ZGP2
General Purpose
Oxygen Probe

Operating Instructions

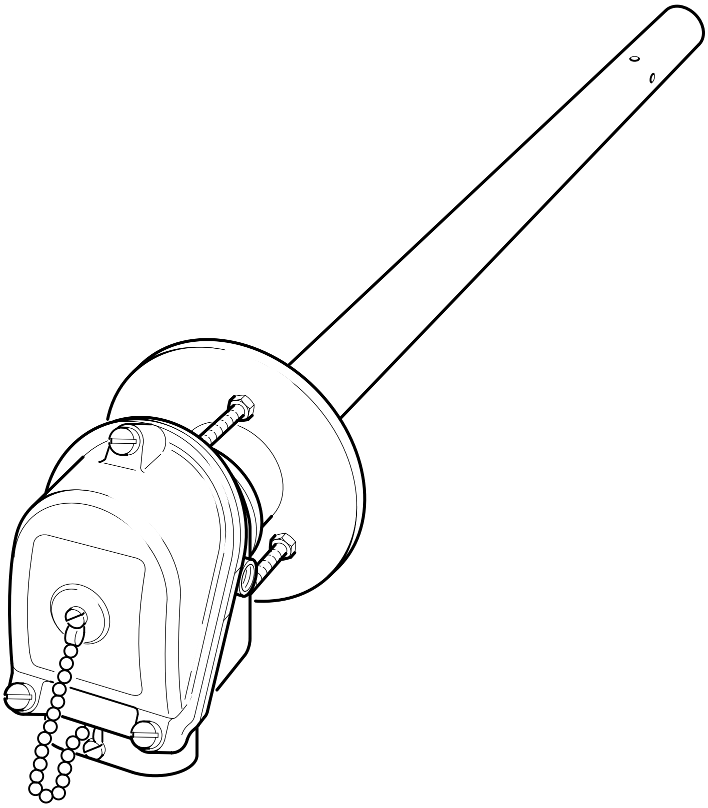


ABB Process Analytics

ABB PROCESS ANALYTICS

The Company

ABB Process Analytics specializes in the engineering, manufacture, sale and support of high quality, highly functional, analytical instrumentation for on-line analysis of process streams.

ABB Process Analytics is committed to quality leadership in the on-line analyser industry. The Company-wide, world-wide commitment is well expressed in the **quality statement** for ABB Process Analytics:

> **'We will conform to requirements and deliver defect-free products on time, to satisfy the needs of our internal and external customers.'**

Use of Instructions

Warning.
An instruction that draws attention to the risk of injury or death.

Note.
Clarification of an instruction or additional information.

Caution.
An instruction that draws attention to the risk of damage to the product, process or surroundings.

Information.
Further reference for more detailed information or technical details.

Although **Warning** hazards are related to personal injury, and **Caution** hazards are associated with equipment or property damage, it must be understood that operation of damaged equipment could, under certain operational conditions, result in degraded process system performance leading to personal injury or death. Therefore, comply fully with all **Warning** and **Caution** notices.

Information in this manual is intended only to assist our customers in the efficient operation of our equipment. Use of this manual for any other purpose is specifically prohibited and its contents are not to be reproduced in full or part without prior approval of Technical Communications Department, ABB Process Analytics.

Health and Safety

To ensure that our products are safe and without risk to health, the following points must be noted:

1. The relevant sections of these instructions must be read carefully before proceeding.
2. Warning labels on containers and packages must be observed.
3. Installation, operation, maintenance and servicing must only be carried out by suitably trained personnel and in accordance with the information given.
4. Normal safety precautions must be taken to avoid the possibility of an accident occurring when operating in conditions of high pressure and/or temperature.
5. Chemicals must be stored away from heat, protected from temperature extremes and powders kept dry. Normal safe handling procedures must be used.
6. When disposing of chemicals ensure that no two chemicals are mixed.

Safety advice concerning the use of the equipment described in this manual or any relevant hazard data sheets (where applicable) may be obtained from the Company address on the back cover, together with servicing and spares information.

CONTENTS

1 INTRODUCTION

The ZGP2 Zirconia Oxygen Probe is designed to measure oxygen in oxidising, and some reducing, furnace atmospheres. When used in conjunction with an appropriate electronics unit the probe output voltage may be converted to a signal related either to oxygen concentration, or oxidising potential, terms i.e. $\%O_2$, $ppmO_2$, kilocalories or millivolts.

Concentration terms are usually applicable to measurements in oxidising atmospheres and potential terms are used for reducing atmospheres.

Atmospheres which are strongly reduced, and which may have free carbon present, are best monitored using the Z-CS2 Carbon Sensor Probe.

The probe provides a true measurement of the atmospheric conditions in situ and permits continuous and accurate measurement over a wide temperature range without frequent maintenance associated with external sampling systems. It also eliminates ‘equilibrium shift’, common to other systems in which gas samples are cooled before measurement, and has a fast response to changes in atmosphere, enabling rapid corrective action to be taken when necessary.

The probe comprises a ceramic detector cell housed in a protective sheath. A thermocouple is fitted within the probe to enable the process temperature to be monitored or for automatic temperature compensation to be provided – see Section 5.1. The sheath material is either aluminous porcelain (recommended for oxidising atmospheres) or Incoloy 800 (recommended for reducing atmospheres) for use at maximum temperatures of 1250°C (2282°F) and 1000°C (1832°F) respectively. Special sheaths are available for use up to 1400°C (2552°F). A connector head (protected to IP54 or IP56) facilitates connection of the cell output, thermocouple and reference air connections.

A calibration gas inlet port is provided to enable the probe to be checked using test gas mixtures without removing it from the process.

Reference air, at a volume of 100 to 250 ml/min. (0.2 to 0.5 ft^3/hr), is required for accurate operation. This can be supplied from a mains-powered pump unit (Part No. 003000240) or a flow regulator unit (Part No. 003000241), full details of which are included in the Operating Instructions: Zirconia Reference Air Supply Units – Part No. 003000239, Issue 1 onwards.

The ZGP2 probe can be operated with any of the following instrumentation supplied by the Company, full details of which are included in their respective Operating Instructions:

Z-MT Oxygen Analyzer – IM/ZMT, Issue 5 or later,

COMMANDER PR100 Strip Chart Recorder – IM/PR100–PAK.

2 PREPARATION

2.1 Unpacking

> ⚠ **Caution.** The probe is very fragile. Unpack and handle with care.

Each probe is despatched with its components individually placed within a common pack. Retain this pack to facilitate return of the probe to the manufacturer if necessary. Remove the probe from its packing as follows:

a) Place the polystyrene pack, top uppermost, on a flat surface and cut the tapes holding the two halves together.

b) Carefully lift the top half of the pack, to gain access to the probe components which are individually located within the bottom half.

c) When removing the components from the pack take great care to support the terminal head and not to twist or bend the electrode assembly attached to it.

d) Re-assemble the packing for future use.

> ✶ **Note.** If for any reason a non-standard sheath is fitted adjust the diameter of the wadding at the end of the probe to allow a snug fit.
>
> To reduce its diameter the wadding may be compressed slightly.
>
> To increase its diameter, apply slight end pressure on the wire bonding at both ends of the wadding. Mould the wadding by hand to ensure a light push fit into the sheath.

2.2 Checking the Code Number

Ensure that the correct equipment is being installed – check the code number on the probe against Table 2.1 below. Code number labels are fitted inside the probe head.

2.3 Assembling the Probe – Fig. 2.1

> ⚠ **Caution.** Take care to avoid damage to the probe when fitting the sheath assembly.

① Drill the fixing flange to suit the local fixing requirements.

② Push the three long countersunk-head screws through the fixing flange and secure them in position with the three lock nuts.

③ Position the clamp ring over the boss on the probe head, ensuring correct orientation of the ring's centre taper.

④ Position the sealing ring over the boss, ensuring that it locates correctly in the centre taper.

⑤ Carefully insert the probe into the ceramic sheath ensuring that the wadding at the probe end is not damaged and that the filter washer is in position at the end of the sheath.

⑥ Secure the sheath to the boss with the three cheesehead screws.

⑦ Slide the fixing flange over the sheath, ensuring that it is seated over the locating step.

⑧ Locate the clamp ring over the three screws on the flange ② and secure using three nuts. Tighten the nuts down equally so that the fixing flange is pulled tightly against the locating step on the sheath and the sealing ring is compressed until the adjacent faces of the clamp ring and sheath are 1 to 1.5mm apart. Use a 1mm drill or shim to set the gap correctly.

ZGP2 Zirconia Oxygen Probe		**ZGP2 /**	**X**	**X**	**X**	**X**	**X**
Insertion length	600mm		1				
	1000mm		2				
	Special		9				
Thermocouple	Pt/Pt 13% Rh BS4937 Pt 3 Type R			1			
	NiCr/NiAl BS4937 Pt 4 Type K			2			
	Special			9			
Sheath	Aluminous Porcelain (standard)				1		
	Incoloy 800				2		
	Special				9		
Mounting	Flange					1	
Connector Head	Standard						0
	Twin Gland Type C95						1

Table 2.1 Checking the Code Number

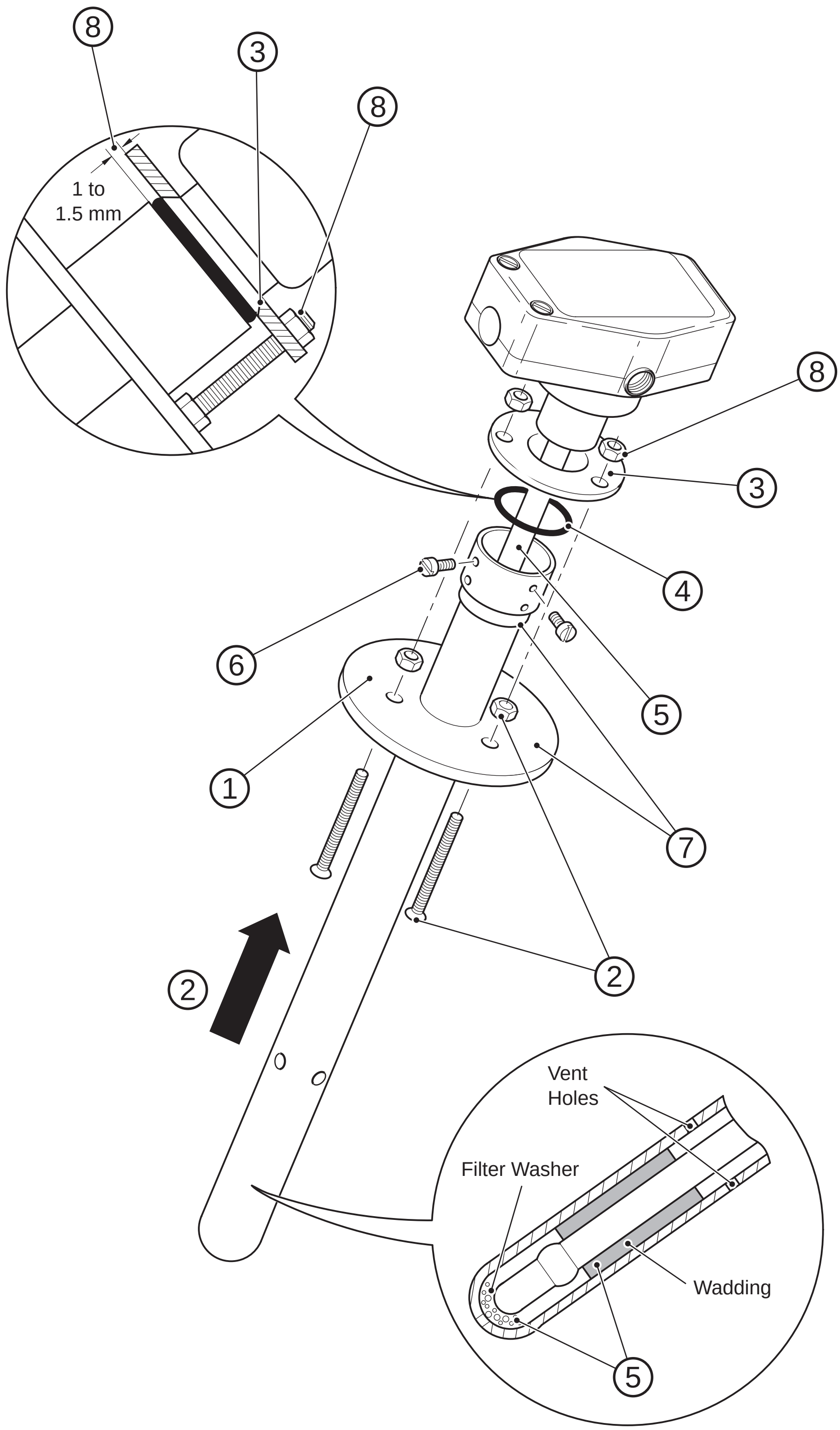


Fig. 2.1 Assembling the Probe

3 INSTALLATION

Warning. The probe operates at high temperatures – take all necessary precautions to avoid injury through burns.

Caution. Thermal shock may damage the zirconia cell if the flue is cleaned using a high pressure water hose. If this method of cleaning is employed, remove the probe from the flue prior to cleaning. Never use the probe without the sheath.

3.1 Types of Measuring Systems – Figs. 3.1 to 3.3

When an oxygen concentration measurement is required, i.e. $\%O_2$, $ppmO_2$ or O_2 partial pressure, temperature compensation of the probe output is usually necessary.

If the process temperature is constant, or if variations in operating temperature do not produce unacceptable errors, as in some flue gas measurement, it is possible to measure O_2 concentration without temperature compensation using a system similar to that for oxygen potential.

Systems for two types of measurement are shown in Figs. 3.1 to 3.3.

In metal heat treatment applications oxygen potential is normally measured and temperature compensation of the probe output is therefore not required.

Full installation details for other units are given in their respective instruction manuals.

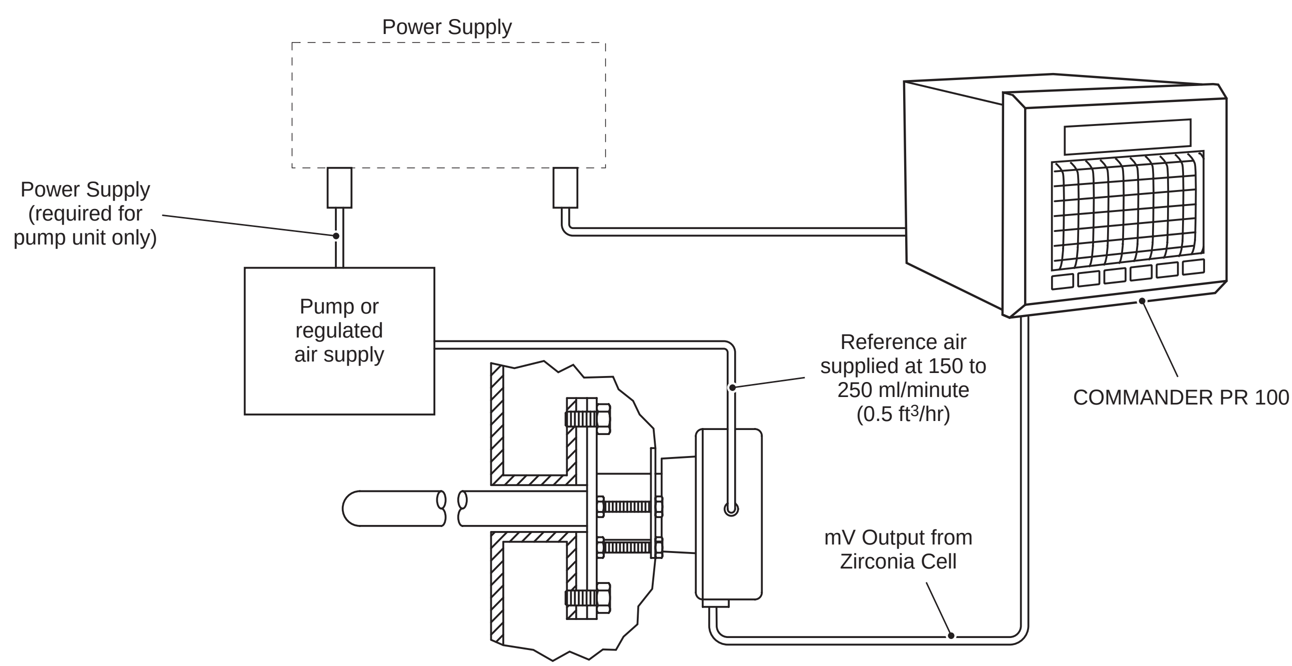


Fig. 3.1 Oxygen Potential Measurement using COMMANDER PR100 Strip Chart Recorder

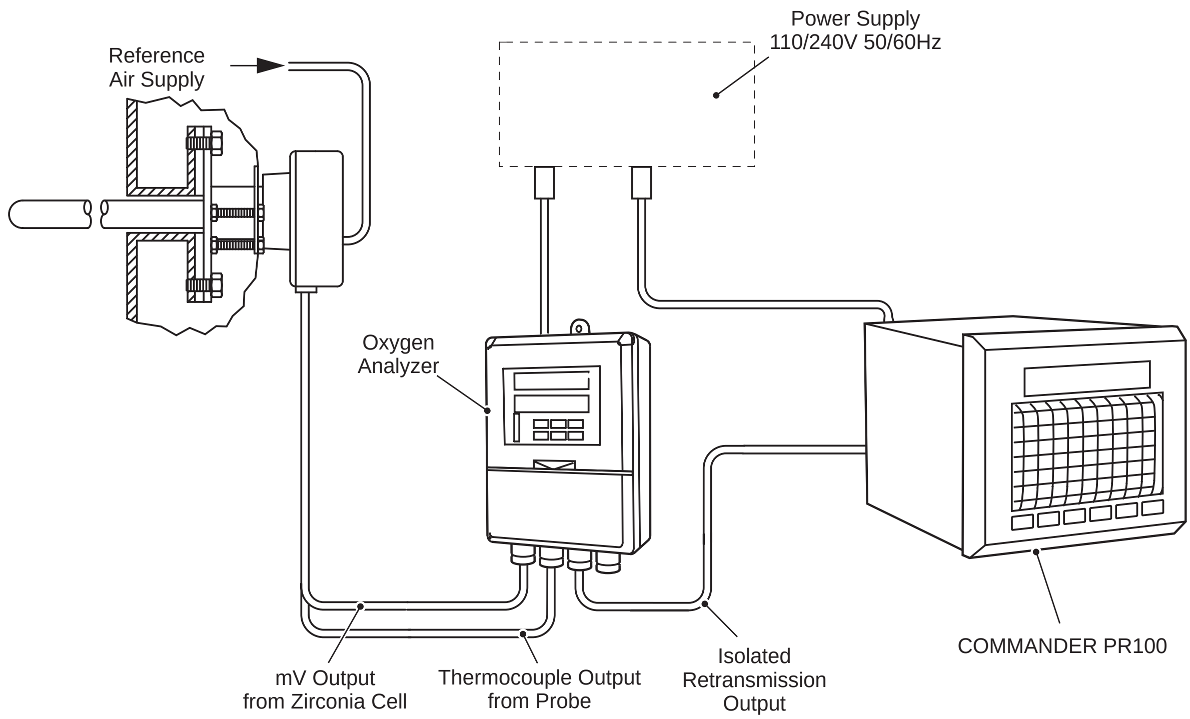


Fig. 3.2 Oxygen Concentration Measurement using Basic Oxygen Analyzer

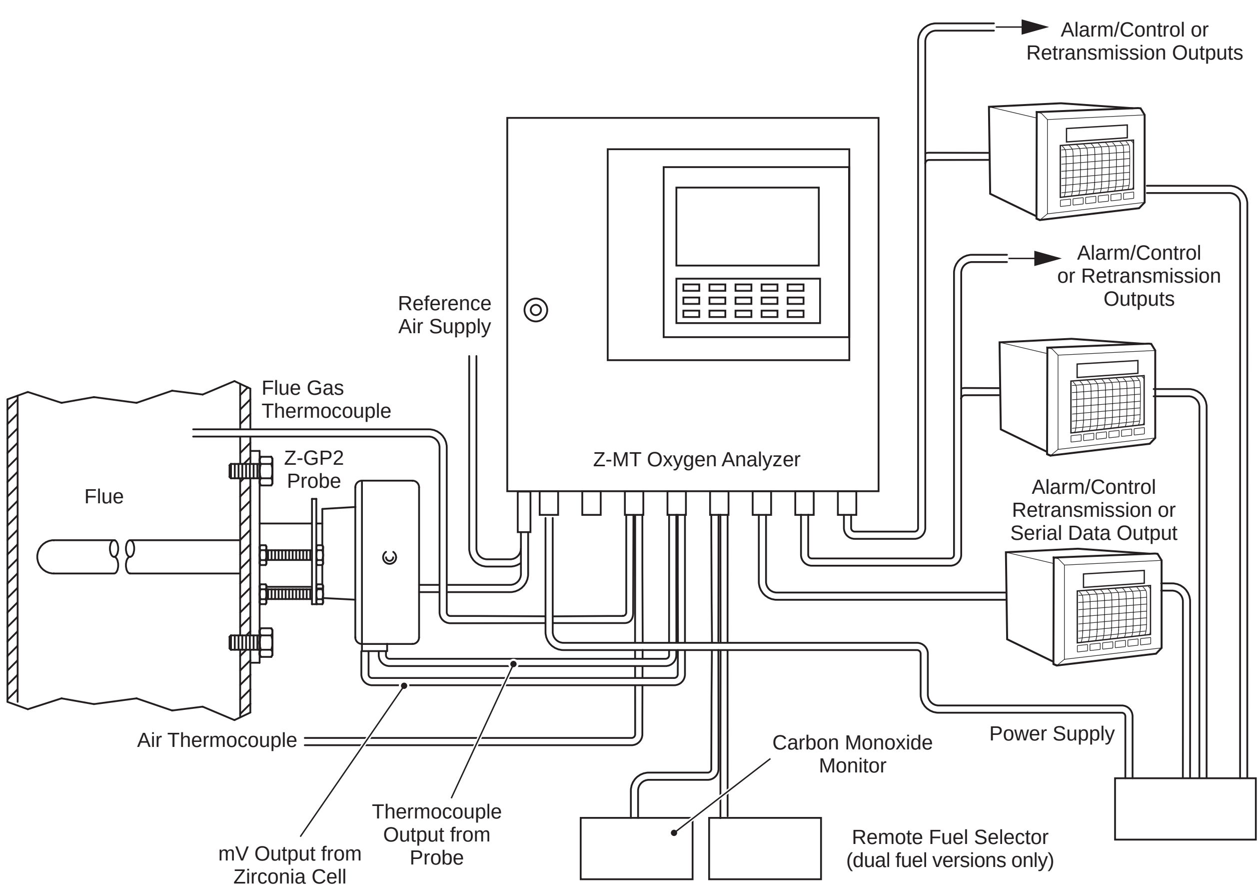


Fig. 3.3 Oxygen Concentration Measurement using Z-MT Oxygen Analyzer

3.2 Siting – Figs. 3.4 and 3.5

Select the position for the probe avoiding obstructions which may inhibit insertion or subsequent removal. Dimensions for the probe are shown in Figs. 3.4 and 3.5. A clearance of at least 25mm in excess of the overall probe length is necessary for installation or removal procedures.

Caution. The probe **MUST NOT** be sited:

a) Where it is subjected to mechanical or thermal shock.

b) In the presence of aggressive components, e.g. molten slags, molten silicates, metals and vapours of lead, zinc, silicon and vanadium.

c) Where it is subject to temperatures in excess of those specified in Table 3.1.

d) Where gas components attack the platinum electrode above 600°C (1112°F), e.g. in atmospheres containing sufficient concentrations of heavy metals such as sodium, vanadium, lead, zinc etc.

Sheath Type	Thermocouple Type			
	Type K		Type R	
Incoloy 800	900°C	1652°F	1000°C	1832°F
Aluminous Porcelain	900°C	1652°F	1250°C	2282°F
Recrystallised Alumina (special)	900°C	1652°F	1400°C	2552°F

*Reduced probe life may result if probe is operated above 1250°C (2282°F).

Table 3.1 Temperature Limits

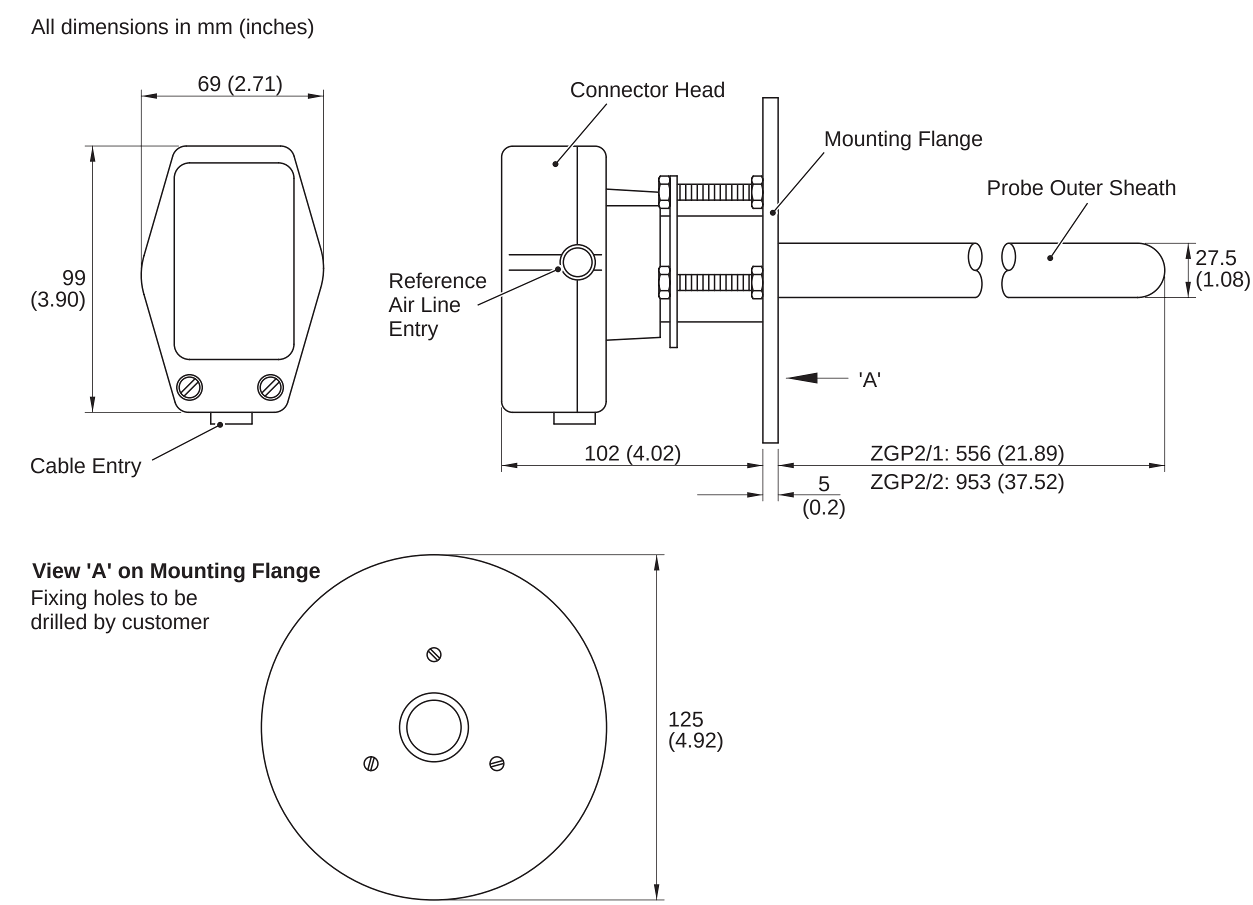


Fig. 3.4 Overall Dimensions – Standard Head

All dimensions in mm (inches)

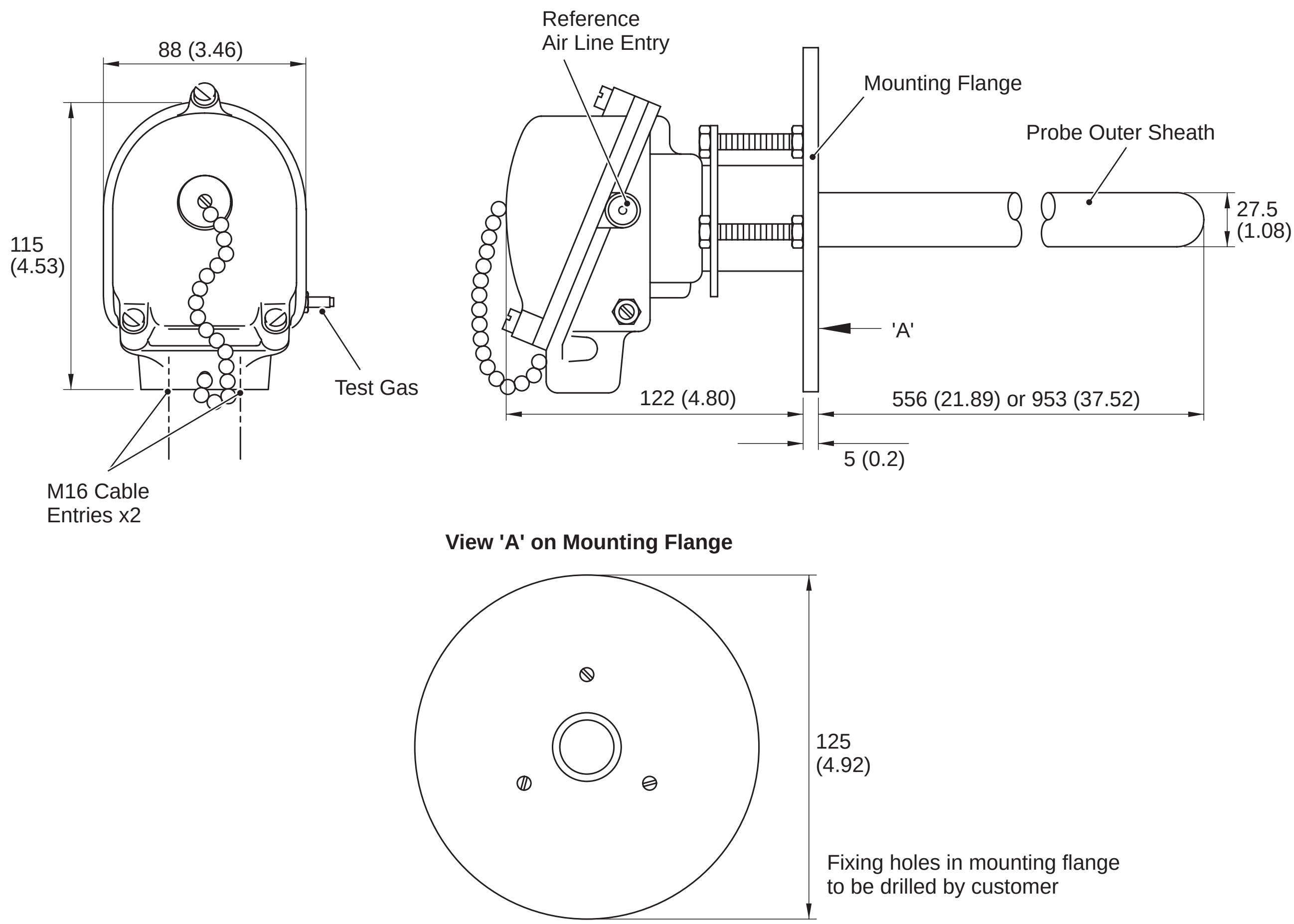


Fig. 3.5 Overall Dimensions – Twin Gland C95 Head

3.3 Mounting – Figs. 3.6 to 3.8

The probe may be fitted horizontally or, preferably, vertically for prolonged high temperature operation.

Mount the probe through the furnace wall using the preferred method shown in Fig. 3.6. Ensure that a sufficiently large hole is provided through the mounting (min. bore 42mm diameter) to avoid damage to the probe during insertion or use.

Drill the fixing flange to suit the local fixing requirements before assembling the probe – see Section 2.3.

> **Caution**. To prevent furnace gas from contaminating the reference air, always ensure that the clamp ring, fixing flange and sealing ring are fitted to the probe as described in Section 2.3.

In applications such as high temperature incinerators, fluid bed boilers, and ore roasters, where the level of water vapour in the waste gases to be measured can be extremely high, it is important that the mounting flange of the probe, including any stand-off which may be used, is thermally insulated to minimize condensation within the probe – see Fig. 3.6. Condensation within the probe sheath, particularly in outdoor installations, can be sufficient to allow water to come into contact with the hot ceramic (zirconia) tube leading to thermal shock and failure of the sensor. This problem is most likely to occur on such installations where the plant is shut-down regularly over the week-end. Additionally, take care to protect the head of the probe from the elements in out-door installations.

Raising the temperature of the probe as rapidly as possible will assist in reducing the level of condensation. This is not possible on some processes where the plant temperature is gradually raised to the normal operating level. The temperature rise at the head of the probe can be assisted by having a large clearance hole in the refractory allowing hot gases to get up to the mounting flange/stand-off – see Fig. 3.7.

The problems described above are more likely to occur on horizontal installations. Where it is not possible to mount the probe in the vertical position, install the probe with a slope of at least 10 to 15° downwards from the head of the probe – see Fig. 3.8.

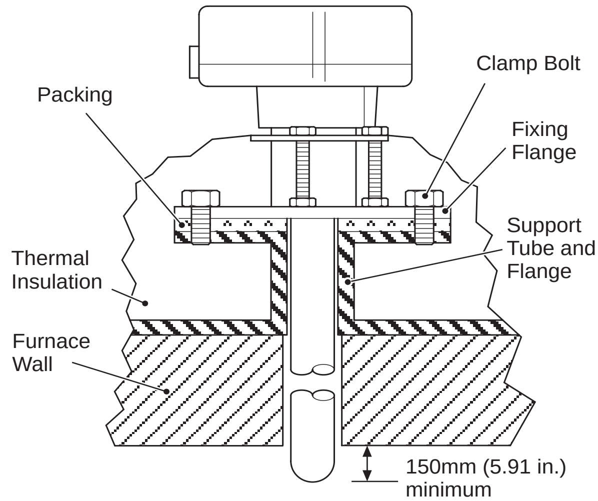


Fig. 3.6 Probe Mounting (standard configuration)

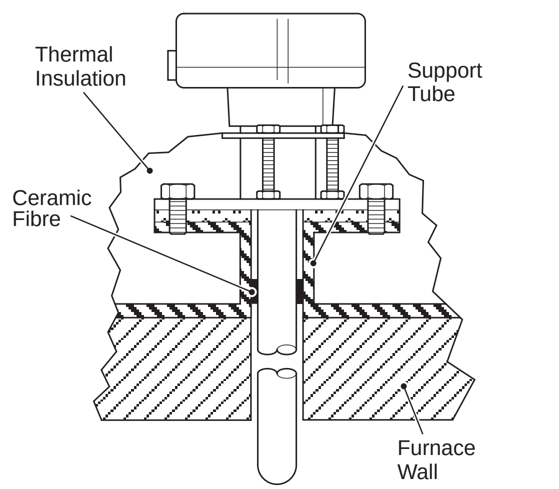


Fig. 3.7 Probe Mounting (for improved probe heating)

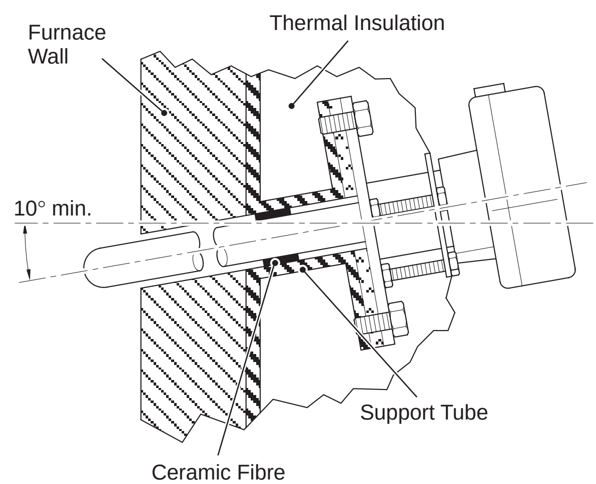


Fig. 3.8 Probe Mounting (inclined configuration)

4 CONNECTIONS

4.1 Access to Electrical Connections – Fig. 4.1

For access to the terminal block:

① **Standard Head** – remove the two screws and open the hinged cover.

① **Twin-gland C95 Head** – remove the three screws retaining the cover and lift off the cover and gasket.

4.2 Cable Details

Make connections to the oxygen cell via 16/0.2mm red and blue twin copper braid with overall PVC sheath. Where the ambient temperature in the vicinity of the probe head exceeds 100°C use 0.75mm^2 silicone rubber sheathed (part no. YBM0614) and join to the screened cable via a suitable junction box where the ambient temperature is lower.

Type K thermocouple – 3/0.9mm^2 flat twin compensating cable for use with NiCr/NiAl thermocouples to BS4937, sheathing to BS6746 (part no. E35).

Type R thermocouple – 3/0.9mm^2 flat twin compensating cable for use with Pt/Pt 13% Rh thermocouples to BS4937, sheathing to BS6746 (part no. E37).

4.3 Electrical Connections – Fig. 4.2

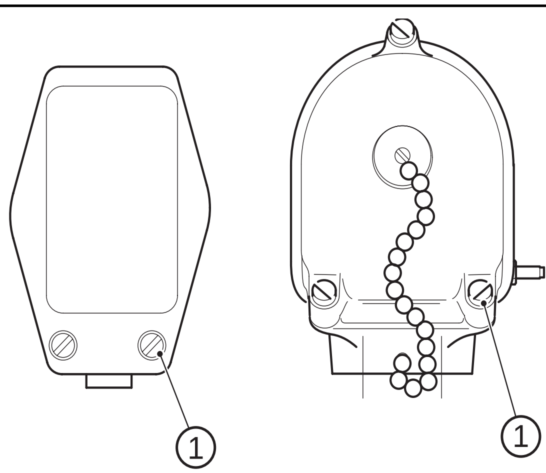
Make connections as shown in Fig. 4.2 and on the label inside the probe head cover. The connecting cable must enter the probe head via the bush provided (standard head) or suitable cable glands (twin gland C95 head).

4.4 Reference Air Connections – Fig. 4.2

The reference air connector is $^{1}/_{8}$in. BSP fitted with an adaptor to accept $^{1}/_{4}$in i.d. x $^{3}/_{8}$in o.d. nylon or PVC tubing (100°C/212°F ambient maximum).

The probe requires a supply of clean, dry air at a flow rate of 100 to 250ml/minute (0.2 to 0.5ft^3/hr), which may be supplied from regulated, clean instrument air or preferably atmospheric air from a small pump unit. Suitable air supply units are available from the Company:

Model 003000240	–	mains-powered pump unit with flow gauge
Model 003000241	–	regular unit with flow gauge.



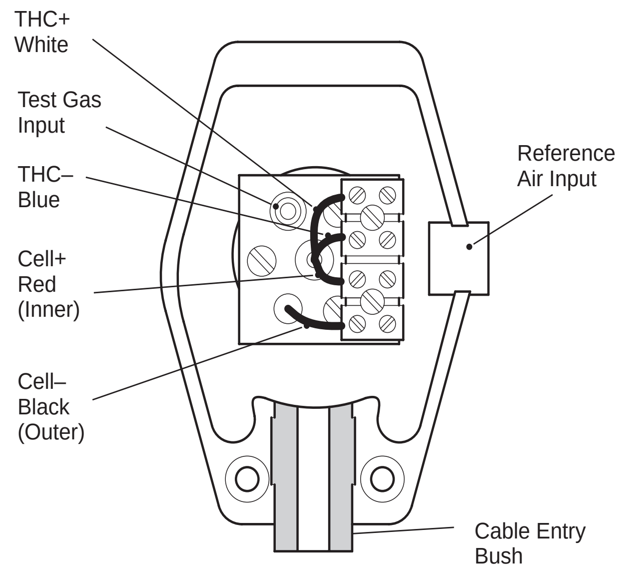
A – Standard Head B – Twin Gland C95 Head

Fig. 4.1 Access to Electrical Connections

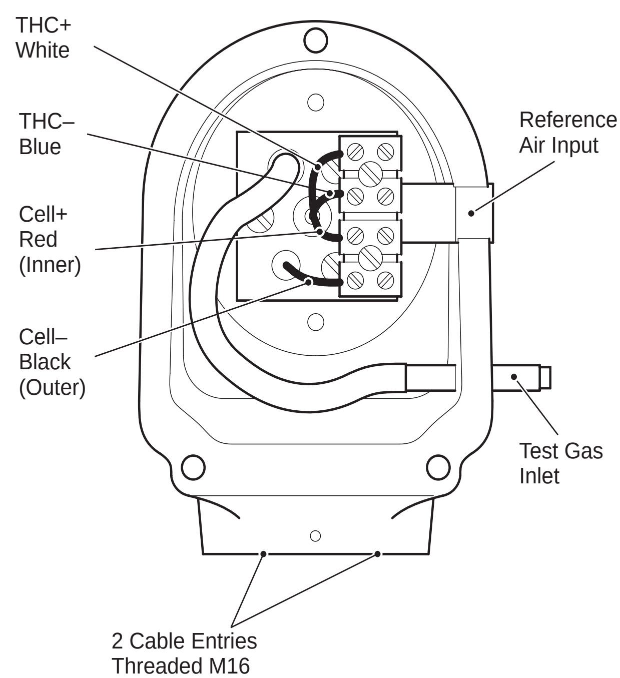
4.5 Test Gas Inlet – Fig 4.2

The test gas inlet on standard heads is situated inside the probe head and is sealed by a screwed plug. The inlet accepts $^{1}/_{4}$ in i.d. x $^{3}/_{8}$ in o.d. plastic/silicone tube.

Twin-gland C95 heads are fitted with a permanent external 6mm o.d. test gas inlet. The inlet is connected internally to the test gas input by means of a silicone tube.



A – Standard Head



B – Twin Gland C95 Head

Fig. 4.2 Connections

5 OPERATION

5.1 Principles of Operation

The ZGP2 probe contains a high temperature oxygen concentration cell using zirconium oxide as a solid electrolyte. Inner and outer electrodes are attached to the cell which is specific to oxygen.

Air is supplied to the inner reference electrode to provide a constant partial pressure of oxygen while the process gas to be measured is in contact with the outer electrode.

A voltage is generated across the electrodes which is a function of the ratio of the oxygen partial pressures at the two electrodes. This voltage output represents ‘oxygen potential’ and can be used to control the atmosphere of annealing processes etc.

For the measurement of ‘oxygen concentration’ it is necessary to correct for absolute temperature of the probe. The temperature term in the Nernst equation, on which the voltage output depends, illustrates this point:

$$E = 0.0496\ T\ (\log_{10} P_0/P_1) + C\ \text{mV}$$

Where:

T	=	Absolute Temperature (°K)
P_0	=	Partial Pressure Reference Gas
P_1	=	Partial Pressure Sample Gas
C	=	Cell Constant

For ‘oxygen potential’ measurement the following two expressions relate the oxygen probe output (E mV) to oxygen potential (μ)

$$E = (10.84\mu + 40) \text{ where } \mu \text{ is in kilocalories}$$

or

$$E = -(2.591\mu + 40) \text{ where } \mu \text{ is in kilojoules}$$

5.2 Range of Operation – Fig. 5.1

The internal resistance of the cell, i.e the resistance of the electrolyte between the electrodes, decreases approximately exponentially with increasing temperature and for this reason it is recommended that the probe is used at temperatures greater than 600°C (1112°F).

The maximum operating temperature is limited by two factors:

a) The onset of electronic conduction through the electrolyte which reduces the measured output below its theoretical value.

b) Evaporation of the outer electrode.

Electronic conduction is a function of both temperature and oxygen partial pressure and, for stabilized zirconia, it occurs at low levels of oxygen and high temperature. For the above reasons it is recommended that the probe is used at temperatures between 600°C (1112°F) and 1250°C (2282°F) – see Fig. 5.1. [900°C (1652°F) max. for Type K thermocouple].

6 MAINTENANCE

> **Caution.** No maintenance is necessary, or possible, on the probe and any attempt to dismantle it could cause irreparable damage. The probe can be tested for accuracy whilst connected to its measuring system but without removal from its operating position.

It is recommended that at least one spare probe is held for replacement or comparison purposes.

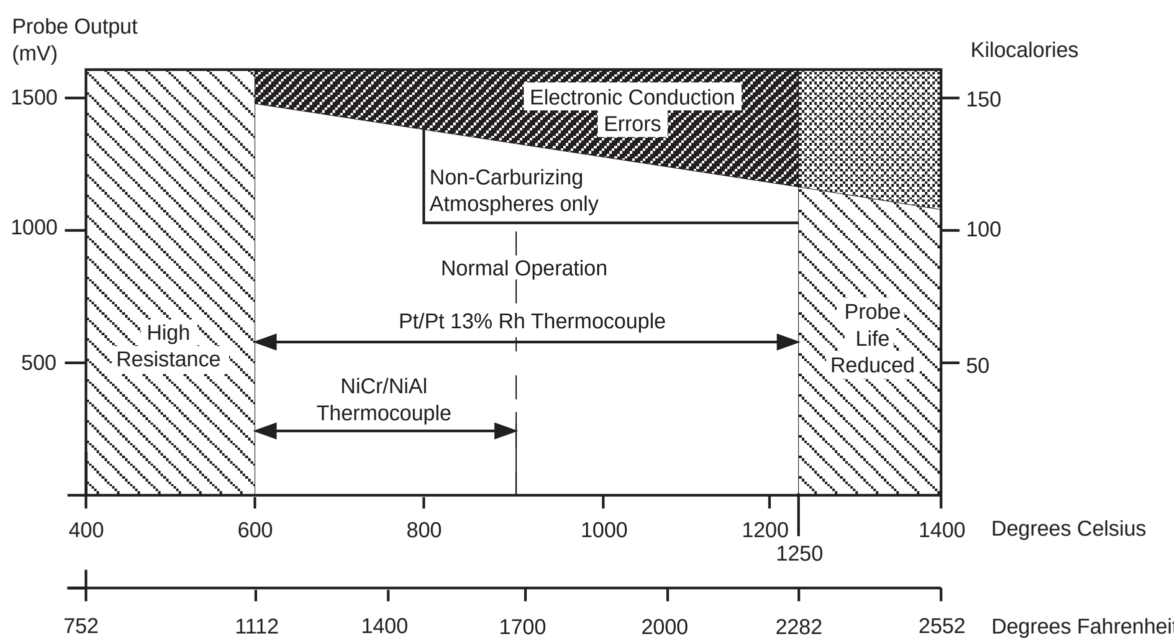


Fig. 5.1 Range of Operation

7 FAULT FINDING

Warning. The probe operates at high temperatures. Take all necessary precautions to avoid injury through burns.

During its working life under normal recommended conditions the probe output remains accurate and without drift. Probe malfunctions can result from a fault in the probe or from incorrect operating conditions.

The testing of a suspect probe can only be carried out satisfactorily in its working position or in a furnace controlled within the normal probe operating temperature range.

If a probe failure is suspected, first perform a test gas check as described in the following sections.

7.1 In Situ Checking Using a Test Gas

Introduce a test gas of known concentration around the outer electrode in the space between the filter washer, at the bottom of the sheath, and the wadding around the lower end of the probe – see Fig. 2.1. Four vent holes prevent the gas from being trapped in the upper part of the sheath.

7.1.1 Standard Head

a) Gain access to the interior of the probe head by unscrewing the lid fixing screws – see Section 4.1, **Access to Electrical Connections**.

b) Remove the screwed plug from the test gas connector – see Fig. 4.2A.

c) Fit $^1/_4$in i.d. x $^3/_8$in o.d. plastic or similar tubing and supply a test gas of known oxygen concentration to the probe at a steady flow rate of 800 to 1000ml/min (1.7 to 2.1ft^3/hr). Allow at least 5 minutes for the system to stabilize before making a measurement.

d) Check that the oxygen concentration measured by the probe system indicator or recorder, compares with the specification for the test gas used.

e) Disconnect the test gas and ensure that the screwed plug is replaced in the test gas connector. Failure to do this may result in serious measurement errors due to the entry of air into the probe.

f) Proceed to Table 7.1.

7.1.2 Twin Gland C95 Head

a) Remove the blanking screw in the external test gas inlet and connect a gas supply of known oxygen concentration – see Fig. 4.2. If a permanent test gas connection is used, switch on the gas supply.

b) At a steady flow rate of 800 to 1000ml/min (1.7 to 2.1ft^3/hr), allow at least 5 minutes for the system to stabilize before making a measurement.

c) Check that the oxygen concentration measured by the probe system indicator or recorder, compares with the specification for the test gas used.

d) If the test gas supply is not connected permanently to the probe head, disconnect the supply from the external test gas inlet and replace the blanking screw.

e) Proceed to Table 7.1.

Result of Test Gas Check	Possible Cause of Operation Malfunction	Action
Correct.		None.
Incorrect.	Reference air supply failure (high O_2 reading).	Check probe reference air supply.
	Faulty electronics unit or indicator.	Check operation of units concerned.
	Leak in zirconia tube within probe or broken zirconia tube (high O_2 reading).	Compare operation with another O_2 probe. Replace if necessary.
Zero or drifting readings with no response to test gas.	Open circuit probe.	Check for continuity – see below.
	Faulty electronics unit indicator or connections.	Check operation of units concerned.

Table 7.1 Fault Finding

7.2 Comparison with Another O_2 Probe

The probe may be checked by comparison with another of known reliability, either by replacing the suspect probe with the known probe or by mounting the known probe in close proximity and monitoring both probes continuously for a short period.

7.3 Returning the Probe to the Factory for Checking

If it is not possible to carry out the above tests on site and failure or malfunction is suspected, the probe may be returned to the Company for checking, in which case the probe must be carefully dismantled and repacked in its original packing to ensure safe carriage.

7.4 Continuity Check

Connect a 100kΩ resistor across the probe output. If the output drops to near zero millivolts and then drifts when the resistance is removed, this indicates that the probe may be open circuit or have a high impedance.

8 SPECIFICATION

General
Operating temperature ranges:

Pt/Pt 13% Rh BS4937 Pt 2 Type R	600 to 1250°C (1112 to 2282°F)
NiCr/NiAl BS4937 Pt4 Type K	600 to 900°C (1112 to 1652°F)

Sheath temperature limits:

Incoloy 800	1000°C (1832°F)
Aluminous porcelain	1250°C (2282°F)
Recrystallized alumina	1400°C* (2252°F)
Reference air flow	100 to 250 ml/min. (0.2 to 0.5 ft^3/hr)
Response rate	0.1s estimated
Measuring range	Refer to Fig. 5.1. The lower limit of operation, determined by the onset of electronic conduction in the solid electrolyte is dependent on temperature. As a guide, the limits are given in Table 8.1 for 1% electronic conduction but, in practice, it may be possible to measure even lower oxygen potential levels without introducing significant errors.

Electrical Data

Temperature		Min. O_2 Potential (k cal)	Min. O_2 Concentration (bar)		Output (mV)
°C	°F		(bar)	(PSI)	
600	1112	–145	10^{-36}	145^{-36}	1532
900	1652	–132	10^{-25}	145^{-25}	1391
1200	2192	–117	10^{-17}	145^{-17}	1228

Table 8.1 Measuring Range

Cell Constant	0V ±2mV
Probe accuracy	Typically better than ±5% of reading
System accuracy	±2% of test gas reading when calibrated against a certified test gas
Cell output impedance	Typically <100kΩ @ 700°C (1292°F)
Thermocouple	Pt/Pt 13% Rh Pt 2 BS4937 Type R
	NiCr/NiAl Pt 4 BS4937 Type K

Connections

Probe output	2-core copper screened overall
Thermocouple	2-core compensated to suit type of thermocouple fitted

Mounting

Flange mounted	Vertical or horizontal. 42mm (1.65 in.) o.d. minimum bore clearance hole
Overall dimensions (nominal):	
Type C95 head	683 or 1080mm (26.9 or 42.5 in.)
Standard head	663 or 1060mm (26.1 or 41.7 in.)
Insertion length (nominal):	556 or 953mm (21.89 or 37.52 in.)
Clearance for removal	Overall length +25mm (1 in.)
Weight	2.5kg (600mm probe) [5.5lb (24 in. probe)] 2.8kg (1000mm probe) [6.2lb (38 in. probe)]

Mechanical Data
Construction:

Solid electrolyte	Stabilized zirconia oxide
Protective sheath	Aluminous porcelain, Incoloy 800 or recrystallized alumina

*Reduced probe life may result if probe is operated above 1250°C (2282°F).

CUSTOMER SUPPORT

Service, Support and Maintenance

ABB Process Analytics' commitment to quality doesn't end when we deliver our equipment.

We also provide, at the client's request: start-up services, maintenance services, training services, reconditioning, repair and replacement parts services.

Training services are available for virtually every aspect of operating and maintaining ABB Process Analytics analyzers and systems. Training may be arranged on-site or at any of our training centres.

Maintenance services are available on an unscheduled, as needed basis, or by way of long-term, scheduled maintenance agreements.

Facilities

ABB Process Analytics' primary manufacturing and administrative facility is located in Lewisburg, West Virginia. We also operate sales and service centres in Houston, Texas; Baton Rouge, Louisiana; Sarnia, Ontario; UK; France; Italy; The Netherlands and Singapore. Training centres are located in Lewisburg, Houston and Europe.

For complete information and assistance with ABB Process Analytics analyzers, systems and services, contact any of our facilities for details of your nearest Service and Repair Centre.

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