Instruction manual
MTL gas analysers & systems

February 2017
INM MTL 130-0183 Rev 6

CROUSE-HINDS SERIES

Z1030

MTL zirconia oxygen analyser

Powering Business Worldwide

DECLARATION OF CONFORMITY

A printed version of the Declaration of Conformity has been provided separately within the original shipment of goods. However, you can find a copy of the latest version at -

http://www.mtl-inst.com/certificates

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1 INTRODUCTION

1.1 General Description

The Z1030 is a microprocessor controlled oxygen analyser based on a zirconia oxygen sensor. It provides a range of features and a performance without parallel for an analyser of this type and cost. Standard features include auto-ranging over a span of 100% to 0.01ppm, user programmable alarm levels, hysteresis and analogue output. The unique sensor and heater design gives very fast warm-up times, rapid response, and long sensor life.

The instrument measures oxygen over the range of 0.1ppm to 100% in non-reactive gases (nitrogen, argon etc). Standard features include an auto-ranging display over the full span of the instrument, user programmable alarm levels, hysteresis and analogue output.

1.2 Manual symbols

The following methods are used in this manual to alert the user to important information:-

WARNING

Warnings are provided to ensure operator safety and MUST be followed.

CAUTION

A Caution is provided to prevent damage to the instrument.

NOTE

These are used to give general information to ensure correct operation

1.3 Information

Waste Electrical and Electronic Equipment directive (WEEE) 2002/96/EC
(RoHS) directive 2002/95/EC

WARNING

This equipment must only be used in accordance with the manufacturer's specification, instructions for installation, use and maintenance to ensure that the protection of the operator is not impaired. It is the responsibility of the installer to ensure the safety and EMC compliance of any particular installation.

2 SPECIFICATION

2.1 Display

Multi digit LCD- character height 12.7mm

2.2 Display ranges

Standard version: - Display range 0.01ppm to 100%, auto ranging

2.3 Display Resolution

From 100% to 103%	1%
From 10.0% to 99.0%	0.1%
From 1.00% to 9.99%	0.01%
From 0.100 to 0.999%	0.001%
From 100ppm to 999ppm	1ppm
From 10.0ppm to 99.9ppm	0.1ppm
From 0.00ppm to 9.99ppm	0.01ppm

2.4 Accuracy

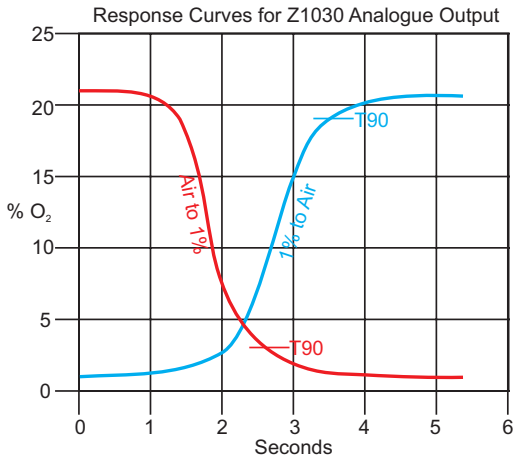
100ppm to 25%	±2% of reading or better
10 - 99ppm	±1ppm
0 - 9.9ppm	±0.1ppm

2.5 Stability

Better than 2% of reading or 0.5ppm/month, whichever is greater.

2.6 Speed of response

T90: less than 4 seconds at 500ml/min sample flow – see graph for details



2.7 Sample flow

Between 100 and 500 ml/min for optimum operation.

2.8 Sample inlet pressure

10mbar to 8bar

The sample is heated to ~650°C in the sensor; only samples that contain non-reactive, non-corrosive gases can be applied – e.g. oxygen in nitrogen, inert gases (Group 0), carbon dioxide etc.

2.9 Sampling system material

Stainless steel, platinum, zirconia, nickel plated brass and nylon.

2.10 Analogue output - isolated

Output (programmable): †	4 to 20mA	0 to 5 volts
Isolation:	1kV *	1kV *
Maximum load:	500 ohms	N.A.
Minimum load:	N.A.	10 kohms
Resolution:	0.01 mA	2.5 mV
Accuracy:	+/- 0.2% of programmed range	+/- 0.2% of programmed range
Linearity:	+/- 0.5%	+/- 0.5%
Minimum under range:	3.8 mA	N.A.
Maximum over range:	20.5 mA	N.A.
Upper error band:	21.0 to 24.0 mA	N.A.

† This is user programmable for full-scale values of between 1ppm and 100% oxygen and zero-scale values of between 0ppm and 90%.
* Isolation must only be considered as forming basic or function insulation as defined in BS EN 61010-1:2010

2.11 Alarm outputs

2 alarms each user programmable for:

Mode - HIGH, LOW or OFF;

Level - full range of instrument.

Hysteresis - 0% to 10% of set point.

Volt free C/O contacts rated at 48V ac or dc, 0.5A, normally energised.

2.12 Serial Communications

RS232 interface, 9600 baud, ASCII protocol (see Section 9)

2.13 Ambient operating temperature range

0°C to 45°C (0- 90% R.H. non-condensing)

2.14 Power requirements

24V DC +/- 10%, 24W
A standalone power unit may be specified at the time of order. (Input: 100 to 240V AC, 50/60 Hz / Output 24V DC)

2.15 Dimensions

Instrument

See Section 4 - Figure 1

Sensor/heater

Maximum overall: 68mm (H) x 150mm (L) x 55mm (W)

Lead lengths: 300mm nominal

Enclosure

See Section 4 - Figure 3

2.16 Weight

Z1030 instrument: 400g

Wall mounted enclosure: 1250g

Mains power adapter: 200g

3 INSTALLATION

3.1 Mounting

The instrument should be installed where free air ventilation around the whole case is provided. The ambient operating temperature should not exceed the value stated in Section 3.13. Dust and dirt should be kept to a minimum.

WARNING
The sensor heater has a hot surface that is present in normal operation. Take care when handling

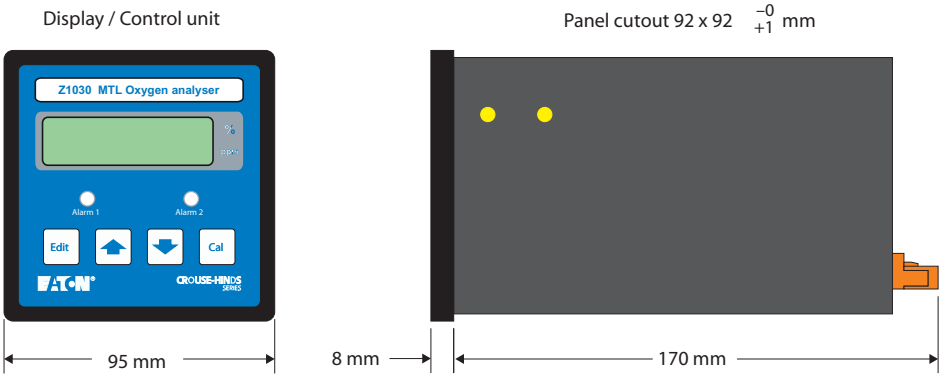


Figure 1 - Instrument dimensions

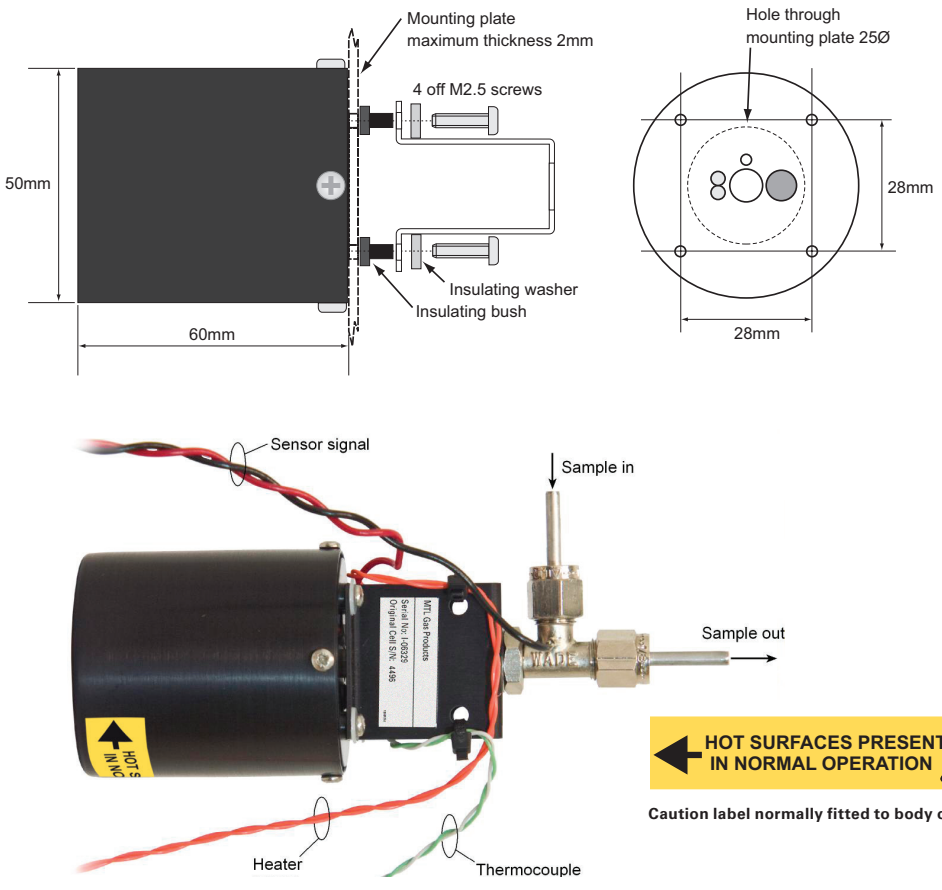


Figure 2 - Stand alone sensor showing mounting bracket detail

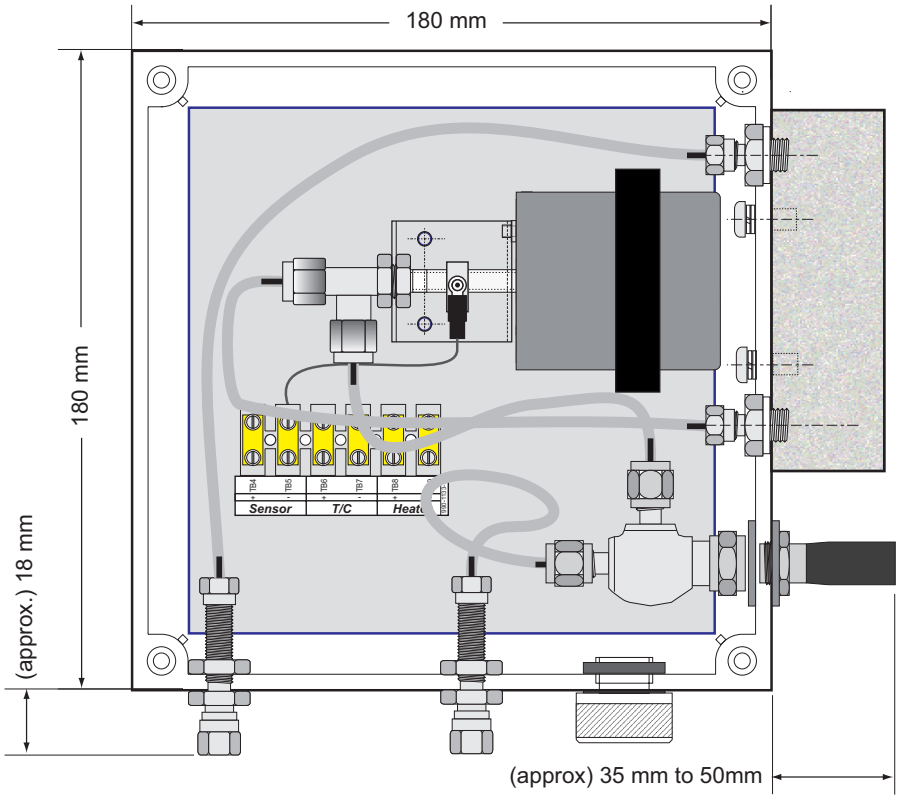


Figure 3 - Sampling system in wall-mounting enclosure

3.2 Sample

WARNING

IT IS IMPORTANT THAT NO FLAMMABLE MIXTURES ARE ALLOWED TO COME INTO CONTACT WITH THE MEASURING CELL AS THIS MAY CAUSE IGNITION OF THE GAS. GASES CONTAINING HALOGENS, SULPHUR OR SILICON, MUST BE AVOIDED. IT IS THE RESPONSIBILITY OF THE USER TO ENSURE THAT ANY ADVICE OFFERRED CAN BE SAFELY APPLIED TO THEIR PARTICULAR SITUATION

CAUTION

THE DEW POINT OF THE SAMPLE MUST ALWAYS BE LESS THAN THE AMBIENT TEMPERATURE TO AVOID THE RISK OF LIQUID DROPLETS FORMING IN THE MEASURING CELL

3.3 Electrical connections

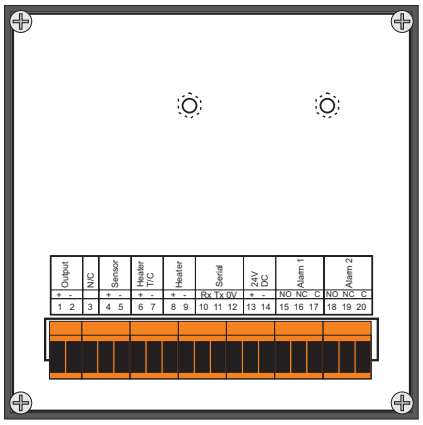
For electrical and mechanical integrity, it is recommended that wires to all connectors are fitted with boot-lace ferrules.

3.3.1 Power supply

Power connections should be made to the instrument using the connector provided. Take note of the supply voltage label on rear of the instrument. The power demand is approximately 24VDC maximum 1A at turn on.

If an external mains power supply option with IEC lead has been chosen (see right), any external fuse should be rated at 5A. As the instrument is low voltage, the only protective earth connection is in the IEC lead.

3.3.2 Alarm and Analogue Output connections



Output		N/C	Sensor		Heater T/C		Heater		Serial			24V DC		Alarm 1			Alarm 2		
+	-		+	-	+	-	+	-	Rx	Tx	0V	+	-	NO	NC	C	NO	NC	C
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

CAUTION

The recommended cable used for external connection is double insulated.

WARNING

ALTHOUGH RELAY CONTACTS ARE RATED AT 48V AC OR DC, VOLTAGES ABOVE 33V AC ARE DEFINED AS HAZARDOUS BY BS EN 61010-1 (SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR MEASUREMENT, CONTROL AND LABORATORY USE). APPROPRIATE PRECAUTIONS SHOULD BE TAKEN WHEN CONNECTING SIGNALS TO ALARM TERMINALS.

3.3.3 Sensor Connection

The sensor and instrument should be interconnected as shown in Table 1. Thermal compensation cable is recommended for connecting the thermocouple.

NOTE

A loose issue cable gland is supplied.
The enclosure will need to be drilled to suit, according to customer requirements.
Suggested location would be between the inlet and outlet ports.

Instrument		Sensor		Description
Sensor +	4	Sensor +	TB4	Sensor signal
Sensor –	5	Sensor –	TB5	Sensor signal
T/C +	6	T/C +	TB6	Thermocouple
T/C –	7	T/C –	TB7	Thermocouple
Heater +	8	Heater +	TB8	Heater power
Heater –	9	Heater –	TB9	Heater power

Table 1

3.3.4 RS232 Connection

Connect the serial RS232 interface as shown in Table 2. See also Section 9- COMMUNICATION PROTOCOL

Instrument			DTE (PC) pin no.	
Conn.	Signal	Description	25-way	9-way
10	RX	Data received by instrument	2	3
11	TX	Data transmitted from instrument	3	2
12	GND	Signal gnd	7	5

Table 2

4 COMMISIONING

4.1 Applying power

When the analyser is fully connected it may be switched on. The cell heater will begin to warm up. During this time the display will flash "HE xxxxx and the concentration display will make high and low excursions. Once the correct temperature is reached, the "HR" will end and the display will stabilise. Allow a further 15 minutes before relying on the oxygen reading. Note that the temperature controller settings are locked and no attempt should be made to change them. The instrument is calibrated prior to shipment and may be used immediately after the warm-up time has elapsed. If, however, you wish to check calibration go to Section 6.

4.2 Programming

The user programmable features are accessed by pressing and holding the Edit button for approximately 8 seconds when the instrument is in normal measurement mode (as turned on). Each momentary press of the "⇧" or "⇩" arrow buttons will then step the display through the following sequence of adjustable parameters.

Analogue Output top-scale value → Analogue Output low-scale value → Alarm 1 Setpoint → Alarm 1 Hysteresis → Alarm 1 Mode → Alarm 2 Setpoint → Alarm 2 Hysteresis → Alarm 2 Mode- then wraps round to start of sequence.

All Programming screens operate on the same principle.

- Use the "⇧" or "⇩" arrows to step through the parameters
- Press "Edit" and the parameter number (xP- see below) will flash, then use the "⇧" or "⇩" arrows to edit the value. Press "Edit" to save any changes or "Exit" to leave value unchanged

4.2.1 Analog output

1P xxxx

Where **"xxxx"** is the oxygen concentration setting required for the top end (20mA / 5V) of the analogue output. To the right of the display a % or ppm symbol is displayed to indicate the measurement units.

2P xxxx

Where **"xxxx"** is the oxygen concentration setting required for the bottom end (4mA / 0V) of the analogue output. To the right of the display a % or ppm symbol is displayed to indicate the measurement units.

4.2.2 Alarm 1

NOTE

All alarm outputs will be in the 'alarm' state while the instrument is booting (for approximately 20 seconds after power on) or if the instrument registers an error, regardless of the alarm setting.

3P xxxx

Where **"xxxx"** is the required concentration level setting that will trigger Alarm 1 - observe the **"%"** and **"ppm"** symbols to ensure the correct setting Hysteresis

4P x.x

Where **"x.x"** is the value of the hysteresis for Alarm 1. The value is in % of the set-point or alarm level and is variable from 0% to 10%.

5P x

Where **"x"** indicates one of the following alarm operating modes.

'0'- Alarm off

'H' – High (alarm when above set point)

'L'- Low (alarm when below set point)

'S' – Status (alarm while cell heater is warming up)

4.2.3 Alarm 2

The operation of alarm 2 is identical to that of alarm 1. Refer to Section 5.2.2.

6P xxxx

Where **"xxxx"** is the oxygen concentration at which Alarm 2 is set.

7P xxxx

Where **"x.x"** is the value of the hysteresis for Alarm 2.

8P xxxx

Where **"x"** indicates the operating mode of Alarm 2.

4.3 Introducing the sample

To measure a flowing sample, establish a flow rate as specified in Section 3.7. The instrument should respond immediately once the instrument heater status is normal. For best results the sample exhaust gas should be vented directly to the atmosphere.

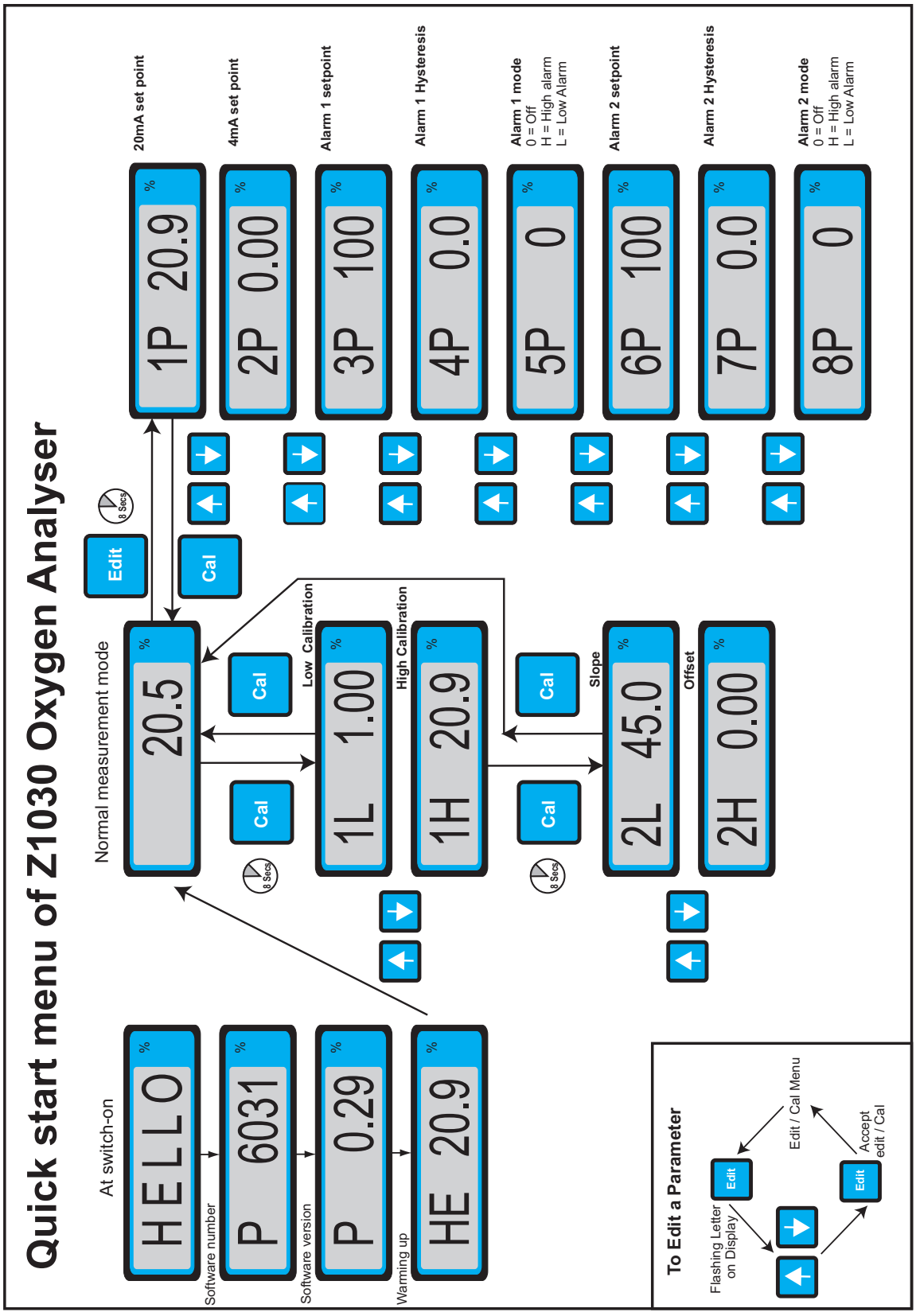


Figure 1 - Instrument dimensions

5 CALIBRATION

CAUTION

Various procedures associated with calibration maintenance affect the outputs of the instrument. Any of these outputs that are being used for control (or the associated control loop) should be disabled before commencing.

5.1 Calibration overview

The Z1030 is a very stable analyser with minimal drift (see Section 3.5). The frequency of calibration checks or verifications depends upon the quality regime being operated at the installation site. Typically, monthly checks are found to be adequate.

The recommended calibration technique starts by checking or verifying the response of the analyser, then altering the calibration of the analyser only if the errors are significant. The readings may be verified by introducing a gas mixture of known concentration (i.e. a calibration gas), allowing the system to stabilise, then checking that the reading is correct.

A full calibration requires the use of two standard gases to establish two points, equivalent to 'zero' and 'span'. (A new user will find probably find it useful to read Section 8, to obtain a technical description of the sensor and how it works).

The gas calibration points are referred to as "high" and "low". Air is frequently used as the "high" gas, while the "low" gas should ideally have approximately the same sort of oxygen concentration that is encountered in a 'normal' sample.

As with most instruments of this type it is important to have a reasonable difference between the two concentration calibration points- H and L. For the Z1030 the recommended difference is around 0.25 decade; i.e. log (H/L) > ±0.25.

Because the most common "high" level gas is air, and in order to maintain an adequate difference in concentration, the instrument will not accept a "low" level calibration gas with a concentration greater than 10%.

5.2 Calibration gases

Because the sensor operates at high temperature, the calibration gases must not contain any flammable or reactive components. Typically this means using mixtures of oxygen with nitrogen, argon or helium; nitrogen is by far the cheapest and most obtainable. If the calibration gases used contain ppm levels of oxygen then take note of the requirements detailed below when measuring ppm gas mixtures.

5.3 Calibration gas piping and cylinder regulators

All piping should be of good quality material with sound joints and couplings.

If concentrations are being measured in ppm units, then the piping chosen must be of hard plastic or metal. Suitable plastics are Nylon 6 and rigid P.V.C., while P.T.F.E. and flexible P.V.C. are not regarded as suitable. Cylinder pressure regulators and gauges should also be chosen carefully. Chose regulators that have a metal diaphragm and pressure gauges that have low volume. These measures avoid contamination and the problem of cavities containing air/ oxygen, which can take several hours to purge.

5.4 Calibration procedure

Refer to Figure 5: 1030 series menu on previous page.

> **NOTE**
>
> Calibration limits are set in the software to prevent the user from calibrating the instrument outside of the sensor's operational range. If, on pressing the Cal button, the reading returns to the original value, the calibration has been rejected, and a change of cell is recommended. Return the instrument to your local MTL Gas sales office.

All calibration screens operate on the same principle :-

- The display shows the present reading. This may be changed by pressing **"Edit"** and then using the "⇧" or "⇩" arrows to adjust the value.
- **"Edit"** saves change.
- **"Cal"** cancels the change.

5.4.1 'High point' calibration

Expose the process side of the cell to air at normal ambient pressure.

Press and hold the **"Cal"** button for about 8 seconds until the display changes to show **"1L xxxx"**, where **"xxxx"** is the gas concentration measured by the instrument (if the button is released before the display changes then the analyser will remain in normal measuring mode).

Cycle through the menu entries using the "⇧" or "⇩" arrows until display shows **"1H xxxx"** (pressing "⇩" at the bottom of the menu returns you to the top).

When the reading has stabilised, press the **"Edit"** button and use the "⇧" or "⇩" arrows to adjust the reading to the correct level, then press the **"Edit"** button to store the calibration setting (or **"Cal"** to cancel).

To return the unit to measuring mode press and release the **"Cal"** button, otherwise the "⇧" or "⇩" arrows until the display changes to **"L xxxx"** to continue with setting the **"Low"** calibration point.

5.4.2 'Low point' calibration

Change the sample gas supply to the **"Low"** level concentration and establish a flow of the gas through the analyser.

In measuring mode, Press and hold the **"Cal"** button for about 8 seconds until the display changes to show **"1L xxxx"**.

In high point calibration, use the "⇧" or "⇩" arrows until the display changes to **"L xxxx"**.

When the reading has stabilised, press the **"Edit"** button and use the "⇧" or "⇩" arrows to adjust the reading to the correct

level, then press the **"Edit"** button to store the calibration setting (or **"Cal"** to cancel).

With the calibration complete press and release the **"Cal"** button to return the unit to normal measuring mode.

5.5 Maintenance

Calibration is the only routine operation that is necessary on a regular basis. However, the response time of the measuring cell will gradually lengthen with use. When the **"Air to 1%"** response time reaches 10 seconds, or more, a change of cell is recommended. The instrument should be returned to your local MTL Gas sales office to enable a replacement to be fitted.

6 SPARES AND REPAIRS

Should any failure occur, the instrument should be returned to your local MTL Gas sales office for repair. When ordering spare parts or raising queries on an instrument, it is important that the serial number is quoted. This will be found on the data label attached to the right-hand side of the instrument.

Our contact details can be found on the back page of this manual.

MTL Gas Products

Z1030
Serial No: I-06723 **Build: 825-9002 / 1**

Gas & Display Range	O/P Type	O/P Range	Alarms
O2 100ppm to 50%	4 to 20mA	Programmable	2xProg

Supply: 220/240V 50/60Hz 10VA Max
Fuse: 400mA (F)

7 TECHNICAL DESCRIPTION OF SENSOR

The zirconia oxygen sensor (see sketch below) is an impervious tube-shaped zirconia (zirconium oxide) element with a closed end coated externally and internally with porous metal electrodes, typically platinum. At high temperatures, typically above 400°C, the zirconia becomes an oxygen ion conductor, which results in a voltage being generated between the electrodes dependent upon the differences between the partial pressures of the oxygen in the sample and the oxygen in a reference gas (generally air). The voltage generated is determined by the Nernst equation:-

$$\text{Cell output} = \frac{2.303RT}{4F} \log \frac{P1}{P2}$$

where:-

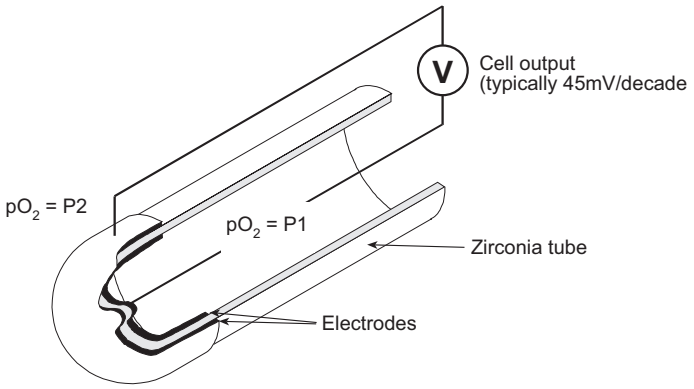
R = molar gas constant

T = absolute temperature of cell in °K

F = Faraday constant

P1 = partial pressure of oxygen in the reference (air in most cases)

P2 = partial pressure of oxygen in the sample.



Thus, with air on both sides of the cell, the output is zero (log1=0).

The reference electrode is negative with respect to the sample electrode for sample concentrations of oxygen higher than that of air and positive for concentrations less than that of air. Depending on the application either the internal or external electrode is used as the reference.

The output voltage is processed electronically to provide signals suitable for display or for process control purposes.

8 COMMUNICATION PROTOCOL

Communication parameters are 9600 Baud, 8 bits, no parity, 1 stop bit and no handshaking.

The instrument is DTE. The general form of the protocol is:

1. The protocol is a single command-and-response protocol. Multiple commands cannot be sent without waiting for a response.
2. A command consists of an "address" and an "action". A command with a valid address will always receive a response even if the action is invalid.
3. A Response consists of a "tag" and "data".
4. A command message can not be more than 30 characters without a message terminator (<CR><LF>). Exceeding this length will result in an error "? 90" response.
5. A response message can not be more than 30 characters without a message terminator (<CR><LF>). Exceeding this length will be assumed to be a communications error.
6. A command message timeout is defined as 10 seconds. This is the maximum time permitted between a valid address "Ax" and the message terminator (<CR><LF>). This time is long to permit keypad entry (e.g. with HyperTerminal).
7. The response message "failure to respond" timeout is defined as 300 milliseconds. This is the maximum time from a valid command message terminator (<CR><LF>) until the first character of the response.
8. A response message line maximum duration is defined as 1 second. This is the maximum time from the first valid response character to the line message terminator (<CR><LF>).
9. A response message maximum duration is defined as 3 second. This is the maximum time from the first valid response character to the last message terminator (<CR><LF>). This is to allow multiple line responses. No card response can hold the bus for more than 3 seconds. Factory commands are the only exception.
10. Exceptions to items 7, 8 and 9 above.
    a) Starting up: The card start up is defined as taking up to 10 seconds. The card will then assert an error "? 97" in R1, R4 and R5 on the first reading after the 10 second period. Subsequent readings will show the correct values.
    b) Calibration obtains exemption from item 7 and 8 but must comply with item 9.

The general form of the response is:

1. Read whole group: 'AxP0' where x is the network address of the unit. The unit will respond when x is its own address or 0 (any unit responds to address 0), otherwise it will not respond at all. If the No Zero Param bit in sysflags is set, 'AxP' OR 'AxP0' to send all.
2. Read specific group item: 'AxPy' where y is the line (or item) number.
3. Write specific group item: 'AxPy=<new value>. The format and (where appropriate) precision of the new value is as it is displayed. With the 'verbose' flag cleared: Py itemname=value unit.
4. With the 'verbose' flag set: Py =value.
5. A read command will return 0 when it has no value to report (e.g. A0E6 returns A0E6=0).
6. A 'do now' write command (e.g. clear logs 'E6') will do nothing if set with a 0 as argument, will execute with a 1 as an argument and will ?93 any other argument. A 'do now' write command returns 0 for fail and 1 for success. E.g. A0E6=1 returns A0E6=1.

Table 1 - Common groups

Send	Function	Reply (verbose)	Reply (terse)	Limits (where applicable)	Notes
AxCy	Calibration	C9 Load def=0	C9=0	0 or 1	Load defaults
		C8 Sens 2 os=0.00	C8 =0.00		N/A
		C7 Sens 2 K=1	C7 =45.0		N/A
		C6 Sens 2 H cal =100%	C6 =0		N/A
		C5 Sens 2 L cal=0%	C5 =100		N/A
		C4 Sens 1 os=0.00	C4 =0.00	Set in I3 (6dp)	Cell offset.
		C3 Sens 1 K=45.0	C3 =45.0	Set in I1,2 (4dp)	Cell slope.
		C2 Sens 1 H cal =100%	C2 =0	Zr limits	Calibrate high.
		C1 Sens 1 L cal=0%	C1 =100	Zr limits	Calibrate low.

Note:- Sending AxC1=xxx calibrates to xxx, and AxC1 RETURNS the last C1 cal value, but changes nothing.
AxC9=1 makes the instrument load HARD CODED DEFAULTS. User will be asked to type 'y' to confirm, or load will be abandoned.

AxDy	Data (read only)	D6 ADC 3 = 12345cts	D6 = 12345	0 to 16777216	ADC raw counts
		D5 ADC 2 = 12345cts	D5 = 12345	0 to 16777216	ADC raw counts
		D4 ADC 1 = 12345cts	D4 = 12345	0 to 16777216	ADC raw counts
		D3 Sens 3 = N/A	D3 =0		N/A
		D2 Sens 2 = 11.56mV	D2 =11.56		Thermocouple mV
		D1 Sens 1 = 11.55mV	D1 =11.55		Oxygen cell mV
AxEy	Error logs (read only except E9)	E9 Clear Log=0	E9=0	1 to clear logs	Clear all counters
		E8 Calibration=0	E8=0	0 to 65353	Calibration error counter
		E7 Sensor=0	E7=0	0 to 65353	Sensors error counter
		E6 AO=0	E6=0	0 to 65353	Analogue output counter
		E5 Float=0	E5 =0	0 to 65353	Float error counter
		E4 CRC=0	E4 =0	0 to 65353	EEPROM CRC error counter
		E3 Other=0	E3 =0	0 to 65353	Other error counter
		E2 Last=0	E2 =0	0 to 99	Last error code
		E1 Current=0	E1 =0	0 to 99	Current error code
AxIy	Input (Read only)	I17 R3 SP=N\A	I17 =N\A	0 to 10	
		I16 R2 BG=N/A	I16 =N/A	8 ascii characters or 0 to 10	
		I15 R2 SP=N/A	I15 =N/A	8 ascii characters or 0 to 10	
		I14 R2 MMW comp=1	I14 =1	0.10 to 5 (2dp)	
		I13 R2 RangeT =100	I13 =100	Instrument range and resolution	
		I12 R2 RangeB =0	I12 =0	Instrument range and resolution	
		I11 R2 Os Range=0	I11 =0	+/-1000 (6dp)	
		I10 R2 K Range=1	I10=0	+/-1000 (2dp)	
		I9 R2 Base K =-4.7	I9=1	+/-1000 (4dp)	
		I8 R1 BG=N2	I8 =N2	8 ascii characters or 0 to 10	
		I7 R1 SP=O2	I7 =O2	8 ascii characters or 0 to 10	
		I6 R1 MMW comp=1.00	I6 =1.000	0.10 to 5 (2dp)	
		I5 R1 RangeT =100	I5 = 100	Instrument range and resolution	
		I4 R1 RangeB =0	I4 = 0	Instrument range and resolution	
		I3 R1 Os Range=0.01	I3 =0.01	+/-1000 (6dp)	
		I2 R1 K Range=1	I2 =1	+/-1000 (2dp)	
		I1 R1 Base K =-4.7	I1 =-4.7	+/-1000 (4dp)	

continued on the next page

Table 1 - Common groups (continued)

Send	Function	Reply (verbose)	Reply (terse)	Limits (where applicable)	Notes
AxPy	Parameters.	P9 Terse=0	P9=1	0 or 1	1 to set instrument into terse mode – 0 to set verbose
		P8 A2 Mode=1	P8 =1	0 to 3	0, 1, 2, 3 in terse - Off, High, Low, status in verbose
		P7 A2 Hyst=1.0%	P7 =1.0	1 to 10 (1dp)	Alarm hysteresis
		P6 A2 Level=5.0%	P6 =5.0	0 to 100	Alarm trip point
		P5 A1 Mode=1	P5 =1	As alarm 2	As alarm 2
		P4 A1 Hyst=1.0%	P4 =1.0	As alarm 2	As alarm 2
		P3 A1 Level=5.0%	P3 =5.0	As alarm 2	As alarm 2
		P2 4mA=0%	P2 =0		Will show 0V or 4mA depending on variant.
		P1 20mA=50%	P1 =50	0 to 100	Zero and FSD limits are interactive.
AxRy	Reading * see (8) below	R5 Comp2=N/A	R5 =0		
		R4 Temp=Normal	R4 =1		Heater state – see also heater errors.
		R3 Alarm2=Normal	R3 =0	0 to 2	Alarm state – Off, Normal, ALARM or N/A (if not fitted)
		R2 Alarm1=Normal	R2 =0	0 to 2	In terse mode alarm state is 1 in alarm and 0 for all other states
		R1 Conc=5.00%	R1 =5.00	Instrument range and resolution	Measure and Concentration

Notes on readings:- In over-range condition (110% of instrument span) xxxxx will be '+++++' (e.g. 'R1 Conc= +++++'). Similarly in under-range condition (-5% of instrument span) xxxxx will be '-----'. In the case of a system error R1 will be replaced by the error code e.g. ? 72 In verbose mode a brief fault description will be appended. 'Conc' & '%' are determined by sensor type and unit – see 'U' below. Resolution is application dependant. Where a fault is present in the secondary reading it will be indicated by a text description in verbose mode and by a code in the case of Zr units (heater does not return a numeric value in R4) or by -999 or +999 to indicate downscale or upscale failures respectively.

AxUy	Unit (read only)	U13 Test Flags=0	U13=0	0 to 65,535	See table below for details
		U12 Factory Flags=0	U12=0	0 to 65,535	See table below for details
		U11 Output=mA*	U11=1	0 to 2	Analogue output: 0=4/20mA, 1= 0/1V, 2 = 0/5V, 3=0/20mA
		U10 Sens 2 Ch=1	U10=1	0 to 3	Sens 2 ADC chan (9)
		U9 R2 unit=mV	U9=2	0 to 255	See table for unit definitions
		U8 R2 type=T/C	U8 =14	0 to 99	See table for Sensor 2 types (8)
		U7 R1 Ch=1	U7 =1	0 to 3	Sens 1 ADC chan (9)
		U6 R1 unit=%	U6 =1	0 to 255	See table for unit definitions
		U5 R1 type=Z	U5 =13	0 to 99	See table for Sensor 1 types (8)
		U4 F/w rev=0.24	U4 =0.24		
		U3 F/w p/n=290-6031	U3 =290-6031		
		U2 S/n = I-700123	U2=I-700123	8 ascii characters or 0 to 10	
		U1 Addr=0	U1 =0	0 to 9	Sensor Card Address

Table 2 - Error messages

Error messages take the form '? xx' where 'xx' is a numeric code as explained below.

Code	Error	Description
90	Buffer overflow	More than 30 characters were received without message terminator (<CR><LF>). Any subsequent characters will begin a new message.
91	Timeout	10 seconds has elapsed since the last character was received without message terminator.
92	Bad opcode	Message was received correctly terminated but not understood (e.g. 'A0Q1<CR><LF>')
93	Bad operand	Message was received correctly terminated and understood but the argument was malformed or out of bounds (e.g. 'A0C2=999.9<CR><LF>').
94	Read only	An attempt was made to write to a read-only parameter (e.g. 'A0R1=1.2<CR><LF>').
97	Initialising	Sensor card is initialising asserted for 10 seconds after a reset or cold start
51-69	Configuration errors	51 Primary cell illegal for this board, 52 Secondary cell illegal for this board,
71-79	CRC error (NVRAM errors)	Error 71 - user parameters CRC error. if this area is restored user calibration etc is LOST. Error 71 will be reported in response to ANY read request until either a calibration is performed or the instrument rebooted. Error 73 & 75 automatically clear themselves so will not be seen. Errors 72, 74 & 76 will be reported in response to any read request and cannot be cleared.

Specific errors

21-22	Calibration errors (20 is OK)	21 K out of bounds during R1 low calibration 22 offset out of bounds during R1 low calibration

Sensor specific errors - report via the reading group (ie R1, R4 or R5

81	O/C	Sensor open circuit
82	S/C	Sensor short circuit
83	Reversed	Sensor reversed
84	Not Normal	Sensor behaving erratically (Heater Timed Out)
85	Not responding	Drive to sensor on but shows low reading
86	Out of control	Drive to sensor off but shows high reading

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