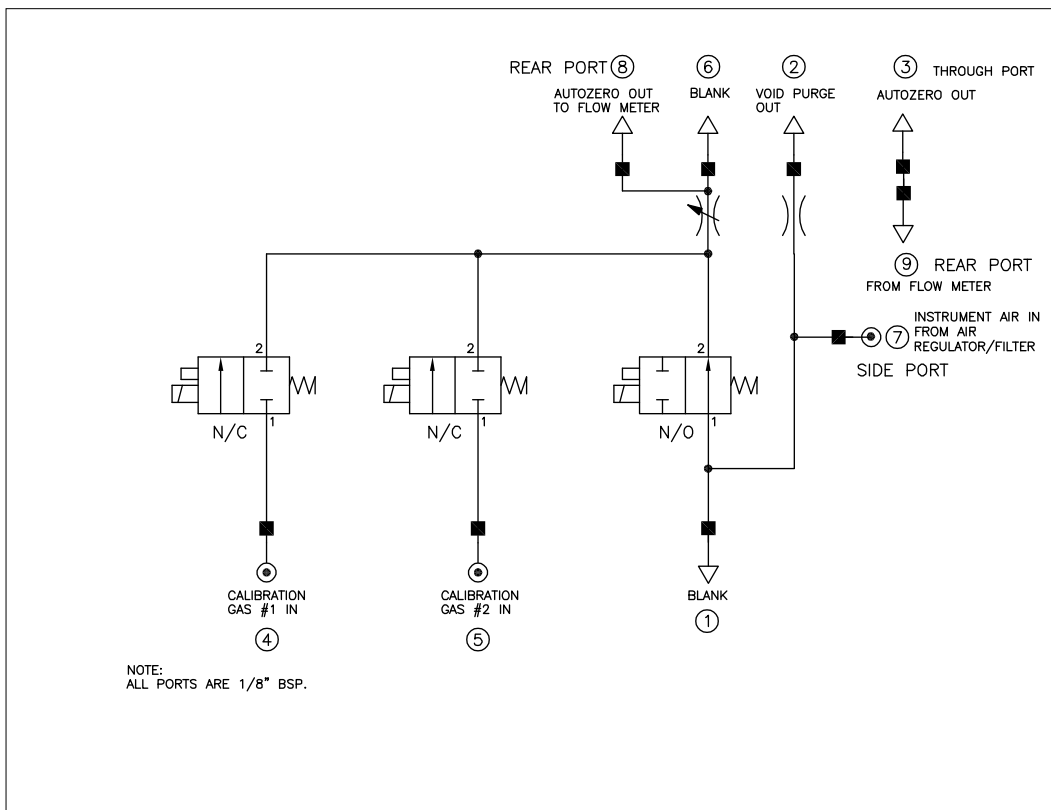


Figure 2-4 AVU schematic diagram

During installation of the Auto-Verify Unit, you may need to refer to the relevant installation drawing in the *Order-specific information* section of this manual, particularly if you will be making up your own interconnecting cables.

Fitting the Auto-Verify Unit

The AVU must be firmly secured to a suitable vertical surface as close as possible to the Analyser and with the following services:

- Clean dry instrument air at pressure of 1 barG above the process gas pressure, up to a maximum 6.8 barG. The flow-rate available should be between 0.5 l/min (constant) and up to 10 l/min (intermittent during auto-zero/auto-purge)
- Pressurised gas cylinders (Up to two) containing a known mixture of the gases under analysis.

Figure 2-5 gives mounting details for the AVU.

Note that the AVU should be mounted vertically such that all glands are on the underside of the Unit.

Note the air supply should have an isolation valve within 1 meter of the AVU.

Connection points for the AVU are shown in Figure 2-6.

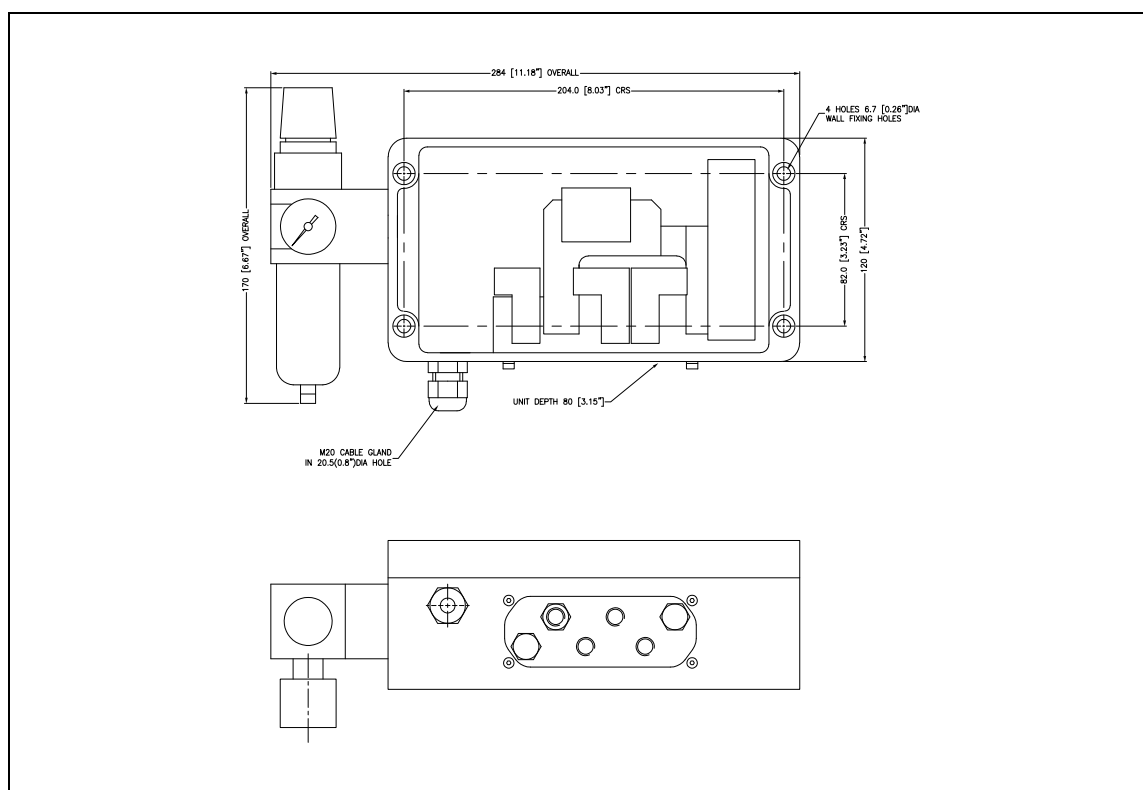


Figure 2-5 Mounting details for the Auto-Verify Unit

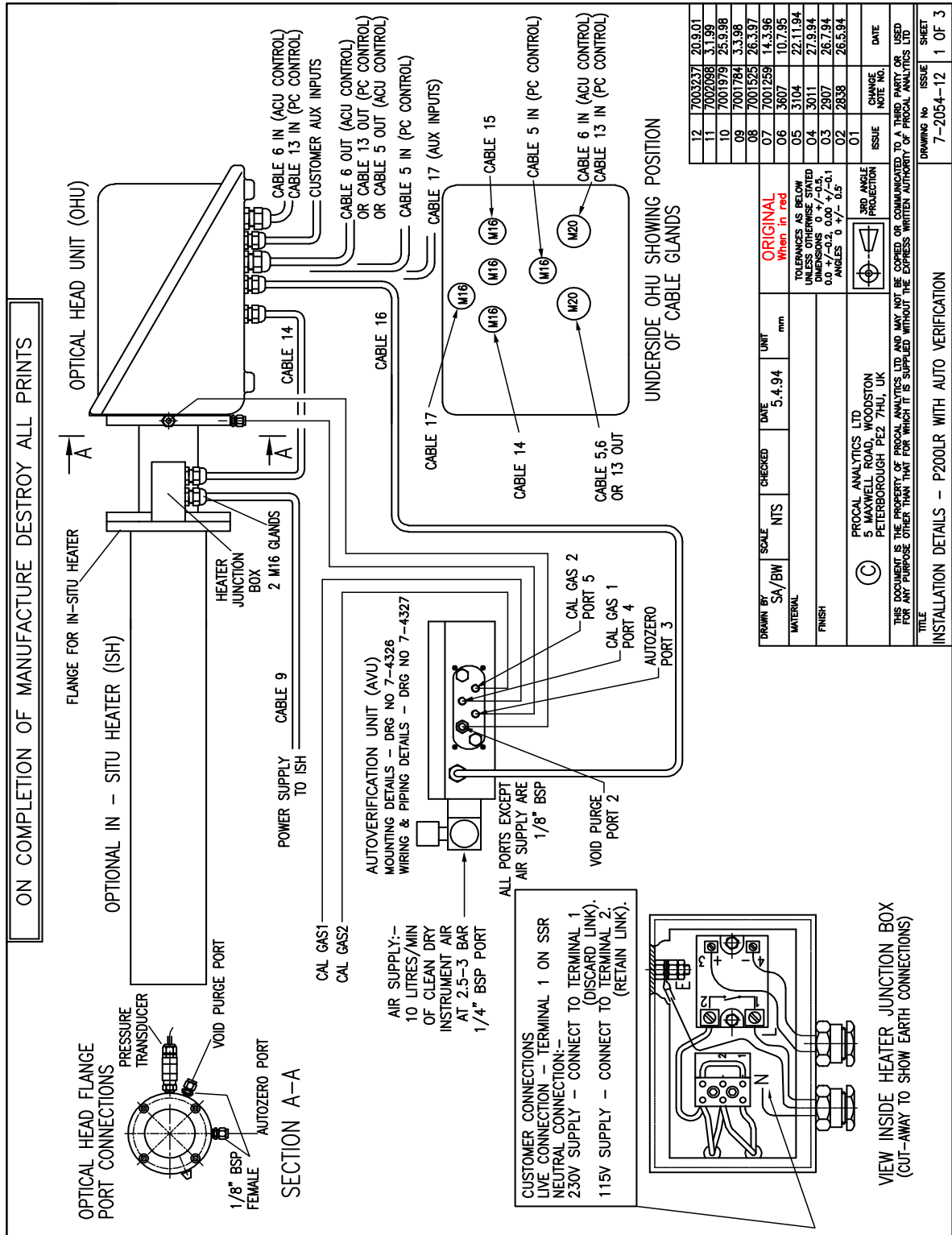
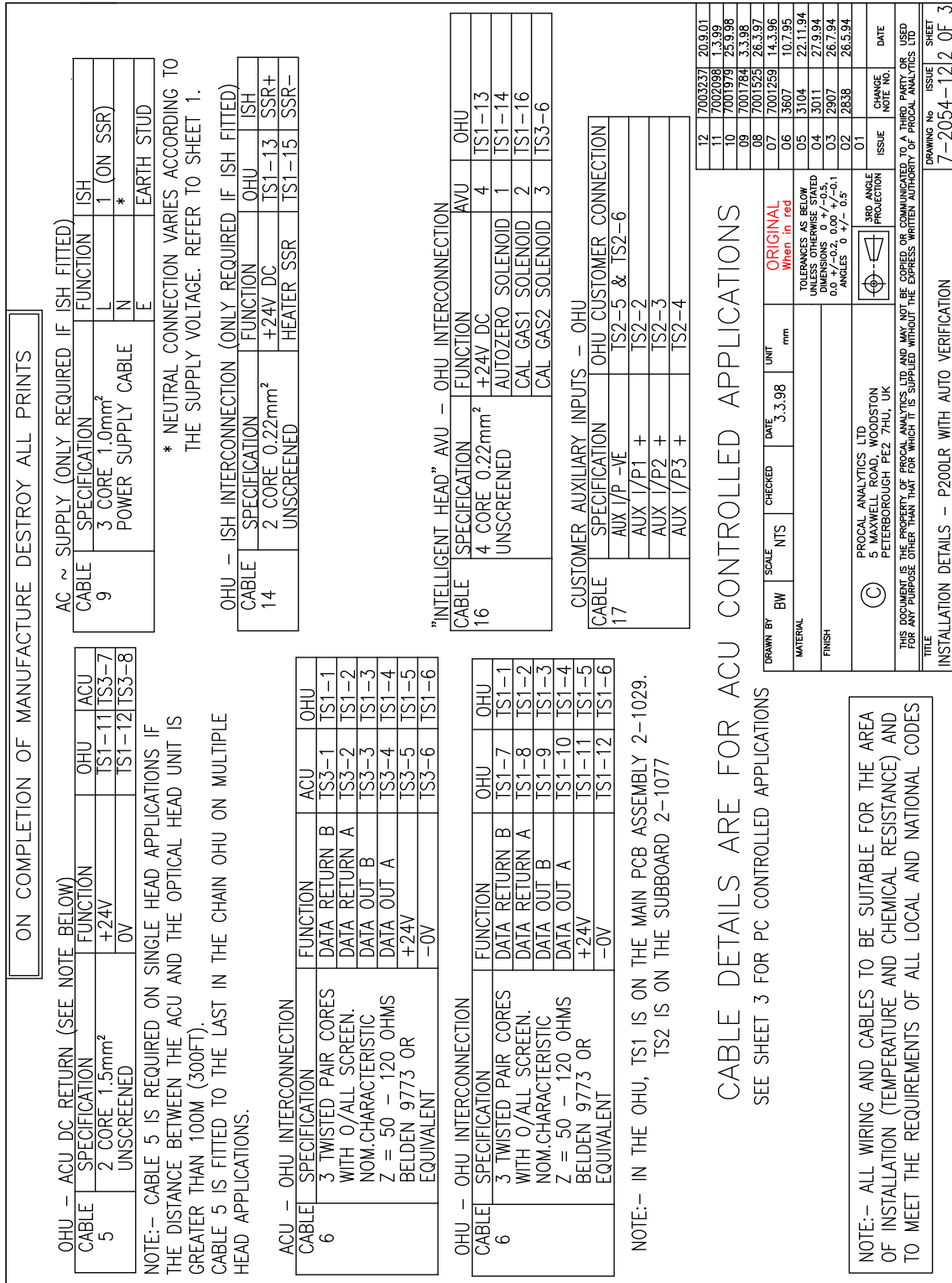


Figure 2-7a Connections between OHU and ACU



Gas port connections to Auto-Verify Unit & Optical Head Unit

Four gas ports are available on the underside of the AVU. Two are connected to external supplies, and the remaining two are connected to ports on the Optical Head Unit. All these ports have 1/8" BSP threads, and the connections to the Optical Head Unit are stainless steel compression fittings. Push-on connectors must *not* be used. The Instrument Air Regulator/Filter assembly has a 1/4" BSP thread. Fittings applicable to the installation region may be fitted as required.

Connections are as follows:

Port 1	Blanked Optional Analyser Purge (Used on P5000 only)
Port 2	Void purge (Restricted) To port P on Optical Head Unit flange
Port 3	Auto-zero (via Flow Meter) To port A on Optical Head Unit flange
Port 4	Cal Gas Cylinder 1
Port 5	Cal Gas Cylinder 2
Port 6	Blanked Optional Auto-zero Out (Used on P5000 only)
Port 7	Instrument Air Supply
Port 8	Internal port to Flow Meter.
Port 9	Internal port to Flow Meter.

Ports on the analyser are shown in Figure 2-6.

Fitting the Optical Head Unit

Caution

As soon as the OHU is inserted into the process it is subject to the corrosive effects of the process gases. For this reason it is important that both the void purge and the protective Auto-purge are active at all times when the OHU is installed, and at the flow rates indicated in the section entitled *Gas port connections to the Auto-Verify Unit & Optical Head Unit*. Failure to follow this procedure is likely to result in damage to the sample cell.

- 1 If no ISH has been fitted, fit the supplied circular gasket to the four M16 studs on the flange already fitted to the process gas duct.
- 2 If an ISH has been fitted with retaining nuts for safety, carefully remove these nuts, ensuring that the In-Situ Heater remains in place.
- 3 Fit the sealing gasket, and then offer the OHU up to the flange. Introduce the OHU gently into the process duct (or ISH if fitted) and fit the OHU flange onto the four M16 studs.
- 4 Fit washers and nuts to the four M16 studs, and tighten with a 16 mm spanner.
- 5 Replace any lagging material removed while fitting the vertical flange.
- 6 Make a visual check that all installation work has been carried out as instructed in this section.

- 7 Installation is now complete. Refer to the section entitled *Operation* under the heading *Starting up the system* for instructions on how to start up and then use the analyser.
- note It is important that the OHU is protected from direct sunlight, rain, snow and direct lightning strikes. If the OHU is to be mounted in the open air, it is recommended that a cover is installed over the OHU for added protection (Procal part number 4-0398). The PULSI 200LR is immune to all but direct lightning strikes, from which it must be protected.
- note If the ambient temperature is likely to exceed 45°C, an Optical Head Cooler should be used. *See Appendix E – Optical Head Cooler.*
- note If ranges less than 0 - 500 ppm NO and CO are being measured, then the Optical Head Cooler/temperature controller system should be used.

Setting the Auto-zero purge flow rate

The air purge rate into Port 1 is factory set to 300 l/hour (5 l/min). This flow rate will typically purge the sample cell of gas in 90 seconds such that the two minute 'zero flush' of the automatic cycle is sufficient.

Under certain conditions, a complete purge may not be achieved. You can check this and perform a full purge as follows:

- 1 On the ACU, select MENU then OPTIONS.
 - 2 Select the AIR PURGE option (if shown) and set it to ON. If your analyser does not include this feature, select MENU then SET ALARMS (LOW). In the sub-menu that is displayed, locate TS and note its setting then set it to minimum.
 - 3 Return to the MAIN or TEST screen. The air purge solenoid will de-energise, allowing purge air to flow into the sample cell.
 - 4 On the TEST screen, observe the readings in the abs column for H₂O. As the sample gas is replaced by air the readings will decrease until equilibrium is reached (making allowance for some jitter between readings).
 - 5 When equilibrium is reached, increase the air purge flow to 360 l/hour (6 l/min) and again observe the readings in the abs column. If no further reduction is observed, reset the flow rate to the original value to complete the procedure (ignoring the following steps).
 - 6 If a further abs reduction is noticed, increase the flow rate again by 1 l/min and repeat the observation. Continue this procedure until no further change is observed, then reduce the flow rate by 1 l/min.
- note If the flow rate has to be increased by such an amount that the flow meter reaches full scale, please Contact your Procal distributor for advice.
- 7 On completion of the procedure, reselect MENU on the ACU and then either select air purge off in the OPTIONS menu or set the TS low alarm back to its original setting.

3 Operation

Introduction

The PULSI P200LR Optical Head Unit must be operated as part of a system incorporating a Procal Analyser Control Unit. There are no user accessible controls or indicators on the OHU as the whole system operates under the control of the ACU. Full operating instructions for both the ACU and the complete PULSI system are given in the *Operator's Manual* supplied with the ACU.

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4 Technical description

Introduction

This section outlines the basic theory of infra-red measurement of gas concentrations, and explains how this theory is applied to the PULSI 200LR range of analysers.

Following a brief overview of the PULSI 200LR analyser, each of the individual components is described - Optical Head Unit, ACU and Auto-zero/Auto-purge Unit. The optional In-Situ Heater and Optical Head Cooler are described in *Appendices* to this manual.

This section is intended for those people who need or would like to know how the PULSI 200LR analyser works as a measuring instrument. Understanding the technical aspects of the analyser and the theory behind its operation are not necessary for installation and routine operation.

Infra-red absorption theory

Infra-red (IR) radiation lies in the electromagnetic spectrum at wavelengths between 2 μm and 16 μm (10^{-6} m). When a beam of broadband IR radiation passes through most types of gas, the level of IR emerging will be reduced at certain wavelengths. This is due to absorption by the gas of some of the radiation at particular wavelengths. The pattern of such absorption - known as an absorption spectrum - is characteristic of a particular gas. Absorption spectra are highly effective in identifying gases and concentrations.

A typical absorption spectrum for Carbon Dioxide (CO_2) is shown in the illustration below. It can be seen that CO_2 absorbs IR radiation most readily at wavelengths of 4.4 μm and 2.7 μm . Consequently, these two wavelengths are widely used in the detection and concentration measurement of CO_2 .

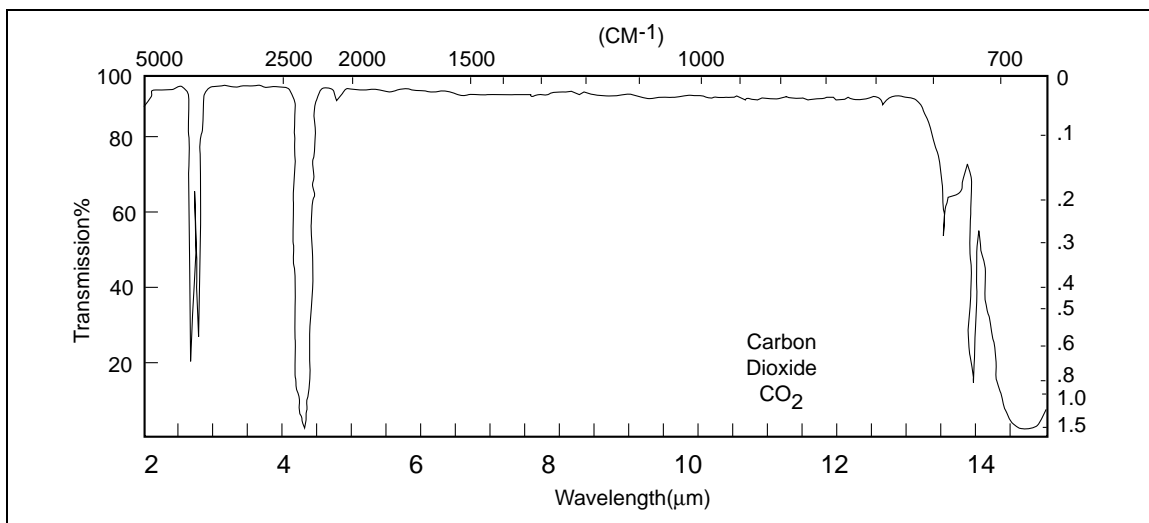


Figure 4-1 Typical absorption spectrum for CO_2 .

The *amount* of radiation absorbed by a gas at its critical wavelength(s) is directly proportional to the concentration of the gas under study. The illustration below plots the radiation absorbance of CO₂ against its concentration. This plot is known as a *calibration curve*. Using this calibration curve allows the *concentration* of a CO₂ sample to be calculated by measuring its *absorbance*.

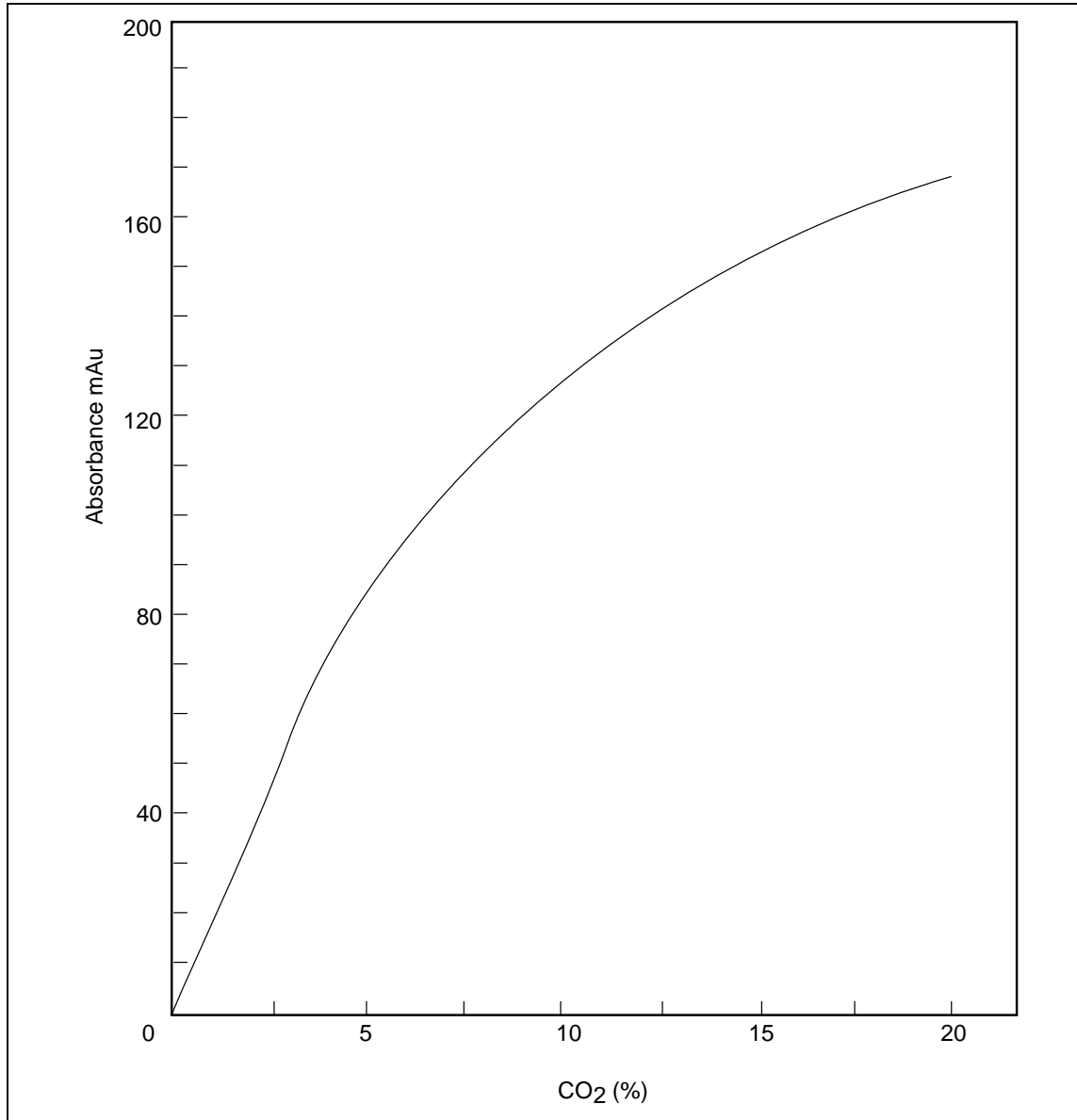


Figure 4-2 Calibration curve for CO₂

Most process gas analysers - including the PULSI 200LR - operate at a number of fixed wavelengths, which are chosen according to the gases to be measured. Within the analyser is an IR source which emits broadband IR radiation. An IR detector detects the radiation which has passed through the sample gas. With a single gas, it should be a straightforward matter to measure absorbance, identify the gas and calculate concentration. In practice, however, there are usually several gases. More than one gas may exhibit absorption at a given wavelength. This effect is termed 'cross-sensitivity', and may be compensated for such that accurate concentrations of individual gases may still be displayed.

IR theory applied to the PULSI 200LR

In the PULSI 200LR, interference filters are placed in the path of the broadband IR radiation. Two filters are used per component. One selects a measuring wavelength, while the other selects a reference wavelength. The filters are mounted on a rotating disc immediately in front of the IR source. This arrangement gives rise to an IR beam alternating rapidly between measuring wavelength and reference wavelength for each component. This alternating beam passes through the gas to be measured, eventually striking the IR detector.

Filters have been selected such that if any of the gas to be measured is present, then a significant amount of radiation will be absorbed at the measuring wavelength, with very little or none at the reference wavelength.

The quantity of radiation per unit time is a function of two factors: (1) the number of molecules within the optical path *and* (2) the extent to which these molecules absorb radiation, expressed as the absorption coefficient.

Absorbance may be defined in the following expression:

$$A = E.C.l = -\log_{10} (I_M/I_R) + O_Z$$

where: A is the absorbance
E is the Extinction Coefficient
C is the gas concentration
l is the length of sample through which the beam has passed
 I_M is the IR signal strength at the measuring wavelength
 I_R is the IR signal strength at the reference frequency
 O_Z is the zero offset.

It will be seen that there is a logarithmic relationship between the concentration and the ratio of the IR signal strengths at the measuring and reference wavelengths.

It is these two signal strengths which are shown on the TEST screen under the titles *measured value* and *reference value*.

During calibration of the analyser, the measured absorbance is recorded for known sample gas concentrations over the range required for the specific application. Results of this exercise are recorded within the system's memory in the form of a look-up table. During live operation of the analyser, the system calculates concentration levels from absorbance levels by continual reference to this look-up table.

Cross-sensitivity

While IR absorption measurement is the optimum solution for many continuous process gas analysis requirements, it is not perfect. Conventional IR analysers can suffer from the problem of cross-sensitivity, caused when more than one gaseous component absorbs radiation at a selected wavelength.

Water vapour is the most common component to cause cross-sensitivity, followed by carbon dioxide. Water vapour exhibits absorption across a wide part of the IR spectrum. Since most flue emissions contain high percentages of water vapour, conventional cross-stack IR analysers often suffer from inaccuracies caused by cross-sensitivity. When using extractive analysers, water needs to be removed by condensation.

PULSI 200LR analysers do not suffer appreciably from cross-sensitivity due to water vapour, carbon dioxide or other 'problem' gases. PULSI 200LR units configured for applications where cross-sensitivity would normally be a problem are equipped with additional measuring channels and the unique PROCxsens (iterative) calculating software. NO_x analysis provides a good example of how these additions work. Normally, a 3-channel analyser would be used, analysing NO, NO₂ and the sum of these NO_x gases. Measurement of NO is subject to cross-sensitivity to water vapour. So, the PULSI 200LR for NO_x has two additional undisplayed channels, measuring water vapour and carbon dioxide. Once the absorbances of these two components at NO measuring wavelengths are known, they can be compensated for, to arrive at a true figure for NO concentration.

Gas filter correlation

Gas filter correlation spectroscopy is used in the PULSI 200 series of IR analysers in order to enhance their sensitivity and reduce their cross-sensitivity to interfering components. This technique is useful for gases at lower concentrations and those that have a lot of fine structure in their IR spectrum.

The technique effectively increases the resolution of the interference filters used, which typically have a bandwidth of 2% of their peak transmission wavelength. In terms of spectroscopy, this is quite broad. Figure 4-3 shows the structured spectrum of HCl with sharp, narrow bands which are too narrow to be well matched to the interference filter. The absorption, which is sensed when a filter on its own is used, is the average absorption rather than the much higher peak absorption of the HCl gas.

One way of increasing the selectivity of gases when using interference filters is to use sealed cells filled with the gas under study. Procal Analytics has produced sealed cells filled with HCl, NO, Methane and CO, and is likely to add other gases to this range. To show how these sealed cells work, refer to Figure 4-4. A matched pair of filters is used with both filters being as similar as possible in their transmission and wavelength characteristics.

If they were used individually, they would produce identical reference and measurement pulses at the IR detector, and both would react to the presence of the gas being measured. The example given is for hydrogen chloride, HCl.

However, if a gas cell filled with HCl is put in series with one of the filters, the pulses become unbalanced and the pulse caused by the reference filter becomes weaker. When HCl gas enters the sample tube of the PULSI analyser, the measurement pulse falls much more than the reference pulse. The reason for this is that the reference pulse has been filtered by the sealed cell, so the sharp narrow bands of wavelength at which HCl absorbs are absent. Therefore, further absorption by the HCl is small. The measurement pulse, on the other hand, reacts to HCl in the normal way. Therefore, the introduction of the sealed gas cell has sensitised the pair of matched filters to HCl.

When interfering gases - such as water vapour - come into the sample cell, both pulses reduce in almost the same proportion. This is because the water vapour absorption is broadband and does not follow the same pattern as the HCl absorption. It therefore causes absorption of both pulses. The method of signal processing divides the intensity of the measurement pulse by the intensity of the reference pulse before calculating the absorbance. Therefore, equal, proportionate changes which occur to both pulses are cancelled out. This shows that substantial immunity to water vapour and other interfering gases can be achieved in this elegant fashion.

There are further advantages in the use of gas filter correlation, as opposed to the conventional use of reference wavelengths. Since the measurement and reference wavelengths are the same, and as they come from matched filters and only differ by the filtering caused by the gas in the sealed cell, any effect due to temperature change of the source also cancels out. When different wavelengths are used there can still be some effect due to temperature fluctuations in the infra-red source. The signal-noise ratio has been raised by the use of gas filter correlation, permitting the measurement of smaller amounts of gas. Procal Analytics uses gas filter correlation in combination with software, such as PROCxsens and matrix algebra, which enable complete correction to cross-sensitivity to be achieved, even eliminating the small cross-sensitivities that remain after gas filter correlation cells are used. In practice, an improvement in the immunity to water vapour of more than a order of magnitude is achieved. In the case of measuring HCl - one of the most demanding analyses - the main improvement is in the immunity to the interference effects of hydrocarbons.

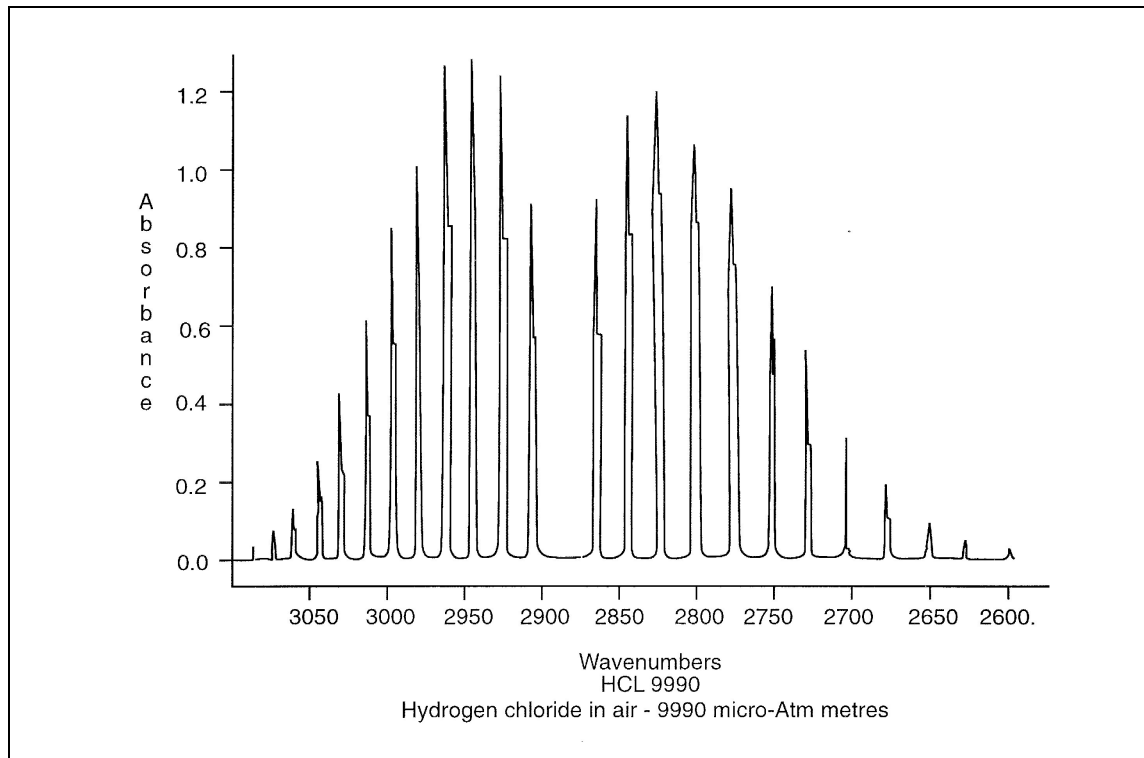


Figure 4-3 IR absorption spectrum of HCl gas

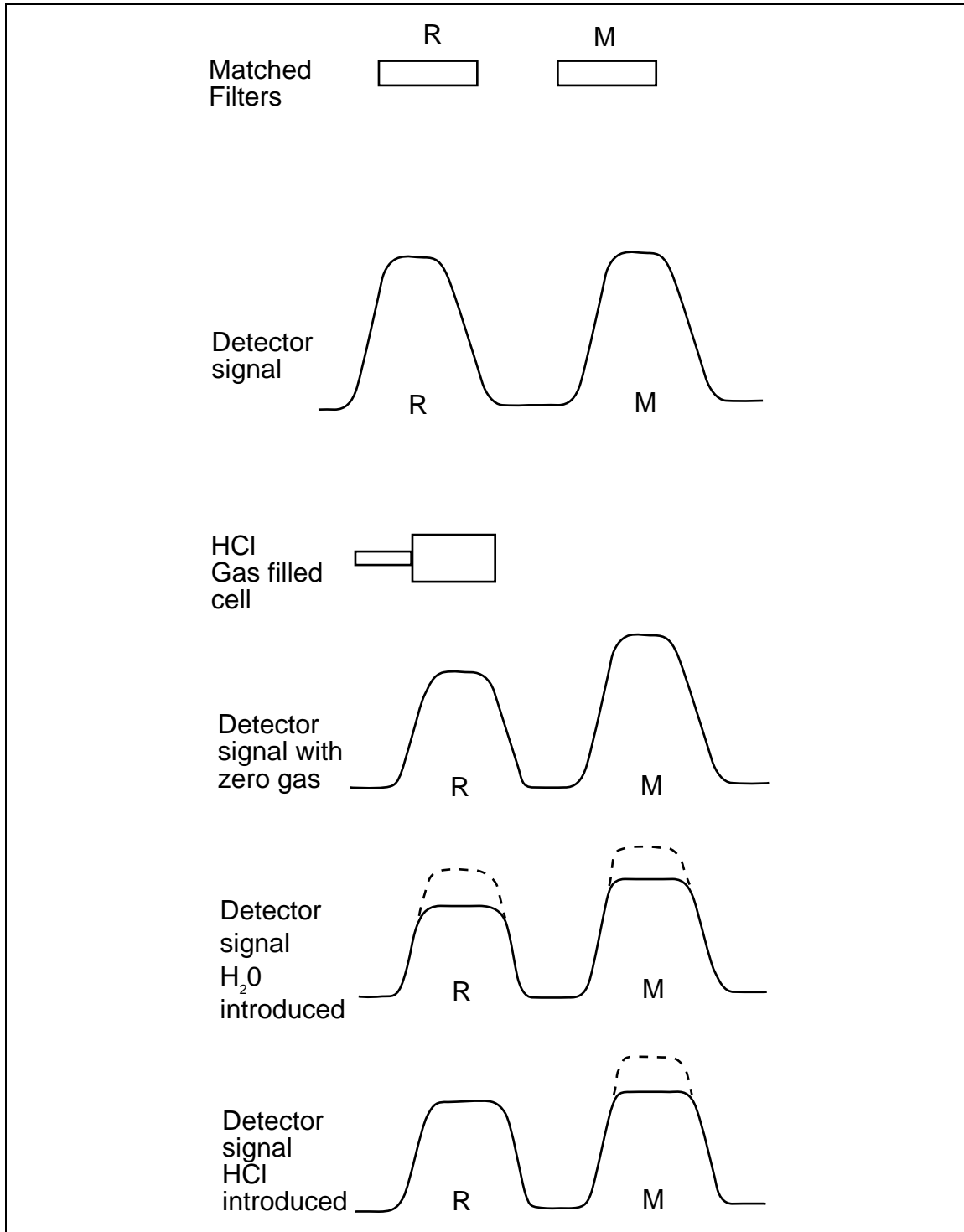


Figure 4-4 Detector responses with HCl sealed cell

Optical Head Unit

The Optical Head Unit is shown, with its cover removed, in Figure 4-5 below. All the principal components are annotated on the illustration, and described in text.

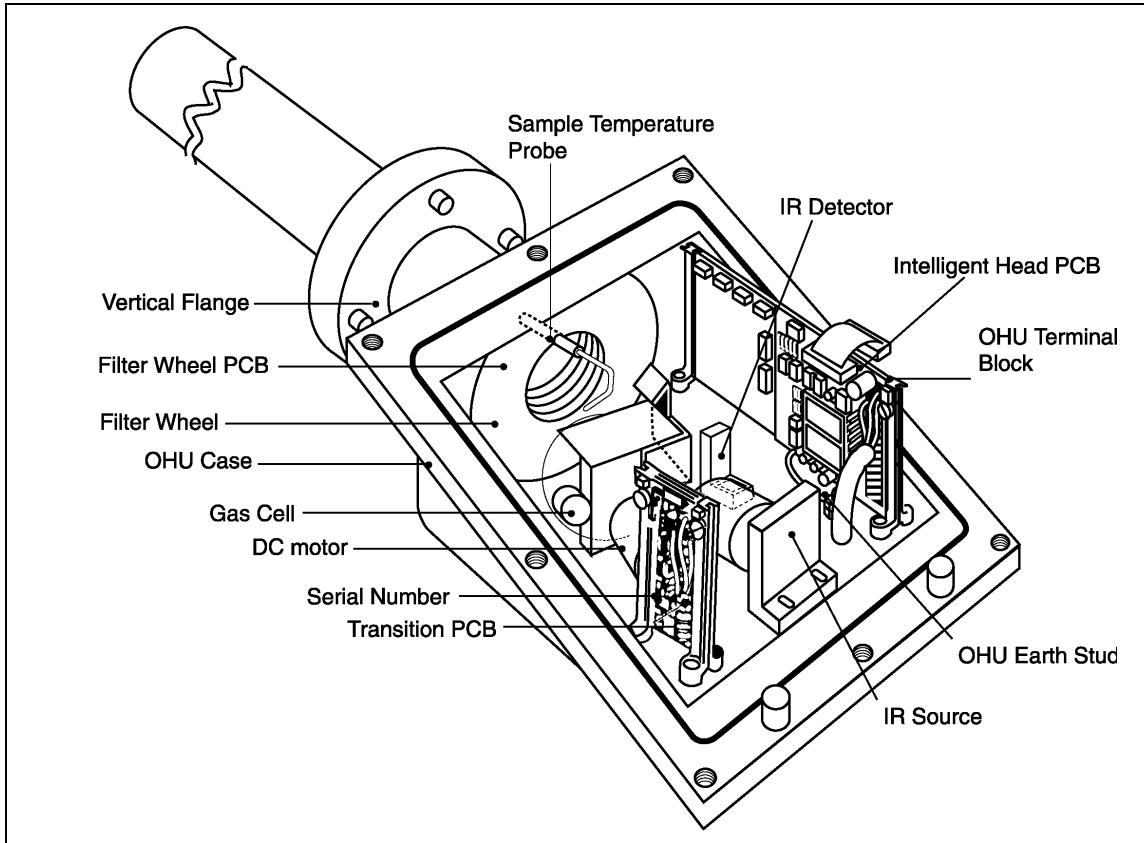


Figure 4-5 PULSI 200LR Optical Head Unit with cover removed

Within the OHU is a broadband infra-red (IR) source, which is an enclosed electrical filament consuming about 8 W and running at about 1100°C. Radiation from the source passes through the filter wheel. This wheel is fitted with up to 8 filters, and sometimes a gas cell for special applications. Drive of the filter wheel is by means of a DC motor at a controlled speed of around 7.5 revolutions per second. On the rim of the filter wheel are a series of slots. These slots pass through a light source-detector assembly on either side of the wheel. The time is detected, amplified on the filter wheel pcb, and passed to the ACU. The ACU uses the timing pulses to match each reading with the filter in the optical path at any moment.

Once the IR beam has passed through the filter, it passes through the head exit lens and into a void that is purged with a non-absorbent gas. This void acts as a spacer between the OHU and the sample cell so that the latter can be inserted fully into the duct, thus avoiding stratification of the gas which can occur near the wall of the duct. The lens is normally made of calcium fluoride. For measurement of longer wavelengths, a zinc selenide lens is used. Lens materials are selected for their good IR transmission characteristics and their inert nature.

When the IR beam has passed through the sample gas and been returned to the OHU, it is incident on the detector. This detector is a high-performance solid state device working on the pyro-electric principle. Radiation striking the detector causes minute temperature changes which are translated into electrical signals. These signals are proportional to the level of irradiation, and are largely independent of wavelength.

Within the OHU is the optical head pcb. This has a number of functions. It amplifies the signal from the IR detector, and passes this to the ACU. It supplies and regulates DC power to all parts of the OHU. Lastly, it amplifies and transmits the temperature signals from the two temperature sensors in the sample cell and the OHU respectively.

Optical Head Unit specification

Principle of operation	Infra-red absorption with multiple wavelength selection using Gas Filter Correlation (GFC) where advantageous. Interference filters and gas cells mounted on a rotating filter wheel. Sample cell uses the enveloped folded beam principle.
Gases measured	Up to 6 hetero-atomic gases as determined by the application.
Spectral range	Specific application-dependent wavelengths (up to 8) are selected between 2 μm and 12 μm .
Infra-red source	Enclosed hot filament.
Infra-red detector	Solid state pyro-electric type.
Sample path length	1 m.
Sample Temperature	Up to 350°C.
Cross-sensitivity	Minimal, due to the wavelength selection, gas filter correlation technique and advanced algorithms in the processor software.
Accuracy	Typically $\pm 2\%$ of full scale concentration, but dependent on application.
Response time	Application-dependent, but typically less than 120 seconds to 90% of full scale.
Calibration requirements	Supplied pre-calibrated. Short term drift of less than the quoted accuracy is removed by automatic zero calibration, performed automatically at preset intervals, typically 4 - 24 hours. Span verification recommended every 3 - 6 months, depending on application.
Enclosure	Aluminium alloy casting with high protection finish, sealed to IP65, NEMA 4X.
Operating environment	Operating temperature range: -10°C to +45°C.

Materials contacting sample	Calcium fluoride, glass, 316 stainless steel, graphite.
Services required	Power for the electronics provided by the ACU electronic unit. 115/230 V ac 10 W required for Optical Head Cooler (if fitted). Instrument air for the analyser void purge, auto-zero and sample cell protection, controlled by the Auto-zero/Auto-purge Unit. Pressure 6.8 bar max; flow rate 30 litres/hour constant and 600 litres/hour intermittent during Auto-zero (typically 5 minutes every 12 hours).
Interconnecting cable	6-way 3 twisted pair with overall screen. Maximum resistance 4.0 ohm: 0.5 mm ² cross section cable normally used which allows 100 m spacing between OHU and ACU..
Auxiliary inputs	Up to four analogue inputs, 0/4 - 20 mA or 0 - 5 V (link selectable) as specified by the customer.
Outputs	Seven 24 V dc outputs for auto zero control, auto calibration control (x2), In-Situ Heater control (optional), Head Cooler and Optional Heater and optional Special Drive.

Auto-zero/Auto-purge Unit (Auto-Verify Unit, AVU)

All PULSI 200LR analysers should be used with an Auto-zero/auto-purge Unit or Autoverification Unit.

The Auto-zero/Auto-purge Unit has two primary functions. Firstly, it provides totally automatic zeroing of the system, and secondly it acts as a safety purging system to prevent condensation forming in the sample cell of the Optical Head Unit.

In its Auto-zero function, a zero check is instigated on a periodic basis by a command signal from the ACU. The control voltage switches a solenoid valve on the Auto-zero/Auto-purge Unit which diverts a regulated flow of instrument air to the Optical Head Unit.

After a predetermined stabilisation period, the ACU will read the zero gas signal and, if necessary, adjust the zero offsets on every channel until a true zero is obtained. Once zeroed in this manner, a further signal from the ACU will shut off the supply of instrument air, and natural purging action will quickly refill the sample cell with process gas. The unit will go back to on-line process measurements.

During this Auto-zero procedure, all displays and outputs are frozen at the last 'on line' levels before commencement of the Auto-zero routine. This includes the time required for the sample cell to purge clear of instrument air at the end of the Auto-zero cycle. The frequency and duration of the flush times in the

Auto-zero routine can be altered as described in the Operation section of the ACU Operating Manual.

In the event of a power failure to the system, the In-Situ Heater element (when fitted) and the sample cell will cool, possibly to below the dewpoint. Condensation would then occur on the process side of the main lens. The de-energised solenoid valve on the Auto-zero/Auto-purge unit opens and floods the sample cell with dry instrument air, thus removing the possibility of condensation. The unit will continue to purge the cell until the fault condition is rectified.

The auto-zero/auto-purge system hardware is a single panel of components mounted inside a weather-proof cabinet. The software to operate the system is fully pre-programmed into the ACU and OHU.

Auto-zero/Auto-purge Unit (AVU) specification

This unit will, on automatic command from the ACU signal processor, divert a flow of instrument air to the P200LR analyser. This will occur under any of three conditions:

- 1 when an auto-zero is required
- 2 when the sample temperature falls below a preset level, typically 120°C.
- 3 when the sample temperature rises above a preset level, typically 350°C

The AVU contains:

- Instrument air regulator for 6.8 barG supply (max)
- Filter
- Needle valve
- Void purge Restrictor
- Solenoid valve (controlled automatically by the ACU)
- Two off - Calibration gas valves (controlled automatically by the ACU)

Services required: Clean, dry instrument air at a maximum of 10 barG

External protection: IP65 enclosure

Weight: 4 kg

Maximum dimensions: 284 x 170 x 80 mm (H x W x D)

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5 Maintenance

Introduction

The PROCAL PULSI P200LR is a high-technology analytical tool. Like other specialised industrial equipment, it needs regular maintenance if it is to operate at peak performance.

It is strongly recommended that if a PULSI 200LR system is purchased, a service contract is taken out. This will cover regular cleaning, calibration and routine preventative maintenance. A service contract will assure priority response to emergency call-outs. Please contact Procal Analytics or Procal distributors for further information about service contracts.

Caution

While the instrument is accurately aligned and calibrated as part of the standard production procedure, it is possible that components may become misaligned due to prolonged vibration in operation. If misalignment is suspected, the user should not attempt to re-align the instrument. Incorrect realignment will invalidate the calibration. Call Procal Analytics or your Procal distributor.

Routine maintenance schedule

If the user does not have a service contract and decides to undertake routine preventative maintenance in-house, the following schedules should be strictly followed.

Please note that if the system is not properly maintained, the manufacturer's guarantee may be voided or limited.

Calibration may be required more frequently by the local pollution inspectorate or other regulatory authority.

Weekly schedule

- access the TEST screen on the ACU, and check all operational data displayed
- keep a record of the signal readings so that any deterioration due to lens clouding or electrical faults can be quickly identified.

Quarterly (three-monthly) schedule

- visual inspection of Optical Head Unit for cracks, corrosion or any other signs of physical damage
- visual inspection of Auto-zero/Auto-purge Unit for cracks, corrosion or any other signs of physical damage

- visual inspection of all cables and gas connections for integrity, and for cracks, corrosion or any other signs of physical damage.
- calibration (see under the heading *Field calibration check* within this section); note that calibration may need to be performed more frequently if required by regulatory authorities

Annual schedule

- internal visual inspection of Optical Head Unit for signs of ingress of dust, moisture or process fluids and/or gases
- check that the source is emitting and that its exit lens is clean
- check all mirrors, lenses and optical filters for cleanliness
- check the filter wheel motor (when unplugged) for ease of rotation, and replace the motor if any friction is apparent
- visual inspection of all cables and gas connections for integrity, and for cracks, corrosion or any other signs of physical damage.
- Pt100 platinum resistance thermometer resistance check. The resistance should be $100 + (38/100) \times \text{temperature}$.

If the results of any of the above checks cause you any concern, contact Procal Analytics, or your Procal distributor or agent, immediately.

Cleaning

Please do not attempt to clean any of the optical surfaces within the instrument. Contact Procal Analytics, or your Procal distributor or agent, for a cleaning service. If you attempt to clean optical surfaces and cause damage, the warranty on the PULSI 200LR system may be voided or limited.

Field calibration check

Introduction

The gases used in the original factory calibration are of known accuracy and the calibration achieved using them should not be discarded lightly.

Each test can be carried out individually or as part of a comprehensive field calibration check.

Note that the *Routine maintenance* schedule within this section calls for an annual Field Calibration Check.

Calibration Equipment

The calibration gases must be in cylinders that can be located close to the OHU. Each cylinder must be fitted with a regulator. It is very important that each cylinder has a supplier-independent certificate of calibration, since experience has shown that large variations in actual concentration can be encountered.

It is important that the person carrying out the calibration should be aware that he/she is dealing with toxic gases and carries out all safety procedures associated with the handling of high pressure gas cylinders.

Other equipment required for the tests:

- pressure gauge with 1/8" BSP male fitting; scaled 1 barG FSD
- if water concentration is to be checked: Water vapour generator (Procal Part number 1-1390)

Void pressure Test

- 1 Turn the Void flowmeter regulator to the fully OFF position.
- 2 Unscrew the sintered muffler fitted at the Void purge outlet. Screw to the Void purge outlet a pressure gauge with the same 1/8" BSP male taper fitting, sealed with PTFE tape.
- 3 Open the Void purge flowmeter regulator slightly until the gauge reads approximately 1 bar, and then turn the regulator fully OFF again.
- 4 After 10 minutes, check that the gauge reading has dropped by less than 5%. If the drop has been greater than this, check that the pressure gauge fitting is not leaking and then repeat the test. If the test fails again it is likely that the sealing of the centre lens is defective. In this case, the analyser will have to be dismantled and the centre lens re-sealed.
- 5 Unscrew the pressure gauge from the Void Purge port and refit the sintered muffler. Adjust the Void Purge flowmeter to set the Void Purge flow rate to 30 l/hour.

Sintered panel flow Test

Observe the stack pressure under normal operation and note the reading. Select Manual Air Purge and observe the pressure again. If the increase is greater than 50 mbar, the sintered panel is partially blocked.

Gas calibration

(for US EPA instruments see Appendix F)

- 1 From the SET menu select AUTOZERO NOW and let the analyser run through a normal auto-zero cycle.
- 2 Connect the outlet of the gas cylinder to AZU port 2 (Test gas entry). Turn the Test Gas Valve lever on the front of the AZU to OPEN.
- 3 Open the gas cylinder regulator and then use the auto-zero flowmeter and regulator to achieve the same flow rate that was determined for auto zero.
- 4 To ensure that all water vapour and auto-zeroing gas has been driven out of the sample cell, perform the instruction given in step 3 then wait for at least two minutes. Observe the TEST screen and note the abs reading for water vapour, which should have reduced to a level of less than 2% of the abs reading during normal operation. If it is higher than this, increase the gas flow rate until this condition is met.
- 5 Allow time for the gas concentration reading to stabilise. If the displayed reading is within $\pm 2\%$ of the anticipated level then no recalibration should be attempted.
- 6 If the displayed reading shows a deviation of $> \pm 2\%$ from the predicted level, then recalibration should be undertaken as described in steps 7 to 9.
- 7 Using the SERVICE menu as described earlier in this section of the manual, select the Calibration option.
- 8 The analyser will average the gas concentration reading for 1 minute and then display it on the ACU screen. Adjust required concentration such that it reads the same as the certified gas concentration.
- 9 Move the cursor to the Calibrate option and select it. The analyser will immediately recalculate the calibration table values for the gas so that on returning to the RUN mode screen the correct value will be displayed.
- 10 Disconnect the gas cylinder from AZU Port 2 and turn the Test Gas Valve lever back to CLOSED.

Water vapour calibration check

This check should be performed only if there is reason to doubt the calibration, as field calibration is less accurate than laboratory calibration.

- 1 Adjust the Auto-zero flow rate to 300 l/hour.
- 2 Disconnect the pipe connecting the Auto-zero port 1 to OHU port A. Take a length of flexible pipe from the Auto-zero port 1 to the Water Vapour generator inlet. Connect the Water Vapour Generator outlet to the OHU port A via a heated pipeline (supplied with the water vapour generator).

- 3 Consult the graph shown in Figure 5-1, to ascertain the water temperature required in the Water Vapour generator to create the water vapour level typically encountered in the duct. Set this on the Water Vapour generator temperature controller and wait until the actual temperature has risen to this set temperature.

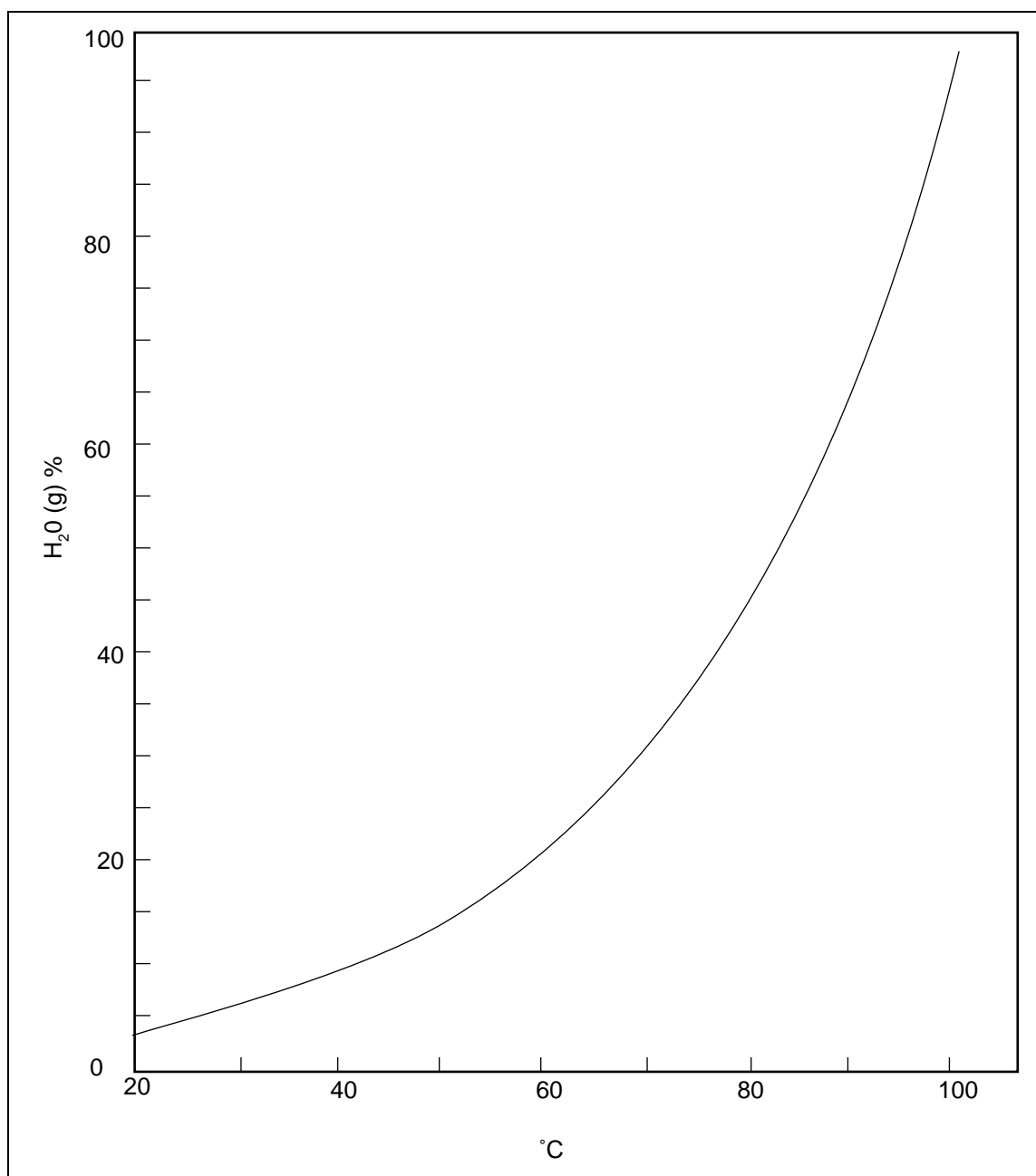


Figure 5-1 Water vapour curve

- 4 Check that the auto-zero flow rate is still 300 l/hour and allow time for the water vapour readings to stabilise. At water vapour concentrations greater than 25% there may be sudden surges in the displayed concentration followed by a return to a steady level. This is due to droplets of water condensing in the feed pipe and then blowing into the analyser. It is important that the steady level be noted, ignoring occasional surges.
- 5 If the displayed water vapour reading is within $\pm 5\%$ of the predicted concentration, then no recalibration should be attempted.

- 6 If the displayed steady reading shows a deviation of $> \pm 5\%$ from the water vapour concentration, then recalibration should be undertaken as described in steps 7 to 10 immediately below.
- 7 Using the SERVICE menu as described in this section, select the Calibration option.
- 8 The analyser will average the water vapour reading for 1 minute and then display it as shown in as in the calibration graph above. If the *required concentration* figure is significantly different from the previously observed average, then it is likely that one of the surges occurred during the 1 minute averaging time. In this case, repeat steps 3 to 8 of this procedure.
- 9 Adjust *required concentration* to read the same as *predicted concentration*.
- 10 Move the cursor to the Calibrate option and select it. The analyser will immediately recalculate the calibration table values for water vapour so that on return to the RUN mode screen the correct value will be displayed.
- 11 Disconnect the Water Vapour generator and remake the connection from the AZU to the OHU.

Fault-finding

Presented below is a list of faults which Procal Analytics considers can be diagnosed and rectified by some users.

WARNING

You must not attempt to FAULT-FIND OR REPAIR this system unless you are qualified, competent and authorized to work on electrical equipment operating at your local mains electrical supply voltage.

MAIN screen shows variable readings

- 1 check whether the TEST screen shows rapid changes in concentration, inconsistent with expected levels
- 2 if the TEST screen shows low readings, check for condensation on, or contamination of lenses and mirrors.
- 3 the quality of the IR signal may be poor. Check with an oscilloscope that the waveform shown in Figure 5-2 (a) appears at TP1 on the OHU pcb (with ground connection to E). It is important that the observed waveform is as smooth as in Figure 5-2.
- 4 connect the second channel of a dual-beam oscilloscope to the OHU terminal LK21 (top). With the oscilloscope trace mode set to 'CHOP', check that the 'phasing' of the wheel pulses shown in Figure 5-2 (b) is such that they coincide with the peaks and troughs in the IR signal. If they do not, please contact Procal as your system may need recalibration. *DO NOT UNDER ANY CIRCUMSTANCES ATTEMPT ANY ADJUSTMENT OF YOUR OHU.*

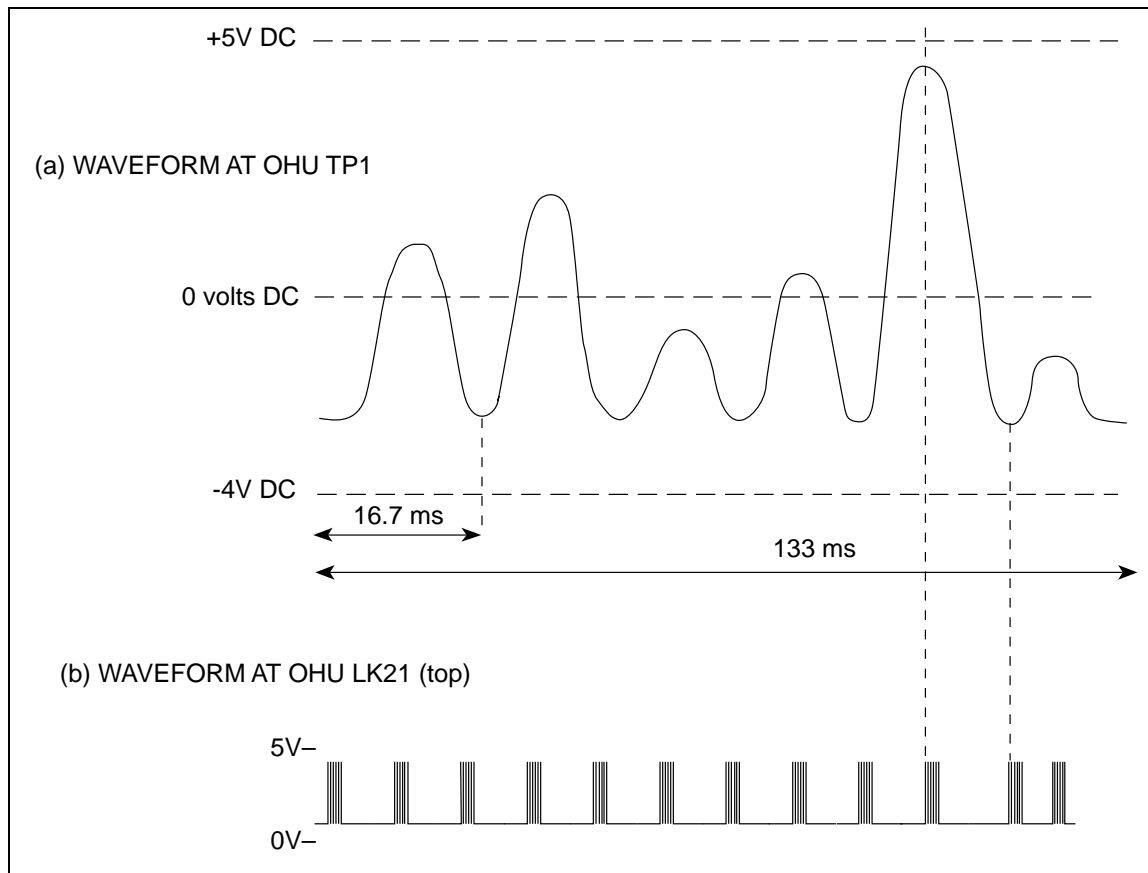


Figure 5-2 Expected IR signal at the OHU

Repair policy

Procal Analytics recommends that repairs to the PULSI 200LR system are only made by its own trained support staff, or by those of its distributors world-wide.

If you have the necessary technical qualifications, training and experience you may wish to make straightforward repairs in-house. A spares list is given for this purpose. However, you should note that if a repair is incorrectly carried out, this may void or limit the warranty on the system. You should also note that this manual is *not* intended to describe fault-finding or repair down to component level.

WARNING

You must not attempt to FAULT-FIND OR REPAIR this system unless you are qualified, competent and authorized to work on electrical equipment operating at your local mains electrical supply voltage.

Spares list

Part No	Description	Number
1-1914	IR Source Assembly (integral)	1
1-1444	Source Element	1
1-2034	Detector Assembly >8µm	1
1-1904	Detector Assembly <8µm	1
1-1524	Filter Wheel DC Motor Assembly	1
1-1336	Sintered Tube Assembly	1
4-8048	Mirror	1
1-1532	PT100 Temperature Sensor	1
2-1039	Filter Wheel PCB	1
2-1029	Optical Head PSU & CPU PCB	1
4-8047	Process Lens	1
1-8013	Gasket set	1

The figure in the right-hand column is the quantity of that part fitted to the analyser.

If you wish to order a spare part, please contact Procal Analytics, or your Procal distributor or agent.

If you require a spare part that is not listed here, please contact Procal Analytics, or your Procal distributor or agent.

When ordering spare parts, please quote both the Part Number *and* the serial number of the part of your system concerned - OHU, ACU, AZU or ISH. This will provide you with a quick and efficient service.

Procal Analytics Ltd. reserves the right to change the prices, specifications or manufacture of any component parts at any time.

Changing PULSI 200LR components

Certain components can be changed by the user within the PULSI 200LR system, when necessary.

Changing the integral IR source filament

This procedure will be necessary if the filament has become open circuit. This will be indicated by the alarm message on the ACU ALARM screen and will be confirmed by very low signal levels on the TEST screen.

The IR source has a replaceable filament, part number 1-1454, that is the only part which needs replacing. Provided the protective air purge is maintained through the analyser during the time that it is switched off, it is possible to change an IR source filament without withdrawing the OHU from the process duct.

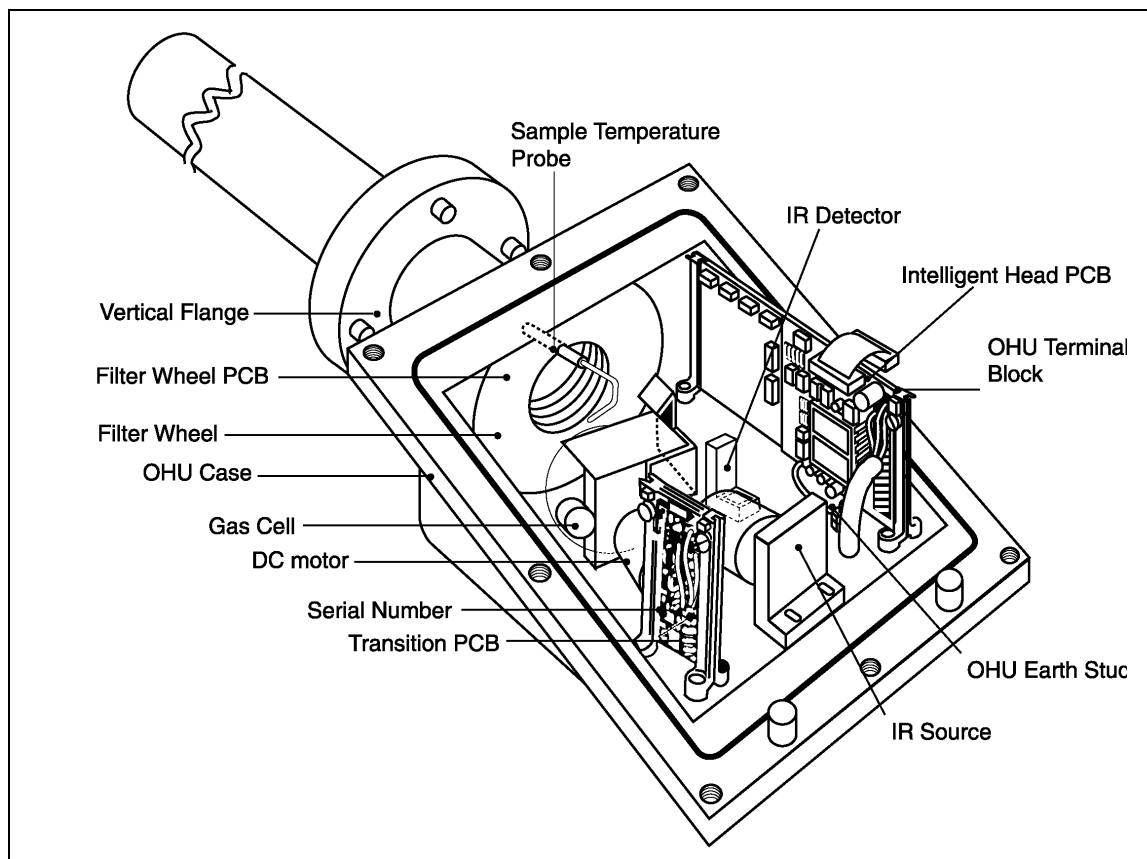


Figure 5-3 OHU unit with cover removed, showing position of IR source

- 1 Switch off the mains supply to the ACU. Check that the air purge has automatically switched on.
- 2 Remove and retain the eight 5 mm socket head screws securing the cover of the OHU to the OHU case.
- 3 Lift the cover clear and place to one side.
- 4 Locate the Integral IR source by reference to Fig 5-3.
- 5 Unplug the two-pin (Berg-type) pcb connector on the end of the cable from PL1 on the optical head pcb. Figure 5-4 shows the position of PL1.

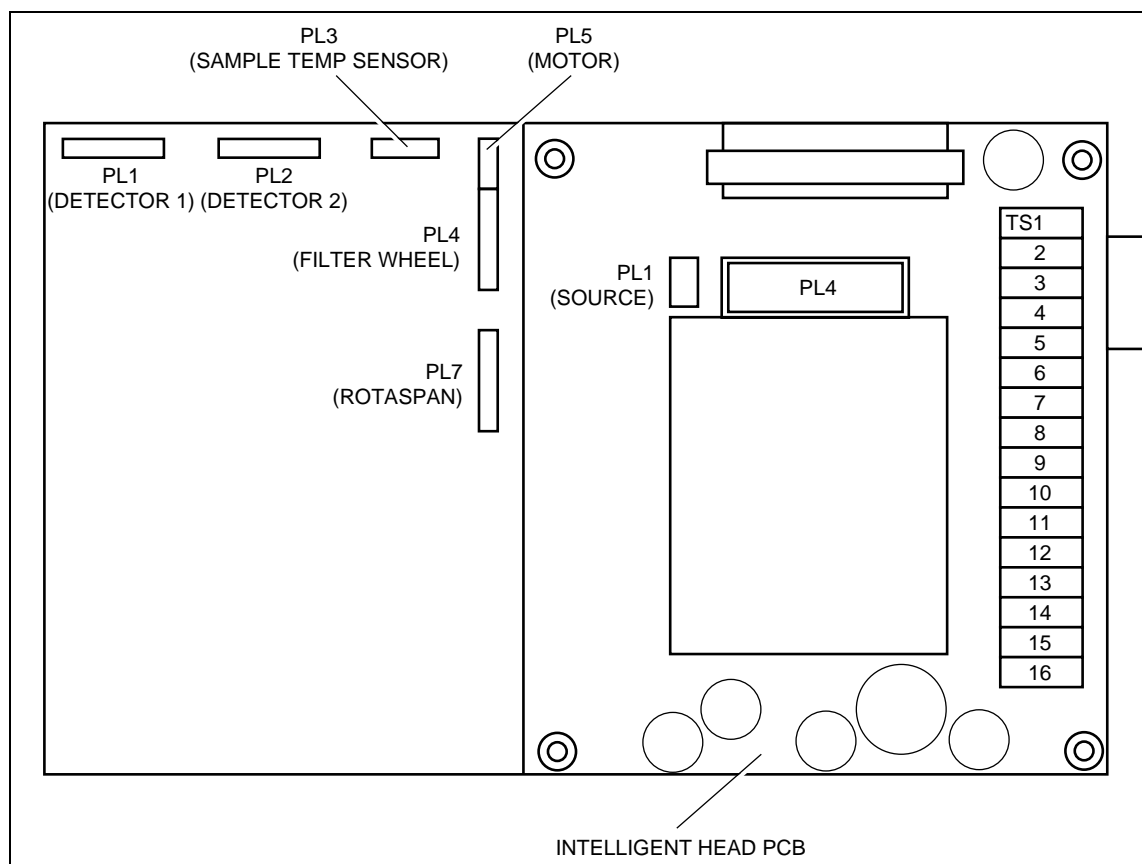


Figure 5-4 Optical head pcb, showing positions of connectors

- 6 Loosen the two pan head M3 screws at the top of the integral source that hold the filament in position until it is possible to rotate the filament through 90° and withdraw it. Note the orientation of the filament flange as it is withdrawn.
- 7 Taking great care not to damage it, insert the new filament carefully into the hole in the top of the Integral source observing the same orientation as when the old filament was withdrawn.
- 8 Rotate the inserted filament through 90° so that the elongated portion of the flange is positioned under the M3 screws, then tighten them.
- 9 Restore mains power to the ACU and check that the filament can be seen glowing inside the Integral source.
- 10 Replace the OHU cover and tighten the eight fixing screws.
- 11 Note the readings on the TEST screen and confirm that they are within 10% of the despatch data.
- 12 Using the SET key select Autozero NOW.

Changing the filter wheel motor (Part number 1-1524)

This procedure will be necessary if the motor has ceased to rotate despite there being at least 1.5V dc across its terminals. If this occurs, the number shown adjacent to Q on the TEST screen will be less than 50.

- 1 Switch off the mains supply to the ACU.
- 2 Remove and retain the eight 5 mm socket head screws securing the cover of the OHU to the OHU case.
- 3 Lift the cover clear and place to one side.
- 4 Locate the filter wheel motor by reference to Fig 5-3.
- 5 Remove and retain the two M3 socket head screws and washers securing the filter wheel pcb to the bracket, then place the pcb to one side (taking care not to strain the ribbon cable connected to the pcb).
- 6 Remove and retain the two M3 socket head screws and washers that secure the filter wheel bracket to the baseplate then withdraw the assembly from the OHU.
- 7 Note the connector to which the motor cable is connected, and the orientation, then disconnect the cable.
- 8 Using a 1.5 mm Allen key, loosen the screw holding the filter wheel on to the motor spindle and withdraw the filter wheel. This contains a number of fragile optical filters so should be placed where it is protected from damage.
- 9 Locate the three small pan head motor fixing screws on the newly-exposed face of the bracket. Remove and retain these screws, then remove the motor.
- 10 Fit the new motor to the bracket using the three small pan head screws and tighten them.
- 11 Fit the filter wheel on to the motor spindle with the wheel boss facing the motor. Leave the centre fixing screw fairly loose at this stage.
- 12 Screw the bracket to the baseplate with the two retained sets of screws and washers. Position the bracket using the pencil lines and tighten them. Rotate the filter wheel by hand and check that it rotates freely.
- 13 Fit the filter wheel pcb to the top of the bracket using the retained screws and washers.
- 14 Connect the motor cable to the connector noted in step 8 above, observing the correct orientation.
- 15 Restore mains power to the ACU and check that the motor is rotating clockwise as viewed from the rear of the OHU. If it is rotating in the wrong direction, switch off the ACU and reverse the motor cable connection to either the filter wheel pcb or the OHU pcb (as applicable to your OHU). Switch the ACU on again.
- 16 Replace the OHU cover and tighten the eight fixing screws.

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