NOVATECH

COMBUSTION CONTROLLER / OXYGEN TRANSMITTER MODEL 1533

CONTENTS

NOTE: This manual includes software modifications up to -
Version 441, 14th April 1994.

The product described in this manual and products for use with it, are subject to continuous developments and improvement. All information of a technical nature and particulars of the product and its use (including the information in this manual) are given by Novatech Controls in good faith. However, it is acknowledged that there may be errors or omissions in this manual. A list of details of any amendments or revisions to this manual can be obtained upon request from Novatech Controls Technical Enquiries. Novatech Controls welcome comments and suggestions relating to the product and this manual.

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USING THIS MANUAL

The Novatech 1533 Oxygen Transmitter has a variety of user-selectable functions.

They are simple to use because each selection is menu driven. For options you are not sure about, read the manual on that particular item.

Please read the safety information below and the 'Installation' section, before connecting the analyser.

CAUTION
1

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 exp losive atmospheres. This danger is normally avoided with flue gas trim systems by adjustment so that 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 inferred or cell type.

CAUTION
2

The oxygen sensor may be heated to above 700°C and can be a source of ignition. Since raw fuel leaks can occur during burner shut down, the analyser has an interlocking relay which 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 1533 analyser with a heated probe may be unsuitable for your application.

An unheated probe can be utilised in such applications, however the oxygen readings are valid only above 650°C.

CAUTION
3

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 and thermal conductivity bridge, would be more appropriate where incomplete combustion is possible.

Also read the probe electrical shock caution in Section 2.5, the trim actuator caution in Section 3.16, the oxygen trim caution in Section 4.8, and the probe heater interlock caution in Section 6.5.9

SPECIFICATIONS

1

SECTION
NUMBER

1.1 ANALYSER DESCRIPTION AND SPECIFICATIONS

DESCRIPTION

The Novatech Model 1533 oxygen analyser/controller provides in-situ measurement and control of oxygen in furnaces, kilns and boilers and in flue gases with ambient temperatures up to 1400°C. The analyser provides local indication of oxygen plus thirteen other selectable variables.

Two linearised and isolated 4–20 mA output signals are provided. Alarms are displayed at the analyser and relay contacts drive remote alarm functions. The analyser, which can be used with heated or unheated zirconia oxygen probes, provides automatic on-line gas calibration checking of the probe and filter purging, when used with the 1536 purge/cal panel. The electronics self-calibrate all inputs every minute.

The 1533 has an internal keyboard for selecting the output range, type of TC, etc., as well as maintenance and commissioning functions. The instrument is microprocessor based and all adjustments are made using the internal keyboard.

- Used for air/fuel ratio combustion control
- Simple to install
- Linear output of % 0_2 for recording or control
- Built in safety features
- 15 different alarm functions warn the operator of combustion, or probe or analyser problems
- Printer/Computer interface on RS-232 ports
- Safety interlock relay for heated probe

Figure 1.1 Probe and Analyser System

SPECIFICATIONS

Inputs

- Zirconia oxygen probe, heated or unheated.
- Furnace, kiln or flue thermocouple, field selectable as type T, J, K, R, S, N. Use isolated junction TC.
- Boiler rear head TC (type K).
- Main flame established safety interlock (for heated probes only).
- Remote set point for oxygen control.
- Ambient air temperature sensor (optional).
- Relative Humidity Sensor (optional)
- Purge and Reference Air flow switches.
- Dual Fuel selector contactor.
- Trim motor feedback.
- Burner fire rate transmitter.
- Remote neutral switch.

Outputs

- o Two linearised 4–20 mA DC outputs (max. 600 Ω load).
- o Common Alarm relay.
- o Probe Not Ready relay (under temperature).
- o Auto Cal/purge occurring relay (output is frozen when probe cal or purge is occurring).
- o Alarm Horn Driver relay.
- o Alarm relays including:
  1) High Oxygen and Analyser Self Diagnostic Fault
  2) Low Oxygen or Oxygen deviation
  3) Very Low Oxygen

Computer

- o RS 232/485 for connection of a computer terminal or serial printer for analyser function logging.

Range of Output 1

- o Field selectable from the following:

Output	**Zero Range**	**Span Range**
Linear	0% O_2 Fixed	1%–100% O_2
Log	0.1% O_2 Fixed	20% O_2 Fixed
Reducing	10^{-25}% O_2 Fixed	10^{-1}% O_2 Fixed

Range of Output 2

- o Field selectable from the following:

Output	**Zero Range**	**Span Range**
Probe EMF	0–1100 mV in 100 mV steps	100–1300 mV in 100 mV steps
Carbon Dioxide	0–10%	2–20%
Efficiency	0% Fixed	100% Fixed
Flue Temperature	0–1000°C in 100°C steps	100–1400°C in 100°C steps
Log Oxygen	0.1% oxygen fixed	20% oxygen fixed
Reducing Oxygen	10^{-1}–10^{-10} % oxygen in one decade steps	10^{-5}–10^{-25} % oxygen in one decade steps

Range of Indication, Upper Line

- o Auto ranging from 10^{-30} to 100% oxygen

Indication Choice, Lower Line

Any or all of the following can be selected for lower line display.

Options:

- o Probe EMF
- o Efficiency
- o Probe Temperature
- o Flue Temperature
- o Ambient Temperature
- o Rear Head Temperature
- o Date - time
- o Run Hours since last service
- o Date of last service
- o Relative Humidity
- o Probe Impedance
- o Carbon Dioxide
- o Oxygen Set point/Fire rate
- o Trim Actuator Position

Accuracy

- ±3% of actual measured oxygen value with a repeatability of ±0.5% of measured value.

Relay Contacts

- 4 amps 240 VDC, 2 amps 50 VDC.

Ambient Temperature

- 0–50°C.

Power Requirements

- 240 or 110V, 50/60 Hz, 150 VA (heated probe)
  20 VA (unheated probe).

Weight

- 12 kg

Figure 1.2 Typical excess air characteristics for combustion appliances

Figure 1.3 Two methods of trimming air/fuel ratio

MODEL 1533 OXYGEN ANALYSER CONNECTION DETAILS

TERMINAL NUMBER	TERMINAL DESIGNATION	TERMINAL FUNCTION	FIELD CONNECTION
1 2 3 4 5 6	PROBE + PROBE – PROBE TC + PROBE TC – STACK TC + STACK TC –	Oxygen sensor (+) input, Ref. air side Oxygen sensor (-) input, O2 sense side Internal probe TC (optional on unheated probe) To separate flue TC	Probe lead orange, probe pin C Probe lead purple, probe pin B Probe lead red, probe pin F Flue TC compensating lead
7 8 9	RH I/P+ RH I/P– +12V O/P	Relative humidity input 0–1V(+) Relative humidity input 0–1V (–), 12V comm Supply to RH Transmitter Max.40 mA	Relative Humidity Transmitter required to be connected if high accuracy efficiency display or output is required. For Lee Integer CH15 RH Transmitter and 12V fire rate transmitter (FBT-20)
10 11	AMB TEMP + AMB TEMP –	Ambient temp input+ Ambient temp input–	Analog Devices AD590 temp sensor To sense primary combustion air temp
12 13	CH1 O/P + CH1 O/P –	Channel 1 signal output 4–20 mA(+) Channel 1 signal output 4–20 mA(-)	Isolated % oxygen signal output For receiver, computer or controller
14 15	CH 2 O/P + CH 2 O/P –	Channel 2 signal output 4–20 mA (+) Channel 2 signal output 4–20 mA (–)	Isolated signal output as selected in setup 7 and setup 54 section 5.4
16 17	R HEAD TC + R HEAD TC –	K Type TC + input for rear head K Type TC – input for read head	Separate thermocouple for alarm temperature limit. See section 3.8
18 19 20	BRNR POT HI BRNR POT W BRNR POT LO	Firing rate transmitter supply +5V. For 12V supply use term 9. See Section 3.16 Firing rate input 0–5V or 1–5V Firing rate, supply & signal common	Firing rate transmitter can be either 1) Potentiometer 135–1000_ 2) Novatech hall effect position transmitter, 12V supply 3) Fuel flow transmitter 4-20 mA
21 22 23	TRIM POT HI TRIM POT W TRIM POT LO	Air/fuel ratio trim motor FB pot supply +5V Air/fuel ratio trim motor FB pot input 0–5V Air/fuel ratio trim motor FB pot common	Trim motor pot 130–1000Ω. Connect terminal 21 to end nearest wiper when fuel rich. Connect 22 to wiper and 23 to other end.
24 25	REM SP+ REM SP -	Controller remote set point input 4–20 mA(+) Controller remote set point input 4–20 mA(-)	When the analyser is used as a local controller with remote set point
26 27	REF AIR SW REF AIR SW	Reference Air Flow Switch Reference Air Flow Switch	Connect Reference Air Flow Switch Normally closed.
28 29 30 31	PURGE FLO SW PURGE FLO SW FUEL 2 FUEL 2	Purge air flow switch Purge air flow switch Fuel 1/Fuel 2 selector switch Fuel 1/Fuel 2 selector switch	Repeated on PCB 1533-3 CN12 Connect flow switch. Normal open Connect flow switch. Normal open For dual fuel burners. Closed contacts operate fuel 2 menu selected software parameters

MODEL 1533 OXYGEN ANALYSER CONNECTION DETAILS

TERMINAL NUMBER	TERMINAL	TERMINAL FUNCTION DESIGNATION	FIELD CONNECTION
32 33	ALARM #1 ALARM #1	Analyser fail and very low oxygen alarm	Connect to alarm and or trip system as required. All alarm relays and horn relay rated 5 amps 240VAC or 0.5 amp 30VDC
34 35	ALARM #2 ALARM #2	Neutral trim common alarm auto purge or cal occurring. Normally open	
36 37	ALARM #3 ALARM #3	Oxygen deviation from setpoint, or low oxygen alarm. Normally open	
38 39	LO TEMP LO TEMP	Probe not ready relay normally open	Probe below 650°C Oxygen readings not valid
40 41	HORN NO HORN C	Horn Relay normally open Horn Relay common	Connect alarm horn or bell and correct supply to 40 &41
42 43 44	SOLN COM PURGE CAL 1	Solenoid Valve Active 24VAC Purge Solenoid Valve Cal Gas 1 Solenoid Valve	For Purge & Cal solenoid valves. Connect direct to valve. Max. 1 amp from SSR.
45 46	MOTOR INC MOTOR COMM	Motor control output increases excess air Motor control output, common	To operate air/fuel ratio trim motor External transformer required if
47	MOTOR DEC	Motor control output, decreases excess air	motor not line powered. Contact rating 240VAC 10 amps or 30 VDC 1 amp.
48 49	REF PUMP REF PUMP	Switched 110VAC to ref pump Automatic test of flow switch Repeated on 1533-3 CN12	To 110VAC pump
50 51	HTR SUPPLY HTR SUPPLY	Heater Supply (Heated probe only) Heater Supply (Heated probe only)	Probe Lead White, Probe Pin D Probe Lead White, Probe Pin E
52 53	BRNR ON I/P BRNR ON I/P	Main flame established signal Main flame established signal	Connect 110 or 240 VAC when main fuel supply is on Probe heater off when voltage not present (for explosion safety).RL10 coil to suit voltage connected.
54 55 56	SUPPLY N SUPPLY A EARTH	Mains Power Supply 110V or 240V Neutral Mains Power Supply 110V or 240V Active Mains Earth	Check that supply voltage bridge is at correct position. Connect to case earth and solid mains earth
EARTH		Case Earth	Connect all Shields and Solid Earth

Do not connect shields at field end, but carry shield connection through any junction boxes above Earth to avoid noise from Earth loops.

1.2 SERIES 1230 OXYGEN PROBES

FEATURES

- o Fuel savings and pollution control in boilers, furnaces and kilns
- o Low cost
- o Simple to install

DESCRIPTION

Novatech series 1230 oxygen probes provide in-situ measurement of the oxygen level in boilers, kilns and furnaces. Series 1230 probes allow major fuel savings in combustion control applications. In atmosphere control of metal and ceramic heat treatment processes, series 1230 probes provide improved quality control. Ask for separate literature on this subject.

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

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

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

All Novatech oxygen probes are designed and manufactured to exacting standards of performance and reliability. Series 1230 probes are the result of extensive research and development by Novatech, industry and government agencies, including the CSIRO. Novatech Controls provides application and after-sales support for oxygen probes and analysers, world-wide.

Figure 1.4 Oxygen Probes

ORDERING INFORMATION

Orders may be placed by submitting the following information (please number each item as below):

1. Combustion plant (e.g. boiler, furnace, kiln, etc.).
2. Type and size of plant.
3. Type of fuel(s).
4. Contaminants in gas being measured (e.g. sulphur, zinc, etc.) State percentage of contaminant if known.
5. Probe insertion length (from process end of mounting thread to probe sensing tip).
6. Probe cable (run distance between the probe and the analyser- maximum length 50 metres.)
7. Lagging extension length, if required.
8. Mounting thread (process connection)—BSP or NPT (for size of thread refer to Specifications).
9. Operating temperature range—maximum and minimum temperatures for which probe readings are required.
10. If model 1232 probe, state preferred thermocouple type (Refer to Specifications).
11. If model 1231, state if separate flue gas thermocouple is required (refer to Note 3—Specifications).Also state preferred type: T, J, K, R, S or N; insertion length; preferred thread—1/2" BSP or NPT; and length of lagging extension, if required.
12. If a 1231 probe longer than 1000 mm is required, specify flow guide tube type 1239 and required overall length. The oxygen probe fits into the flow guide tube. The probe sensing tip must be inside the flue wall 200 mm (8") or more.
13. Choose reference air kit or purge/cal panel.

Ask your local Novatech Distributor for assistance in ordering.

STANDARD PROBE 'U' LENGTHS

1231	1232	1233
250 mm (9.8")	300 mm (11.8")	457 mm (18")
500 mm (19.7")	500 mm (19.7")	609 mm (24")
750 mm (29.5")	750 mm (29.5")	914 mm (36")
1000 mm (39.4")	1000 mm (39.4")	1160 mm (45.8")
	1160 mm (45.8")	

Above 1000 mm use a Model 1239 Flow Guide Tube

Note: Non standard sizes- within the range of standard lengths- can be specified on request.

Figure 1.5 Oxygen Probe Mounting

SPECIFICATIONS

MODEL	1231	1232	1233
Application	Combustion flue gases below 900°C (1830°F) refer to note 1	Combustion flue gases above 700°C (1290°F) with no contaminants. e.g. natural gas, light oils	Combustion flue gases above 700°C (1290°F) with contaminants such as zinc or sulphur. Refer note 2.
Temperature Range	0–900°C (32–1830°F)	700–1400°C (1290–2550°F)	700–1200°C (1290–2190°F)
Length	250–1000 mm (5.5–39 ")Above 1000 mm refer to Ordering info. 12	300–1160 mm (12–46 ")	300–1160 mm (12–46 ")
Process Connection	1 1/2" BSP or NPT	3/4" BSP or NPT	1" BSP or NPT
Heater	Yes	No	No
Flue Gas Thermocouple	Ordering info. 11 & note 3	R , integral	R, integral
Response Time	Typically less than 4 secs. See note 4.	Typically less than 1 sec. See note 4.	Typically less than 1 sec. See note 4.
Head Temperature	150°C (300°F) Max	150°C (300°F) Max	150°C (300°F) Max
Reference Gas	Ambient air 50 cc/min approx. Pump supplied with probe		
Reference Gas Alarm		Piston actuated flow switch	
Reference Air Connection	1/8" NPT female	Integral air line in probe cable. Barbed fitting to 3/16" ID PVC tube.	
Probe Cable	Supplied with connector to specified length - maximum 50 m (160 ft)		
Calibration Gas	1/8" NPT female	1/16" NPT female	1/16" NPT female
Weight	0.6 kg (1.35 lbs) plus 0.33 kg/ 100 mm (0.75 lbs/in)	0.4 kg (0.9 lbs) plus 0.1 kg/100 mm (0.6 lbs/in) length	

Probe M.T.B.F. Typically 1-2 years. -A low cost refurbishing service is available

Notes:

(1) Care must be taken to avoid contact with explosive or inflammable gases with 1231 heated probes when hot. Novatech analysers have built in safety protection.

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

(3) A separate flue gas thermocouple is required if an efficiency or oxygen deficiency display is needed from the analyser The probe thermocouple is used to control probe temperature.

(4) For normal probe. Typically 70 seconds for 500 mm (19.7") probe with 2000 mm (78.7") flow guide tube.

OXYGEN PROBE MODEL SELECTION GUIDE

1.3 FLOW GUIDE TUBES

The maximum insertion length of Novatech oxygen probes is 1000 mm. Occasionally, for large flues, there is an advantage to have a longer insertion length to obtain a proper oxygen reading. In 99% of applications, 1000 mm is an adequate insertion length.

For longer insertion lengths a filtered flow guide tube is available. This tube diverts the flue gas stream from the point of sensing to a probe long enough to protrude through any flue lagging, typically 500–750 mm long.

Flow guide tubes are available in lengths from 1500–3000 mm. Longer flow guide tubes normally need supporting within the flue. The response time of flow guide tubes vary depending on the length and the amount of filter blockage. For a two metre tube it is typically 70 seconds. Particles blocking the filter can normally be removed by back-purging.

The weight of flow guide tubes is – 2000 mm: 10 kg, 3000 mm: 15 kg.

Figure 1.6 Flow Guide Tube

FLOW GUIDE TUBE SELECTION GUIDE

1.4 MODEL 1536 PURGE/CALIBRATION PANELS

Due to the absolute measurement characteristics of zirconia sensors and the self calibration features of Novatech analysers, probe calibration checks with calibrated gas are not normally required. In some installations however, automatic gas calibration checks are required by Environmental Protection Authorities and by production engineering management in Power Stations, Oil Refineries and similar large end users.

Novatech purge/calibration panels provide a ready method of connecting on-line calibration gases, and have a probe zero off-set check facility. They provide on-line automatic checking of probe and analyser calibration, as well as a probe purge facility and a reference air facility.

The absolute characteristics of zirconia sensors require only one calibration gas to properly check the probe's performance. Where required however, purge/cal panels are available to handle two calibration gases.

Dirty flue gas applications often require the back purge facility to keep a probe filter free from blockage. (In these applications, it is more reliable to install probes pointing vertically downwards with no filter). The purge and cal solenoid valves can be operated manually or automatically from a 1533 series transmitter or a 1533 trim monitor or controller.

Each panel is supplied with:
- A reference air flow meter/regulator
- A reference air flow switch
- A hand valve for zero off-set calibration
- A calibration gas flow meter/regulator
- A 24 VAC solenoid valve for each calibration gas

Panels with filter purge include:
- A 24 VAC purge solenoid valve
- A purge flow switch to test for filter blockage.

The customer should supply:
- Span gas cylinder(s), typically 2 % oxygen in nitrogen or a similar percentage of 0_2 close to the normal level in the gas stream being measured, to ensure fast recovery.
- A 100 kPa (15 P.S.I.) clean and dry instrument air supply when filter purging is required. If purging is not required and instrument air is not available, an electric pump should be used for reference air and zero off-set calibration air.

PURGE/CAL PANEL MODEL SELECTIONS

Model Number	No of Span Gases	Filter Purge	For Class 1 Hazardous Area
1536–1	1	No	No
1536–2	2	No	No
1536–3	1	Yes	No
1536–5	1	No	Yes
1536–6	2	No	Yes
1536–7	1	Yes	Yes

1.5 SPECIFICATIONS – AMBIENT HUMIDITY PROBE

(Required only if improved accuracy is required on efficiency or oxygen deficiency outputs)

Model	CH15
Humidity Range	0 –100 % RH
Temperature	–20 – +90 ° C
Output	0 –1 VDC , linearly proportional to 0 –100 % RH

1.6 SPECIFICATIONS – REFERENCE AIR & FILTER PURGE FLOW SWITCHES

Model –	Reference Air	LPH–125–0 *
	Filter Purge	LPH–125–7 *
Range –	Reference Air	50 cc/minute
	Filter Purge	2500 cc/minute
Dimensions	50 mm high by 14 mm wide	
Type		Magnetic piston & reed switch, 1 AMP.
Mounting		Vertical only

* Suffix 'A' denotes acrylic body with flying leads. (Not suitable for outdoor installation) e.g. LPH 125-0A
Suffix 'B' denotes brass body with conduit thread entry for leads. Suitable for outdoor installation.

DESCRIPTION

2

DESCRIPTION

2.1 THE ZIRCONIA SENSOR

The analyser input is provided from a solid electrolyte oxygen probe which contains a zirconia element and thermocouple. The probe is designed to be inserted into the boiler or furnace exit gas flue. Sampling lines and filters are not required. A reference air supply or pump is required for probes with insertion length 250 mm and above.

The probe sensing end construction is shown in Figure 2.1.

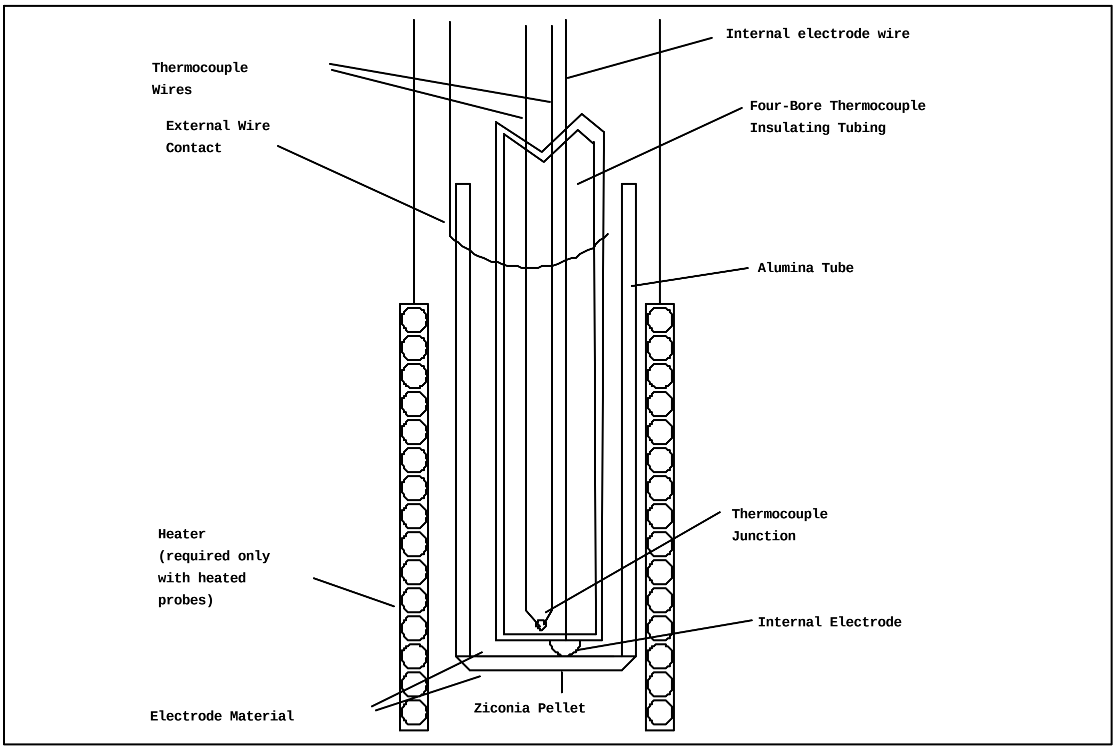

Figure 2.1 Schematic View of a Sensor Assembly

The heater control is a time proportioning temperature controller and triac so that the thermocouple junction is controlled to approximately 720°C. Probes operating in a combustion environment above 700°C 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 sensor (> 650°C), 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:

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

Transposing this equation

$$(\%O_2) \text{ OUTSIDE (ATM)} = 21 \text{ EXP } \frac{-46.421E}{T}$$

The 1533 transmitter solves this equation which is valid above 650°C. The probe heater, or the process maintains the sensor temperature at this level.

2.2 THE OXYGEN PROBE

The probe assembly provides a means of exposing the sensor to the atmosphere to be measured with sensor, thermocouple and heater wires connected via a weatherproof plug to 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 for an in-situ gas calibration check. A cleaning purge of air can be admitted via the cal. gas entry. The outer sheath can be metal or ceramic, depending on the application.

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.

Probes of 1000 mm normally have sufficient length for any installation. Customers requiring probes longer than 1000 mm are supplied with a flow guide tube which uses the flue velocity to pull flue gas through a filter at the sensing tip and exhaust it near the flue wall.

2.3 THE ANALYSER

The 1533 analyser is a transmitter with two 4–20 mA outputs. One output is % oxygen with selectable span (Refer to set-up steps 4 and 5 in Section 5.5).

The second output can be selected as oxygen deficiency, efficiency, flue temperature, reducing oxygen, percent carbon dioxide, probe EMF or a logarithmic oxygen range. Four alarm relays are provided. Refer to the specifications section for more details.

The 1533 analyser is designed to operate with either a heated or unheated zirconia probe. The analyser maintains the temperature of heated probes at 720°C If the flue gas temperature is above 730°C, the probe heater cuts out completely and the process provides probe heating. The analyser solves the Nernst equation and will provide accurate oxygen measurements up to 1400°C (2550°F), although most probes are suitable only to 1400°C (2250°F) and

A block diagram of the analyser is shown in Figure 2.2 and details on its functions are given in the remainder of this section.

2.4 ALARMS

Refer to OPERATOR FUNCTIONS Section 4.3 for details on alarm functions.

2.5 HEATER SUPPLY

CAUTION

The probe heater is supplied with 110 VAC at 1 A (cold). This supply has electrical shock danger to maintenance personnel. Always isolate the analyser before working with the probe. For maximum safety the heater supply is transformer isolated.

Figure 2.2 1533 Analyser Block Diagram

2.6 APPLICATIONS WHERE SENSING POINT IS NOT AT ATMOSPHERIC PRESSURE

To apply the 1533 analyser to processes which have pressure at the point of measurement significantly above or below atmospheric pressure, then a compensation must be applied. (Refer to set-up steps 12 and 13 in Section 5.5)

2.7 PROBE IMPEDANCE

The probe impedance is a basic measurement of the reliability of the oxygen reading. A probe with a high impedance reading will eventually produce erroneous signals. The analyser checks the probe impedance once per minute, and if the impedance is above the maximum level for a specific temperature, then the impedance alarm will be activated. As a guide, a probe with about 3 months service will have an impedance of approximately 2kΩ.

2.8 AUTO CALIBRATION — ELECTRONICS

The analyser input section is self calibrating. There are no adjustments. The analog to digital converter input stages are checked against a precision reference source and calibrated once every minute. Should the input electronics drift slightly, then the drift will be automatically compensated for within the microprocessor. If a large error occurs due to an electronic fault, then an 'A/D CAL ERR ' alarm will occur.

A one-off calibration procedure of the precision reference sources should never need to be repeated for the instrument life, unless the instrument undergoes a 'COLD START ' (Refer to Section 3.21). If there is any doubt about the accuracy of the instrument readings, then refer to Maintenance Section 6.5, Items 6 to 11 for a full description of this simple calibration procedure.

The digital to analog converters or output section of the analyser are tested for accuracy every time 'AUTOCAL' is selected from the keyboard (in Maintenance or Setup modes), or when a COLD START is performed, and if they are found to have an error, then a 'D/A CAL ERR' alarm will occur. The D/A signal isolators are re-calibrated in two seconds by pressing the 'AUTO CAL' button on the technicians keyboard. All output signals will go to 0 mA and 20 mA for the two second period. It is suggested that a D/A re-calibration be performed after the instrument has stabilised, approximately 30 minutes after first switching on and after Maintenance Section 6.5, Items 6,7, 8 and 9 have been completed, and then annually.

2.9 AUTO CALIBRATION — PROBE

On-line automatic gas calibration checking is not normally required. Where it is required however, the probe can be checked for accuracy in-situ and on-line. Solenoid valves can admit calibrated gas mixtures into the probe via a solenoid valve under microprocessor control on a timed basis. For details on installation refer to Section 3.12. For details on setting up this facility, refer to set-up steps 34 to 40 in Section 5.5.

During probe auto calibration checking, the analyser output will freeze and remain frozen for a further adjustable period, allowing the probe time to recover and continue reading the flue gas oxygen level.

Calibration gases may be manually admitted by pressing the 'CAL1' button on the keyboard while in 'RUN' mode. The analyser output is frozen during the pressing of these buttons and immediately becomes active when the button is released.

2.10 AUTO PURGE

In oil and coal fired plant, it is possible for the probe sensing filter to become blocked. An automatic purge cycle can be set up so that a blast of air, maximum 100 kPa, will automatically back-flush the probe filter on a timed basis. Refer to set-up steps 29 to 33 in Section 5.5.

A purge flow switch will sense that there is sufficient flow to clear the filter during the purge cycle, otherwise a 'FILTER BLOCKED' alarm will occur.

The probe can be manually purged from the keyboard while in 'RUN' mode by pressing 'PURGE'. The analyser output is not frozen during or after the pressing of this button.

2.11 DETERMINING THE CORRECT FLUE GAS OXYGEN LEVELS

To set up a flue gas oxygen analyser system, it is normally necessary to use a portable carbon monoxide analyser to determine the optimum operating levels of flue gas oxygen for any particular firing rate. As the air/fuel ratio is adjusted toward the fuel rich end, the carbon monoxide emission will increase suddenly at the knee of the curve.

The oxygen level should be selected so that it controls the carbon monoxide level on the excess air side of this knee. It is important that the burner be mechanically limited so that if the trim actuator fails at the fuel rich end, dangerous flue gas conditions will not occur.

This adjustment is important over the whole firing range, for example, if the trim actuator fails at the fuel rich end at high fire, it is important that dangerous conditions do not occur when the burner is driven to low fire.

Figure 2.3 Carbon Monoxide/Oxygen Curves

2.12 RS 232/485 PORTS

The serial port provided is intended to be used to log the oxygen or other variables that are either fed into or calculated inside the 1533 analyser. Alarm messages are transmitted as they occur with the date/time, and a range of other variables may be put on list to be logged to a serial printer or computer for analysis of intermittent probe of analyser faults. A sample print-out is shown in Appendix 1.

The print-out is available of the characterisation table entered in the MAINT mode, steps 19 to 22. See section 6.5.18 to 6.5.22.

2.13 OTHER INPUTS — HUMIDITY, AMBIENT TEMPERATURE, FLUE TEMPERATURE AND REAR HEAD

Applications requiring higher accuracy for the display of combustion efficiency can have the relative humidity of the combustion air included in the calculation.

This requires the connection of a Lee Integer CH15 sensor/transmitter with a range of 0–100% RH and output of 0–1 volt.

A flue thermocouple and ambient temperature sensor must also be connected when efficiency display is required.

An additional thermocouple input has been provided on Terminals 16 and 17. It is often used on ‘piggy-back’ boilers, where the rear head temperature must be kept below a critical limit. This input may also be used for any other thermocouple input. An alarm trip point is set in SETUP step 47.

2.14 WATCHDOG TIMER

The watchdog timer, is started if the microprocessor fails to pulse it within any three second period, (i.e. fails to run its normal program).

The microprocessor will then be repeatedly reset until normal operation is resumed. Reset cycles are displayed by the RESET light on the internal keyboard. A steady ‘ON’ light indicates normal operation.

If the program has not resumed normal operation after two attempts to reset, the common alarm relay will be activated.

2.15 BACK-UP BATTERY

The analyser's RAM and real-time clock are backed up by a lithium battery in the event of power failure. All set-up and maintenance variables are saved and the clock is kept running for approximately ten years with the power off. The average life of the battery with the power on is 38 years.

INSTALLATION & COMMISSIONING

3

INSTALLATION

3.1 MOUNTING THE ANALYSER

Surface mount the transmitter case on to a flat surface or bracket, using the four holes provided. Refer to Figure 3.1. If the hole layout provided is not suitable then the circuit boards may be removed and additional holes drilled in the rear of the case. Mounting screws should not come into contact with the printed circuit boards.

All wiring should comply with local electrical codes. The lead between the probe and transmitter should be ordered with the probe. It has an integral weatherproof connector to plug into the probe head.

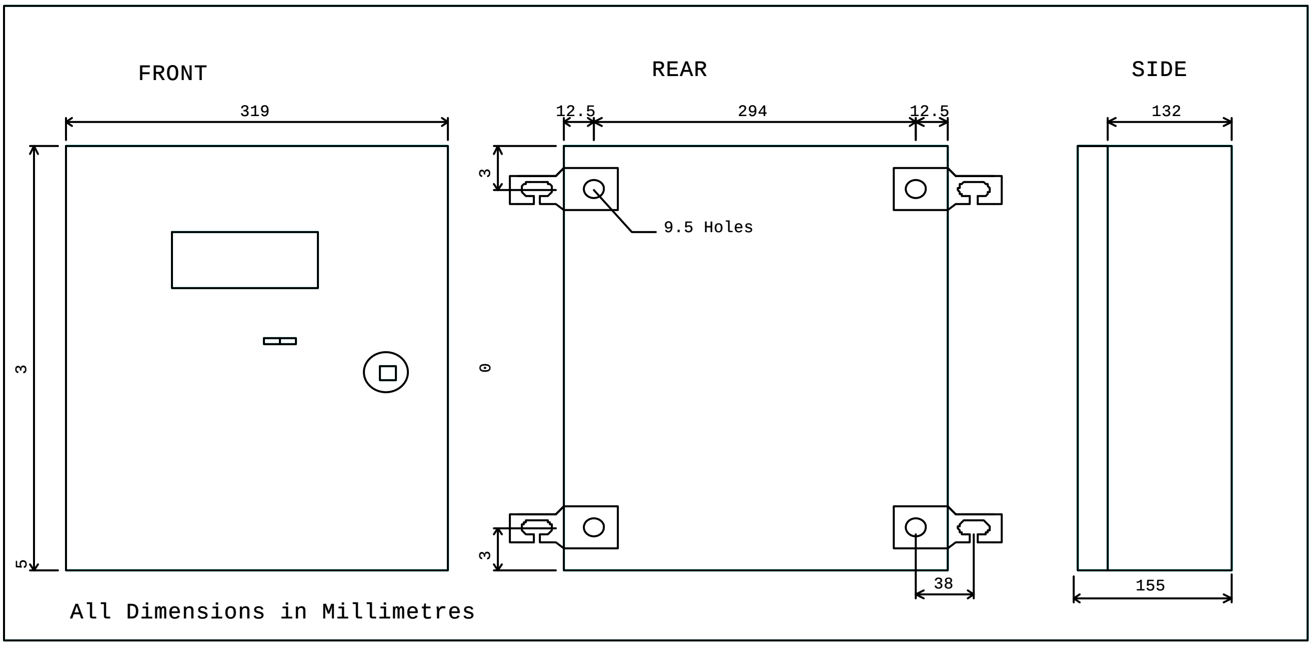

Figure 3.1 Case Mounting Dimensions

3.2 HEATER INTERLOCK RELAY

CAUTION

Explosion protection for heated probes is achieved by switching the power to the probe heater off whenever the main fuel valve is closed.

The principle of safety is that if the main fuel valve is open then main flame has been established. With this primary source of ignition on, the probe heater can be safely switched on. The most dangerous situation is if fuel leaks into the combustion appliance when the fuel valve is supposed to be closed. When power is removed from the main fuel valve the heater should also be switched off.

To achieve this protection, connect the main fuel valve power to the ‘BURNER ON I/P’ terminals and check that relay RL10 is compatible with the voltage connected e.g. 110 or 240 VAC. For installations where there is no risk of explosion, connect a constant mains supply to terminals 52 and 53. Refer to Figure 3.2.

Before the heater supply voltage will be applied to the heater, RL10 must be on. It is normally interlocked with the burner, which will provide the relay coil voltage to terminals 52 and 53.

If trim enable is attempted by pressing the ‘NEUTRAL’ button on the inside keyboard, or the ‘NEUTRAL’ button on the door before the relay RL10 is turned on, the message ‘BRNR OFF’ will be displayed on the lower line.

Figure 3.2 Heater Supply Interlock Connection For Heated Probes

Figure 3.3 Earth, Shield and Power Connections

3.3 EARTH, SHIELD & POWER CONNECTIONS

All external earthing should be shielded. The printed circuit boards are fully floating above earth. All earth and shield connections should be connected to the earth terminal No. 57.

The mains earth should be connected to a sound electrical earth

Do not connect shields at the field end. Simply clip off and insulate. An extra terminal strip may be required to connect all shields together. This should be supplied by the installer.

Before connection of mains power check that the correct solder links are installed as shown in Figure 3.3.

3.4 CONNECTING THE PROBE CABLE

Connect the probe lead supplied as shown in Figure 3.4. 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.

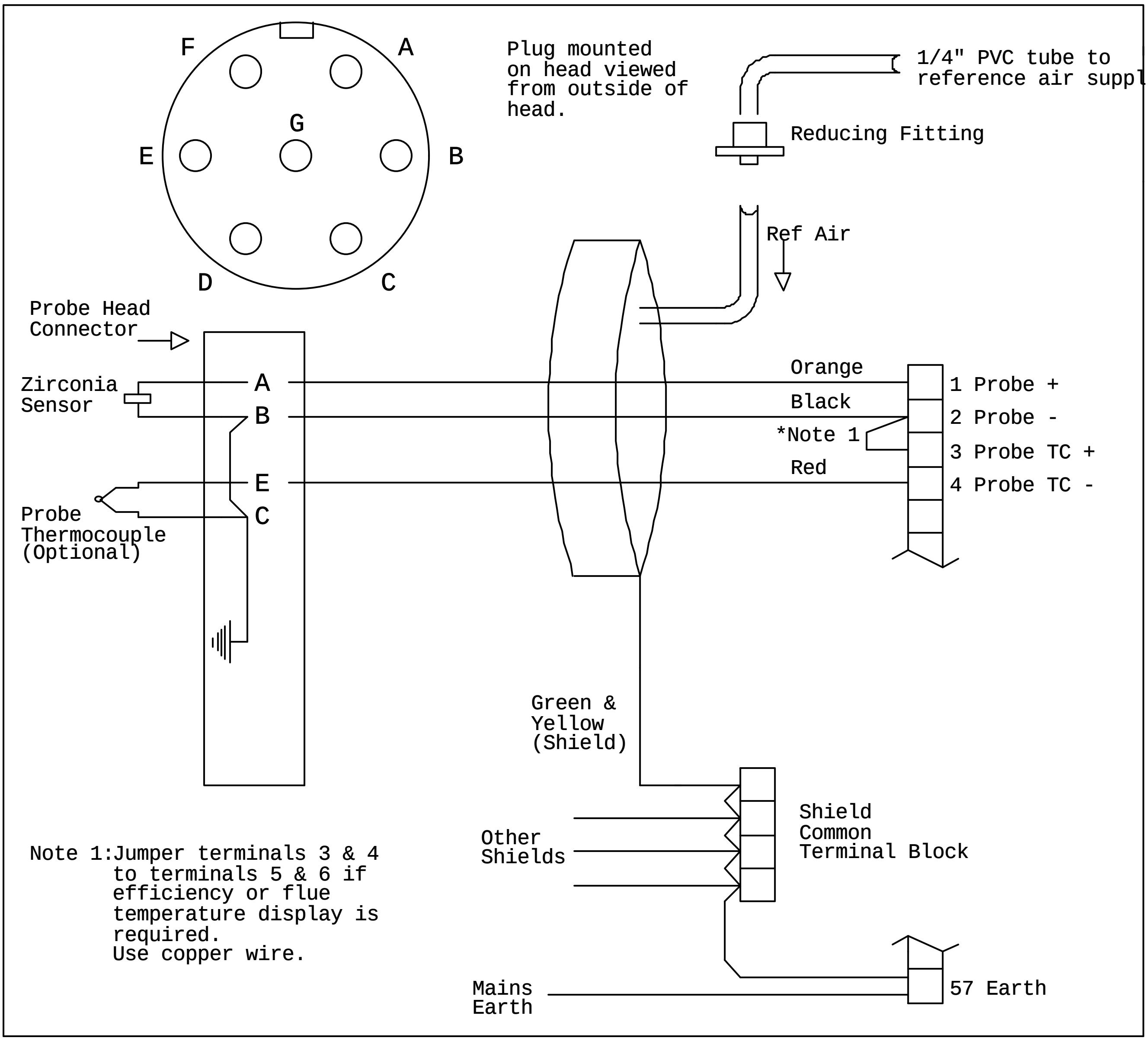

Figure 3.4a Connection of Probe Cable for Unheated Probes Models 1232 and 1233.

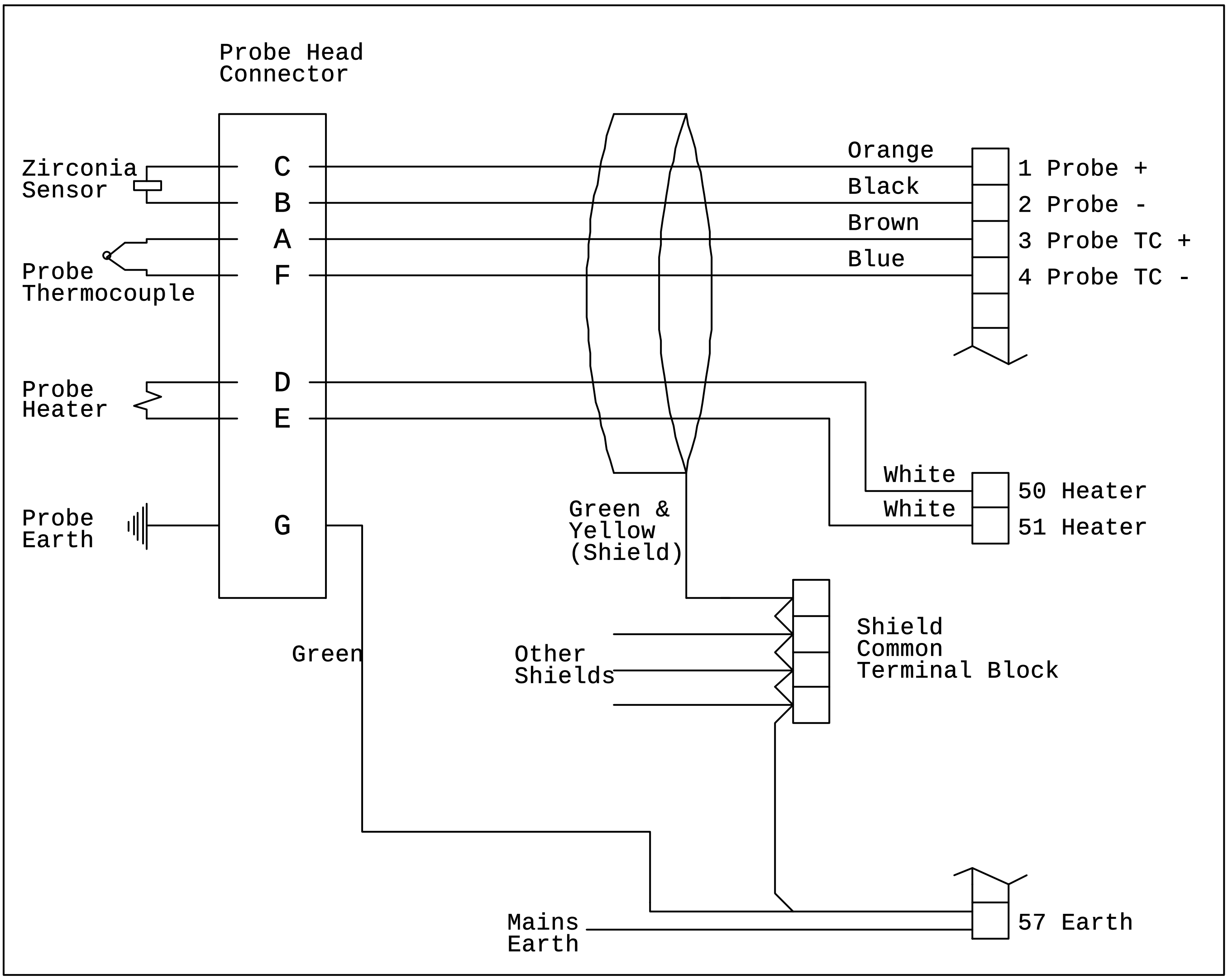

Figure 3.4b Connection of Probe Cable for Heated Probe Model 1231.

3.5 CONNECTING THE STACK THERMOCOUPLE

For heated probes the stack thermocouple must be a separate TC with the junction isolated from earth, mounted near to and upstream of the oxygen probe. It can be any one of types T, J, K, R, S or N. It is optional. If efficiency or flue temperature display or transmitted signals are not required then a flue TC is not necessary. For unheated probes the probe TC can also serve as a stack TC. For this option jumper in copper wire from Terminals 3 and 4 to Terminals 5 and 6.

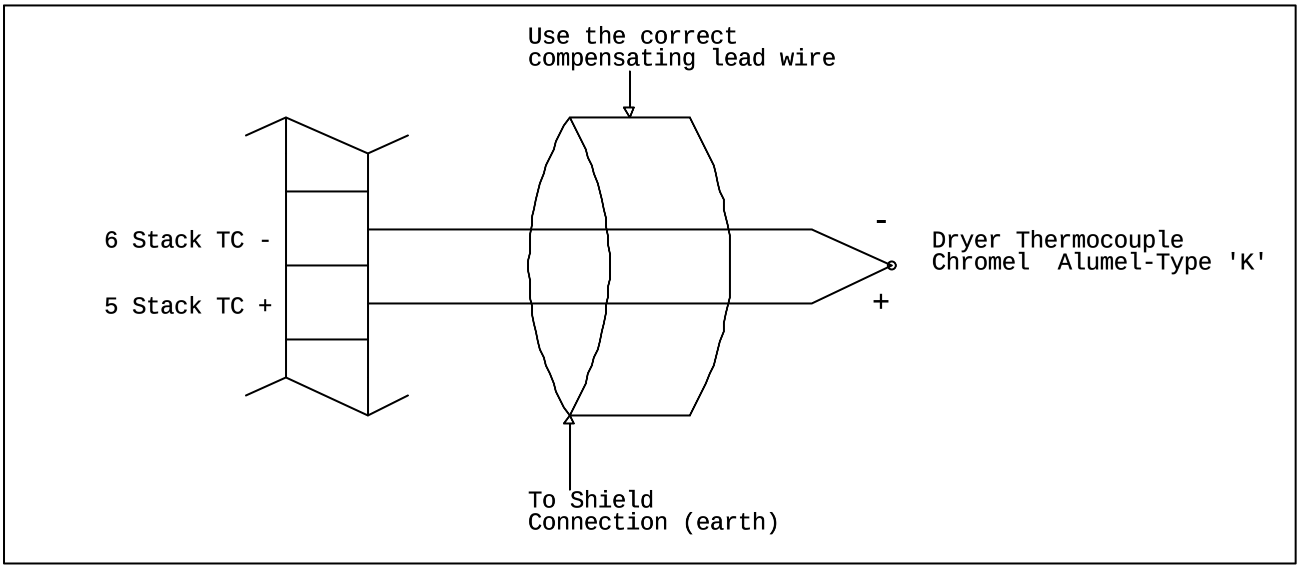

Figure 3.5 Stack Thermocouple Connection

3.6 CONNECTING THE RELATIVE HUMIDITY INPUT

Refer to Section 2.13 for details on this optional input. Mount the relative humidity sensor in a position to sense air with equivalent RH to combustion air.

The RH sensor is only necessary if efficiency is to be calculated. If a RH sensor is not installed, a value of 50% RH is assumed. See Section 5.5.51. For connection details refer to Figure 3.6.

Figure 3.6 Connections for Relative Humidity Sensor

3.7 CONNECTING THE REAR HEAD TEMPERATURE THERMOCOUPLE

An additional input has been provided to accept a type 'K' thermocouple input. It is often used on 'piggy-back' boilers, where the rear head temperature cannot be allowed to exceed a certain limit. This input may be used as a temperature alarm for other purposes, if required. Refer to Figure 3.7.

Figure 3.7 Rear Head Thermocouple Input Connections

3.8 CONNECTING THE AMBIENT TEMPERATURE SENSOR

This input is only required if an efficiency or ambient temperature display is required. The ambient temperature sensor is only required if efficiency is to be measured. Mount the sensor in a position to sense air temperature equal to combustion air. The sensor may be supplied within the relative humidity sensing enclosure or separately if no RH sensor is required. Refer to Figure 3.8 for connection details. Refer to Section 6.8 for calibration of this sensor.

Figure 3.8 Connection of Ambient Temperature Sensor

3.9 CONNECTING THE OUTPUT CHANNELS

The two 4–20 mA DC output channels are capable of driving into a 600 Ω load. Refer to Figure 3.9.

Figure 3.9 Connections for Transmitter Output Channels.

3.10 CONNECTING THE ALARMS

The alarm relay functions are described in detail in Operator Functions, Sections 4.2 and 4.3. Each relay has a normally open contact available. All systems should have the analyser fail ‘ALARM #1’ relay and the probe not TEMP’ relay connected. The other alarm relays are optional. Alarm wiring should be shielded.

3.11 CONNECTING THE HORN RELAY

The horn relay operates as a true alarm system and can be connected directly to a horn. The horn relay is latching and can be reset by pressing the alarm button. Refer to Figure 3.10.

Figure 3.10 Connections for Alarm Horn

3.12 CONNECTING THE AUTOMATIC PURGE AND CALIBRATION SYSTEM

The on-line auto purge and calibration system is optional. For details on its operation refer to Sections 1.1, 2.9 and 2.10. Typical connection details are shown in Figures 3.11 and 3.12.

After installation the purge/cal system should be tested thoroughly for leaks. Any leaks can cause significant errors if the flue is at negative pressure. If the flue is at positive pressure, an outward leak can cause corrosion in the purge/cal system piping and fittings.

If the pump power is taken from terminals 48 and 49, REF PUMP, the pump will be automatically turned off for two seconds every five minutes, to check that the flow switch is functioning correctly. If this is not the way the pump power is connected, select ‘NO’ in set up step 52. The reference air pump and flow switch may both be connected to CN12 at the top of the 1533-3 PCB if they are installed within the 1533 analyser.

Figure 3.11 Automatic Purge & Calibration System
Piping Schematic

Figure 3.12 Automatic Purge & Calibration System
Wiring Schematic

3.13 CONNECTING REFERENCE AIR

A reference gas supply is required for the oxygen probe. Connect as shown in Figure 3.12. Reference air must be clean and dry. The best way to get the reference gas supply is to use the pump supplied in the 1533 cabinet. If the pump and flow switch are supplied in the cabinet, they will be connected to CN12 at the top of the 1533-3 PCB.

A reference air flow switch is required. Connection details are shown in Figure 3.12. The flow switch causes an alarm if the reference air flow is insufficient. Failure of reference air can cause indeterminate errors which may result in a dangerous combustion situation.

Reference air pressure should be regulated to 20 mm W.G. to provide approximately 21% oxygen. As a guide, if the end of the air supply tube is held 15 mm under water, then you should see several bubbles per second. The flow should be sufficient to actuate the reference air flow switch.

Cooling effect errors will occur if the reference air flow is too high. This can be checked by turning the flow on and off while reducing the flow until no difference in oxygen reading is noticed between flow and no-flow.

Figure 3.13 Reference Air Connection

3.14 CONNECTING THE DUAL FUEL INPUT

If burner efficiency is to be displayed or transmitted, and the appliance is capable of firing more than one fuel, then an external contact must be connected for the analyser to determine which fuel is being burnt. See Figure 3.14 for details.

Figure 3.14 Fuel Selector Input Contacts Connection

3.15 CONNECTING THE BURNER FEEDBACK POT

If it is required that the oxygen set point be characterised to the burner firing rate, it is necessary to install a burner fire rate transmitter.

If a fixed set point is to be used, it is entered in the keyboard in maintenance step 16.

The signal must be in the range of 0 to +5 volts (or 1–5 volts if a 4–20 mA device is being used).

The transmitter may be:
1. A potentiometer of from 135–1000 Ω.
2. A Novatech hall effect position transmitter, model BFT-20.
3. A fuel flow transmitter (Input can accept 0–5 volts, or 1–5 volts.
   Refer to Figure 3.15)

Set-up steps 55 and 56 allow the burner to be set to the low fire and high fire positions, and the level of the signal checked. All levels of signal between these two positions are then proportioned to be a percentage between 0 and 100% of firing rate.

Figure 3.15 Connections for Fire Rate Transmitter

3.16 CONNECTING THE TRIM MOTOR

There are two types of output available to drive the trim actuating device. For details refer to Figures 3.16 and 3.17.

The most common method of trimming the air/fuel ratio is to alter the air fed to the boiler in relation to the fuel fed to the boiler. A linear actuator may be used to do this. Inside the actuator is a bi-directional motor and a potentiometer driven by the motor. The length of the actuator is altered by power in either direction. (refer to Figure 3.16.) The link arm that couples the air feed and the fuel feed devices, is replaced by a modified link that contains the linear actuator.

When the ‘DECREASE’ contact (terminal 47), is closed, the actuator must shorten and the wiper of the potentiometer move towards the wire on ‘TRIMPOT LO’ (terminal 23), and the oxygen level at the probe must decrease.

Figure 3.16 Connecting the Trim Motor Contact Output

NOTE:

If the fuel lean/fuel rich directions must be reversed, swap the white and green wires (terminals 21 to 23 and 23 to 21) and the black and white wires (terminals 45 to 47 and 47 to 45)

Figure 3.17 Connecting the Trim Motor 4 –20 mA Output

CAUTION

It is important that, in the event of a failure in the system, it will not be possible for the actuator to be driven far enough to cause a dangerous reduction in the level of oxygen in the boiler.

The actuator should always be used at the short end of its travel, and that the shortest length will be the fuel rich end of its travel. (CO level is less than 400 ppm. anywhere in the boiler firing range.)

The length of travel of the actuator used must be no more than 40mm, and the internal motor limit switch must be set to restrict the maximum travel to this length.

3.17 CONNECTING THE PRINTER

The RS 485–232-C port is available at the connector on the lower right hand side of the main circuit board.

A printer with a serial port, or a data logger, or a computer terminal may be connected to the port.

Data is logged out of the port as arranged in Set-up steps 48 and 49. The baud rate is selectable in step 50. Refer to Section 2.11. The characterisation table can be printed by using maintenance step 23. Refer to Section 6.5.23.

Connection details are shown in Figure 3.18. Note: For the RS 485–232-C port to work as an RS 232-C port, there must be no other connection from the external device back to the transmitter, (including an earth return).

If an RS 485 input is available, the TX+ and TX– may be used as shown in Figure 3.18. A quick release ribbon connector may also be used.

Figure 3.18 Serial Port Connections

3.18 INSTALLING THE 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 1.2. The closer to the source of combustion the smaller will be the sensing lag time, allowing better control. Also the efficiency calculation requires the probe to be as close to the final heat exchange as possible. 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.

It is necessary to angle the probe downwards at about 20 ° minimum angle from horizontal, to avoid water vapour building up in the probe housing. The sensing tip should be lower than the head.

If a flow guide tube is used (heated probes only) it is important that the fin be pointing directly downstream. If the exact flow direction is not known, use a wind vane which can be made from a piece of wire and flat metal. If the flow guide tube is installed facing the wrong direction for any period, the suction filter may block with flue gas dust particles.

The maximum temperature for an unsupported flow guide tube is 750°C (1382°F). Above this temperature provide a support and flanged flexible rubber joint as shown in Figure 3.18. The maximum temperature of a supported flow guide tube is 900°C.

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, it should take approximately ten minutes to install a 500 mm probe moving it in about 20 mm steps.

CAUTION

It is important that there is no air in leakage prior to 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 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.

Figure 3.19 Mounting of Flow Guide Tube

3.19 INSTALLING THE FLUE THERMOCOUPLE

Weld a 1/2 inch BSP mounting socket to the flue within about 300 mm and upstream of the oxygen probe. The thermocouple should be of similar length to the oxygen probe to prevent flue temperature distribution errors.

Figure 3.20a Summary of Typical Boiler Installation Field Connections

Figure 3.20b Alternative Method of Connecting Internal Reference Air Pump and Flow Switch

3.20 CONNECTING POWER — COLD START

In direct fired dryers, before commissioning the probe or transmitter, read the three Caution paragraphs at the front of this manual.

Check that the mains supply voltage link is in the correct place for the supply voltage. To locate this link refer to Section 3.3

After the power is turned on, 'WARM START' will show on the display for a second prior to a microprocessor initialising sequence, which takes about seven seconds.

After a 'COLD START', it is necessary to set all new variables in 'MAINTENANCE' and 'SET-UP' modes, including calibration voltages and time and date.

To perform a 'COLD START', apply power to the transmitter while at the same time holding down one of the nine internal keyboard buttons.

A 'WARM START', which is performed by applying power without holding down an internal keyboard button, will retain all data previously entered in Maintenance and Set-up modes.

3.21 REFERENCE AIR FLOW SWITCH

Ensure that reference air is flowing and that the reference air flow switch is closed by pressing the alarm button to ensure a 'REF AIR FAIL' alarm is not occurring.

3.22 MAINTENANCE MODE

Switch the mode switch to 'MAINT'. Enter the date and time. If the analyser has performed a 'COL
then the reference voltage calibration will have to be performed. If a 'COLD START' has been performed, or a new probe installed then the probe offset will need to be set. Refer to Section 6 for full details on calibration.

3.23 SET-UP MODE

Switch the mode switch to 'SET-UP' and enter all set-up functions as listed in Section 5.

3.24 RUN MODE

Switch the mode switch to 'RUN'. The upper line of the display will now read % oxygen. If the probe is still

Over 650°C the lower line can read a variety of parameters by pressing the 'DISPLAY' button. If the 'ALARM' light is flashing, the 'ALARM' button can be used to display the alarm messages.

'AUTOCAL' for calibration of the D/A 4–20mA sections of the analyser will only operate if the mode switch is NOT in 'RUN' mode.

up step 57, the ‘NEUT’ value entered for point number one is used to determine the length of the trim actuator in ‘NEUTRAL’ mode.

Note: When not in ‘RUN’ mode, all automatic control of the trim motor is suspended. The trim controller output is frozen and oxygen trim is disabled.

3.26 AUTO/MANUAL MODE

The trim motor control actuator on the modulation motor is normally automatically controlled to maintain the correct oxygen content. It may be manually adjusted however, to any position by toggling the ‘AUTO/MAN’ button on the inside keyboard.

When in ‘MANUAL’ mode (‘M’ is flashing in the upper right corner of the display), the trim motor control actuator can be manually moved by using the ‘TRIM↑’ and the ‘TRIM↓’ buttons on the inside keyboard.

3.27 HEATER BY-PASS SWITCH

Heated probes should have their heater supply interlocked with RL10. If the combustion appliance is not running, then power will not be supplied to the heater.

To commission an oxygen probe when the main burner is turned off, switch power off the analyser, remove the probe from the mounting point, and connect the lead with the probe laying on a metal or ceramic surface external to the flue and capable of withstanding 700°C.

Re-apply power to the analyser, press the burner by-pass switch into the ‘DOWN’ position. This will apply power to the probe heater even when the plant is not running. The probe offset can now be set and calibration checked with appropriate calibration gases (typically 2% oxygen in nitrogen).

Ensure that the burner by-pass switch and the power are turned off before the probe is re-installed. An alarm will occur if the burner by-pass switch is turned on (down) during normal operation.

If any alarms are present, the alarm LED should be lit, either flashing or steady. To interpret the alarms, press the alarm button until all alarm functions have been displayed. Rectify the cause of each alarm until no further alarms appear on the display. For details on the operation of the alarm button and the alarm functions refer to Section 4.

3.28 PROBE CALIBRATION

The zirconia sensor in the probe provides an absolute measurement of oxygen partial pressure. There are no calibration adjustments, apart from ‘PROBE OFFSET’, for the probe. The probe EMF is either correct or the probe is faulty.

To check that the probe is functioning correctly, firstly check that the high probe impedance alarm is not activated. The display would show ‘SENSOR FAIL’. The actual impedance can be displayed on the lower line.

Once it is established that the probe impedance is normal, the probe offset may be tested and set (Refer to Section 6.5.12). A small flow of air must be admitted to both the ‘REF’ and ‘CAL’ ports when testing probe offset. Gas calibration tests can be carried out. Apply a calibration gas, typically 2% oxygen in nitrogen to the ‘CAL’ port and gradually increase the flow until a correct oxygen reading is obtained. If the flow rate is too low a high reading will normally result. If the flow rate is too high then temperature differential errors will occur at the sensor. Use approximately 0.3 l/minute.

3.29 DUST IN THE FLUE GAS

For unheated probes with no filter, entrained solids or dust in the flue gas do not present a problem unless the dust, when settled, is not porous. Allow the dust in the process to build up on the probe. It will form a porous layer slowing the response time.

To avoid mechanical abrasion of the electrode material, pack ‘SAFFIL’ or equivalent alumina based ceramic fibre in the sensing holes to protect the electrode. Do not use silica based ceramic fibres such as ‘KAOWOOL’, which can attack the electrode at high temperatures. Once the dust has built up, the response time of the probe will be slower.

For heated probes, the preferred method of mounting for dust laden applications is facing vertically downwards with the filter removed. With no filter some errors in gas calibration can occur when the gas sample has an oxygen content significantly different from that of the flue gas. Allow for this when setting auto-calibration tolerances in the set-up mode.

Probes can also be mounted horizontally with no filter with some dusts. An occasional automatic back purge is helpful in this case.

Normally, heated probes are supplied with filters for dusty applications or with flow guide tubes with filters. The probe response time should be tested when the probe is first installed, and then regularly until it remains constant for a significant period. Filter purging should be set to the time periods determined by these tests. To test the probe response time, use a stop watch to obtain the time for a probe to achieve a 63% change from one reading to another.

If a probe filter blocks completely in a short period of time, then there is no option but to use the probe without the filter. A trial probe with filter is available to test whether filter blockage is likely to occur.

3.30 STRATIFICATION

If the analyser and probe have been fully tested and the oxygen readings in the flue gas are incorrect, gas stratification may be occurring.

The phenomena cannot be anticipated for any particular installation. Generally, large flues have oxygen differences of approximately one percent across the flue. Occasionally an oxygen error of several percent may occur in a flue of any size. This problem is normally solved by moving the probe to a new location.

OPERATOR FUNCTIONS

4

SECTION
NUMBER

OPERATOR FUNCTIONS (RUN MODE)

4.1 DISPLAY BUTTON

The upper line on the display will always read % oxygen. The following are available for display on the lower line.

1 PROBE EMF. (Millivolts)

2 PERCENT EFFICIENCY

3 PROBE TEMPERATURE

4 FLUE TEMPERATURE

5 AMBIENT TEMPERATURE

6 REAR HEAD TEMPERATURE, A separate type 'K' thermocouple input alarm. Can be used as rear head temperature alarm for piggy-back boilers or for another temperature input.

7 DATE — TIME

8 RUN HOURS

9 DATE OF LAST SERVICE

10 RELATIVE HUMIDITY. (If RH sensor is connected)

11 PROBE IMPEDANCE. A measure of integrity of the sensor's electrode, the part of the probe that normally wears out first.

12 PERCENT CARBON DIOXIDE, dry. Calculated from the oxygen reading. Assumes complete combustion.

13 SETPOINT OXYGEN PERCENT The current oxygen setpoint can be displayed (either calculated from the characterisation table, fixed local, or remote input) as well as the current firing rate in percent.

Any number of these variables can be displayed sequentially by pressing the 'DISPLAY' button. Items can be selected for display or deleted in Set-up step 11 on the technicians keyboard.
In addition to the above lower line displays the analyser will automatically display:

14 TRIM POSITION. Shows the position of the trim actuator or the trim modulation mo tor.

15 PROBE UNDERTEMP. When the probe is below 650 °C

16 PROBE CALIBRATION, occurring for Cal Gas

17 PROBE PURGE occurring

18 TRIM ENABLED/DISABLED. For approximately one second after either the inside 'NEUTRAL' button or the front door 'NEUTRAL' button is pressed, one of these two messages will be displayed, to indicate the new status of the trim controller.

19 ALARM. If 'ALARM' is displayed after pressing either of the 'NEUTRAL' buttons, there is an alarm currently active and trim will not be enabled. All alarms must be removed before trim can be enabled.

20 BURNER OFF. if there are no alarms, but the heater supply relay RL10 (See Section 3.2) is not on when trim enable is attempted, (See Section 3.25) this message will be displayed.

NOTE

The run time will be the period of time the fuel valve contract is closed (i.e. main fuel valve open). If no explosion protection is required, a permanent bridge between the fuel valve terminals to mains power will register run time whenever the analyser is powered. This timer can be used as a probe replacement and/or boiler service schedule aid. The start time is reset by changing the ‘SERVICE DAY’ in Maintenance mode on the technicians keyboard. (Refer to Section 6.1.3)

Figure 4.1 Operator's Panel

4.2 ALARM BUTTON

Repeatedly pressing the operators ‘ALARM’ button will produce alarm displays in sequence on the lower line of the LCD display. If an alarm has cleared prior to pressing the ‘ALARM’ button, it will not re-appear on a second run through the alarms. Active alarms which have been previously displayed will have ‘ACC’ (accepted), displayed alongside. New alarms will not have ‘ACC’ displayed until a second press of the ‘ALARM’ button. After the last active alarm is indicated, the lower line of the display will return to the last displayed lower line variable.

The alarm ‘LED’ will flash on alarm. Pressing the ‘ALARM’ button will cause the LED to go steady if any alarms are still active, or extinguish if there are no active alarms. The hom relay will operate when an alarm occurs. Pressing ‘ALARM’ will mute the horn relay which will re-initiate on any new alarms.

The alarm LED will flash on alarm. Pressing the ‘ALARM’ button will cause the LED to go steady if any alarms are still active, or extinguish if there are no active alarms.

The horn relay will operate with alarm relays RL3, 4 and 5. Pressing ‘ALARM’ will mute the horn relay, which will re-initiate on any new alarms.

4.3 ALARM SCHEDULE

4.3.1 SUMMARY OF ALARMS

All alarms will activate the ‘ALARM #1’ relay.

ALARM	DESCRIPTION
‘SENSOR FAIL’	Oxygen cell or electrode failure (high impedance)
‘PROBE HEATER FAILURE’	In the first 20 minutes of power being applied to the heater after being switched on, this alarm will not occur, but a ‘PROBE UNDER–TEMPERATURE’ display will occur and relay RL8 will be activated. Refer to Section 6.13.
‘PROBE TC O/C’	Probe thermocouple is open circuit. The heater in heated probes will switch off.

ALARM	DESCRIPTION
‘REF AIR FAIL’	Low reference air flow to probe.
‘FLOW SWITCH’	The reference air flow switch has failed. This is tested by automatically switching off the reference air pump once every ten minutes for three seconds to check the operation of the flow switch. See set up step 52.
‘A/D CAL ERROR’	The analog to digital converter has been found to fall outside the normal calibration specifications. This is an electronic fault.
‘A/D MAINS ERROR’	Total failure of the analog to digital converter (IC15) or of the mains frequency signal from the power supply used to synchronise the A/D converter.
‘D/A CAL ERROR’	The digital to analog and voltage isolator circuit has been found to fall outside the normal calibration specifications. This check is only performed when the ‘AUTO CAL’ button is pressed in ‘SETUP’ or ‘MAINT’ modes Refer to Section 6.6.
‘FILTER BLOCKED’	Blocked probe filter, low purge flow. This test is only performed when automatic purging of the probe is requested. Refer to step 30 in the set-up menu Section 5.5.
‘GAS-1 CAL ERROR’	Probe does not correctly calibrate to calibration gas 1.
‘HEATER BY-PASS’	The safety interlock relay has been bypassed by turning on the ‘BURNER BY-PASS’ switch on the terminal printed circuit board. Refer to Section 3.2 and 3.27
‘OXYGEN VERY LOW’	The oxygen level has been below the level set in set up step 45 for more than the time set in set up step 46
‘WATCHDOG TIMER’	This alarm will not appear on the display. The ‘RESET’ light will flash on every watchdog timer time-out.

4.3.2 SUMMARY OF OTHER ALARMS

All of these alarms will operate relays other than the common alarm relay See section 4.3.3 Summary of Alarm Relays

ALARM	DESCRIPTION
‘LOW OXYGEN’	Low oxygen alarm has been selected in set up step 41, and the oxygen level has been below the level set in set up step 42 for more than the time set in set up step 43.
‘OXYGEN DEVIATION’	Deviation oxygen alarm has been selected in set up step 41, and the oxygen deviation from set point level has been greater than the level set in set up step 42 for more than the time in set up step 43.
‘HIGH OXYGEN’	The oxygen is above the level set in set up step 44.

ALARM	DESCRIPTION
'REAR TEMP HIGH'	The rear head temperature thermocouple on terminals 16 and 17 is above the temperature set in set up step 47, or is open circuit.

4.3.3 SUMMARY OF ALARM RELAYS

ALARM NO.	FUNCTION	LATCHING
1	Watchdog/Very Low Oxygen %	No
2	Common Alarm/Neutral/Auto Cal-Purge Occurring	No
3	Oxygen Deviation/Low Oxygen	No
LO TEMP	Probe Not Ready	No
HORN	Horn Driver	Yes

NOTE

The 'PROBE NOT READY' relay is used with unheated probes to indicate that the oxygen reading is invalid (the probe is below 650 °C), in case the process temperature falls below this level. For heated probes, this relay will be energised while the probe is heating up from ambient.

4.4 NEUTRAL BUTTON

There are two 'NEUTRAL' buttons. One is on the door of the 1533, the other is on the inside keyboard, labelled 'NEUTRAL'. They serve the same purpose. Pressing either 'NEUTRAL' button with the mode switch in will toggle between 'TRIM' and 'NEUTRAL' (trim disabled) modes.

If the message 'ALARM' appears on the lower line of the display while pressing the 'NEUTRAL' button, there is an active alarm. This alarm must be removed before trim will be enabled. The burner must be on, or the message 'BURNER OFF' will be displayed. Refer to Section 3.25

4.5 NEUTRAL LAMP

When the 'NEUTRAL' lamp, either on the door or on the inside keyboard is on, the 1533 is in the 'TRIM

4.6 AUTO/MAN BUTTON

The 'AUTO/MAN' button is on the inside keyboard. It is used to toggle between automatic trim or neutral control of the trim actuator, and manual adjustment using 'TRIM↑' and 'TRIM↓' buttons. Refer to Section 3.26

4.7 AUTO AND MANUAL INDICATORS

The status of the auto manual modes is indicated by either a flashing 'M' or 'A' on the right hand end of the top line of the display.

'M' — Manual adjustment of actuator.
'A' — Automatic trim or neutral (depends on neutral status)

4.8 TRIM - AND TRIM ¯ INDICATORS

When the 'M' is flashing on the display, (Refer to Sections 4.6 and 4.7), the 'TRIM↑' and 'TRIM↓' buttons may be used to adjust the trim actuator.

CAUTION

If the boiler is running when this is done, be careful not to adjust the oxygen content too fast or too low as to cause a dangerous gas mixture in the boiler.

When the ‘TRIM↑’ button is used, the actuator should move in a direction to increase the amount of oxygen in the boiler. If the oxygen decreases, swap the connections on terminals 45 (motor control, increase excess air) and 47 (motor control, decrease excess air), or if a 4–20 mA modulating motor is being used, change 4–20 mA FWD/4–20 mA REV in Set-up step 54 Section 5.5

4.9 RESET LAMP

A steady illumination indicates that the power is on to the analyser. When the lamp is flashing, it indicates that the watchdog timer is timing out and trying to reset the analyser. This only occurs when:

1. The power is first applied to the analyser. This is normal start up procedure.

2. There has been a major hardware failure. If the lamp continues to flash, and the ‘ERROR’ lamp is also lit, call Novatech Controls or your agent for assistance.

3. There has been a short burst high intensity interference. The watchdog timer will allow the analyser to automatically recover from the interference without danger, including automatically going to out of trim mode to neutral mode for safety.

4.10 ERROR LAMP

As a safeguard in case the microprocessor fails, a watchdog timer will attempt to restart it every second. The ‘RESET’ lamp will flash on every attempt. If however, the analyser does not respond to a reset, the ‘ERROR’ lamp will be lit within two seconds. At the same time, the ‘ALARM #1’ relay will be activated.

SETTING UP THE ANALYSER

5

SECTION
NUMBER

SET UP MODE SUMMARY

5.1 SET UP MODE FUNCTIONS

1. Sensor Type
2. Probe Thermocouple Type
3. Flue Thermocouple Type
4. Rear Thermocouple Type
5. Transmitter Output Channel 1
6. Transmitter Span Channel 1

Set up steps 7 to 9 will be skipped automatically if Motor Driving is not selected in set up step 57.

7. Transmitter Output Channel 2
8. Transmitter Zero Channel 2
9. Transmitter Span Channel 2
10. Centigrade/Fahrenheit Selection
11. Lower Line Display Functions
12. Flue Pressure mm/inches/kilopascals
13. Flue Pressure Value
14. Single or Dual Fuel
15. Type of Fuel #1
16. Fuel #1 ‘A’ Value
17. Fuel #1 ‘H’ Value
18. Fuel #1 ‘O’ Value
19. Fuel #1 ‘N’ Value
20. Fuel #1 ‘S’ Value
21. Fuel #1 ‘M’ Value

Set-up steps 14 to 21 will be skipped automatically if Efficiency or CO_2 are not selected in Set-up step 7.

22. Type of Fuel #2
23. Fuel #2 ‘A’ Value
24. Fuel #2 ‘H’ Value
25. Fuel #2 ‘O’ Value
26. Fuel #2 ‘N’ Value
27. Fuel #2 ‘S’ Value
28. Fuel #2 ‘M’ Value

Set-up steps 22 to 28 will be skipped automatically if Single Fuel is selected in Set-up 14.

29. Purge/Cal Time
30. Automatic Purge
31. Time Between Purges
32. Purge Duration
33. Purge Freeze Time

Set-up steps 31 to 33 will be skipped automatically if Automatic Purge is not selected in Set-up step 30.

34. Automatic Gas Calibration Check
35. Oxygen Content of Cal Gas 1
36. Maximum Acceptable Positive Error Gas 1
37. Maximum Acceptable Negative Error Gas 1
38 Period Between Gas 1 Autocals
39. Duration of Autocal Gas 1
40. Freeze Time Gas 1

Set-up steps 35 to 40 may be skipped automatically, depending on the selection in Set-up step 34.

41. Deviation or Low Oxygen Alarm Select
42. Deviation or Low Oxygen Trip Level
43. Deviation or Low Oxygen Delay Time
44. High Oxygen Alarm

↓’ to decrement to the previous function.

5.4 ENTER OPTION OR VALUE

A. Options.

To step through the available options for each function press the 'OPTION _' or 'OPTION

When the required option is selected press the 'ENTER' button. An asterisk will then appear alongside the option selected. When stepping through the set-up functions, the display will always first indicate the last options entered. The 'LOWER LINE SELECT' and 'DATA TO PRINT' functions 11 and 48 are multiple options. One or more options may be selected for these functions.

B Values

To set a value for a particular function press the 'OPTION _' button to increase the value and the 'OPTION ' button to decrease the value. A momentary press will change the value one digit. Holding the button will change the value more quickly.

Once the correct option or value is displayed it can be entered into the analysers memory by pressing the 'ENTER' button. When a value has been entered an asterisk will appear at the R.H.S. of the lower line.

The only exceptions to this entry method are the date/time real time clock function of the 'MAINT' mode.

5.5 SET UP FUNCTION DETAILS

1. SENSOR TYPE

Options :

Model No.	Enter the probe in use
1. 1231	Heated Probe
2. 1232	Unheated Probe
3. 1233	Unheated Probe for high sulphur applications (cermet sheath)

2. PROBE THERMOCOUPLE TYPE

The probe can have either a type K, R, or N thermocouple as a sensor temperature detector.

Options :

1. K	Check in the manual
2. R	Section 1 for the probe
3. N	Model No. Enter the correct TC type.

3. FLUE THERMOCOUPLE TYPE

Select the flue thermocouple type.

Options :

1. T
2. J
3. K
4. R
5. S
6. N
7. Nil

NOTE:

For heated probes the flue thermocouple is a separate sensor from the oxygen probe and should be mounted near to and upstream from the probe. It is optional.

If no thermocouple is required, select option ‘NIL’. In this case efficiency and flue temperature read-outs will not be operable.

With an unheated probe, the thermocouple within the probe may be used to sense flue temperature. In this case connect Terminals 3 and 4 to Terminals 4 and 6 with copper wire.

4. REAR THERMOCOUPLE TYPE

The thermocouple type for boilers that require a temperature measurement at the rear of the firing chamber may be selected. This temperature may then be displayed on the lower line (See set up step 11), and will cause an alarm if the temperature rises above the level set in set up step 47.

5. TRANSMITTER OUTPUT CHANNEL ONE

Select the type of output required from channel 1. Linear is the most common output required. The Logarithmic output is often used where analog indicators give an exploded view of the oxygen range near stoichiometry. You can draw your own scale using data in Appendix 3.

Options :
1. Linear
2. Logarithmic
3. Reducing

The reducing output is for special applications requiring extreme reducing conditions e.g. ceramic surface treatment.

Linear output spans are adjustable in set-up step 6.

The logarithmic output is fixed at 0.1–20% oxygen and the reducing output is fired at 10^{-1} to 10^{-25}% oxygen. If either of the latter two are selected in set-up step 5 then set-up step 6 will be skipped.

6. TRANSMITTER SPAN CHANNEL ONE

Applicable only to linear outputs Select transmitter span for output channel one. For combustion applications, typical linear spans are 0–10% or 0–15% oxygen.

7. TRANSMITTER OUTPUT CHANNEL TWO

Select transmitter output for channel two. Note that this step and steps 8 and 9 will be skipped if ‘4–20mA O/P FWD’ or 4–20mA O/P REV’ is selected in set up step 57.

Options :
1. Probe EMF
2. % Carbon Dioxide dry
3. % Efficiency
4. Flue Temperature °C
5. 0.1–20% oxygen logarithmic
6. 1 x 10^{-1} to 10^{-25}% Oxygen (for reducing conditions)

8. TRANSMITTER ZERO CHANNEL TWO

The output zero and span of channel two is set in set-up steps 8 and 9. Range limits are shown below.

9. TRANSMITTER SPAN CHANNEL TWO

OUTPUT	ZERO RANGE	SPAN RANGE
PROBE EMF	0–1100 mV in 100 mV steps	100–1300 mV in 100 mV steps
CARBON DIOXIDE	0–10%	2–20%
EFFICIENCY	0% fixed	100% fixed
FLUE TEMPERATURE	0–1000 °C in 100 °C steps	100–1400 °C in 100°C steps
LOG OXYGEN (see Note 1)	0.1 % oxygen fixed	20 % oxygen fixed
REDUCING OXYGEN (see Note 2)	10^{-1} –10^{-10}% oxygen in one decade steps, non overlapping	10^{-1} –10^{-25}% oxygen in one decade steps. Min span two decades

NOTE

1 For log oxygen scale details, Refer to Appendix 3.
2 Note that the reducing oxygen span is shown on the display as the exponent only. -1 represents 10^{-1} % oxygen.

10. CENTIGRADE/FAHRENHEIT SELECTION

Select whether displays and outputs are to be in °Celsius or Fahrenheit

Options:
1. Celsius (Centigrade)
2. Fahrenheit

11. LOWER LINE DISPLAY FUNCTIONS

In the run mode the upper line on the LCD display will always read % oxygen. The lower line can be set to read one or more of the following. Select as many as are required to be displayed by pressing the ‘ENTER’ button. Those selected will have an asterisk displayed alongside.

Options:
1. Probe EMF
2. Efficiency (see Note)
3. Probe temperature
4. Flue temperature (see Note)
5. Ambient temperature
6. Rear head temperature
7. Date — time
8. Run hours since last service
9. Date of last service
10. Relative humidity
11. Probe impedance
12. Carbon dioxide
13. Oxygen setpoint/fire rate
14. Trim actuator position

NOTE

A flue thermocouple on terminals 5 and 6, or unheated probe TC, jumped from Terminals 3 to 4 (Refer Section 3.5) must be fitted to obtain a proper reading on 9 or 11. Sensors must be connected to obtain a proper reading on 4, 13 and 14.
If no lower line options are required then do not enter any. If options already selected are required to be deleted, select the required option and press the 'ENTER' button. The asterisk will be remo ved.

12. FLUE PRESSURE

The average flue operating pressure must be entered. Select whether to enter in inches W.G., mm. W.G. or Kilopascals.

Options :
MM W.G.
Kilopascals
Inches W.G.

13. FLUE PRESSURE VALUE

Enter flue pressure e.g. 3 mm W.G.

Limits :
-200 to +200 mm W.G.
-9 to +9 inches W.G.
-200 to +200 kpa.

14. SINGLE OR DUAL FUEL

Enter single or dual fuel (for the efficiency calculation). This step and steps 15 to 28 will be skipped if efficiency is not selected in set-up steps 7, 11 or 48 for display or output to the printer port.

Options :
Single/Dual

15. TYPE OF FUEL NUMBER 1

If efficiency is not selected in set up steps 7, 11 or 54, steps 14 to 28 will be skipped. Select fuel type #1. If the fuel constants in Appendix 1 are not correct for your fuel, they can be altered and entered. Two special fuel options are available if the required fuel designation is not on the list in Appendix 1.

16. FUEL NUMBER 1 'A' VALUE

Enter the correct value of 'A' (Refer notes in Appendix 1).

17. FUEL NUMBER 1 'H' VALUE

Enter the correct value of 'H' (Refer notes in Appendix 1).

18. FUEL NUMBER 1 'O' VALUE

Enter the correct value of 'O' (Refer notes in Appendix 1.)

19. FUEL NUMBER 1 'N' VALUE

Enter the correct value of 'N' (Refer notes in Appendix 1).

20. FUEL NUMBER 1 'S' VALUE

Enter the correct value of 'S' (Refer notes in Appendix 1).

21. FUEL NUMBER 1 'M' VALUE

Enter the correct value of 'M' (Refer notes in Appendix 1).

For single fuel applications the next set-up step will be 29, for dual fuel the next step is 22

22. TYPE OF FUEL NUMBER 2

Select fuel type 2. If the fuel constants in Appendix 1 are not correct for your fuel they can be modified as in set-up step 14. Refer Appendix 1

23. FUEL NUMBER 2 'A' VALUE

Enter the correct value of 'A' (Refer notes in Appendix 1).

24. FUEL NUMBER 2 'H' VALUE

Enter the correct value of 'H' (Refer notes in Appendix 1).

25. FUEL NUMBER 2 'O' VALUE

Enter the correct value of 'O' (Refer notes in Appendix 1).

26. FUEL NUMBER 2 'N' VALUE

Enter the correct value of 'N' (Refer notes in Appendix 1).

27. FUEL NUMBER 2 'S' VALUE

Enter the correct value of 'S' (Refer notes in Appendix 1).

28. FUEL NUMBER 2 'M' VALUE

Enter the correct value of 'M' (Refer notes in Appendix 1).

29. PURGE/CAL TIME

Set the purge time to occur at the correct time-of-day. If purging is not required but on-line auto gas calibration is required, enter a time-of-day value suitable for the auto calibrations. Cal Gas 1 will be tested ten minutes after the purge/cal time. If neither purge nor auto calibration is required, ignore the time setting.

Range :
0–23 hours in one hour steps.

30. AUTOMATIC PURGE

For oil and coal fired plant, sensor filters if fitted, should be back-purged with sufficient frequency to avoid blocked filters. The output will be frozen during purging. If no purge is required, set-up steps 31, 32 and 33 will be skipped.
Options:
Yes
No

31. TIME BETWEEN PURGES

Set the time between purges e.g. a two hourly purge or a 100 hourly purge.

Range:
1–199 hours

32. PURGE DURATION

Set up purge duration to a number between one and ten seconds. The filter is actually purged in less than one second, but three seconds are required for the purge flow switch to check that the filter is not blocked.

Range :
1–10 seconds

33. PURGE FREEZE TIME

After the purge period the transmitter output will remain fixed (frozen) for an adjustable period to allow the probe reading to return to the correct process level and avoid output ‘bumps’. The freeze period time required will depend on the probe response time and thus its design, and whether it has a filter or not. To determine the required freeze time, manually perform a purge while the plant is in operation and note the time required for the reading to return to the correct process level within approximately 0.5% oxygen.

Range :
10–1000 seconds in ten second steps

34. AUTOMATIC GAS CALIBRATION CHECK

During the timed calibration periods the transmitter outputs will be frozen, and the analyser will alarm if readings are not within the accuracy limits sets in set-up steps 36 and 37. If autocal is not required enter ‘NO CAL GAS’, and the transmitter will step to set-up 46.

Options:
No Cal Gas
Single Cal Gas

35. OXYGEN CONTENT OF CAL GAS 1

Enter value of Cal Gas 1 (to one decimal point).
Range :
0.1 – 21 % oxygen

36. MAXIMUM ACCEPTABLE POSITIVE ERROR GAS 1

Set the maximum positive error above which the ‘AUTOCAL ERROR HIGH’ alarm will be initiated after the timed period set in set-up step 39.
Range :
0.1 –3.0% oxygen

37. MAXIMUM ACCEPTABLE NEGATIVE ERROR GAS 1

Set the maximum negative error below which the ‘AUTOCAL ERROR LOW’ alarm will be initiated after the timed period set in set-up step 39.
Range :
0.1 –3.0% oxygen

38. PERIOD BETWEEN GAS 1 AUTOCALS

Set the number of hours between autocal Gas 1. A typical time would be 24 to 168 hours. (Daily or weekly).

Range:
1–1999 hours

39. DURATION OF AUTOCAL GAS 1

Set the number of seconds that the autocal gas solenoid will be open. At the end of this period, if the oxygen level measured is not within the limits set for Cal Gas 1, an 'AUTOCAL ERROR' will initiate. To determine the minimum time required for a particular length or design of probe to settle, manually admit cal gas while observing the oxygen reading in 'RUN' mode. Typical minimum times vary from 15 seconds to 90 seconds, depending on the probe length and gas plumbing arrangement.

Range:
1–90 seconds

40. FREEZE TIME GAS 1

After the Cal Gas 1 period, the transmitter output will remain fixed, (frozen) for an adjustable period to allow the probe reading to return to the correct process level and avoid output 'bumps'. The freeze period time required will depend on the probe response time, and thus its design and whether or not it has a filter.

Range:
10–100 seconds in ten second steps
To determine the required freeze time, manually perform a calibration with Gas 1 while the plant is in operation and note the time required for the reading to return to the correct process level within approximately 0.5% oxygen.

41. DEVIATION OR LOW OXYGEN ALARM

Select whether ALARM #3 is to be an oxygen deviation from set point or a low oxygen alarm. The alarm level and the delay-before-alarm is set in steps 42 and 43.

The two alternatives are available in set up steps 42 and 43.

42A. OXYGEN DEVIATION ALARM

Set the alarm level for the oxygen deviation. For example, if the oxygen set point was 5.0% oxygen, and the deviation alarm was set to 1.0%, the oxygen deviation alarm would be initiated if the actual oxygen level exceeded 6.0% or fell below 4.0%, after the delay time set in step 43.

Range:
0.1 – 21.0% oxygen

42B. LOW OXYGEN ALARM ALTERNATIVE

Set the operating point for the low oxygen alarm relay. Typically set at 2.0% oxygen, depending on the burner, it can be used as a safety warning.
Range:
0.1 –100% oxygen

43A. OXYGEN DEVIATION DELAY

Typically set at 30 seconds. This delay is to avoid nuisance alarms when the burner is undergoing transitions in firing rate which can cause it to deviate from the oxygen set point, but recover quickly.

Range:
0–200 seconds.

43B. LOW OXYGEN ALARM TIME DELAY ALTERNATIVE

Typically set at 30 seconds, this delay is to avoid nuisance alarms when the burner is undergoing a sudden transition in firing rate, which can cause it to produce reducing oxygen levels but then recover to normal.

Range:
0–200 seconds

44. HIGH OXYGEN ALARM

Set the operating point for the high oxygen alarm relay.
Range:
0.1 –100% oxygen

45. VERY LOW OXYGEN ALARM

Set the operating point for the very low oxygen alarm relay, typically 0.5% oxygen. This limit can be used as a shut down on a boiler as the normal operating level should never be this low. A separate relay, 'ALARM #1' is activated when the oxygen is below this level.

46. VERY LOW OXYGEN ALARM DELAY

Set the very low oxygen alarm delay to the smallest possible period to avoid nuisance alarms/shut-downs, but still maintain the fastest response to a fuel rich atmosphere. ALARM #1 contacts should be wired to the safety shut-down of the boiler.

47. REAR HEAD TEMPERATURE HIGH ALARM

Set the alarm level for the rear head thermocouple input.
Range:
0–1400 °C

48. DATA TO PRINT

Any or all of the following values may be printed on a printer or computer connected to the 1533. They may be selected or de-selected using the 'ENTER' buttons as in set-up step 11. The log period follows in set-up steps 49 to 50. A sample of a print-out is contained in Appendix 4. RS232-C protocol is as follows:

Data word length	Eight bits
Stop bits	One
Parity	None

Options:
1. Probe EMF
2. Efficiency (see Note)
3. Probe temperature
4. Flue temperature (see Note)
5. Ambient temperature

6. Rear head temperature
7. Date — time
8. Run hours since last service
9. Date of last service
10. Relative humidity
11. Probe impedance
12. Carbon dioxide
13. Oxygen setpoint/fire rate
14. Trim actuator position

49. PRINT LOG PERIOD

Select the time interval between data print-outs on the printer.

Range :
1–2000 minutes

50. PRINTER BAUD RATE

Select the correct BAUD rate of data to be transmitted to the printer.

Options:
300
1200
2400
4800
9600

51. RELATIVE HUMIDITY SENSOR CONNECTED

For improved accuracy in the calculation of efficiency of the burner, the air inlet relative humidity may be measured and included in the calculation. Provision has been made on Terminals 7 and 8 for a 0 to +1 volt signal, proportional to 0–100% RH. If an RH sensor is not available, the option 'SENSOR NOT CONNECTED' may be used to set a constant RH input of 50%.

Options:
1. Sensor Connected
2. Sensor Not Connected.

52. SWITCHED REFERENCE AIR SUPPLY

It is recommended that the reference air supply for the oxygen probe is supplied to the probe through a flow sensor (See Section 3.13 Connecting Reference Air). The pump that supplies the reference air supplied by Novatech can be installed inside the 1532 transmitter. The power lead of the pump is connected to terminals 48 and 49 (See Figure 3.2). The flow switch contacts are connected to terminals 26 and 27 (See Figure 3.12).

The flow switch would be on all the time, with the possibility that the float in the sensor may stick. To exercise the switch and to actually check its reaction to a break in reference air flow, the power to terminals 48 and 49 (Ref air pump) is interrupted for about three seconds every five minutes.

If a plant air supply is being used, a mains voltage solenoid valve may be used to switch the reference air supply off. Connect the coil of the solenoid to terminals 48 and 49 (Ref air pump). If a switched reference air supply is not being used, select 'NO' to inhibit the 'FLOW SWITCH' alarm.

Options
1. YES
2. NO

53. DAMPING READINGS AVERAGED

In most installations, the response time of the probe to gas fluctuations is too fast. Adjustable damping of these unwanted fluctuations is done by a rolling average of a number of the most recent readings of oxygen. For example, if the number of samples averaged was set to five, the time constant of the display and the 4–20 mA output signal will be about 12 seconds.

54. TRIM CONTROL ACTUATOR

The trim actuator may be a 4–20 mA input or contacts for driving a motor up and down. The 1533 analyser may also be used to monitor the boiler only, without actually trimming the oxygen. In this mode, the analyser will still produce alarms on oxygen deviation etc., but will disable the output to the trim actuator.

55. BURNER MINIMUM

In order to calibrate the burner fire rate transmitter for the range of low fire to high fire, the minimum and maximum positions for the transmitter must be entered into the analyser. Set the boiler to low fire and press the ‘ENTER’ button. This will record the value for the transmitter.

56. BURNER MAXIMUM

Set the boiler to high fire and press ‘ENTER’. This will record the value for the transmitter.
Range:
0 – 500

If the difference between the values entered for low fire (Setup step 54)and high fire is less than 150, the message ‘SPAN IS LOW’ is displayed on the lower line of the display. In this case, readjust the linkages to the fire rate transmitter until a greater arc is covered by the transmitter. If the linkages are altered, re-enter set-up steps 54 and 55.

57. SET POINT OPTION

The set point is the level of oxygen in the boiler that the 1533 analyser will attempt to maintain. This set point may be selected to come from either a calculated level which is ‘CHARACTERISED’ from the burner firing rate using the characterisation table entered by the user (Refer to Maintenance Sections 6.5.17 to 6.5.23), a ‘LOCAL FIXED’ set point. (Refer to Maintenance Section 6.5.16), or a 4 20 mA ‘REMOTE’ signal from terminals 24 and 25 (REM SP +/-).

Options:
1. Characterised
2. Local Fixed
3. Remote

Note that when ‘LOCAL FIXED’ or ‘REMOTE’ set point is selected, the ‘NEUTRAL’ position, ‘PROPORTIONAL BAND’ and ‘DEAD BAND’ are still entered into the characterisation table in Maintenance Mode. (Refer to Sections 6.5.18 and 6.5.20 to 6.5.23). If it is not required to have the ‘NEUTRAL ’ position, ‘PROPORTIONAL BAND’ and ‘DEAD BAND’ characterised to the burner fire rate, then remove the fire rate transmitter fromterminals 18, 19 and 20, and replace it with a link between terminals 19 and 20. Now the ‘NEUTRAL’ position, ‘PROPORTIONAL BAND’ and ‘DEAD BAND’ may also be entered into POINT #1.

58. NEUTRAL ALARM?

Select the option ‘YES’ if it required to have external indication of the analyser in neutral (no trim) mode (see Section 4.3.3, SUMMARY OF ALARM RELAYS).

The analyser can provides an open contact on alarm relay #2 when the analyser goes to neutral mode. Neutral mode will occur if

-The boiler appliance main fuel valve closes (see Section 3.2, HEATER INTERLOCK RELAY).
-The probe temperature is under 650 °C.
-An alarm occurs.

If external NEUTRAL indication is not required, select ‘NO’, and press ‘ENTER’.

MAINTENANCE

6

SECTION
NUMBER

TRANSMITTER MAINTENANCE

PROBE MAINTENANCE

ANALYSER MAINTENANCE

6.1 MAINTENANCE MODE SUMMARY

1. ENTER DATE, YEAR
2. ENTER DATE, MONTH
3. ENTER DATE, DAY
4. ENTER TIME, HOURS
5. ENTER TIME, MINUTES
6. SET 20MV REFERENCE (CALIBRATION)
7. SET 70MV REFERENCE (CALIBRATION)
8. SET 1200MV REFERENCE (CALIBRATION)
9. SET 2500MV REFERENCE (CALIBRATION)
10. SET CALIBRATION FACTOR FOR 4–20 MA CHANNEL #1
11. SET CALIBRATION FACTOR FOR 4–20 MA CHANNEL #2
12. SET PROBE OFFSET (PROBE CALIBRATION)
13. ENTER SERVICE YEAR
14. ENTER SERVICE MONTH
15. ENTER SERVICE DAY
16. ENTER LOCAL SET POINT
17. CHARACTERISATION ENTRY METHOD
18. ENTER CHARACTERISATION POINT #
19. SET FIRING RATE CHARACTERISATION POINT VALUE
    SET OXYGEN LEVEL CHARACTERISATION POINT VALUE
20. SET NEUTRAL TRIM POSITION CHARACTERISATION POINT VALUE
21. SET PROPORTIONAL BAND CHARACTERISATION POINT VALUE
22. SET DEAD BAND CHARACTERISATION POINT VALUE
23. SET FINISHED OPTIONS
24. PRINT CHARACTERISATION TABLE.

6.2 SET-UP/MAINTENANCE/RUN/SWITCH

For the ‘MAINTENANCE’ mode on the keyboard to operate, move the toggle switch to ‘MAINT’. The outputs will be frozen when in maintenance mode. If purges or auto calibration occur while the mode switch is in ‘MAINT’ they will be delayed until the mode switch is returned to ‘RUN’.

6.3 FUNCTION SWITCH

When the ‘SET-UP/MAINTENANCE/RUN SWITCH’ is moved to ‘MAINT’, the display will automatically read the last maintenance function selected. To select other functions operate the ‘FUNCTION ↑’ button to increment to the next function, or the ‘FUNCTION ↓’ to decrement to the previous function.

Figure 6.1 Internal Technicians Keyboard

6.4 ENTER VALUES

To set a value for a particular function press the 'OPTION↑' button to increase the value and the 'OPTION ↓' button to decrease the value. A momentary press will change the value one digit. Holding the button will change the value more quickly. Once the correct option or value is displayed, it can be entered into the analysers memory by pressing the 'ENTER' button. When a value has been accepted an asterisk will appear at the R.H.S. of the lower line, (except for calendar date and time values).

6.5 MAINTENANCE FUNCTIONS DETAIL

1. ENTER YEAR DD/MM/YR

Enter year e.g. 04-08-92 = 4th August, 1992.

2. ENTER MONTH

Enter month.

3. ENTER DAY

Enter day.

4. ENTER HOURS

Enter hours e.g. 22:04 = 10.04 pm.

5. ENTER MINUTES

Enter minutes.

6. SET 20 MV REF.

Enter the 20 mV reference voltage to calibrate the transmitter.

7. SET 70 MV REF.

Enter the 70 mV reference voltage.

8. SET 1200 MV REF

Enter the 1200 mV reference voltage.

9. SET 2500 MV REF

Enter the 2500 mV reference voltage.

Functions 6 to 9 are used to calibrate the A/D of the instrument. This should be done 30 minutes or more after the instrument has been on, approximately once every year. The calibration constants are retained in battery backed memory unless a 'COLD START' is performed. Refer to Section 3.20.

Connect a 3½ digit multimeter negative lead to the terminal marked 'COMMON' to the left of the internal keyboard. Measure the four test point voltages on the test pins marked 1 to 4 below the common test pin with the positive lead. Refer to Figure 6.2

These voltages should be approximately:
1) 2482 mV
2) 1159 mV
3) 64.4 mV
4) 18.9 mV

Enter the measured values in functions 6 to 9. Whenever new values are entered the D/A section should be re-calibrated, Refer to Section 6.6.

Figure 6.2 Location of Calibration Test Points

10. SET CALIBRATION FACTOR FOR 4–20 CHANNEL #1

The calibration of the 4–20 mA outputs is done by reading back the output into the input and calibrating this against a known standard. The standard however, may vary from analyser to analyser. To allow for this a trim factor has been provided to set the calibration of each channel for your particular analyser. These two values should only have to be entered once for the life of the instrument, then the only calibration of the outputs should be to press the ‘AUTOCAL’ button every six months.

To determine the factors, generate a full scale value to be sent to the output. eg. For Channel #1, if set up steps 5 and 6 were set for a full scale output of 10% oxygen, then generate input signals until the top line of the display reads 10% oxygen. This is best done with the use of a Novatech probe simulator test box, but can also be achieved with a millivolt generator.

Read the output of channel #1 with a three and a half digit multimeter.
i.e. The output should be 20mA.
If your meter reads 19.65mA.
20.00 – 19.65 = 0.35
(0.35/19.65) *100% = 1.78% error.

Enter the value of 101.8 into ‘MAINT’ step 10, 4 20 mA #1 CAL, and press ‘AUTOCAL’ before leaving the maintenance mode.

NOTE

The accuracy of the output channels without trimming these factors is generally within 2% after using the ‘AUTOCAL’ procedure. In most cases the instrument can be used without this further trimming of the calibration.

e.g., if ‘PROBE OFFSET’ was 0.8 mV, enter 0.8 mV.

When reading the EMF offset the flue pressure compensation must be set. If the probe has been removed from the flue, set the flue pressure compensation to 0 in set-up step 6.16.

13. ENTER SERVICE YEAR

For a new ‘DATE OF LAST SERVICE’, enter the service ‘YEAR’. This can represent the last time the probe was serviced or the last time the boiler was serviced. It is recommended that probes be refurbished every two years

14. ENTER SERVICE MONTH

Enter the current MONTH.

15 ENTER SERVICE DAY

Enter the current DAY of the month.
Altering this value will reset the ‘RUN TIME’.

convenient to actually set the boilers, measuring the CO levels, and observing the flame to obtain the optimum point and have the microprocessor register this level.

'MANUAL' entry is used when the characteristics of the boiler are already known. To avoid having to make all of the actual measurements on the boiler, the table can simply be entered manually.

The firing rate, % oxygen, neutral position, proportional band and dead band can be entered for each of up to ten characterised points.

Options:
1. Manual
2. Actual

18. ENTER CHARACTERISATION POINT

Up to ten positions can be used to form a characterised curve for flue gas oxygen level (air/fuel ratio), and neutral position. It is important that the whole of the firing range be covered. For best accuracy, the greater the variations through the firing range, the greater the number of points should be entered. Use the option buttons to select the point to be edited, and press 'ENTER'.

Range:
1 – 10

19. SET FIRING RATE CHARACTERISATION POINT VALUE

If 'MANUAL' was selected in characterised entry mode, this function allows for the fire rate at which the following oxygen, neutral, proportional band and dead band values are to be related.

If 'ACTUAL' was selected, the fire rate % and the actual oxygen % are read from the burner feedback transmitter and oxygen probe, and are entered into the characterisation table when the 'ENTER' button is pressed..

SET OXYGEN LEVEL CHARACTERISATION POINT VALUE

For each firing rate adjusted on the burner, a number would have been displayed on the lower left hand side of the display. Once the burner has been correctly set by observing the CO level and the flame, the actual oxygen level will be displayed. This can be entered in memory by pressing the 'ENTER' button. As usual, an asterisk will appear on the right hand side of the display once the value has been selected.

20. SET NEUTRAL TRIM POSITION CHARACTERISATION POINT VALUE

Using the trim motor 'INCREASE/DECREASE' buttons while in 'RUN' mode, the burner should be driven to an excess air position suitable for the trim controller to drive the trim motor to in case of failure or alarm. To determine the oxygen level at any particular trim setting, switch the mode switch to 'RUN'.

If 'MANUAL' was selected in step 17, read the trim motor position after it has been set in 'RUN' mode from the lower line, (see 5.5.11, Trim Actuator Position), and use the 'OPTION' buttons to enter this value. If 'ACTUAL' was selected in step 17, check and enter the neutral position of the trim motor by switching the main mode switch back to 'MAINTENANCE' and pressing the 'ENTER' button.

21 SET PROPORTIONAL BAND CHARACTERISATION POINT VALUE

Enter a typical proportional band, e.g. 2.0%, and switch to 'RUN' mode so that the boiler can trim. If no hunting occurs (control cycling or overshoot), reduce the proportional band setting by approximately half and check for hunting.

Hunting may be induced by switching the trim motor to 'MANUAL' via the 'AUTO/MAN' button on the keyboard, and driving it a short distance, then switching back to 'TRIM'. Continue this process until hunting is induced into the trim system. Then switch back to 'MAINTENANCE' mode and increase the proportional band setting by a factor of two. e.g. if the proportional band was at 4%, increase to 8%.

Switch again to 'RUN' mode and allow the boiler to trim, inducing a process 'bump' on the trim motor to check that hunting will not be induced in normal operation.

22. SET DEAD BAND CHARACTERISATION POINT VALUE

The next step is to set the dead band. The dead band sets the sensitivity of the system and could be typically set at 0.2%.

The dead band is measured and set in % oxygen, i.e. a setting of 0.2% DB will allow the actual oxygen reading to fluctuate 0.1% either side of the set point without any control being taken by the analyser.

Too wide a dead band setting would allow the system to drift to slightly beyond the dead band. Too narrow a dead band will cause the trim motor to operate too frequently and maybe even hunt. The trim motor should not be activated more than about once every minute under steady state conditions.

23. SET FINISHED OPTIONS

Once the complete burner range from low fire to high fire has been covered by characterisation entry points, select 'FINISHED', press 'ENTER' and then 'FUNCTION↑'. A complete table of oxygen, neutral, proportional band and dead band positions, for each firing rate entered, will be printed on a printer if connected to port number two. If no printer is connected there will be some delay while the processor writes the necessary table information to the serial port.

24. PRINT CHARACTERISATION TABLE

Printing the characterised table is in progress. Wait six seconds for completion, and the set-up menu will return to set-up step 1.

6.6 D/A CALIBRATION

If a 'COLD START' is performed (Section 3.21), then the D/A section of the analyser will be automatically calibrated. The D/A section should be manually re-calibrated after the instrument has been switched on for 30 minutes and stabilised. (See Section 6.5.10 and 6.5.11, calibration factor for the 4–20 mA channels) This is achieved by pressing the 'AUTO CAL' button. This button should be pressed bi-annually, or if the reference voltages are altered in 'MAINT'. Refer to Section 6.5, items 6 to 11 to re-calibrate the D/A converter and isolated output section. An 'AUTO CAL' will be performed in three seconds after pressing the button. The transmitter outputs will go to 0 mA and 20 mA for this three second period.

6.7 BACK-UP BATTERY REPLACEMENT

The back-up battery is contained within the module, plugged into socket IC2. It is rated for an average service life of 38 years with power on, and for ten years with the power off. The battery is not re-chargeable and should be replaced every year.

After replacing the battery module, re-enter all maintenance and set-up mode functions.

6.8 ELECTRONIC REPAIRS

Electronic schematics are included in Appendix 6. A competent electronic technician could perform troubleshooting with these schematics, aided by the analyser self-diagnostic alarms.

It is recommended that service be performed on a change-over circuit board basis. A fast turn-around or replacement service is available from Novatech or accredited service agents.

Other service aids, including a firmware package and input simulator are also available from Novatech. These two items are invaluable if fast diagnosis and fault isolation is required.

PROBE MAINTENANCE

6.9 TEST EQUIPMENT REQUIRED

All measurements are simplified if an analyser is connected to the probe. Readings can then be easily taken of probe impedance, EMF, temperature and percent oxygen. The analyser also provides proper heater control for heated probes.

The following tests are described using readily available workshop equipment where an analyser is not available. If an analyser is available the same test procedures will apply. First check all alarms on the analyser, allowing time for the probe to heat up after switch on.

An instrument to measure probe EMF and temperature is required. A 3 ½ or 4 ½ digit multimeter will perform both measurements. A separate temperature indicator to suit the probe thermocouple type is also useful, although not necessary.

A reference air pump is required and a cylinder of calibration gas e.g. 2% oxygen in nitrogen. The cylinder should have a pressure and flow regulator. Both of these are inexpensive devices available from gas supply companies. The calibration gas should be chromatograph tested to an accuracy of 0.1% oxygen.

UNHEATED PROBES

A small test furnace capable of raising the probe tip temperature to 720 °C is required. The furnace should have a uniform temperature for about 50 mm either side of the sensor tip.

HEATED PROBES

If a 1533 analyser is available at the test location then no other equipment will be required. If not, then a controllable power source for the heater is required. A Variac (variable transformer), set to approximately 100 volts will regulate the probe temperature to 720 °C approximately.

6.10 TESTING A PROBE

With the probe tip heated to approximately 720 °C, either from a small test furnace or its own internal heater, connect a digital multimeter to the probe electrode conductors. Connect the multimeter positive to the internal electrode conductor. Connect reference air to the probe and also apply a gentle purge of air to the probe calibration port. Reference air flow should be the smallest flow available (less than 50 cc per minute). The multimeter should read zero millivolts ± two millivolts. If not, then there is a problem with the probe electrodes and the sensor needs refurbishing. Normally a faulty probe electrode is indicated with a high source impedance.

To test the source impedance, set the multimeter to read ohms and take a measurement, within a couple of seconds, of the probe impedance. Reverse the multimeter and repeat the reading. Take the average of the two readings for an approximate measurement of impedance. If the impedance is above 2000Ω, then the electrode needs refurbishing. The probe must be at 720 °C or above for this measurement.

The reason that impedance measurements need to be performed quickly, is that the zirconia sensor polarises with the DC voltage from the multimeter across it. Where a probe electrode requires refurbishing it is suggested that they should be returned to Novatech or an accredited service organisation.

If the probe tests reveal less than 2 mV. offset and a good impedance reading, the next step is to apply a calibration gas. The calibration gas should be inserted in the calibration port. With the calibration gas flowing, the probe should develop an EMF according to the tables in Appendix 2. If the EMF reading is low then there may be insufficient calibration gas flow. Increase the calibration gas until the reading is correct. An excessive calibration gas flow will cause cooling on one surface of the sensor, giving temperature differential errors on the sensor.

If the calibration gas flow is high and it is left to flow on a probe at a high temperature for more than about 15 seconds, the ceramic parts of the sensor and probe sheath can be cooled to the point where, when the flow is removed, they can break due to thermal shock. If the flow is kept on for a long time it should be reduced slowly to allow the ceramic surfaces to heat at a rate of not more than 50 °C per minute. ie. To remove a flow which has been running for some time on a probe at 1100 °C, the time taken should be about 22 minutes. The sensor accuracy should be within 0.5 mV. with the same offset which was measured with air on both sides of the sensor. If the probe EMF is not within this tolerance, then it will require the electrodes to be refurbished.

As an alternative, using the reference air port, the calibration gas can be inserted into the inside of the sensor. This requires a lower flow rate, and thus lower usage of calibration gas. The flow rate should be similar to that of the reference air, which should be removed for internal calibration. The probe EMF reading will be identical but negative in polarity. A small flow of air should be flowing over the outside of the sensor, when testing in this way.

Occasionally, a sensor can develop offset with a polluted electrode caused by contaminants in the flue gas stream. In this case, the old electrode material must be completely cleaned off before re-applying the fresh electrode material. Again, return the probe or sensor to Novatech or an accredited service organisation.

6.11 SENSOR IMPEDANCE

If the sensor impedance is found to be high in the test described in Section 6.10 it is occasionally necessary to cause a small movement of the inner electrode conductor to re-establish contact. This is achieved by gently pulling the four bore ceramic tube against its spring loading for approximately 1 mm and slowly releasing. This procedure is normally only required with a probe which has been sitting cold for many months.

With some probes it is possible to view the sensor electrode material from outside the outer sheath. The electrode material should be either grey or green and should fully cover the end of the sensor. If any cream coloured ceramic material is visible at the sensor end, then the electrode has been degraded and will require refurbishment.

6.12 PROBE THERMOCOUPLE

Although some unheated probes are specified without a thermocouple, most probes, both heated and unheated, have an integral thermocouple which is fitted in to the four bore insulator. The analyser has an alarm function which will advise the operator of an open circuit probe thermocouple, however bench testing can be performed by simply measuring the thermocouple continuity. If the thermocouple requires replacement, care should be taken not to physically damage the inner electrode material during removal and replacement of the thermocouple and insulator.

6.13 HEATER FAILURE

For heated probes, a heater failure will cause a ‘PROBE UNDER TEMPERATURE’ or ‘HEATER FAILURE’ alarm. Heaters can be tested from the probe head with a continuity test.

The heater resistance should be approximately 100Ω. Should the heater be open circuit, contact Novatech or an accredited service agent.

6.14 FILTER BLOCKAGE

For oxygen probes or flow guide tubes with filters in installations with entrained solids in the flue gas, it is sometimes necessary to replace the filter. Filters are normally cleared with back purging. However fine fly-ash, or other particles can ultimately completely block a filter necessitating filter replacement. A new probe filter can be fitted by Novatech or an accredited service agent. Flow guide tube filters are field replaceable.

6.15 PACKING

To return a probe for refurbishment to our factory, please ensure that it is properly packed. We recommend a cardboard box which is normally dropped with less force than a heavy wooden box. Use polystyrene beads for internal packing and some cardboard to inhibit end travel of the probe.

Due to the delicate ceramic inner components of the probe, probes improperly packed are normally broken by the time they arrive at our factory.

Refurbishment is normally an inexpensive operation that can be made expensive with improper packing.

APPENDICES

1. CONSTITUENT VALUES FOR VARIOUS FUELS
2. PROBE EMF TABLES
3. % OXYGEN SCALE — LOGARITHMIC
4. CHARACTERISATION TABLES
5. CIRCUIT SCHEMATICS

APPENDIX 1

CONSTITUENT VALUES FOR FUELS

If the analyser is set up to have readout or output of efficiency, then the fuel constituents must be entered. The analyser has preselected values for typical fuels and these may be sufficiently accurate for your purposes. If not, any or all of the variables can be modified and entered in set-up steps 15 to 21 and 22 to 28. (Refer to Section 5.5). Your fuel supplier or chemist should be able to give you all these values.

A is the heat of combustion of the fuel per gram atom of contained carbon.

H is the H/C atom ratio in the fuel.

O is the O/C atom ratio in the fuel.

N is the N/C atom ratio in the fuel.

S is the S/C atom ratio in the fuel.

M is the ratio of H_20 molecules to C atoms in the fuel

FUEL	A	H	O	N	S	M
Blast furnace gas	50.55	0.08	1.30	3.08	b	a
Coke oven gas	256.88	5.60	0.25	0.23	b	a
Producer gas	101.98	1.18	1.02	2.90	b	a
Natural gas	209.90	3.86	0	0.10	0	0
Propane, natural	176.40	2.69	0	0	0	0
Butane, refinery	166.10	2.34	0	0	0	0
Methanol	172.59	3.97	1.00	—	—	—
Gasoline, motor	157.58	2.01	0	0	0	0
No 1 Distillate oil	149.65	1.83	0	—	0	—
No 2 Distillate oil	145.18	1.71	—	—	0	—
No 4 Fuel oil	145.54	1.60	—	—	0.01	0
No 5 Residual oil	142.25	1.44	—	0	0	0
No 6 Residual oil	136.52	1.25	0.01	0	0	0
Wood, non-resinous	110.91	2.26	1.07	0	0	c
Coal, bituminous	116.88	0.74	0.05	0	0	0.03
Coal, anthracite	104.98	0.35	0.05	0	0.01	0.04
Coke	99.63	0.11	0.01	0.01	0	0.01

a. The moisture level varies depending on the process details.
The calculated values assume M = O.

b. The sulphur level varies depending on the process details.
The calculated values assume S = O.

c. Variable.

Values calculated from the North American Combustion Handbook, Tables 2.1a and 2.1b.

APPENDIX 2

PROBE EMF TABLES

ZIRCONIA OXYGEN PROBE OUTPUT (mV), PROBE TYPE 1231

% OXYGEN	mV at 720 ° C
20.0	0.99
19.5	1.53
19.0	2.09
18.5	2.66
18.0	3.25
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
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	**29.965**

Using air as a reference,
the probe e.m.f. is calculated using
the Nernst equation:

e.m.f. = 0.02154 x T x ln (21/ % Oxygen)   in % Oxygen in the gas

These tables are based on the Nernst equation:

Probe e.m.f. = 0.0254 x T x 1n (21/% oxygen),   where T = ° K (° C + 273).

ZIRCONIA OXYGEN PROBE OUTPUT (mV), PROBE TYPE 1232

				TEMPERATURE					
% O2	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**
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’	20.609	24.526	28.456	32.370	36.248	40.076	43.836	47.502	–

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

ZIRCONIA OXYGEN PROBE OUTPUT (mV), PROBE TYPE 1233

	TEMPERATURE								
% O2	**600**	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**
20	-14.310	-15.346	-19.380	-22.511	-25.760	-29.120	-32.570	-36.077	-39.612
19.5	-13.008	-15.776	-18.795	-21.872	-25.066	-28.371	-31.767	-35.219	-38.699
19	-12.520	-15.294	-18.195	-21.215	-24.354	-27.603	-30.943	-34.339	-37.763
18.5	-12.019	-14.735	-17.578	-20.541	-23.622	-26.814	-30.096	-33.435	-36.802
18	-11.503	-14.161	-16.945	-19.849	-22.871	-26.004	-29.227	-32.507	-35.815
17.5	-10.974	-13.571	-16.294	-19.137	-22.099	-25.171	-28.323	-31.553	-34.800
17	-10.428	-12.963	-15.624	-18.345	-21.304	-24.314	-27.403	-30.570	-33.755
16.5	-9.867	-12.338	-14.934	-17.651	-20.485	-23.431	-26.466	-29.559	-32.679
16	-9.288	-11.693	-14.223	-16.873	-19.641	-22.521	-25.490	-28.516	-31.570
15.5	-8.691	-11.027	-13.489	-16.071	-18.771	-21.582	-24.483	-27.441	-30.426
15	-8.075	-10.340	-12.731	-15.243	-17.872	-20.612	-23.442	-26.330	-29.245
14.5	-7.437	-9.630	-11.948	-14.386	-16.942	-19.609	-22.367	-25.181	-28.023
14	-6.777	-8.894	-11.137	-13.499	-15.980	-18.572	-21.253	-23.992	-26.758
13.5	-6.094	-8.132	-10.296	-12.580	-14.983	-17.496	-20.099	-22.760	-25.448
13	-5.384	-7.341	-9.424	-11.627	-13.948	-16.380	-18.902	-21.481	-24.088
12.5	-4.646	-6.519	-8.517	-10.636	-12.872	-15.220	-17.657	-20.152	-22.675
12	-3.879	-5.663	-7.574	-9.605	-11.753	-14.013	-16.362	-18.769	-21.203
11.5	-3.078	-4.771	-6.590	-8.529	-10.586	-12.754	-15.012	-17.327	-19.670
11	-2.243	-3.840	-5.563	-7.406	-9.367	-11.439	-13.602	-15.821	-18.068
10.5	-1.368	-2.865	-4.488	-6.231	-8.092	-10.064	-12.126	-14.244	-16.391
10	-0.450	-1.842	-3.360	-4.998	-6.754	-8.621	-10.578	-12.591	-14.633
9.5	0.514	-0.767	-2.175	-3.702	-5.347	-7.104	-8.950	-10.853	-12.785
9	1.531	0.366	-0.925	-2.336	-3.865	-5.505	-7.235	-9.021	-10.836
8.5	2.606	1.564	0.396	-0.892	-2.297	-3.814	-5.421	-7.085	-8.777
8	3.746	2.835	1.797	0.640	-0.635	-2.021	-3.498	-5.061	-6.592
7.5	4.959	4.187	3.289	2.271	1.135	-0.113	-1.450	-2.844	-4.266
7	6.257	5.633	4.884	4.014	3.026	1.928	0.739	-0.506	-1.780
6.5	7.650	7.186	6.596	5.888	5.058	4.120	3.091	2.005	0.891
6	9.155	8.864	8.446	7.909	7.253	6.487	5.630	4.717	3.775
5.5	10.792	10.688	10.457	10.107	9.639	9.060	8.391	7.665	6.911
5	12.584	12.685	12.660	12.515	12.253	11.879	11.415	10.894	10.345
4.5	14.565	14.893	15.095	15.178	15.142	14.995	14.758	14.464	14.142
4	16.780	17.362	17.818	18.153	18.371	18.478	18.495	18.455	18.387
3.5	19.291	20.160	20.904	21.527	22.033	22.427	22.732	22.979	23.199
3	22.190	23.391	24.467	25.422	26.260	26.986	27.623	28.202	28.754
2.5	25.618	27.212	28.681	29.989	31.259	32.378	33.407	34.380	35.324
2	29.814	31.889	33.838	35.667	37.378	38.978	40.487	41.940	43.365
1.5	35.224	37.918	40.487	42.936	45.266	47.486	49.615	51.688	55.732
1	42.848	46.416	49.858	53.180	56.384	59.477	62.480	65.426	68.344
0.5	55.883	60.944	65.879	70.694	75.390	79.976	84.472	88.911	93.322
0.2	73.113	80.148	87.056	93.845	100.516	107.075	113.545	119.957	126.342
TC mV									
‘R’ x 2.58	5.582	6.741	7.949	9.203	10.503	11.846	13.224	14.624	16.035

1233 Probes use the same Nernst equation as 1232 probes, minus 2.58 x TC e.m.f. (mV).

APPENDIX 3

% OXYGEN SCALE – LOGARITHMIC

% OXYGEN	% FULL SCALE
0.1	0
0.15	7.66
0.2	13.1
0.3	20.7
0.4	26.2
0.6	33.8
0.8	39.2
1	43.5
1.5	51.1
2	56.5
3	64.2
4	69.6
6	77.3
8	82.7
10	86.9
12	90.8
14	93.3
16	95.8
18	98
20	100

APPENDIX 4

SAMPLE PRINT OUT —CHARACTERISATION TABLE

12:46 13/02/90
CHARACTERISED TABLE FOR FUEL 1

1#	10FIRE , 9.0O2% , 100 NT , 4.0%PB , 0.30% DB
2#	20FIRE , 8.0O2% , 100 NT , 4.0%PB , 0.30% DB
3#	30FIRE , 5.0O2% , 100 NT , 3.0%PB , 0.20% DB
4#	40FIRE , 4.0O2% , 100 NT , 3.0%PB , 0.20% DB
5#	50FIRE , 3.0O2% , 100 NT , 2.0%PB , 0.20% DB
6#	60FIRE , 2.0O2% , 100 NT , 2.0%PB , 0.20% DB
7#	70FIRE , 1.8O2% , 100 NT , 2.0%PB , 0.20% DB
8#	80FIRE , 1.5O2% , 100 NT , 2.0%PB , 0.20% DB
9#	90FIRE , 1.4O2% , 100 NT , 2.0%PB , 0.20% DB
10#	100FIRE, 1.4O2% , 100 NT , 2.0%PB , 0.20% DB

Installation Site:
Date:

TABLE #	PEG#	% FIRE RATE	MAX CO (PPM)	MIN OXYGEN%	MAX OXYGEN%	TRIM OXYGEN%	NEUT# POSITION	PROP. BAND,%O2	DEAD BAND,%O2
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

ALARMS-

	LEVEL (%O2)	DELAY (Secs)
DEVIATION		
LOW Oxygen		
VERY LOW O2		
HIGH Oxygen		

APPENDIX 5

CIRCUIT SCHEMATICS