Novatech CONTROLS AUST. PTY. LTD.

Zirconia Oxygen Sensors

Model 1230 Series

March 2003

USING THIS MANUAL

CAUTION 1

The probe or sensor heater is supplied with mains voltage. This supply has electrical shock danger to maintenance personnel. Always isolate the analyser before working with the probe or sensor.
The EARTH wire (green) from a heated probe or sensor must ALWAYS be connected to earth.

CAUTION 2

Combustion or atmosphere control systems can be dangerous. Burners must be mechanically set up so that in the worst case of equipment failure, the system cannot generate explosive atmospheres. This danger is normally avoided with flue gas trim systems by adjustment so that in the case of failure the appliance will not generate CO in excess of 400 ppm in the flue. The CO level in the flue should be measured with a separate CO instrument, normally an infrared or cell type.

CAUTION 3

The oxygen sensor, which is heated to over 700°C (1300°F) and is a source of ignition. Since raw fuel leaks can occur during burner shutdown, the analyser has an interlocking relay that removes power from the probe or sensor heater when the main fuel shut-off valve power is off. If this configuration does not suit or if it is possible for raw fuel to come into contact with a hot oxygen probe or sensor then the Model 1632 analyser with a heated probe or sensor will not be safe in your application.
An unheated probe can be utilised in such applications, however the oxygen readings are valid only above 650°C (1200°F).

CAUTION 4

The reducing oxygen signal from the analyser and the associated alarm relay can be used as an explosive warning or trip. This measurement assumes complete combustion. If incomplete combustion is possible then this signal will read less reducing and should not be used as an alarm or trip. A true excess combustibles analyser, normally incorporating a catalyst or thermal conductivity bridge, would be more appropriate where incomplete combustion is possible.
Also read the probe or sensor electrical shock caution in Section 2.5 and the probe or sensor heater interlock caution in Section 3.6.

CAUTION 5

If an external pressure transducer is used to feed the process pressure to the analyser for pressure compensation, it is essential that the pressure transducer is accurate and reliable. An incorrect reading of pressure will result in an incorrect reading of oxygen. It is therefore possible that an explosive level of fuel could be calculated in the analyser as a safe mixture.

SPECIFICATIONS

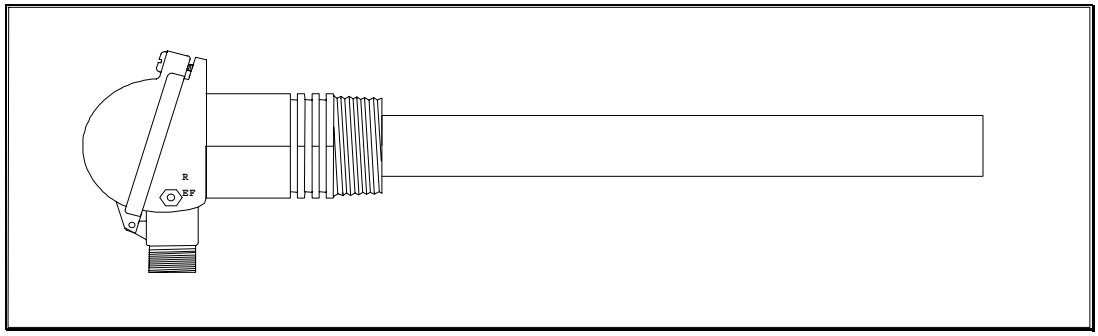
SERIES 1230 OXYGEN PROBES & SENSORS

DESCRIPTION
Novatech series 1230 oxygen probes and sensors employ state-of-the-art zirconia sensors and advanced materials, which provide the following benefits:

- Improved control due to fast response time to typically less than four seconds
- Cost-efficient design provides improved reliability
- Longer-life probes with greater resistance to corrosion from sulphur and zinc contaminants in flue gas
- Low cost allows maintenance by replacement
- Reduced probe breakage due to greater resistance to thermal shock and mechanical damage during installation and start-up

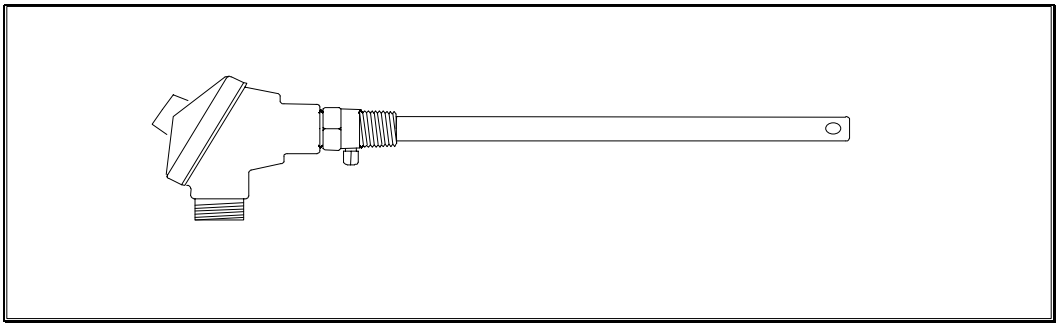
Series 1230 probe or sensors are simple to install and maintain. All models provide direct measurement of oxygen level. On-line automatic calibration check is available if required. Probes or sensors may be used with Novatech oxygen analysers and some model analysers from other manufacturers.

All Novatech oxygen probe or sensors are designed and manufactured to exacting standards of performance and reliability. Series 1230 probe or sensors are the result of extensive research and development by Novatech, industry and government agencies. Novatech Controls provides application and after sales support for oxygen probes, sensors and analysers, worldwide.

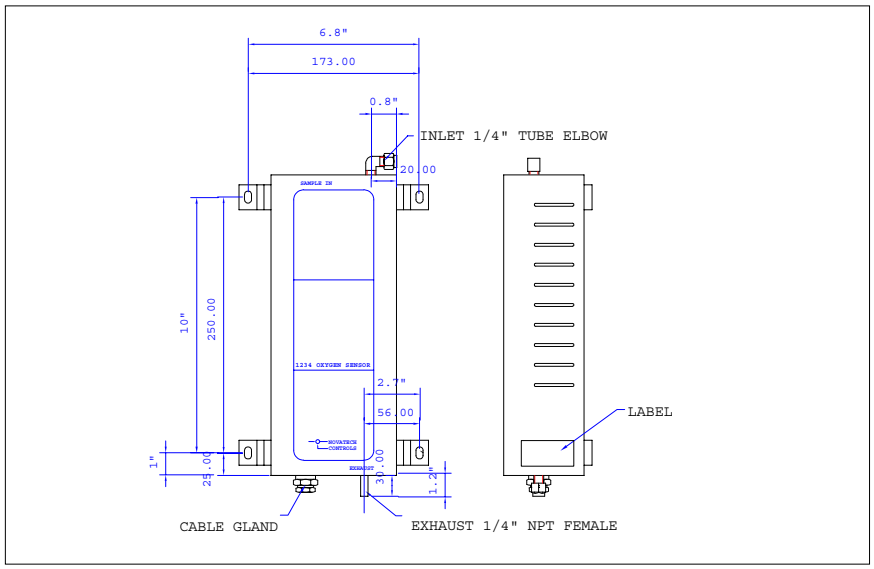


Model 1231 Heated Oxygen Probe

Model 1232 Unheated Oxygen Probe



Model 1234 Oxygen Sensor



STANDARD PROBE 'U' LENGTHS

1231	**1232**
250 mm (10")	250 mm (10")
350 mm (14")	500 mm (20")
500 mm (20")	750 mm (30")
750 mm (30")	1000 mm (40")
1000 mm (40")	
1500 mm (60")	
20000 mm (80")	

Ordering Information

1. Probe insertion length (from process end of mounting thread to probe sensing tip).
2. Mounting thread (process connection), BSP or NPT (for size of thread refer to specifications).
3. Lagging extension length, if required.
4. If model 1232 probe, state preferred thermocouple type (refer to specifications).

Important Notice Regarding
1231 Probe Option - FIL-3

WARNING: The only identifiable standard for flame arresters for general use is British Standard BS7224:1990. British Standard BS7224:1990 refers to an operating environment up to 200 Degrees Centigrade.

The FIL-3 device optionally fitted to 1231 Heated Zirconia Probes (the "Probes" or "Probe") operates in an environment considerably greater than 200 Degrees Centigrade.

Therefore, we know of no Australian, British or USA standard applicable to flame arresters or their testing above 200 degrees Centigrade. Consequently, the FIL-3 device cannot be certified as a safety device.

The probe is only one of several potential sources of ignition. Extreme care is required when using the probes during the start up processes of a combustion appliance.

The Novatech Burner Interlock Relay facility, which is a standard part of the Novatech Analyser, is designed to be wired to the main safety shut-off fuel valves in a way that can shutdown the probe heater when the fuel valves are closed.

The risk of ignition of flammable gas mixture at the hot end of the Probe can only be minimised by correct use, maintenance and operation of the FIL-3 device. The user of the FIL-3 device is responsible for verification and maintenance and correct use and operation of the FIL-3 device.

THE USER AGREES THAT IT USES THE PROBE AND THE FIL-3 DEVICE AT ITS SOLE RISK. NOVATECH CONTROLS (AUST) PTY LTD, TO THE FULL EXTENT PERMITTED BY LAW, GIVES NO WARRANTIES OR ASSURANCES AND EXCLUDES ALL LIABILITY (INCLUDING LIABILITY FOR NEGLIGENCE) IN RELATION TO THE PROBE AND THE FIL-3 DEVICE.

The user must ensure that it correctly follows all instructions in relation to the Probe and FIL-3 device, correctly understands the specifications of the Probe and FIL-3 device and ensures that the Probe and FIL-3 device are regularly inspected and maintained.

FIL-3 equipped Probes should be inspected at least once a year for corrosion and more frequently is there is any reason to suspect that corrosion may have occurred.

OXYGEN PROBE SPECIFICATIONS

MODEL	**1231**	**1232**
Application	Combustion flue gases below 900°C (1650°F) Refer to note 1	Combustion flue gases above 700°C (1290°F) with no contaminants. eg. Natural gas, light oils
Temperature Range	0 to 900°C. Refer to note 2 (32 to 1650°F)	700 to 1400°C (1470 to 2550°F)
Length	250 to 2000 mm (10" to 80")	500 to 1500 mm (20" to 60")
Process Connection	1 ½" BSP or NPT	¾" BSP or NPT
Electrical Connection	Weatherproof plug-in connector or optional screw terminals. The plug connector is supplied with the cable. Ex d heads have screw terminals.	
Cable	Order a specific length with the analyser except for hazardous installations where the cable is supplied by the customer.	
Heater	Yes	No
Thermocouple	K, integral	R, integral
Response Time	Typically < 4 secs.	Typically < 1 sec
Head Temperature	125°C (250°F) Max	125°C (250°F) Max
Reference Gas	Ambient air 50 to 500 cc/min (6 to 60 scfm). Pump supplied with analyser	
Ref Air Connection	1/4" NPT	Integral airline in probe cable. Barbed fitting to 3/16" ID PVC tube.
Filter	Removable sintered stainless steel particulate filter, 30 micron, optional 15 micron available. Refer to note 2	
Calibration Check Gas Connection	1/8" NPT female	1/8" NPT female
Weight	0.6 kg (1.32 lbs.) plus 0.33 kg (0.73 lbs.)/100 mm (4") length	0.4 kg (0.88 lbs.) plus 0.1 kg (0.22 lbs.)/100 mm (4") length

Notes:

1. Care must be taken to avoid contact with explosive or inflammable gases with 1231 heated probes and 1234 oxygen sensors when hot. Novatech analysers have built in safety protection.
2. Process gas temperature must be below 550°C if the filters are fitted.

Please contact factory for corrosives other than sulphur or zinc. We can provide test materials to try in your atmosphere.

OXYGEN PROBE MODEL SELECTION GUIDE

Heated probes-temperature range 0-900°C (1650°F).

1231 -	**U Length -**	**Outer Sheath -**	**Internal Thermocouple -**	**Mounting Thread**
Basic model	2. 250mm (10”) 3. 500mm (20”) 4. 750mm (30”) 5. 1000mm (40”) X. Special 1500mm (60”) Special 2000mm (80”)	1. 316 SS max 850°C (1560°F) 2. Inconel *(1)	1. Type K max 900°C (1650°F)	1. 1 ½ BSP 2. 1 ½ NPT

*Note: (1) The Inconel option has all inconel wetted parts except for the ceramic sensor and viton ‘o’ rings.

Unheated probes for clean gases-temperature range 700-1400°C (1290-2550°F).

1232 -	**U Length -**	**Outer Sheath -**	**Internal Thermocouple -**	**Mounting Thread**
Basic model	3. 500mm (20”) 4. 750mm (30”) 5. 1000mm (40”) 6. 1500mm (60”)	1. 253 MA-max 1000°C (1830°F) 3. High Purity Alumina Max 1300°C (2370°F) Horizontal Max 1400°C (2550°F) Vertical 4. 446 SS max 1000°C (1830°F)	1. Nil *(2) 4. Type R max 1400°C (2550°F)	1. 3/4” BSP fixed 2. 3/4” NPT fixed

*Note: (1) A standard oxygen probe for carburising furnaces has a 253 MA sheath.

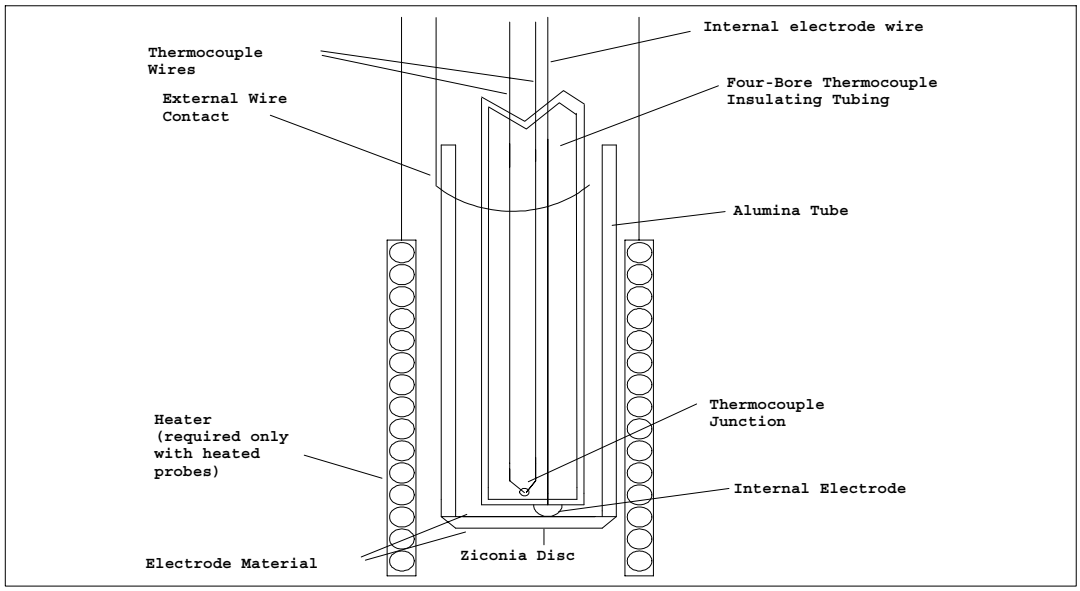
1234 SENSOR SPECIFICATIONS

Range of measurement:	1 ppm to 100% oxygen
Output:	EMF $= 2.154.10^{-2}.T.\log_e (0.209/\text{oxygen level of the sample})$
Accuracy:	± 1%
Thermocouple:	Type K
Heater:	110 VAC, 100 watts
Heater proportional band:	80°C (175°F)
Speed of Response:	Less than 100 milliseconds
Sample flow rate:	1 to 5 litres/minute (120 to 600 scfm)
Differential Pressure:	80 to 800 mm (3 to 30”) WG gives a flow of 1 to 5 litres/min (120 to 600 scfm)
Process Connections:	1/4” NPT female, inlet and outlet
Dimensions:	300 mm (11.81”) high by 125 mm (4.92”) wide by 88 mm (3.46”) deep
Weight:	2.2 Kg (4.85 lbs.)

DESCRIPTION

THE ZIRCONIA SENSOR

The analyser input is provided for a solid electrolyte oxygen probe, which contains a zirconia element and thermocouple. The probe is designed to be inserted into a boiler or furnace exit gas flue or similar process. A 1234 sensor is designed to be installed outside of the flue or process. Sampling lines and filters are not required for in-situ probes but they are required for 1234 sensors. When a sampling line is required, the sample flows to the sensor under process pressure in most applications. In applications where the process pressure is negative or neutral, a suction pump will be required. A reference air pump is provided in the 1632 oxygen analyser. The internal construction of a probe or sensor is shown as follows.



Schematic View of a Zirconia Sensor Assembly

The heater control in the 1632 analysers consists of a time proportioning temperature controller and solid state relay so that the thermocouple junction is controlled to over 700°C (1300°F). Probes operating in a combustion environment above 650°C (1200°F) do not require a heater. When exposed to different oxygen partial pressures at the outside and inside of the sensor, an EMF (E) is developed which obeys the Nernst equation:

$$E\ (\text{millivolts}) = \frac{RT}{4F} \log_e \left(\frac{(PO_2)\ \text{INSIDE}}{(PO_2)\ \text{OUTSIDE}} \right)$$

Where T is the temperature (K) at the disc (>650°C (1200°F)), R is the gas constant; F is the Faraday constant and (PO_2) INSIDE and (PO_2) OUTSIDE are the oxygen partial pressures at the inner and outer electrodes, respectively, with the higher oxygen partial pressure electrode being positive.

If dry air at atmospheric pressure, (21 % oxygen) is used as a reference gas at the inner electrode, the following equations are obtained:

$$E\ (\text{millivolts}) = 2.154 \times 10^{-2}\ T \log_e \frac{0.21}{(PO_2)\ \text{OUTSIDE}}$$

Transposing this equation

$$(\%O_2)\ \text{OUTSIDE (ATM)} = 0.21\ \text{EXP}\ \frac{-46.421E}{T}$$

The 1632 transmitter solves this equation, which is valid above 650°C (1200°F). The probe heater, or the process maintains the sensor temperature at this level.

THE OXYGEN PROBE OR SENSOR

The probe assembly provides a means of exposing the zirconia sensor to the atmosphere to be measured with sensor, thermocouple and heater wires connected via the analyser lead. Reference air is fed via the plug for unheated probes and via a separate gas thread connection for heated probes.
Connections are provided on probes for an in-situ gas calibration check. A cleaning purge of air can be admitted via the calibration gas check entry. The outer sheath of probes can be metal or ceramic, depending on the application.
Calibration check can be achieved on 1234 sensors using a three way solenoid, which blocks the sample and at the same time admits a calibration check gas to the sensor. Purging a probe for any dust build up can be achieved in the same way.

In-situ zirconia oxygen probes will give a lower oxygen reading than a sampled gas measurement on a chromatograph or paramagnetic analyser because the flue gas contains a significant level of water vapour and a sampling system removes the water vapour through condensation. The oxygen content then appears as a higher percentage of the remaining gas. For example: If the gas contained five parts oxygen and fifteen parts moisture, removing the moisture would leave the oxygen at 5.88%. This phenomena will depend on the fuel and the completeness of combustion. They are common to all zirconia oxygen sensors.

INSTALLATION

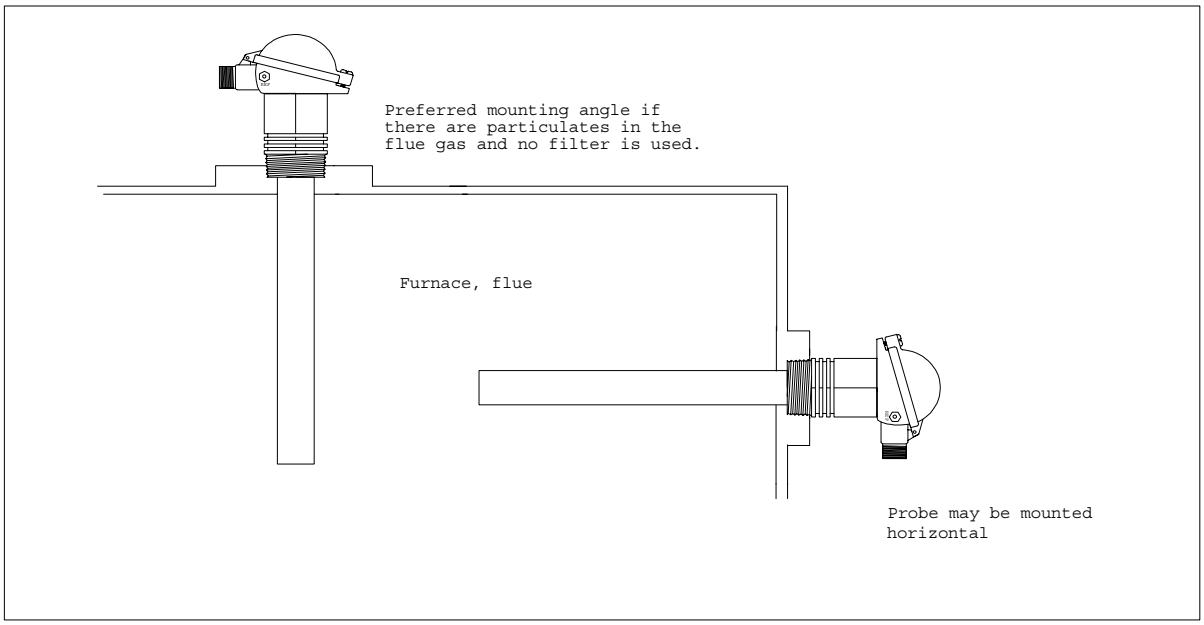
INSTALLING A 1231 OXYGEN PROBE

Weld a BSP or NPT socket to the flue in a suitable position for flue gas sensing. For the correct size of socket refer to probe data in Section 1. The closer to the source of combustion the smaller will be sensing lag time, allowing better control.

The probe has a typical response time of less than four seconds, so most of the delay time is normally the transit time of the gas from the point of combustion to the point of sensing.

Probes can be mounted at any angle. If there are any particulate in the flue gas, a filter can be omitted by pointing the probe vertically downwards. Otherwise the filters may have to be replaced periodically.

If installing a probe into a hot environment, slide the probe in slowly to avoid thermal shock to the internal ceramic parts. If the flue gas is 1000°C (1830°F), it should take approximately five minutes to install a 500 mm (20") probe, moving it in about 50 mm (2") steps.



Oxygen Probe Mounting

CAUTION

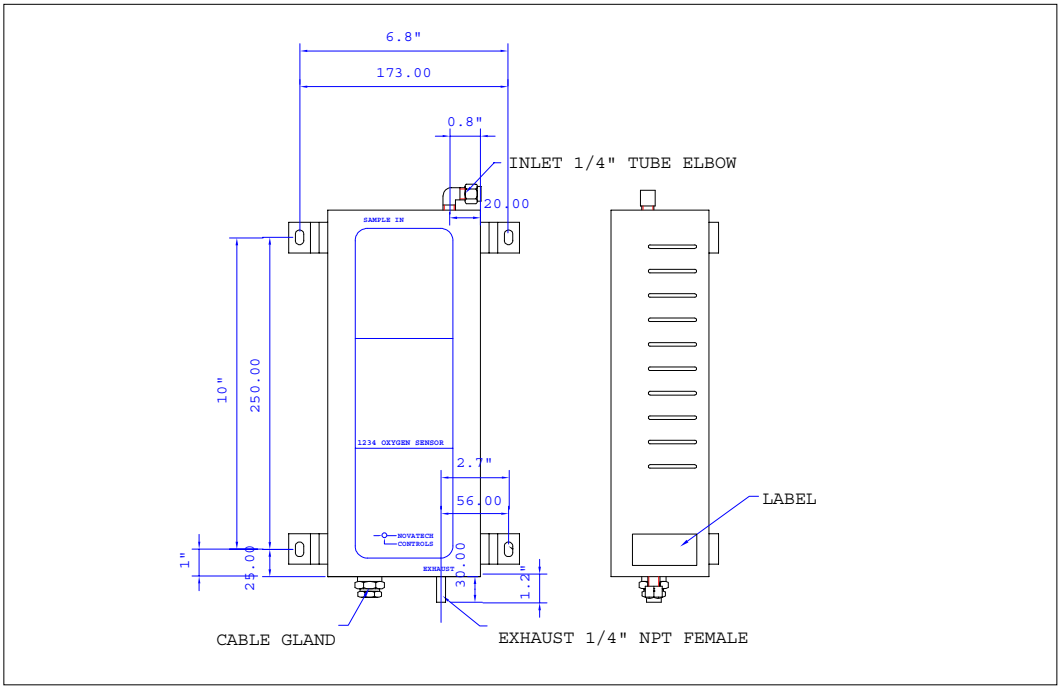
It is important that there is no air in leakage upstream of the oxygen sensing point, otherwise there will be a high oxygen reading.

If the probe is to be installed on a bend in the flue, it is best located on the outer circumference of the bend to avoid dead pockets of flue gas flow. While the standard 1231 probe with a 'U' length of 250 mm (10") will suit most low temperature flue applications, it is occasionally necessary to have a longer probe with the sensing tip in the centre of the flue gas stream.

Although it is rare, occasionally a probe may sense oxygen vastly differently from the average reading in the flue gas. If it occurs, then the probe should be moved, or a longer probe installed. This phenomena is normally caused by stratification of the flue gas.

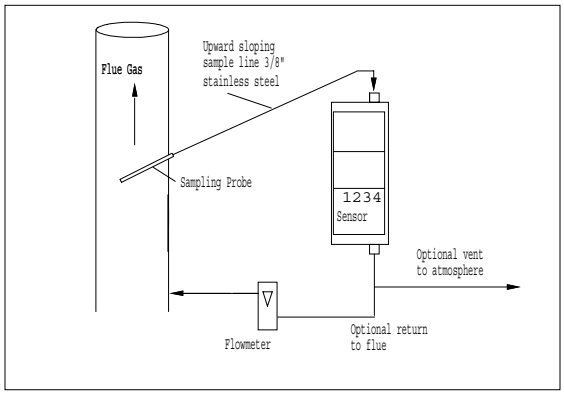
INSTALLING A 1234 OXYGEN SENSOR

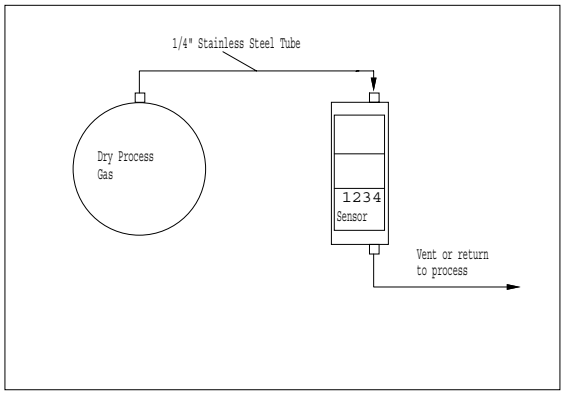
Mounting - Screw the 1234 sensor to a wall or similar surface with the piping connections at the bottom.



1234 Sensor Mounting Dimensions

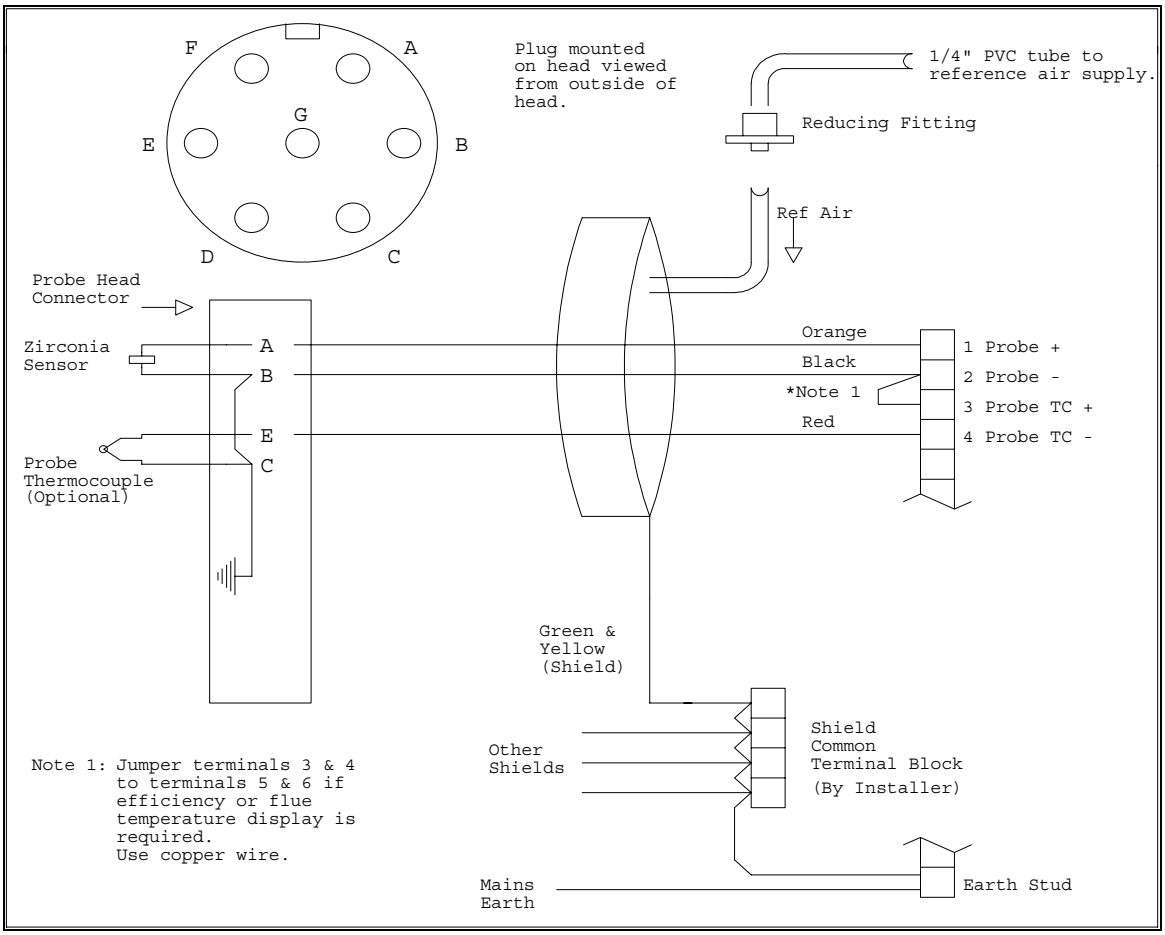
Sample Piping - Connect the gas sample piping to the "sample in" port. If the process, boiler, kiln or furnace has a positive pressure, no suction will be required. If the sample is under a negative pressure, connect a pump to the "inlet" port as shown below. The flow rate should be within the range of 1 to 5 litres/minute (120 to 600 scfm).



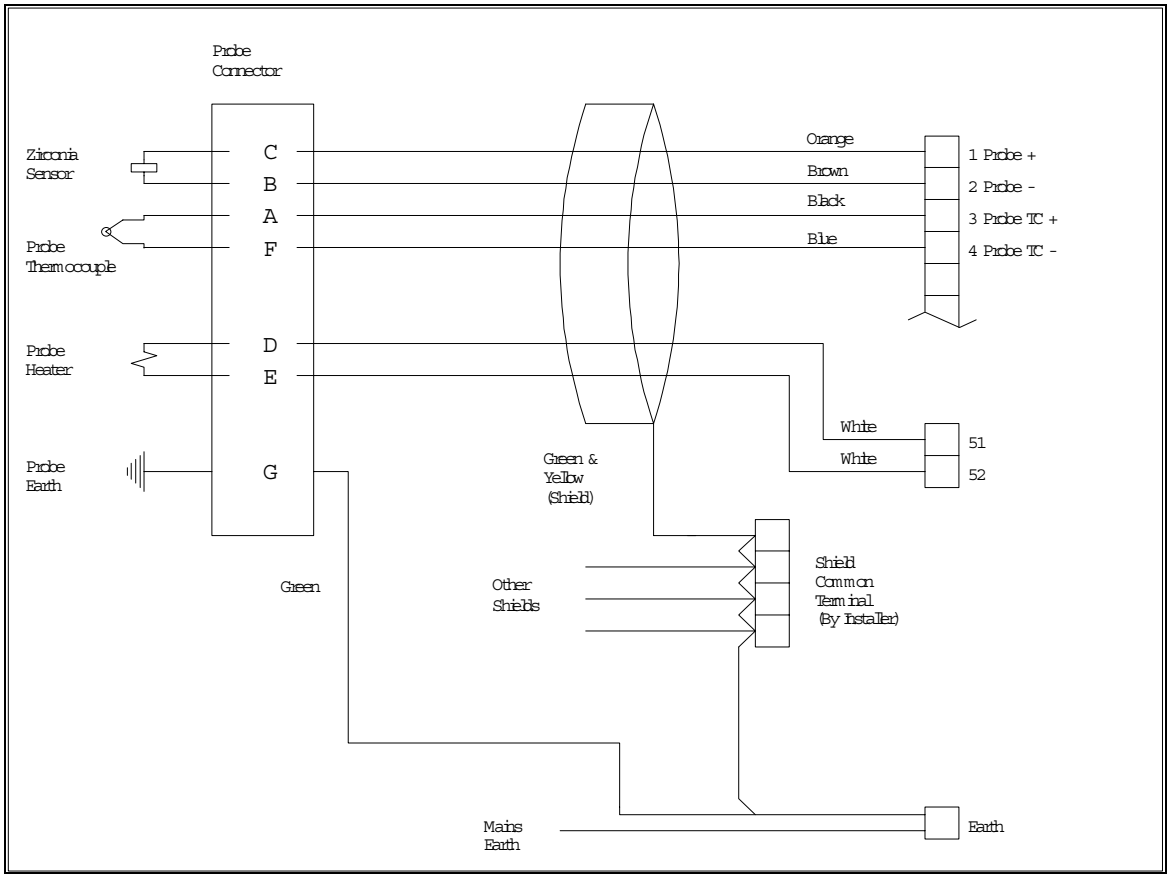


CONNECTING AN OXYGEN PROBE CABLE

Connect the probe lead as shown in the following drawings. Unheated probe leads have integral reference air tube. An adaptor has been supplied to connect this tube to quarter inch flexible PVC tubing, from the air pump or reference air supply.

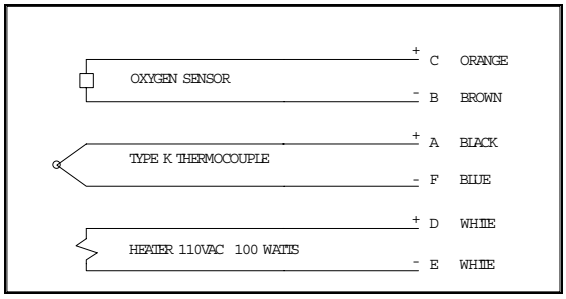


Connection of Probe Cable for Unheated Probes Models 1232.
Connection of Probe Cable for Heated Probes Model 1231.



CONNECTING A 1234 SENSOR CABLE

Remove the two screws from the cable gland end of the 1234 sensor. Connect the wiring as shown below. Be sure to connect an earth to the earth stud. Replace the end plate. Tighten the cable gland onto the cable.



Connecting a 1234 Sensor Cable

CONNECTING REFERENCE AIR

For 1234 sensors, no reference air connection is required. For oxygen probes, a 1/4" tube connector on the analyser should be connected via a nylon, copper or stainless steel tube to the 'REF' connector on the probe.
If two probes are being used, a "T" union must be supplied to provide reference air supply to both probes.
If 'Internal' is selected in set-up 85, and a reference airflow sensor is connected to CN8 on the 1630-2 (terminal) PCB, the reference air pump is cycled on and off each minute.

ZIRCONIA OXYGEN SENSOR OUTPUT (mV)
PROBE TYPE 1231, SENSOR TYPE 1234

% OXYGEN	mV at 720°C (1320°F)
21.0	0.00
20.5	0.46
20.0	0.99
19.5	1.53
19.0	2.09
18.5	2.66
18.0	3.25
17.5	3.85
17.0	4.47
16.5	5.11
16.0	5.77
15.5	6.45
15.0	7.15
14.5	7.87
14.0	8.62
13.5	9.40
13.0	10.21
12.5	11.05
12.0	11.92
11.5	12.83
11.0	13.78
10.5	14.78
10.0	15.82
9.5	16.92
9.0	18.08
8.5	19.30
8.0	20.60
7.5	21.98
7.0	23.45
6.5	25.04
6.0	26.75
5.5	28.61
5.0	30.65
4.5	32.90
4.0	35.42
3.5	38.28
3.0	41.58
2.5	45.48
2.0	50.25
1.5	56.41
1.0	65.08
0.5	79.91
0.2	99.51

'K' TC mV 29.212 at 720°C (1320°F)

These tables are based on the Nernst equation:

Sensor emf. = 0.02154 x T x 1n x 20.95 / % oxygen, where T = ° K (° C + 273), emf is in mV's

ZIRCONIA OXYGEN PROBE OUTPUT (mV)
PROBE TYPE 1232

	TEMPERATURE (ºC (°F))								
% O2	**600 (1110)**	**700 (1290)**	**800 (1470)**	**900 (1650)**	**1000 (1830)**	**1100 (2010)**	**1200 (2190)**	**1300 2370)**	**1400 (2550)**
20	0.917	1.023	1.128	1.233	1.338	1.443	1.548	1.653	1.758
19.5	1.394	1.553	1.713	1.872	2.032	2.192	2.351	2.511	2.671
19	1.882	2.098	2.313	2.529	2.744	2.960	3.175	3.391	3.607
18.5	2.383	2.657	2.930	3.203	3.476	3.749	4.022	4.295	4.568
18	2.899	3.231	3.563	3.895	4.227	4.559	4.891	5.223	5.555
17.5	3.428	3.821	4.214	4.607	4.999	5.392	5.795	6.177	6.570
17	3.974	4.429	4.884	5.339	5.794	6.249	6.705	7.160	7.615
16.5	4.535	5.054	5.574	6.093	6.613	7.132	7.652	8.171	8.691
16	5.114	5.699	6.285	6.871	7.457	8.042	8.628	9.214	9.800
15.5	5.711	6.365	7.019	7.673	8.327	8.981	9.635	10.289	10.944
15	6.327	7.052	7.777	8.501	9.226	9.951	10.676	11.400	12.125
14.5	6.965	7.762	8.560	9.358	10.156	10.954	11.751	12.549	13.347
14	7.625	8.498	9.371	10.245	11.118	11.991	12.865	13.738	14.612
13.5	8.308	9.260	10.212	11.164	12.115	13.067	14.019	14.970	15.922
13	9.018	10.051	11.084	12.117	13.150	14.183	15.216	16.249	17.282
12.5	9.756	10.873	11.991	13.108	14.226	15.343	16.461	17.578	18.695
12	10.523	11.729	12.934	14.139	15.345	16.550	17.756	18.961	20.167
11.5	11.324	12.621	13.918	15.215	16.512	17.809	19.106	20.403	21.700
11	12.159	13.552	14.945	16.338	17.731	19.124	20.516	21.909	23.302
10.5	13.034	14.527	16.020	17.513	19.006	20.499	21.992	23.486	24.979
10	13.952	15.550	17.148	18.746	20.344	21.942	23.540	25.139	26.737
9.5	14.916	16.625	18.333	20.042	21.751	23.459	25.168	26.877	28.585
9	15.933	17.758	19.583	21.408	23.233	25.058	26.883	28.709	30.534
8.5	17.008	18.956	20.904	22.852	24.801	26.749	28.697	30.645	32.593
8	18.148	20.227	22.305	24.384	26.463	28.542	30.620	32.669	34.778
7.5	19.361	21.579	23.797	26.015	28.223	30.450	32.668	34.886	37.104
7	20.659	23.025	25.392	27.758	30.124	32.491	34.857	37.224	39.590
6.5	22.052	24.578	27.104	29.630	32.156	34.683	37.209	39.735	42.261
6	23.557	26.256	28.954	31.653	34.351	37.050	39.748	42.447	45.145
5.5	25.194	28.080	30.965	33.851	36.737	39.623	42.509	45.395	48.281
5	26.986	30.077	33.168	36.259	39.351	42.442	45.533	48.624	51.715
4.5	28.967	32.285	35.603	38.922	42.240	45.558	48.876	52.194	55.512
4	31.182	34.754	38.326	41.897	45.469	49.041	52.613	56.185	59.757
3.5	33.693	37.552	41.412	45.271	49.131	52.990	56.850	60.709	64.569
3	36.592	40.783	44.975	49.166	53.358	57.549	61.741	65.932	70.124
2.5	40.020	44.604	49.189	53.773	58.357	62.941	67.525	72.110	76.694
2	44.216	49.281	54.346	59.411	64.476	69.541	74.605	79.670	84.735
1.5	49.626	55.310	60.995	66.680	72.364	78.049	83.733	89.418	95.102
1	57.250	63.808	70.366	76.924	83.482	90.040	96.598	103.156	109.714
0.5	70.285	78.336	86.387	94.438	102.488	110.539	118.590	126.641	134.692
0.2	87.515	97.540	107.564	117.589	127.614	137.638	147.663	157.687	167.712
TC mV									
'R'	5.582	6.741	7.949	9.203	10.503	11.846	13.224	14.624	16.035
'K'	24.902	29.128	33.277	37.325	41.269	45.108	48.828	N/A	N/A
'N'	20.609	24.526	28.456	32.370	36.248	40.076	43.836	47.502	N/A

These tables are based on the Nernst equation:
Probe emf. = 0.02154 x T x 1n x 21/% oxygen
Where T = ° K (° C + 273)