Novatech CONTROLS PTY. LTD.

Oxygen Probes

Product Manual

For 1231 Heated Probes, 1232 Unheated In-Situ Probes
and 1234 Oxygen Sensors

January 2019

Introduction

Novatech Controls is an Australian owned and operated manufacturer of Oxygen Probes and Gas Analysers for a diverse range of applications ranging from industrial emissions monitoring through to laboratory gas analysis equipment.

The 1230 Series Oxygen Probes designed by Novatech Controls incorporate sensors built using a patented process developed by the CSIRO in Australia to produce sensors of superior strength and durability. The sensors are capable of accurately measuring oxygen concentration ranging from 100% down to 1 x 10^{-30} %.

The oxygen sensor consists of a stabilised zirconia ceramic cell with platinum electrodes. The principles of this technology were first demonstrated over 60 years ago and have since been developed into the foremost sensing technology for in-situ oxygen measurement. The key advantages of zirconia sensing technology over other methods such as electro-chemical cells or optical systems include;

- The ability to measure oxygen over a wide range of temperatures
- Very quick to respond to changes in oxygen concentration
- Provide continuous measurement
- Rugged solid-state design
- As an absolute measuring device there is limited calibration and minimal ongoing maintenance

Warning Symbols

Danger, high voltage. Risk of electrical shock.

Caution hot surface.

Caution, risk of danger. See additional information in the manual.

CAUTION 1

The probe heater is supplied with mains voltage. This supply has electrical shock danger to maintenance personnel. Always isolate the transmitter before working with the probe.

The EARTH wires (green/yellow) from a heated probe 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 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 400ppm in the flue. The CO level in the flue should be measured with a separate CO instrument, normally an infrared or fuel cell type.

CAUTION 3

The oxygen probe is heated to over 700°C (1300°F) and is a source of ignition. Since raw fuel leaks can occur during burner shutdown, the transmitter has an interlocking relay that removes power from the probe 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 then the Model 1732 transmitter with a heated probe 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 transmitter 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 electrical shock caution in the probe heater interlock caution in chapter 4.7

CAUTION 5

FIL-3 filter. If the optional FIL-3 has been fitted to the 1231 probe in this installation, please read the Important Notice regarding probe option FIL-3 on the next page

CAUTION 6

The heater is supplied from the mains power directly, and the temperature is controlled at 720°C (1330°F). The outside of the process end of the probe can get to temperatures that are dangerous to touch. Wear insulating gloves when handling a probe that has been on.

CAUTION 7

Please note that if this equipment is not installed and used in the manner described in this manual then the safety protection provided by the equipment may be impaired.

Important Notice Regarding
1231 Probe Option - FIL-3

WARNING: The only identifiable standard for flame arresters for general use is British Standard BS EN ISO 16852:2016. British Standard BS EN ISO 16852:2016 refers to an operating environment up to 150 Degrees Centigrade.

The FIL-3 device optionally fitted to 1231 Heated Zirconia Probes (the “Probes" or "Probe") operate in an environment considerably greater than 150 Degrees Centigrade.

Therefore, we know of no Australian, British, European or USA standard applicable to flame arresters or their testing above 150 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 transmitter, 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 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 if there is any reason to suspect that corrosion may have occurred.

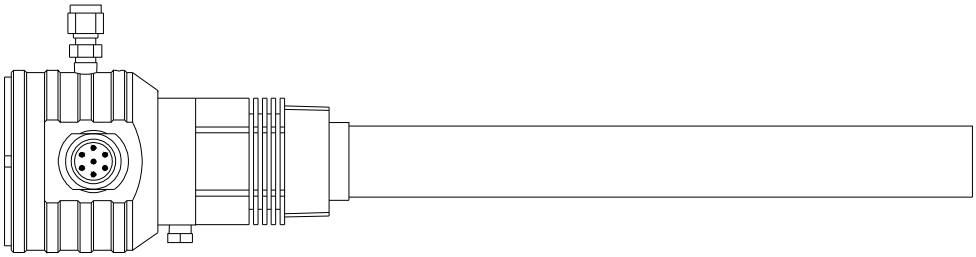
Description

Novatech series 1230 oxygen probes and sensors use zirconia sensors, high quality alumina ceramic tubes and advanced materials, which provide the following benefits:

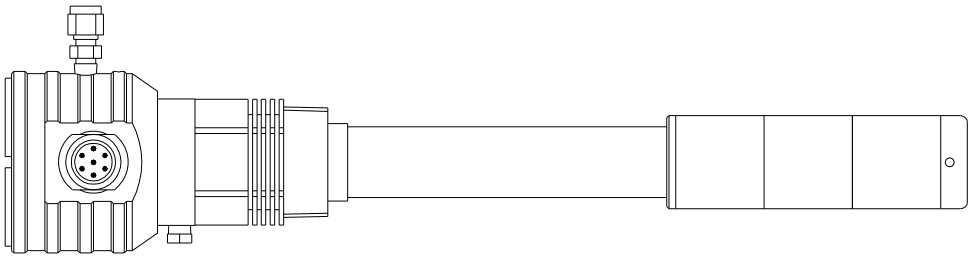
- Improved control due to fast response time to typically less than four seconds
- Cost-efficient design provides improved reliability
- Longer-life probes with greater resistance to corrosion from sulphur and zinc contaminants in flue gas
- Low cost allows maintenance by replacement
- Reduced probe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

Series 1230 probe and sensors are simple to install and maintain. All models provide direct real-time measurement of oxygen level. On-line automatic calibration check is available if required. Probes or sensors are used with Novatech oxygen transmitters, data acquisition systems and some model transmitters from other manufacturers.

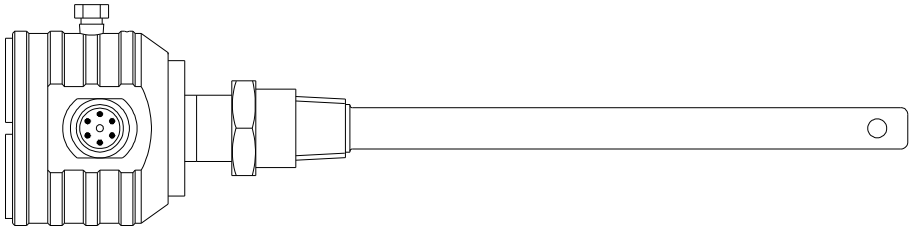
All Novatech oxygen probe or sensors are designed and manufactured in Australia to high standards of performance and reliability. The series 1230 probes are the result of several decades of research and development by Novatech, industry and government agencies. Novatech Controls provides application and after sales support for oxygen probes, sensors and transmitters, worldwide.



Model 1231 Heated Oxygen Probe



Model 1231 Heated Oxygen Probe with Optional Filters



Model 1232 Unheated Oxygen Probe

Operating Principles of the Zirconia Sensor

The sensor consists of a stabilized zirconia ceramic disc sealed to the end of a ceramic tube to create a chamber separating process gas from ambient air. Both sides of the zirconia disc are coated with platinum membrane to act as an electrode and provide an electrical contact for measurement.

While at operating temperature the zirconia sensor acts as a solid-state electrolyte allowing the conduction of oxygen ions between the two sides of the sensor to maintain equilibrium. The movement of oxygen ions creates an open-circuit EMF voltage across the two platinum electrodes which is proportional to the difference in oxygen partial pressure between the two sides.

The EMF voltage generated is described by the Nernst equation, an electrochemical formula used to describe the electromotive potential of an electrochemical cell in a non-equilibrium state:

(1) $$E = \frac{RT}{4F} log_e \left(\frac{p1}{p2}\right)$$

E = open-circuit voltage, in volts
R = molar gas constant (8.3144621 $kg.m^2.s^{-2}.K^{-1}.mol^{-1}$)
F = Faraday constant (96485.3321233 $C.mol^{-1}$)
T = Temperature in degrees Kelvin
p1 & *p2* = oxygen partial pressure on either side of the solid-state zirconia sensor.

Oxygen partial pressure is the product of the oxygen volumetric percentage and the absolute pressure;

$$p = o2 \times pres$$

The above equation expands to;

(2) $$E(mV) = \frac{T}{46.418} log_e \left(\frac{o2_1 \times pres_1}{o2_2 \times pres_2}\right)$$

(3) $$e^{\left(\frac{46.418E}{T}\right)} = \left(\frac{o2_1 \times pres_1}{o2_2 \times pres_2}\right)$$

(4) $$o2_1 \times pres_1 = o2_2 \times pres_2 \times e^{\left(\frac{46.418E}{T}\right)}$$

The equation (4) above is used to calculate oxygen concentration.

By assuming that the difference in pressure between the two faces of the sensor is negligible this formula can be simplified to;

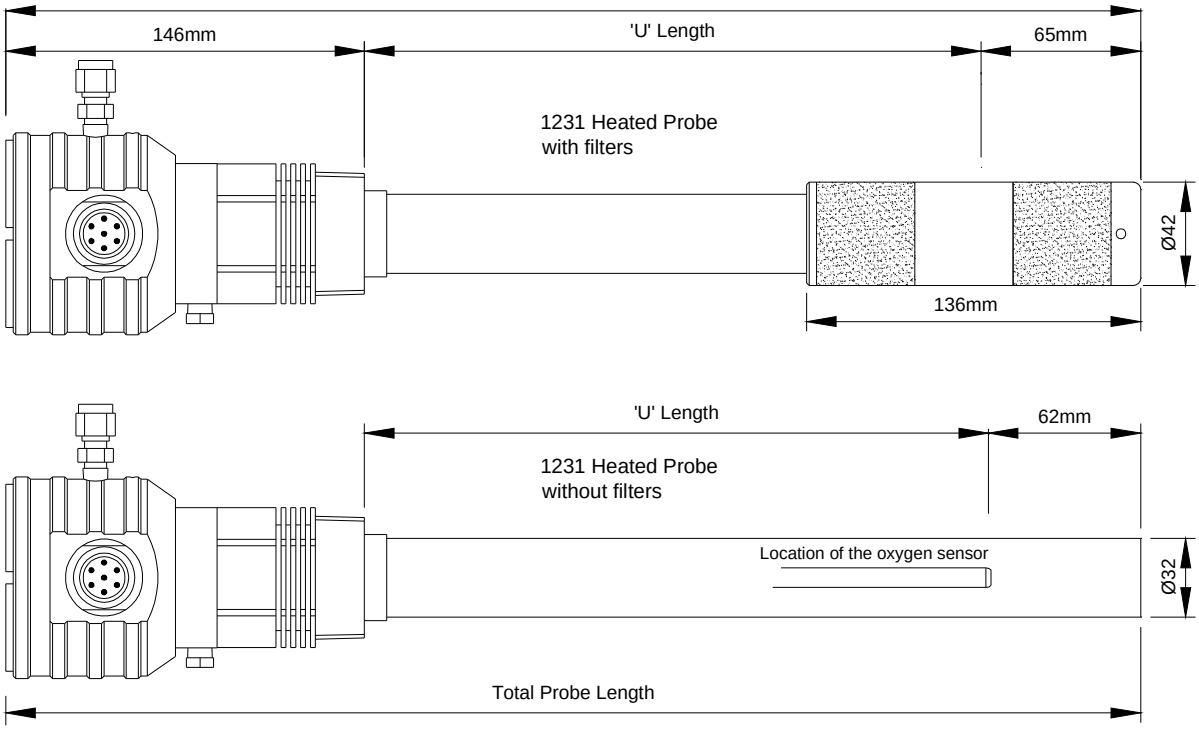
$$process\ oxygen\ \% = ambient\ oxygen\ \% \times e^{\left(\frac{46.418E}{T}\right)}$$

By volume, dry ambient air contains 78.09% nitrogen, 20.95% oxygen, 0.93% argon, ~0.04% carbon dioxide, and trace amounts of other gases. Ambient air also contains a variable amount of water vapour in the form of humidity which displaces some portion of the dry air mixture. Combined this mixture is referred to as 'wet' air.

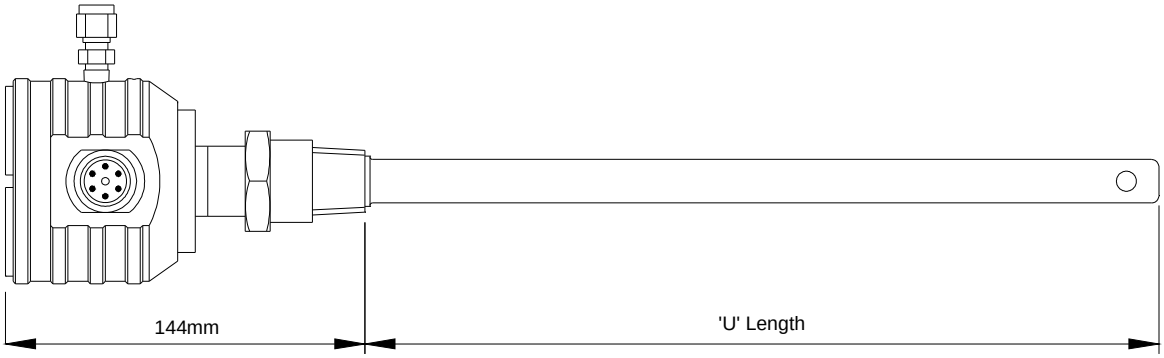
The precise volume of oxygen in wet ambient air will vary depending on temperature and relative humidity. In hot humid environments moisture can displace as much as 1% of the oxygen in ambient air. To calculate process oxygen with the highest accuracy the Novatech 1730 series transmitters use integrated temperature and relative humidity sensors to measure moisture content in the ambient air.

In-Situ Probes Specifications

MODEL	1231 Heated Probe	1232 Unheated Probe
Application	In-situ probe Process gasses below 900°C (1650°F) Refer to note 1	In-situ probe Process gasses above 700°C (1290°F)
Temperature Range	0 to 900°C. Refer to note 2 (32 to 1650°F)	Stainless Steel: 700°C to 1000°C (1290°F to 1830°F) Alumina Ceramic: 700°C to 1400°C (1290°F to 2550°F)
Standard Insertion Lengths ('U' Length)	250 mm (10") 350 mm (14") 500 mm (20") 750 mm (30") 1000 mm (40") 1500 mm (60")	500 mm (20") 750 mm (30") 1000 mm (40")



Dimensional Drawing of the model 1231 Heated Oxygen Probe with and without filters



Dimensional Drawing of the model 1232 Unheated Oxygen Probe

MODEL	1231 Heated Probe	1232 Unheated Probe
Outer Sheath Material	316 Grade Stainless Steel standard (Inconel with all Inconel wetted parts optional)	253MA Stainless Steel or Alumina Ceramic as specified
Process Connection	1.5" BSPT or 1.5” NPT	¾” BSPT or ¾” NPT
Electrical Connection	IP55 Weatherproof plug socket (plug connector supplied with the cable) or Stainless-steel adapter with M20x1.5 or ½” NPS thread for standard cable gland (to be supplied by the technician during commissioning).	
Electrical Cable	To be ordered separately. Can be supplied in lengths up to 50 metres / 165 ft.	
Filter	Removable sintered titanium alloy particulate filter 30-micron standard, optional 15-micron available. Refer to note 2	No filters available for 1232 unheated oxygen probes.
Integrated Heater	Yes	No
Thermocouple	K-Type, integral	R-Type integral or None (K-Type by special request).
Response Time	Typically < 4 seconds	Typically < 1 second
Head Temperature	-25 to 100°C (-15 to 210°F) with weatherproof connector -25 to 150°C (-15 to 300°F) with optional ceramic screw terminals	
Reference Gas	Ambient air, 50 to 150 cc/min (3 to 9scim). Reference Air Pump is supplied with the transmitter	
Ref Air Connection	¼” NPT	Integral air-line in probe cable. Barbed fitting to 3/16” ID PVC tube
Calibration Check Gas Connection	⅛” NPT female	⅛” NPT female
Weight	2 kg (4.4 lb) plus 165 g (5.8 oz.) / 100 mm (4”) length	1 kg (2.2 lb) plus 100g (3.5oz) / 100 mm (4”) length

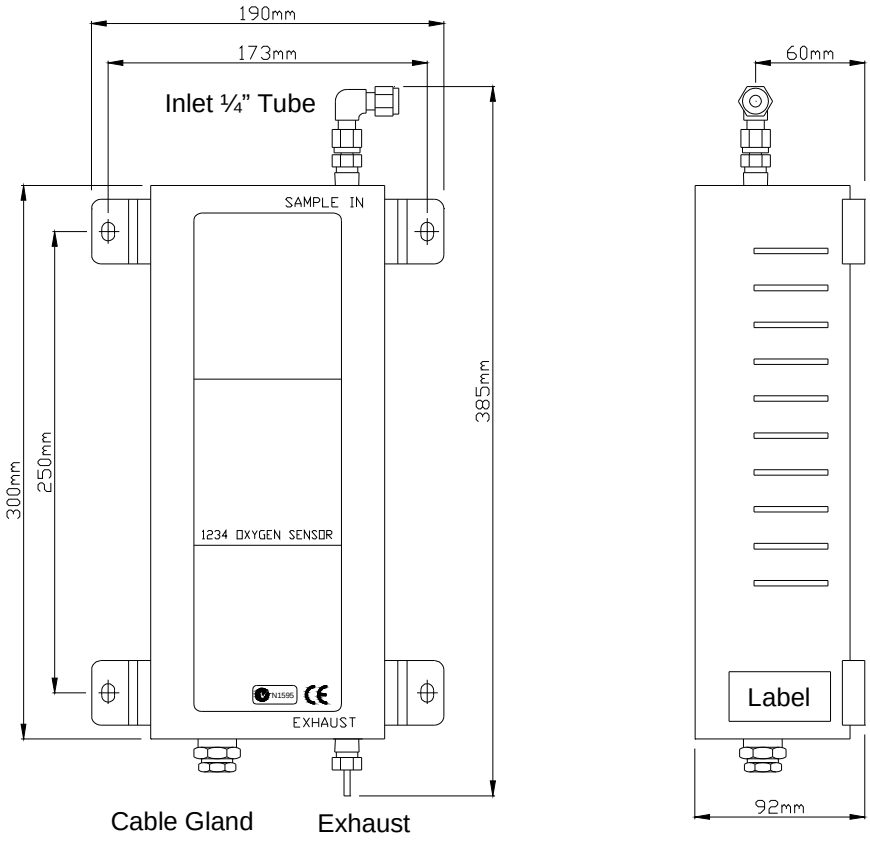
Notes:

1. Care must be taken to avoid contact with explosive or inflammable gases with 1231 heated probes and 1234 oxygen sensors when hot. Novatech transmitters have built in safety protection to disable the probe heater when the process is switched off.
2. Process gas temperature must be below 800°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.

Model 1234 Sampling Sensor Specifications

Application	Sampling Sensor or Used in RGS-17 Reference Gas Sensor
Range of Measurement	1ppm to 100% Oxygen
Accuracy	±1% of actual reading
Process Connection	¼" NPT female, inlet and outlet
Electrical Connection	IP55 Weatherproof plug socket (plug connector supplied with the cable) or Stainless-steel adapter with M20x1.5 or ½" NPS thread for a cable gland (not supplied).
Cable	Order a specific length with the transmitter
Heater	Yes
Sample Flow Rate	1 to 5 litres per minute (2 to 10scfh)
Differential Pressure	80 to 800 mmWG (3 to 30inWG)
Thermocouple	K, integral
Response Time	Typically, <1 second
Reference Gas	n/a
Dimensions	300 x 125 x 85 mm (11.81" x 4.92" x 3.46") H x W x D without mounting brackets
Weight	2.2 kg (4.8 lb)



Dimensional Drawing of the model 1234 Oxygen Sensor

Probe Ordering Information

When ordering an oxygen probe please specify the following required options:

1. Probe to be heated or unheated
2. Probe insertion length (from process end of mounting thread to probe sensing tip)
3. Mounting thread for the process connection, BSP or NPT (for size of thread refer to specifications).
4. Lagging extension length, if required.
5. Electrical Connection Type.
6. Outer Sheath Material, if not specified will assume TP316 Stainless Steel for heated probes or Grade 253MA Steel for unheated probes.
7. For model 1231 heated probe state filter type if required. If not specified will assume no filters
8. For model 1232 unheated probe, state thermocouple type. If not specified will assume R-type.

For a list of options for the above requirements refer to the appropriate probe specification tables in the previous section.

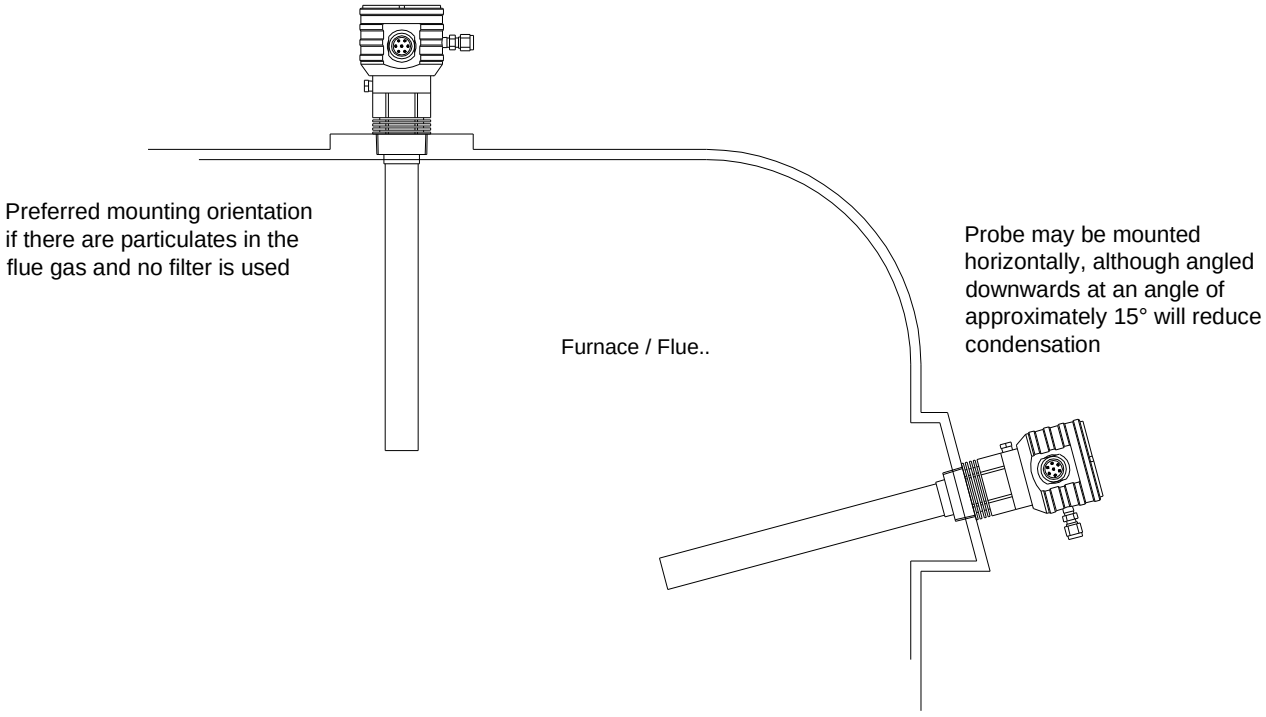
Installation & Wiring

Installation of a 1231 or 1232 In-Situ Oxygen Probe

The 1231 and 1232 oxygen probes are mounted using a BSP or NPT gland plate attached to the flue in a suitable position for flue gas sensing. For the correct size of socket refer to probe process connection information in In-Situ Probes Specifications. The closer to the source of combustion the smaller will be sensing lag time, providing faster response.

When installing probes into ducts it is advised that the probe be located three diameters upstream and five diameters downstream from any bend or protuberance in the gas stream.

Probes can be mounted at any angle, however if the probe is to be mounted on a vertical duct wall, it is recommended to angle the probe (approx. 15°) down to avoid process condensation build-up inside the cold end of the probe. If there are any particulates in the flue gas, a filter can be omitted by pointing the probe vertically downwards. Alternatively, the transmitter can be configured to automatically purge the filters, or they can be replaced periodically.



Oxygen Probe Mounting

CAUTION

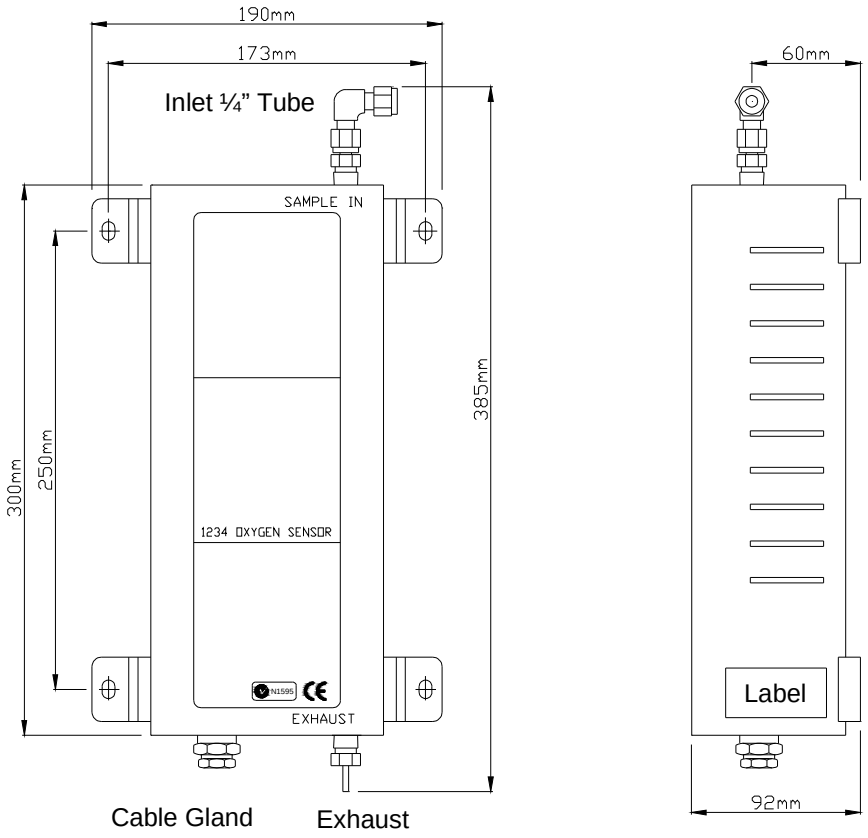
It is important that there is no air in leakage upstream of the oxygen sensing point otherwise there will be a high oxygen reading.

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 phenomenon is normally caused by stratification of the flue gas.

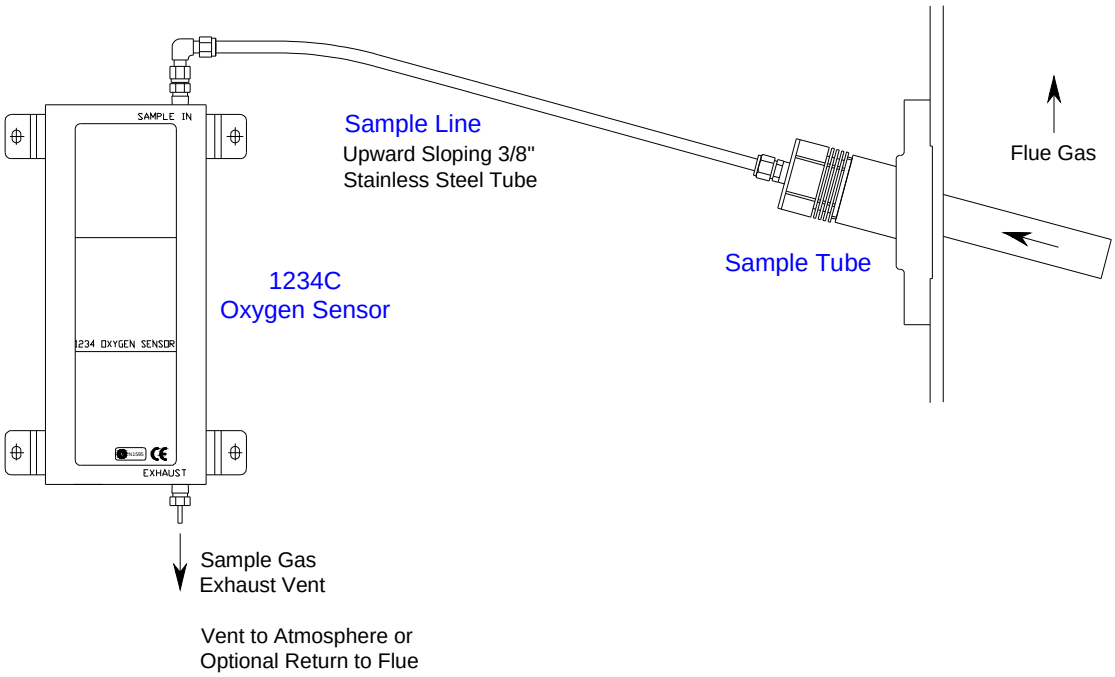
Installation of a 1234 Oxygen Sensor

Mounting - Mount the 1234 Oxygen Sensor to a wall or similar surface with the inlet connections at the top and exhaust 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. The flow rate should be within the range of 1 to 5 litres/minute (2 to 10 scfh).



Electrical Wiring for 1231 / 1232 / 1234 Oxygen Probes and Sensors

NOTE: The model 1231 heated oxygen probes and the model 1234 oxygen sensors use the same electrical wiring.

All Novatech Controls oxygen probes and sensors generate two separate analog outputs, both of which need to be measured separately to calculate process oxygen content. The model 1231 in-situ probes and 1234 oxygen sensors measure temperature using an integral K-Type thermocouple, while the model 1232 in-situ probes have an integral R-Type thermocouple.

Wiring between the 1231 in-situ probe / 1234 oxygen sensor and 1730 series transmitter requires the following electrical connections;

- 2x signal wires for the sensor EMF signal
- 2x K-type thermocouple compensation wires for the temperature sensor
- 2x separately shielded mains voltage power wires for the heater output
- 1x Earth wire

Wiring between the 1232 in-situ probe and 1730 series transmitter requires the following electrical connections;

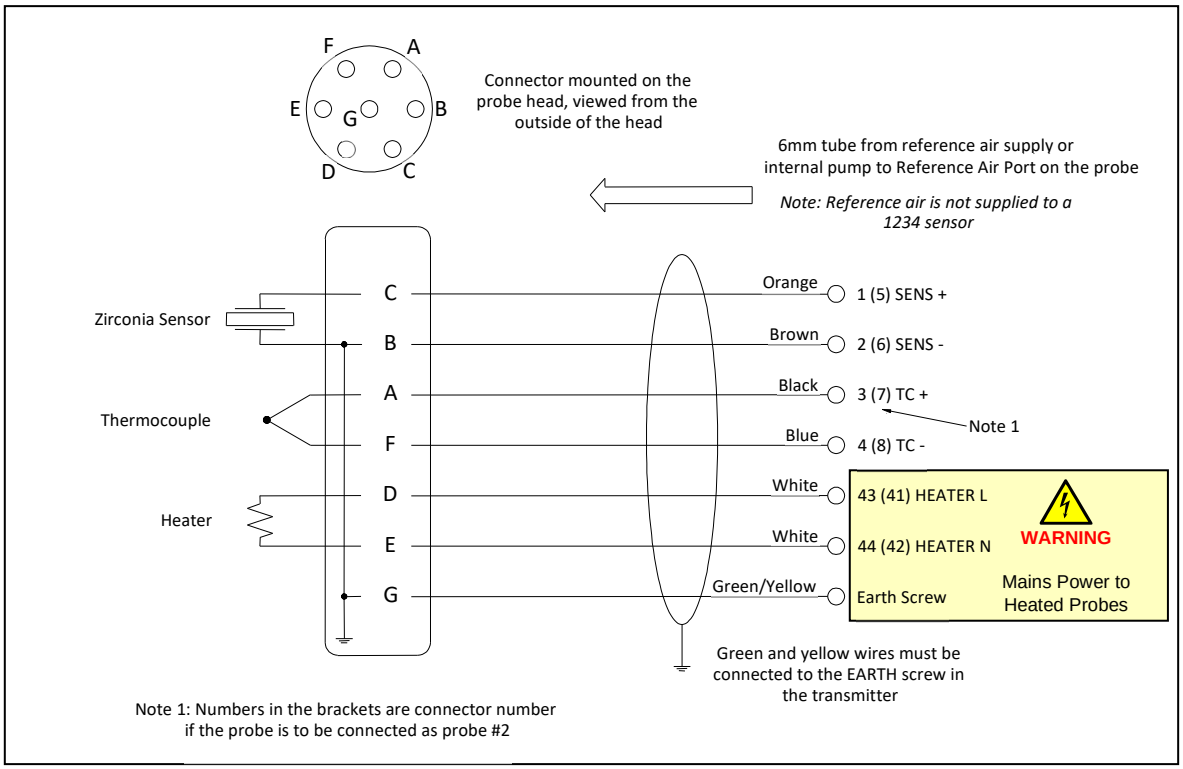
- 2x signal wires for the sensor EMF signal
- 2x R-Type thermocouple compensation wires for the temperature sensor

It is also necessary for the cable to be shielded and the shield to be earthed.

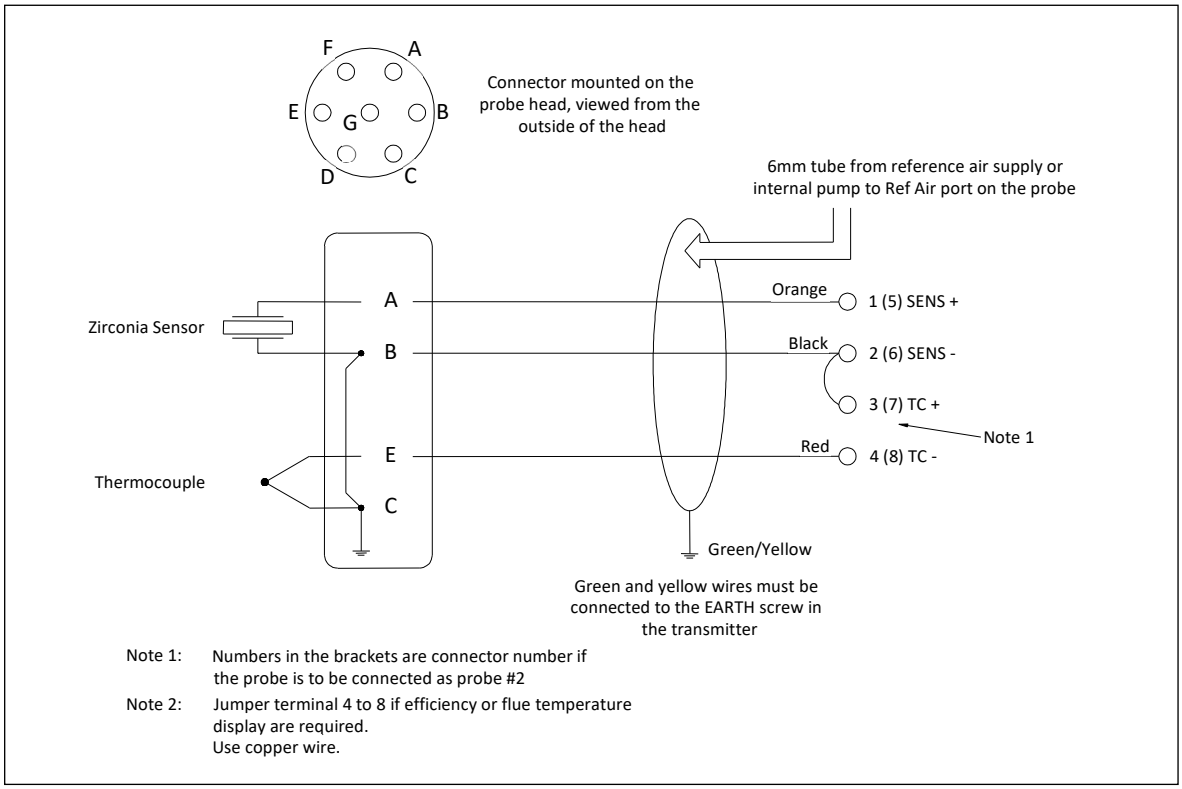
Novatech Controls supplies sensor cable which is made specifically for this application. Cable is supplied as a separate item in lengths up to 50 metres / 165 feet. Cable can be supplied pre-terminated with the IP55 plug connector to match with the corresponding plug socket on the probe (if the probe was supplied with the IP55 weatherproof plug), or as bare wire for direct electrical termination to the screw-terminals inside of the head of the probe. For direct termination a cable gland will need to be supplied during installation.

In addition to the electrical connection, both the 1231 and 1232 in-situ probes require a reference air supply. For the model 1231 in-situ probes the reference air supply is a separate ¼" tube connector on the head of the probe, while the 1232 in-situ probes have the option of using the airline tube integrated into the cable.

For wiring schematics, refer to the following page.



Connection of Probe Cable for Heated Probes Model 1231 and 1234.



Connection of Probe Cable for Unheated Probes Models 1232.

Zirconia Oxygen Probe Output EMF (mV)

	Temperature °C (°F)									
	600 (1110)	700 (1290)	720 (1330)	800 (1470)	900 (1650)	1000 (1830)	1100 (2010)	1200 (2190)	1300 (2370)	1400 (2550)
Oxygen %	**Probe Output EMF (mV)**									
20.0	0.873	0.973	0.993	1.073	1.173	1.273	1.373	1.473	1.573	1.673
19.5	1.349	1.504	1.535	1.658	1.813	1.967	2.122	2.276	2.431	2.585
19.0	1.838	2.048	2.090	2.259	2.469	2.680	2.890	3.101	3.311	3.522
18.5	2.339	2.607	2.661	2.875	3.143	3.411	3.679	3.947	4.215	4.483
18.0	2.855	3.182	3.247	3.509	3.836	4.163	4.490	4.817	5.144	5.470
17.5	3.385	3.772	3.850	4.160	4.548	4.935	5.323	5.711	6.098	6.486
17.0	3.930	4.380	4.470	4.830	5.280	5.730	6.180	6.631	7.081	7.531
16.5	4.492	5.006	5.109	5.520	6.035	6.549	7.064	7.578	8.092	8.607
16.0	5.070	5.651	5.767	6.232	6.812	7.393	7.974	8.555	9.135	9.716
15.5	5.668	6.317	6.447	6.966	7.615	8.264	8.913	9.562	10.211	10.860
15.0	6.284	7.004	7.148	7.724	8.444	9.163	9.883	10.603	11.323	12.042
14.5	6.922	7.715	7.873	8.508	9.300	10.093	10.886	11.679	12.472	13.264
14.0	7.582	8.451	8.624	9.319	10.187	11.056	11.924	12.792	13.661	14.529
13.5	8.266	9.213	9.402	10.160	11.106	12.053	13.000	13.947	14.893	15.840
13.0	8.976	10.004	10.210	11.032	12.060	13.088	14.116	15.144	16.172	17.200
12.5	9.714	10.826	11.049	11.939	13.052	14.164	15.277	16.389	17.502	18.614
12.0	10.482	11.682	11.922	12.883	14.083	15.284	16.484	17.685	18.885	20.086
11.5	11.282	12.575	12.833	13.867	15.159	16.451	17.743	19.035	20.328	21.620
11.0	12.119	13.507	13.784	14.894	16.282	17.670	19.058	20.446	21.834	23.222
10.5	12.994	14.482	14.779	15.970	17.458	18.946	20.434	21.922	23.411	24.899
10.0	13.911	15.505	15.823	17.098	18.691	20.284	21.878	23.471	25.064	26.657
9.5	14.876	16.580	16.921	18.284	19.988	21.691	23.395	25.099	26.803	28.506
9.0	15.893	17.714	18.078	19.534	21.354	23.174	24.994	26.815	28.635	30.455
8.5	16.969	18.912	19.301	20.855	22.799	24.742	26.685	28.629	30.572	32.515
8.0	18.109	20.183	20.598	22.257	24.331	26.405	28.479	30.553	32.627	34.701
7.5	19.323	21.536	21.979	23.749	25.962	28.175	30.388	32.601	34.814	37.027
7.0	20.621	22.982	23.455	25.344	27.706	30.067	32.429	34.791	37.152	39.514
6.5	22.015	24.536	25.040	27.057	29.579	32.100	34.621	37.143	39.664	42.185
6.0	23.520	26.214	26.753	28.908	31.602	34.295	36.989	39.683	42.377	45.070
5.5	25.157	28.038	28.615	30.919	33.801	36.682	39.563	42.444	45.325	48.207
5.0	26.950	30.036	30.654	33.123	36.210	39.296	42.383	45.469	48.556	51.642
4.5	28.932	32.245	32.908	35.559	38.872	42.186	45.499	48.813	52.126	55.440
4.0	31.147	34.715	35.428	38.282	41.849	45.416	48.984	52.551	56.118	59.685
3.5	33.659	37.514	38.285	41.369	45.224	49.079	52.934	56.789	60.644	64.499
3.0	36.559	40.746	41.583	44.933	49.120	53.307	57.494	61.681	65.868	70.055
2.5	39.988	44.568	45.484	49.148	53.728	58.308	62.887	67.467	72.047	76.627
2.0	44.186	49.246	50.259	54.307	59.367	64.428	69.489	74.549	79.610	84.670
1.5	49.597	55.278	56.414	60.958	66.638	72.319	77.999	83.679	89.359	95.040
1.0	57.224	63.778	65.089	70.332	76.886	83.440	89.993	96.547	103.101	109.655
0.5	70.263	78.310	79.919	86.357	94.404	102.451	110.498	118.545	126.592	134.639
0.2	87.499	97.520	99.524	107.541	117.562	127.583	137.604	147.625	157.646	167.667
	Thermocouple mV									
'K'-Type	24.905	29.129	29.965	33.275	37.326	41.276	45.119	48.838	52.41	-
'J'-Type	33.102	39.132	40.382	45.494	51.877	57.953	63.792	69.553	-	-
'R'-Type	5.583	6.743	6.98	7.95	9.205	10.506	11.85	13.228	14.629	16.04
'S'-Type	5.239	6.275	6.486	7.345	8.449	9.587	10.757	11.951	13.159	14.373
'N'-Type	20.613	24.527	25.312	28.455	32.371	36.256	40.087	43.846	47.513	-

These tables are based on the Nernst equation:

$$EMF = \frac{T}{46.418} \times log_e\left(\frac{20.95}{O_2}\right)$$ Where *T* is the probe temperature °K

Thermocouple information from NIST ITS-90 data tables