

# Digital Model 10 and Model 20 Controller

## *Operating Manual*

*Manufactured by:*

**Rank Brothers Ltd**

56, High Street, Bottisham, Cambridge CB25 9DA, England

Tel: +44 (0)1223 811369 Fax: +44 (0)1223 811441

Website: <http://www.rankbrothers.co.uk/>

<b>FCC NOTICE.....</b>	<b>3</b>
<b>EUROPEAN COMMUNITY COMPLIANCE.....</b>	<b>3</b>
<b>1. GETTING STARTED.....</b>	<b>4</b>
1.1 Do NOT.....	4
1.2 Do.....	4
1.3 CONNECTION TO YOUR MAINS SUPPLY.....	4
<b>2. CONTROLS.....</b>	<b>5</b>
2.1 MAINS ON/OFF SWITCH.....	5
2.2 STIRRER ON/OFF SWITCH.....	5
2.3 STIRRER SPEED CONTROL.....	5
2.4 POLARISING VOLTAGE SWITCH.....	5
2.5 POLARISING VOLTAGE ADJUSTMENT.....	5
2.6 SET ZERO CONTROL.....	6
2.6.1 Set Zero Controls (Model 20 only).....	6
2.7 SENSITIVITY CONTROL.....	6
2.7.1 Sensitivity Controls (Model 20 only).....	6
2.8 DISPLAY SELECTOR SWITCH (MODEL 20 ONLY).....	6
<b>3. CONNECTIONS.....</b>	<b>6</b>
3.1 ELECTRODE SOCKET.....	6
3.1.1 Electrode Sockets (Model 20 only).....	6
3.2 RECORDER SOCKET.....	7
3.2.1 Recorder Sockets (Model 20 only).....	7
<b>4. OPERATION.....</b>	<b>7</b>
4.1 OPERATING STAND ALONE.....	7
4.1.1 Operating Stand Alone (Model 20 only).....	7
4.2 OPERATING WITH A CHART RECORDER.....	7
4.3 OPERATING WITH A DATA LOGGER.....	8
4.4 TROUBLESHOOTING.....	8
4.5 TECHNICAL DATA.....	9
<b>5. THE RANK BROTHERS OXYGEN ELECTRODE.....</b>	<b>10</b>
5.1 INTRODUCTION.....	10
THE CELL.....	10
5.2 PRINCIPLES OF OPERATION.....	11
5.3 SETTING UP THE OXYGEN ELECTRODE.....	11
5.4 CALIBRATING THE OXYGEN ELECTRODE.....	12
5.5 OXYGEN CONSUMPTION OF THE ELECTRODE.....	13
5.6 TEMPERATURE SENSITIVITY OF THE OXYGEN ELECTRODE.....	13
5.7 CLEANING AND STORING THE OXYGEN ELECTRODE.....	14

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5.8 TROUBLESHOOTING.....	14
5.9 TECHNICAL DATA.....	15
<b>6. SUGGESTED FURTHER READING.....</b>	<b>15</b>
<b>7. ACKNOWLEDGEMENTS.....</b>	<b>15</b>

## **FCC Notice**

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy, and if not installed and used in accordance with the instructions manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Caution: any changes or modifications to the equipment not expressly approved in this manual may void the user's authority to operate the equipment

## **European Community Compliance**

The Digital Model 10 and Model 20 are both **CE** marked and conform to the following product specifications:

<b>EMC</b>	EN50082-1 (Immunity)
	EN55014 (Emissions)
<b>LVD</b>	BSEN61010

## 1. Getting Started

Thank you for purchasing Rank Brothers equipment. Please ensure that you have read and understood this operating manual before use. You should safely store this manual for future reference.

### 1.1 Do Not

- Do not plug into your local mains supply until you have checked that your supply voltage matches that stated on the label at the rear of the instrument (adjacent to the mains inlet connector).
- Do not change the fuse or remove any covers while the mains inlet lead is still connected to the unit.

### 1.2 Do

- Do ensure that if the moulded plug is removed from the mains lead it is safely disposed of.
- Do ensure you have read and understood this manual before using the instrument.

### 1.3 Connection to your Mains Supply

**Important:** This unit must be earthed to ensure operator safety. The mains inlet lead may have a moulded plug fitted that is not suitable for connection to your local supply. If it is necessary to remove this plug and fit a suitable one, the removed plug must be safely disposed. The removed plug would present a serious shock hazard if plugged into a suitable supply with the bare wires exposed.

The wires of the mains inlet lead are coloured as follows:

<b>GREEN and YELLOW</b>	<b>EARTH</b>
<b>BLUE</b>	<b>NEUTRAL</b>
<b>BROWN</b>	<b>LIVE</b>

As the colours of the wires in the mains lead may not correspond with the coloured markings identifying the connections in your plug, proceed as follows:

- The GREEN and YELLOW coloured wire must be connected to the terminal in the plug that is either marked with the letter E or marked with the earth symbol or coloured GREEN or coloured GREEN and YELLOW.
- The BLUE wire must be connected to the terminal marked N or coloured BLACK.
- The BROWN wire must be connected to the terminal marked L or coloured RED.

Before connecting the unit to your mains supply ensure that your supply voltage matches that on the label at the rear of the instrument (adjacent to the inlet connector).

For operator safety only the correct fuse must be used, failure to comply will result in reduced protection of the operator to fault conditions. Before changing a fuse disconnect

the mains inlet lead from the instrument. The fuse for both the Model 10 and the Model 20 is located at the bottom of the mains inlet connector at the rear of the instrument. The values are as follows:

<b>Model 10 &amp; Model 20</b>	220V/240V	T80mA
	100V/110V	T100mA

The instrument contains no user serviceable parts. The base cover should be removed by competent personnel only (after first switching off the power supply and disconnecting the mains inlet lead).

To carry out any servicing or repairs the instrument should be returned to the manufacturer with a covering letter. Please ensure that the instrument is carefully packaged to avoid damage during shipment.

## 2.Controls

### 2.1Mains On/Off Switch

The power On/Off Switch is located on the top right hand side of the front panel. When switched on the adjacent neon indicator will light and the display will be illuminated.

### 2.2Stirrer On/Off Switch

This switch is located on the bottom right hand side of the front panel. The stirrer can be turned off using this switch.

### 2.3Stirrer speed Control

Located next to the Stirrer On/Off switch, this allows the stirring speed to be adjusted from approximately 120rpm to 1200rpm. Suitable stirring should be obtained when at a setting of 6. N.B. for the stirrer to operate correctly the stirring bar must contain a magnet, just using a magnetic material (i.e. a paper clip) will produce a jumping action instead of a smooth rotation.

### 2.4Polarising Voltage Switch

This switch selects whether the display is reading the Polarising Voltage or the Percentage Saturation of Oxygen. By default the display shows the Percentage Saturation of Oxygen. When the switch is held down the display reads the Polarising Voltage in Volts. When released the display reads the Percentage Saturation.

### 2.5Polarising Voltage Adjustment

The knob below the Polarising Voltage Switch allows adjustment of the polarising voltage applied to the electrode. A voltage of 0.6V is suitable for our electrodes, although it can vary between 0 and 1 Volts approximately. N.B. a reading of 0.6V indicates that the platinum electrode is polarised -0.6V with respect to the silver electrode.

## **2.6 Set Zero Control**

This adjustment zeroes the amplifier circuit ensuring that the display reads zero when there is no electrode connected. It is advisable to allow at least 5 minutes warm up period before adjusting this control. The control can also be used to offset the residual current flow in the electrode when no oxygen is present. This control requires a small screwdriver to make adjustments.

### ***2.6.1 Set Zero Controls (Model 20 only)***

There are two Set Zero Controls on the Model 20, one for each electrode.

## **2.7 Sensitivity Control**

The Sensitivity Control is a 10-turn control and is used to calibrate the electrode when filled with liquid of known oxygen content, typically air saturated water.

### ***2.7.1 Sensitivity Controls (Model 20 only)***

The Sensitivity Controls are 20-turn preset controls and require a small screwdriver for adjustment. They are labelled 1 and 2 corresponding to the electrode they affect.

## **2.8 Display Selector Switch (Model 20 only)**

The Display Selector Switch located under the display selects which electrode's data is being displayed. When switched to the left (position 1) the display shows the reading from the electrode plugged into the left socket (labelled 1). When switched to the right, the display shows the reading from the electrode plugged into socket 2. Therefore it may be more convenient to plug the left-hand electrode into socket 1 and the right hand electrode into socket 2.

## **3. Connections**

### **3.1 Electrode Socket**

The Electrode Socket is a 3-pin DIN socket and allows connection to an oxygen electrode. Rank Brothers electrodes are supplied suitably wired to a 3-pin DIN plug. The connections to a 3 pin DIN Plug are as follows:

<b>Pin 1</b>	Silver Electrode (Red wire)
<b>Pin 2</b>	Not Connected
<b>Pin 3</b>	Platinum Electrode (Blue wire)

The cable screen should be connected to the strain relief clamp in the plug.

#### ***3.1.1 Electrode Sockets (Model 20 only)***

The Electrode Sockets are 3-pin DIN sockets each allowing the connection of one oxygen electrode. The sockets are labelled 1 and 2 so that the appropriate controls can be selected for each electrode. Rank Brothers electrodes are supplied suitably wired to a 3-pin DIN plug.

## 3.2 Recorder Socket

The Recorder Socket is a BNC type and is situated at the rear of the instrument. It can be connected to either a chart recorder or a data-logging device. The output is typically 1.0V when the display reads 100.0, and is supplied with a 'BNC to 4mm banana plugs' lead suitable for use with most chart recorders.

### 3.2.1 Recorder Sockets (Model 20 only)

The Model 20 has two recorder sockets, one for each electrode, situated at the rear of the instrument. With two electrodes connected the outputs from both electrodes are available simultaneously and may be connected to either a dual pen Chart Recorder, or a dual channel Data Logger. The outputs are 1V when the display reads 100.0. N.B. Dual Controllers purchased prior to May 1999 typically had a chart recorder output of 10mV. The instrument is supplied with two Chart Recorder leads.

## 4. Operation

### 4.1 Operating Stand Alone

1. Plug the instrument into you mains supply, switch on and allow 5 minutes warm up. Ensure the electrode is not plugged in.
2. Adjust the Set Zero Control until the display reads zero.
3. Adjust the Polarising Voltage Control until a suitable polarising voltage is set (typically 0.6V). Depress the Polarising Voltage switch so that the display monitors the voltage.
4. Plug in an oxygen electrode that has been set up with water in the incubation chamber (see Section 5).
5. Sit the electrode on the stirring head and lock off with the white plastic retaining screw.
6. Circulate water through the electrode incubation chamber and allow the sample temperature to stabilise.
7. Switch on the stirrer and adjust the stirring speed, typically about 6 on the knob.
8. Bubble air through the water and allow the reading to stabilise.
9. The Sensitivity Control can now be adjusted until the display reads 100.0 percentage saturation.
10. Purge all the oxygen from the sample either with a few crystals of Sodium Dithionite, or by bubbling nitrogen through.
11. If the display does not read zero, this is due to residual current flow in the electrode, and can be trimmed out with the Set Zero Control.
12. Adjusting the Set Zero will affect the calibration, so repeat steps 8, 9, 10 and 11 as necessary. The electrode is now calibrated and ready for use.

#### 4.1.1 Operating Stand Alone (Model 20 only)

Steps 1 to 12 in Section 4.1 must be repeated for both electrodes.

### 4.2 Operating with a Chart Recorder

Any chart recorder that can accept a 1.0V full-scale input would be suitable to connect to the Recorder Output Socket at the rear of the instrument.

1. Once the electrode is calibrated (see Section 4.1) connect the chart recorder with the supplied recorder lead.
2. Switch on the chart recorder and select an appropriate input range (1V if available). The chart recorder should now read full scale providing that the controller is displaying 100.0.
3. If the recorder reading does not correspond to the display reading, the Sensitivity Control can be used to calibrate the recorder rather than the display, if preferred.
4. Select an appropriate chart feed rate and allow the recorder to monitor your experiment.

### 4.3 Operating with a Data Logger

A data logger will allow your experiment to be recorded and then transferred to a computer. Typically lower cost loggers plug into the computer and only operate while the computer is operating, whereas more expensive units operate independently from the computer and are only linked to download data. Most software supplied with these units allows the data to be exported to spreadsheets, where further processing can be carried out, results printed and graphs generated. Consult the logger instructions for operation, but ensure that its inputs are able to accept 1.0V input and are protected to withstand at least 5V. Select a model with a suitable resolution remembering that the controller display has a resolution of 1mV. A logger with a 5V full-scale input and 12 bits ( $2^{12}$ ) resolution will thus have a resolution of about 1.25mV ( $5/2^{12}$ ). The supplied recorder lead may not be appropriate for your logger, a special lead may be required.

### 4.4 Troubleshooting

Symptoms	Possible Causes	Suggested Remedies
Display and indicator fail to illuminate.	<ul style="list-style-type: none"> <li>• Instrument switched off.</li> <li>• Fuse in instrument failed.</li> <li>• Fuse in plug failed.</li> <li>• Faulty mains supply socket.</li> <li>• Instrument faulty.</li> </ul>	<ul style="list-style-type: none"> <li>• Ensure the instrument is on.</li> <li>• Replace fuse in instrument.</li> <li>• Replace fuse in plug.</li> <li>• Check socket with item known to work.</li> <li>• Check in a mains outlet known to be OK. If still faulty return for repair.</li> </ul>
Stirrer(s) fail to function.	<ul style="list-style-type: none"> <li>• Stirrer switched off.</li> <li>• Stirring Head(s) faulty.</li> <li>• Stirrer control circuit faulty.</li> </ul>	<ul style="list-style-type: none"> <li>• Ensure the stirrer is on.</li> <li>• Return for repair.</li> <li>• Return for repair.</li> </ul>
Stirring bar jumps instead of rotating smoothly.	<ul style="list-style-type: none"> <li>• Stirring bar(s) not magnetised.</li> <li>• Stirring Head(s) faulty.</li> <li>• Stirrer control circuit</li> </ul>	<ul style="list-style-type: none"> <li>• Use only magnetised stirring bars.</li> <li>• Return for repair.</li> <li>• Return for repair.</li> </ul>

	faulty.	
Display reads less than 100.0 with an air saturated sample.	<ul style="list-style-type: none"> <li>• Sensitivity too low.</li> <li>• Polarising voltage incorrect.</li> <li>• Electrode faulty.</li> <li>• Model 20 only: Display selector switch positioned incorrectly.</li> </ul>	<ul style="list-style-type: none"> <li>• Recalibrate Instrument.</li> <li>• Re-adjust polarising voltage.</li> <li>• Clean the electrode, return for repair if still unable to obtain reading of 100.0.</li> <li>• Switch display selector switch to select appropriate electrode.</li> </ul>

## 4.5 Technical Data

	Digital Model 10	Digital Model 20
Resolution	0.1% saturation	0.1% saturation
Polarising Voltage	0-1V	0-1V
Recorder Output	0-1V via BNC connection	0-1V via BNC connection
Stirrer	120-1200rpm	120-1200rpm
Power supply	220/240V or 110/120V AC; power cord supplied	220/240V or 110/120V AC; power cord supplied
Size	230mm (w) x 300mm (d) x 200mm (h)	230mm (w) x 300mm (d) x 200mm (h)
Weight	2.5kg	3.0kg

## 5. The Rank Brothers Oxygen Electrode

### 5.1 Introduction

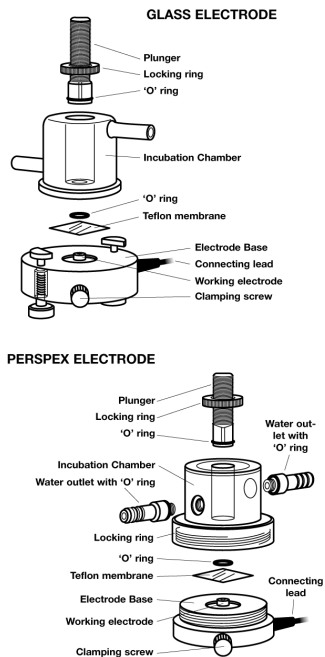
The name 'Oxygen Electrode' is just one of the many titles often used to describe this electrochemical sensor for oxygen. Other names include: 'Clark Cell', after its generally recognised inventor (1956) Leyland C Clark and 'Oxygen Membrane Polarographic Detector' ( $O_2$ -MPD for short), because of the mode of action of the electrochemical device. The Oxygen electrode remains one of the most commonly used devices for measuring the partial pressure of oxygen (sometimes referred to as 'oxygen tension') in the gas phase or, more commonly, dissolved solution. The Oxygen Electrode finds application in a wide variety of diverse subject areas including: environmental studies (e.g.  $O_2$ -levels in natural waters), sewage treatment (vital in monitoring the progress of bacterial attack), alcohol production ( $O_2$ -levels in fermentation tasks need to be continuously monitored and controlled) and medicine (invasive and non-invasive monitoring of a key physiological analyte). The typical range of detection of  $O_2$  of this device is from  $10^{-4}$  atm (i.e. 0.01%) to 1 atm (i.e. 100%). The key to continuing supremacy of the Oxygen Electrode over other electrochemical devices for  $O_2$  detection is the utilisation of a gas-permeable, ion-impermeable, membrane that separates the test system from the sensing electrode (the platinum cathode). This membrane prevents many problems of electrode passivation or poisoning that arise when the sensing electrode is placed in direct contact with the system (usually an aqueous solution) under test.

### The Cell

The Rank Brothers Oxygen Electrode comprises two electrodes. The first is a small (typically 2mm in diameter) central platinum disc working electrode (this is the cathode and it is at this electrode that the  $O_2$  diffusing through the membrane is reduced). Set in a well surrounding this is a silver ring counter and reference electrode (about ten times larger in surface area than the Pt cathode). Conduction between the two electrodes is achieved using a 3M potassium chloride solution to saturate the paper tissue covering the two electrodes. On top of this is placed the key gas-permeable membrane, usually 12.7 $\mu$ m thick Teflon, sealed from the test sample in the incubation chamber by a silicone rubber 'O' ring.

The controller supplied by Rank Brothers is used to apply a voltage to the central platinum electrode that is sufficiently negative, with respect to the silver electrode, that all the oxygen diffusing through the membrane and reaching this electrode is reduced. The resultant current which flows between the two

electrodes is proportional to the oxygen partial pressure in the test system,  $P(O_2)$ . The



controller converts this current directly into a voltage and depending on the model will display this in units of percentage saturation (see Section 5.5 for more details). It can also be measured continuously using a x/t chart recorder or a data logger.

## 5.2 Principles of Operation

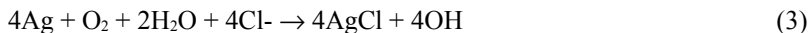
When the platinum electrode is polarised at -0.6V with respect to the silver electrode, every oxygen molecule that reaches its surface from the test medium, via the gas-permeable membrane, is reduced to water through the following reaction:



For every reduction reaction there must be an oxidation and this occurs at the silver electrode as follows:



Thus the overall electrochemical process that occurs in an Oxygen Electrode is as follows:



As the oxygen electrode is repeatedly used, the bright silver ring electrode rapidly becomes 'tarnished'. Eventually an even coat of brown silver chloride forms on the silver electrode. The presence of this silver chloride layer is desirable (it stabilises the overall behaviour of the electrode) and should not be removed except if it grows very thick (after many months of use).

The polarising voltage at the platinum electrode is so negative that the current,  $i_d$  is related to the  $P(\text{O}_2)$ , via the following expression:

$$i_d = 4 \cdot F \cdot P_m \cdot A \cdot P(\text{O}_2) / b \quad (4)$$

Where  $F$  = Faraday's constant ( $9.64 \times 10^4 \text{C} \cdot \text{mol}^{-1}$ ),  $P_m = \text{O}_2$  permeability of the Teflon membrane (typically  $1.05 \times 10^{-12} \text{mol} \cdot \text{atm}^{-1} \cdot \text{s}^{-1}$ ),  $A$  = surface area of the Pt working electrode (typically  $0.031 \text{cm}^2$ ) and  $b$  = thickness of the Teflon membrane (typically  $12.5 \times 10^{-4} \text{cm}$ ). Thus in a test medium which is air-saturated water,  $P(\text{O}_2) = 0.2 \text{atm}$ , the oxygen electrode would have a value for  $i_d$  of  $2 \mu\text{A}$  approximately.

## 5.3 Setting up the Oxygen Electrode

Apart from the electrode itself you need to have the following items:

- Small pair of sharp scissors
- 3M potassium chloride solution
- Teat pipette
- Teflon membrane (supplied by Rank Brothers)
- Tissue paper (lens tissue is ideal, but one ply of ordinary tissue is fine)

1. Using the teat pipette, wet both electrodes and fill the small well containing the silver electrode with the potassium chloride solution.
2. Cut a 1.5cm square piece of tissue paper with a 2mm hole in its centre and float this on the potassium chloride in the well ensuring that the hole is central above the platinum electrode.
3. Touch the empty teat pipette against the tissue paper and use it to suck off the excess electrolyte so that the paper is wet (but not very wet) and clings to the surface of the electrode.
4. Cut a 1.5cm square piece of Teflon membrane and place it so that it covers both electrodes, ensuring that the platinum electrode is underneath the centre membrane and that there are no air bubbles trapped under the membrane.
5. Gently push the silicone rubber 'O' ring over the platinum electrode so as to hold the Teflon membrane in place when the plastic base and the incubation chamber are clamped together (you can use the incubation chamber to gently push the 'O' ring into place).
6. Carefully clamp the electrode base and the incubation chamber together. It is important to ensure that the incubation chamber is not rotated on the base during clamping, as this will damage the membrane. The locking ring should be tightened by hand only. Over tightening may cause problems.
7. Connect the electrode to the controller, adjust the polarising voltage to 0.6V and adjust the stirring speed to a suitable level. Connect the water jacket of the incubation chamber to a constant temperature water bath and allow the sample temperature to stabilise. The electrode is now ready for calibration.

## 5.4 Calibrating the Oxygen Electrode

It is necessary to refer to the individual controller manuals for precise instructions for calibration, however the following general information is still useful. The controllers all convert the current from the electrode to a voltage thus if S is the voltage from the controller, it is proportional to the partial pressure of O<sub>2</sub> in the medium under test, i.e.:

$$S = K \cdot P(\text{O}_2) \quad (5)$$

Where K is the proportionality constant. All our controllers (excluding the Electrochemical Processor) allow the adjustment of K via a sensitivity control so that S can be adjusted to a suitable value when the test sample contains a known level of oxygen. Typically the sensitivity is adjusted with an air saturated aqueous test sample to give a display reading of 100.0 (100% saturation) or until a chart recorder gives a full-scale reading. The readings will then be the percentage air saturation for the test solution being monitored.

Some useful conversion factors are as follows: for 100% air saturated water,  $P(\text{O}_2) = 0.2095$ , atm = 159mm, Hg  $[\text{O}_2] = 2.4 \times 10^{-4} \text{mol} \cdot \text{dm}^{-3} = 8\text{ppm} = 8\text{mg} \cdot \text{dm}^{-3}$ ). It should be noted that the electrode has a small residual current i.e. there is a small current flow even with no oxygen present. Thus when low levels of O<sub>2</sub> are under study (i.e.  $P(\text{O}_2) < 0.002\text{atm}$ ) Equation 5 is not accurate enough and should be modified to:

$$S - S_0 = K \cdot P(O_2) \quad (6)$$

Where  $S_0$  is the background signal when  $P(O_2) = 0 \text{ atm}$ . This can normally be trimmed out on either the controller or the chart recorder during calibration.

### 5.5 Oxygen Consumption of the Electrode

The oxygen electrode consumes oxygen from the test medium reaction (see Equation 3). However, if the electrode is to function properly it is important that the partial pressure of  $O_2$  at the interface between the membrane and the test medium should be the same as that in the bulk of the medium. As a result, when the test medium is an aqueous solution it must be continuously stirred, failure to do so will lead to a signal that drifts downward and general erratic behaviour. For the Rank Brothers oxygen electrode it can be shown that the percentage of the total amount of oxygen lost per minute (%D) from an aqueous solution of low ionic strength is given by the following expression:

$$\%D = 12.5 \cdot i_d / P(O_2) \cdot V_{\text{test}} \quad (7)$$

Where  $V_{\text{test}}$  = volume of the test solution in  $\text{dm}^3$  and  $i_d$  is the current flow through the electrode. For example, if we take  $i_d = 2 \mu\text{A}$  for a sample where  $P(O_2) = 0.2 \text{ atm}$  (i.e. an air saturated solution) we can estimate that only if  $V_{\text{test}} < 0.125 \text{ cm}^3$  will the electrode consume  $> 1\%$  of the total number of oxygen molecules present per minute. It follows from Equation 7 that measurements of  $P(O_2)$  carried out on small isolated volumes of aqueous solution using the oxygen electrode should be avoided since it is likely to lead to a downwardly drifting signal as monitoring proceeds (due to oxygen consumption by the electrode). In such circumstances it is better that the electrode is operated for short times (e.g. monitor for 1-2 minutes, every 10-20 minutes) rather than continuously. It is possible to reduce the oxygen consumption by reducing the diameter of the platinum electrode, however the current flow is also reduced putting more demands on the controller.

It should be noted that although  $P(O_2)$  and therefore  $i_d$  is independent of salinity, the actual concentration of  $O_2$  in solution decreases with increasing salinity (see Reference 1). As a result of this the factor '12.5' in Equation 7 increases with increasing salinity (it is  $\cong 29$  in 3M sodium chloride). Thus care should be taken when monitoring low oxygen levels in isolated low volume solutions of high ionic strength.

### 5.6 Temperature Sensitivity of the Oxygen Electrode

The oxygen electrode is temperature sensitive and should be thermostatted whenever this is possible. If no thermostating is employed the signal is likely to increase with increasing temperature. If the thermostating is inadequate the signal will fluctuate as the oxygen electrode and sample change temperature. Any light shining on the electrode may cause a change in signal due to heating effects.

## 5.7 Cleaning and Storing the Oxygen Electrode

When the electrode is not in use for a few hours (e.g. overnight) it is best dismantled and the electrodes left to soak in distilled water, we can supply a storage cell for this purpose. If the electrode assembly must be left intact, but non-operational for a few hours, it is best if the electrode is left on, but with the stirrer switched off. The platinum electrode needs to have a ‘mirror’ finish, any surface damage will affect the response of the electrode, and it will thus need to be cleaned approximately once every 5-7 days of use or when it has lost its shine. A suitable polish can be made by mixing a thick slurry of 0.3 $\mu$ m polishing alumina (obtainable from BDH Chemicals & Merck for instance) in distilled water. A piece of cotton wool can then be used to polish the platinum electrode until it is smooth, bright and clean (this should only take a few minutes). The silver electrode will need to have the layer of silver chloride removed and the surface polished every 2-3 months of use. A 10% ammonia solution on cotton wool can be used to remove the silver chloride layer. (Ensure that the appropriate handling precautions are observed.) The silver electrode can then be made smooth, bright and clean by polishing with the alumina slurry as described above for the platinum electrode.

## 5.8 Troubleshooting

Simply dismantling the electrode, washing it in distilled water and then re-assembling with a new membrane and fresh potassium chloride can solve most problems encountered with the oxygen electrode. A useful check to see if the electrode is responding properly is to alter the P(O<sub>2</sub>) in the test solution. This can be done by saturating with air, or by removing all oxygen from the test medium by purging with nitrogen (or any inert gas, such as He or Ar) or by adding sodium dithionite. The signal should change very rapidly (typically giving a 90% response within 15 seconds) with a sudden change in P(O<sub>2</sub>). The observation of some signal noise that is synchronised with the stirrer flea rotations is a useful indication that the electrode is working well.

Symptoms	Possible Causes	Suggested Remedies
Noisy signal.	<ul style="list-style-type: none"> <li>Electrical interference.</li> <li>Stirrer flea in contact with the membrane.</li> </ul>	<ul style="list-style-type: none"> <li>Remove the electrode from the source of noise.</li> <li>Ensure the flea is the correct size (it is usual to have some signal noise synchronised with the stirrer flea rotations).</li> </ul>
Sluggish or no change in signal with changes in oxygen level.	<ul style="list-style-type: none"> <li>Incubation Chamber clamped too tight.</li> <li>Insufficient electrolyte soaking the tissue.</li> <li>An air-bubble above Pt electrode.</li> <li>Membrane damaged.</li> <li>Stirrer flea stopped.</li> </ul>	<ul style="list-style-type: none"> <li>Reassemble the electrode. The locking ring should be hand tight only.</li> <li>Reassemble the electrode.</li> <li>Remove the air bubble with teat pipette.</li> <li>Reassemble the electrode.</li> <li>Check stirrer is switched on</li> </ul>

	<ul style="list-style-type: none"> <li>Platinum electrode damaged.</li> </ul>	<ul style="list-style-type: none"> <li>and operating OK.</li> <li>Polish the electrode or return to us for repair.</li> </ul>
Step change in signal.	<ul style="list-style-type: none"> <li>Stirrer flea had stopped turning and now has started again.</li> </ul>	<ul style="list-style-type: none"> <li>Check stirrer is functioning correctly and the flea is OK.</li> </ul>
Smooth but rapid increase in signal.	<ul style="list-style-type: none"> <li>Hole in membrane (the test solution has begun to leak into the electrolyte well).</li> </ul>	<ul style="list-style-type: none"> <li>Reassemble the electrode with a new membrane.</li> </ul>
Smooth but slow increase in signal with constant oxygen level.	<ul style="list-style-type: none"> <li>Inadequate thermostating.</li> <li>The electrode is being warmed up (e.g. by direct sunlight).</li> </ul>	<ul style="list-style-type: none"> <li>Improve the thermostating.</li> <li>Shade from direct sunlight.</li> </ul>
Downwardly drifting signal.	<ul style="list-style-type: none"> <li>Air bubble above platinum electrode.</li> <li>Hole in membrane.</li> <li>Stirrer flea stopped turning.</li> <li>Inadequate thermostating.</li> <li>Electrode consuming too much oxygen.</li> </ul>	<ul style="list-style-type: none"> <li>Remove the bubble.</li> <li>Reassemble the electrode.</li> <li>Check the stirrer and flea are OK.</li> <li>Improve thermostating.</li> <li>This is a problem in samples high in ionic strength, low in volume (&lt; 1cm<sup>3</sup>) and low in oxygen (&lt; 5% saturated).</li> </ul>

## 5.9 Technical Data

Each electrode is supplied with a screened lead connected to a DIN plug, 75mm x 300mm of Teflon membrane, 1 stirring bar (flea), and 1 '0' ring for the Teflon membrane.

Oxygen Electrode	
<b>Size</b>	50mm x 100mm x 50mm approx.
<b>Weight</b>	100g approx.
<b>Response-time</b>	100% - 0% air saturation in less than 15 seconds

## 6. Suggested Further Reading

1. M L Hitchman, *Measurement of Dissolved Oxygen*, 1978, Wiley-Interscience, London, ISBN 0-471-03885-7.
2. Y H Lee and G T Tsao, *Advances in Biochemical Engineering*, 1979, Volume 13, Page 35.

## 7. Acknowledgements

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