Version : 2.0
Date : 06 Mar 96
Author : MS

Model 88-O

Dissolved Oxygen Process Controller

Congratulations ! You have purchased the latest in Instrumentation for Industrial Dissolved Oxygen Process Measurement and control. We hope that your new Model 88-O Controller will provide you with many years of reliable service.

To help with correct installation and operation, please read this manual carefully.

If at any stage we can be of assistance, please contact either your local T.P.S. representative or the TPS factory in Brisbane.

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1. Introduction

The T.P.S. Dissolved Oxygen Process Controller instantaneously measures and controls the Dissolved Oxygen value of industrial aqueous solutions. The system consists of two parts:

(a) Dissolved Oxygen sensor
(b) Controller/readout section.

From this latter section signals are available for voltage or current accessories. In addition there are relay contact closures for control purposes.

2. Controls

2.1 Calibrate Controls

SPAN This is the PRIMARY calibration control and compensates for variations in the electrode sensitivity.

ISO This is the SECONDARY calibration control and sets the ZERO Oxygen value using a Chemically-produced zero Oxygen solution.

2.2 Limit Controls

LOWER This sets the trip point of the Lower relay contacts. It represents a LOW limit to reach. The LOW LIMIT lamp lights when the signal goes BELOW this value.

UPPER This sets the trip point of the Upper relay contacts. It represents a HIGH limit to reach. The HIGH LIMIT lamp lights when the signal goes ABOVE this value.

2.3 Output Controls

RECDR. ZERO This sets the zero of the optional recorder output.

RECDR. SPAN This sets the span of the optional recorder output. (Adjusts full scale voltage).

LOOP 4mA This sets the output value of the optional current loop at low end of the data.

LOOP 20mA This sets the output value of the optional current loop at the high end of the data.

2.4 Display Function Switch

The four position switch is labelled:

LOWER The display INDICATES DIRECTLY, the setting of the LOWER limit. See section *2.2 Limit Controls*, above.

UPPER The display INDICATES DIRECTLY, the setting of the UPPER limit See *2.2 Limit Controls*, above.

STANDBY The display indicates the Dissolved Oxygen data from the sensor, BUT relays are inhibited (off state). The voltage/current outputs are maintained.

AUTO The display indicates the Dissolved Oxygen data from the sensor, AND the LOWER/UPPER relays outputs are enabled under the controller's action.

NOTES: The function switch should not be left in the (a) or (b) position as it is NOT indicating the Dissolved Oxygen data from the sensor at all!

In (a),(b) and (c) positions the COLON ":" is displayed to show that the controller is NOT controlling the relays.

3. Cables and Wiring

Two different Dissolved Oxygen electrodes may be used for different applications.

1. EDYSI electrode for either % Saturation, OR ppM measurements.
   or
2. ED500 for % Saturation measurements only.

The measurement mode (% Saturation or ppM) and range are factory configured before despatch from the factory.

3.1 Sensor connections for EDYSI Dissolved Oxygen sensor

Terminal Block	Terminal No	Connection	
J-2	1	RED	ATC sensor for ppM Compensation
J-2	2	BLUE	ATC sensor for ppM Compensation
J-2	3	n/c	no connection
J-2	4	GREEN	Polarisation voltage to sensor
J-2	5	BRAID	Shield connection for cable
J-2	6	YELLOW	Dissolved Oxygen signal from sensor

3.2 Sensor connections for ED500 Dissolved Oxygen sensor

Terminal Block	Terminal No	Connection	
J-2	1	n/c	no connection
J-2	2	n/c	no connection
J-2	3	n/c	no connection
J-2	4	RED	Polarisation voltage to sensor
J-2	5	GREEN	Shield connection for cable
J-2	6	BLUE	Dissolved Oxygen signal from sensor

3.3 Power and Relay Output Connections

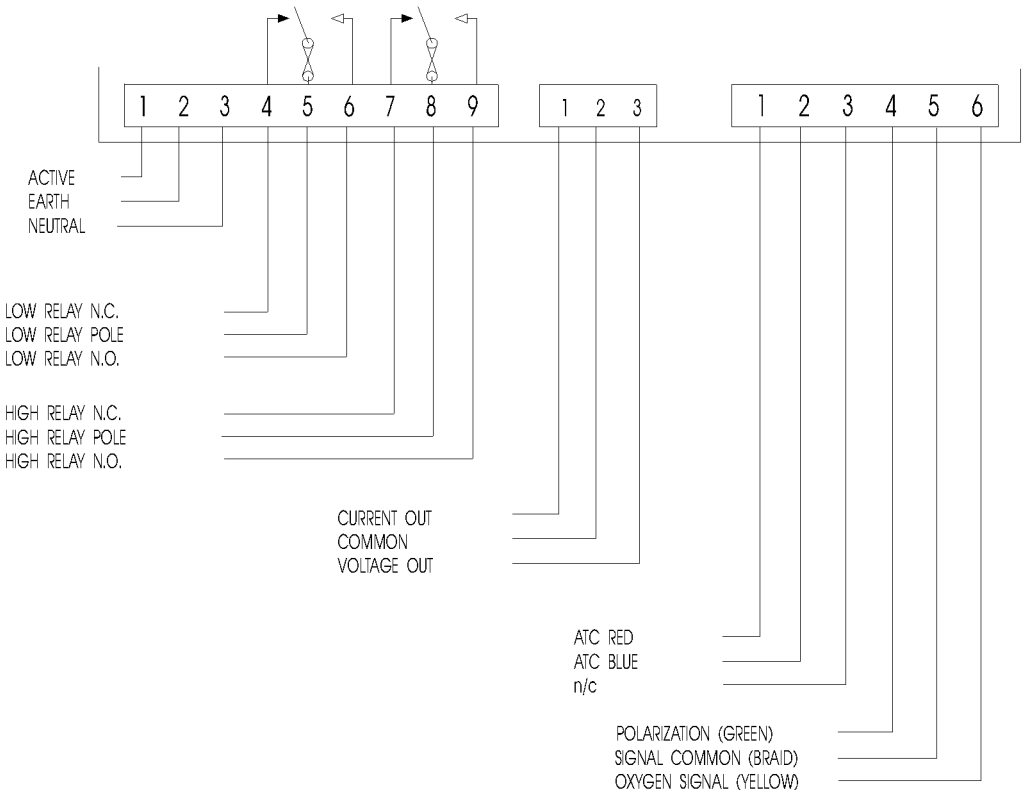
Terminal Block	Terminal No	Connection
J-1	1	Active 240 Vac IN
J-1	2	Earth (mains)
J-1	3	Neutral 240 Vac IN
J-1	4	Lower Relay NC (normally closed)
J-1	5	Lower Relay COM (common)
J-1	6	Lower Relay NO (normally open)
J-1	7	Upper Relay NC (normally closed)
J-1	8	Upper Relay COM (common)
J-1	9	Upper Relay NO (normally open)

NOTES: Relay contacts are undedicated change-over type capable of 1-2A (MAX) at 240V AC The use of external contactors for higher currents and reduced interference is recommended.

3.4 Recorder and 4-20mA Output Connections

Terminal Block	Terminal No	Connection
J-3	1	+ve Current Output 4-20mA (Not Isolated) - (Optional) **NOTE:** Voltage compliance is 12 volts.
J-3	2	Common
J-3	3	Recorder Output. **NOTE:** Impedance is 100 ohms and so 0-10mA is delivered into a low impedance device if required.

3.5 Connection Diagram



4. Calibration

1. Set to STANDBY to disable the Relay functions.
2. New Oxygen sensors are normally shipped filled and ready-to-use, as they have been factory-tested on the controller just prior to shipment. However, we recommend that you check the electrode for leakage or bubbles before use. See the separate instructions for details on membrane replacement, if this is necessary.
   If you have been supplied with the EDYSI Dissolved Oxygen electrode, a humidity cap may be fitted over the end of the electrode to keep the sensor membrane moist and prevent the thin film of electrolyte behind the membrane from drying out. Remove this cap, and keep for future use when storing the sensor.
3. Turn the **88-O** on with the Sensor wired in. Allow at least 5 minutes for the sensor to polarise. BE CAREFUL THAT THE PROBE HAS NOT BEEN SITTING IN THE SUN, AND THAT IT IS, IN FACT, AT THE ACTUAL AIR TEMPERATURE.
4. **Zero Calibration**
   Zero Calibration must be performed the first time a new electrode is used, if the membrane has been changed, or at regular monthly intervals.
   (a) Obtain 5mL of 0.01 Molar Borax solution and add 100 mg. of Sodium Sulphite.
   This zero oxygen solution can be stored for several hours in a closed tube or syringe.
   (b) Place the sensor into this solution and allow the reading to stabilise (approx 2-3 minutes).
   (c) Set the **ISO** control until the display reads zero.
   (d) If the probe does not get to a zero value within 5 minutes, refit the membrane ensuring there are no wrinkles. True zero may require several minutes if the filling solution has to be replaced.
5. **Air Calibration**
   Calibration in air should be performed at least once per week. In applications such as sewage sludge or mining slurries, electrode cleaning and recalibration may need to be performed more often.
   (a) Carefully dry the sensor membrane tip with a soft tissue, and let it stabilise in air.
   The **88-O** should now be reading approximately 100% Saturation or 8 to 9 ppM, depending on the units of Dissolved Oxygen for which it was factory-set.
   (b) **For % Saturation Calibration**
   Set the Calibrate **SPAN** control (See section 2.1, Calibrate Controls) until the display reads 100.0 %.
   OR
   For ppM Calibration
   1. Measure the air Temperature.
   2. Measure the Salinity of the solution that is to be controlled.
   3. Look up the ppM value at the measured Temperature and Salinity values in the table given in section 9.
   4. Set the **88-O** for this value.
6. The Dissolved Oxygen electrode consumes a small amount of oxygen during operation. It is therefore essential that new sample is presented to the tip of the electrode continuously. For in-line use, this simply means ensuring that there is a steady flow past the electrode.

   For pond or tank use, stirring is required. Once again, just ensure that there is a steady flow of sample past the tip of the electrode. Over-rapid stirring, the membrane is flexed and new (oxygen bearing) electrolyte enters the cathode area causing "noise". Also, stirring too fast can cause bubbling in the sample which will raise the Dissolved Oxygen level in the solution.

   Without stirring, the reading will drift slowly downwards.

5. Setting the Limits

5.1 Lower Limit

1. Switch the Function Switch to **LOWER** (see section 2.4, Display Function Switch)
   Note that the output control relays are disabled in this mode. Voltage and current outputs are maintained, as a function of the the digits on the display.
2. Adjust the **LOWER** Limit control (see section 2.2, Limit Controls) until the display shows the value at which you wish to ADD OXYGEN to raise the Dissolved Oxygen value. Oxygen addition can be by aerators, paddle wheels or oxygen from a cylinder, depending on the application.
3. Switch the Function Switch back to **STANDBY** or **AUTO**, as required (see section 2.4, Display Function Switch).

5.2 Upper Limit

1. Switch the Function Switch to **UPPER** (see section 2.4, Display Function Switch)
   Note that the output control relays are disabled in this mode. Voltage and current outputs are maintained, as a function of the the digits on the display.
2. Adjust the **UPPER** Limit control (see section 2.2, Limit Controls) until the display shows the value at which the Dissolved Oxygen is TOO HIGH. This can be used to trigger an alarm etc.
3. Switch the Function Switch back to **STANDBY** or **AUTO**, as required (see section 2.4, Display Function Switch).

NOTE: If this unit has been specially set up to begin Oxygen addition at the **LOWER** limit and stop addition at the **UPPER** limit, then no external wiring should be made to the **UPPER** limit relay.

6. 4-20 mA Current Output Option

This is a current output, proportional to the DISPLAY, positive with respect to common and is NOT isolated.

This option is normally set up as 4-20mA for 0 to Full Scale (eg: 200.0 % Saturation or 20.0 ppM)

The **88-O** has two adjustments to fine-tune the current output:

1. **LOOP ZERO** (4mA adjustment) Range at 4mA = +/- 20%
2. **LOOP SPAN** (20mA adjustment) Range at 16mA (ie: 20mA - 4mA) = +/- 10%

This unit configured as 4-20mA for _____ to _____

7. Recorder Output Option

This is a voltage output proportional to the DISPLAY and is NOT isolated.
This option is normally set up as 0-1 Volt for 0 to Full (eg: 200.0 % Saturation or 20.0 ppM)

The **88-O** has two adjustments to fine-tune the voltage output:
1. **RECDR. ZERO** (Zero adjustment) Range +/- 10%
2. **RECDR. SPAN** (Span adjustment) Range +/- 10%

This unit configured as 0-1 Volt for _____ to _____

8. Troubleshooting

NOISY READINGS:
1. Check terminal wiring is correctly fitted.
2. Check the probe membrane is OK.
3. Bubbles inside probe ? Refit the membrane.

CAN'T ZERO:
1. Is the membrane wrinkled ?
2. Replace the membrane on the probe.
3. Filling solution may be contaminated.
4. Contamination of gold or silver.

CAN'T CALIBRATE:
1 Is the membrane wrinkled.
2 Replace the membrane on the probe.

READING UNSTABLE:
1. Electronics fault ?
   Check controller by disconnecting leads from the electrode (J-2 terminals 4,5,6.) Replace with a wire linking the 2 terminals 5 & 6. If the reading is now stable, and can be adjusted to ZERO with the **ISO** control, the electronics is probably correct. The sensor (or wiring) is probably faulty.

LOW OR EXCESSIVE RESPONSE:
1. Check the sensor in Sodium Sulphite ZERO solution.
   Replace the membrane, Refill, or Replace electrode.
2. Check ATC sensor.
   Measure ATC sensor resistance between the wires that are connected to terminal block J-2, terminals 5 & 6 (disconnected from the controller). This should be approx 2000 Ohms at 25^{o}C for the EDYSI sensor, and 1000 Ohms for the ED500 sensor.

9. Solubility Of Oxygen In Water

Following is a table of Solubility of Oxygen in water exposed to water-saturated air, at 760mm Hg atmospheric pressure.

g/l Cl	0	4	8	16	20
ppK.NaCl	0	6.6	13.2	26.4	33
Temp (^{o}C)	Dissolved Oxygen - ppM (mg/L)				
0	14.57	13.91	13.26	11.94	11.29
1	4.17	13.54	12.90	11.63	11.00
2	13.79	13.18	12.56	11.33	10.72
3	13.43	12.83	12.24	11.05	10.45
4	13.08	12.50	11.93	10.78	10.20
5	12.74	12.19	11.63	10.52	9.96
6	12.42	11.88	11.34	10.27	9.73
7	12.11	11.59	11.07	10.03	9.51
8	11.81	11.31	10.81	9.80	9.30
9	11.53	11.04	10.56	9.58	9.09
10	11.26	10.79	10.31	9.37	8.90
11	10.99	10.54	10.08	9.17	8.72
12	10.74	10.30	9.86	8.98	8.54
13	10.50	10.07	9.65	8.79	8.37
14	10.27	9.86	9.44	8.62	8.20
15	10.05	9.65	9.25	8.45	8.04
16	9.83	9.44	9.06	8.28	7.89
17	9.63	9.25	8.87	8.12	7.74
18	9.43	9.06	8.70	7.97	7.60
19	9.24	8.88	8.53	7.82	7.46
20	9.06	8.71	8.36	7.67	7.32
21	8.88	8.54	8.20	7.53	7.19
22	8.71	8.38	8.05	7.39	7.06
23	8.55	8.22	7.90	7.25	6.93
24	8.39	8.07	7.76	7.12	6.80
25	8.24	7.93	7.61	6.99	6.68
26	8.09	7.78	7.47	6.86	6.55
27	7.95	7.64	7.34	6.73	6.42
28	7.81	7.51	7.21	6.60	6.30
29	7.68	7.38	7.07	6.47	6.17
30	7.55	7.25	6.95	6.34	6.04
31	7.42				
32	7.30				
33	7.18				
34	7.07				
35	6.95				
36	6.84				
37	6.73				
38	6.63				
39	6.52				
40	6.42				

9.1 Salinity Correction, by Formula

The corrected ppM value caused by salinity can be calculated as follows:

$$\text{Salinity-corrected ppM} = \text{ppM} \times (1 - (0.005827 \times \text{Salinity in ppK}))$$

10. THE OXYGEN ELECTRODE

The Electrode used is the amperometric type of Clark Electrode and is suitable for the measurement of oxygen pressures in the range 0 - 100 centimetres of mercury. While the probe actually reads partial pressure of oxygen, the circuit is calibrated to be read in percentage saturation or parts/million (milligrams/ litre). The operation of probes of the Clark type relies on the diffusion of oxygen through a suitable membrane into a constant environment of 0.1 molar potassium chloride. Measurements are best performed with a reasonable flow past the membrane. At sufficiently high flow rates, the oxygen current is totally independent of the flow (few cms/sec.). The cell must not be shaken, however, or
unstable readings will result from electrolyte surge bringing new oxygen from the reservoir to the working cathode surface.

10.1 Operating principle (YSI 5739 Electrode)

The YSI sensor is a Clark oxygen electrode and consists of a gold cathode and a Silver/silver chloride anode, placed in an electrolyte solution. This solution is contained behind a plastic membrane. In this case the plastic is .025mm intermediate density PTFE (Teflon). It must be realised that using membranes of very different thicknesses will result in an error in the temperature compensation that is applied in the instrument for the membrane permeability. This coefficient (here +4.2%/^{o}C at 25^{o}C) is for the applicable PTFE thickness. A polarising voltage of about 800 millivolts is applied between the two electrodes. The gold electrode is placed close to the membrane and because of the polarising voltage, oxygen diffusing through the membrane will be reduced at the gold electrode.

Equation: $O_2 + 2H^+ + 2$ electrons $\rightarrow H_2O_2$

This reduction process will produce a current through the oxygen electrode. A load resistor (actually a thermistor in this case) situated in the electrode itself, converts this current into a voltage proportional to the oxygen partial pressure. The thermistor provided within the body of the electrode can have a temperature coefficient of -4.2%/^{o}C. This gives an accurate temperature compensation for the temperature and permeability effect of the membrane to oxygen, over a range of + or - 20^{o}C about a centre value of 20^{o}C. Note this compensation is not for the solubility effects. A separate sensor (included in the YSI5739 electrode) achieves this.

10.2 Maintenance of the Membrane

The membrane does not require replacement as long as it remains intact. If punctured or suspected of leaking around the edges, it must be replaced. The cap or ring is removed, the old membrane taken off. Make sure the reservoir is full with no bubbles by "pumping" gently on the side rubber membrane with a blunt instrument such as the top end of a pencil or pen. Add a few drops of electrolyte onto the gold cathode, until a "dome" of solution is formed. A new piece membrane material is pulled firmly over the end of the probe so there are no wrinkles close to the gold cathode. The cap or ring is carefully pushed into place. The excess membrane may be trimmed off with a razor blade. During this process the electrolyte will not normally drain out. If it is thought that the electrolyte may be
contaminated or even used (it is actually consumed in the operation of the probe), then the probe may be washed out with distilled water. The gold surface must not be polished. Do not contaminate the gold cathode with oils etc from the skin by touching it.

For the YSI electrode the electrolyte is replaced with half saturated KCl solution, containing Kodak PhotoFlo. No air bubbles should be present between the cathode and the membrane.

If the probe is washed off and put in fresh water, then, by viewing obliquely in a strong light, it is possible to see electrolyte "streaming" from the tip if it is leaking (even slowly). The effect is one of differential refractive index and is quite sensitive. **Do not overstretch**.

If the response is low or reading overranged, fit a new membrane.

10.3 Notes On Units Of Dissolved Oxygen

The terms "Oxygen Concentration" and "Oxygen Partial Pressure", frequently give rise to some confusion.

1: Oxygen Concentration is the absolute quantity of oxygen present per unit mass of the liquid.
2: Oxygen Partial Pressure is the pressure of the oxygen fraction of the total gas (dissolved gaseous).
In any one liquid system, Oxygen Concentration and Oxygen Partial Pressure are proportional. However, if the solubility of oxygen in the liquid should change owing to increased quantities of solutes, etc., then the ratio of the Concentration to the Partial Pressure must change. Thus, if one saturates distilled water and a 25% solution of Sodium Chloride with air at atmospheric pressure (>5^{o}C) both solutions will have almost exactly the same Oxygen Partial Pressure, namely 15.5 cms of mercury. However, the dissolved Oxygen Concentration parts per million (milligrams per litre) will be 8.4 in the distilled water, and 2.01 parts/million (milligrams per litre) in the salt solution. This is a rather extreme example, as ocean water is only 3.6% saline. It does however stress the importance of correct interpretation of the salinity, etc.

The Clark Electrode measures the partial pressure of oxygen diffusing through a membrane. The current is a linear measure of this partial pressure, assuming liquid flow conditions are met. With air, at sea level, the 20.9% oxygen exerts about 15.5 cms (mercury standard) pressure. Water in equilibrium with air and with no COD or BOD, etc., is saturated and has this dissolved oxygen partial pressure. If we define 100% saturation in Partial Pressure terms, then 15.5 cm. Hg = 100% saturation. This is a practical unit to use. The probe linear readout is then a linear function of % Saturation. Organic cell walls behave like the probe and pressure units are valuable. % Saturation is the best unit for industrial control and not ppM, contrary to popular beliefs.

The partial pressure (and consequently the pressure defined % Saturation) varied only slightly with temperature. Recall at this stage that the permeability of the membrane has a temperature coefficient, but the electronics has scaled this out by the operation of the Automatic Membrane Temperature Compensator Thermometer incorporated in the Probe.

If mass units are used for the measurement of Dissolved Oxygen, the temperature problem of relating the linear partial pressure reading of the probe, to the mass (ppM or mg/l) at different temperatures becomes more involved. As well, there is the mass variation due to dissolved salts (salinity correction). Therefore, the only fully corrected instrument of any real value needs 3 different correction systems:
(1) Membrane correction for temperature permeability effects.
(2) Solubility correction of D.O. with temperature.
(3) Salinity correction of D.O. by weight (Salinity has no effect on pressure units readout).

To provide the mass units (ppM) readout (so popular due to the Winkler process used in the past), the 88-O has Automatic Solubility correction via the temperature sensor and the electronics.

The table in section 9 shows the amount of Saturated Dissolved Oxygen (in ppM.) in pure water at each degree of temperature (0^{o}C to 40^{o}C) The partial pressure of oxygen is 20.9%. This table can be used for ordinary fresh water. The amount of Saturated Dissolved Oxygen in ppM. against the solubility of Sodium Chloride in sea water is also shown from 0^{o}C to 30^{o}C at every 1^{o}C.

10.4 Equilibrium conditions

Whilst Saline Water has a lower ppM than does Fresh Water, it does not mean it necessarily has less oxygen, biologically available. Both have 100% Saturation (presuming no COD, BOD etc) because both are in partial pressure equilibrium with air. Any usage of oxygen is immediately supplied by the dissolving of more from the air, to meet partial pressure equilibrium requirements. This is so for both saline and fresh water.

The reporting of oxygen at a lower level (in ppM units) in the Salt Water is therefore QUITE MISLEADING! In closed systems, such as tanks, pipes and deep waters, equilibrium is not so readily available and the Salinity Effects gains in importance in the reporting of Dissolved Oxygen. It is suggested, that, unless such closed (or deep, low diffusion) systems are encountered, Dissolved Oxygen be reported in % Saturation or ppM of equivalent Fresh Water. That is, if ppM is desired, calibrate the 88-O according to the 0 ppK Salinity column in the table in section 9.

10.5 Velocity past the membrane

Workers have shown that the relationship between the diffusion current (oxygen current) and the external velocity of the liquid is exponential. Some workers using thicker membranes have shown even less dependence of the diffusion current on liquid velocity. Because of the exponential nature of the relationship, very considerable changes in velocity have to be made before noticing any change in the diffusing current once the flow is sufficiently high. Tests with this electrode have shown that flow rates above 0.2 litres/minute past the membrane give results indistinguishable from those with appreciably higher flow rates (5 litres/minute). Fluctuations in readings due to air bubbles passing through the membrane are, however, a different matter. With the type of electrode to be used with this instrument, very little changes in diffusion current are caused by altering the pH of the external
environment. Pressure changes over a moderate range exerted on the membrane also cause no change. The probe is sealed by glands for total immersion to a few 1O's of metres.

11. WARRANTY

TPS Pty. Ltd. guarantees all instruments and electrodes to be free from defects in material and workmanship when subjected to normal use and service. This guarantee is expressly limited to the servicing and/or adjustment of an instrument returned to the Factory, or Authorised Service Station, freight prepaid, within twelve (12) months from the date of delivery, and to the repairing, replacing, or adjusting of parts which upon inspection are found to be defective. Warranty period on electrodes is three (3) months.

There are no express or implied warranties which extend beyond the face hereof, and TPS Pty. Ltd. is not liable for any incidental or consequential damages arising from the use or misuse of this equipment, or from interpretation of information derived from the equipment.

Shipping damage is not covered by this warranty.

PLEASE NOTE:
A guarantee card is packed with the instrument or electrode. This card must be completed at the time of purchase and the registration section returned to TPS Pty. Ltd. within 7 days. No claims will be recognised without the original guarantee card or other proof of purchase. This warranty becomes invalid if modifications or repairs are attempted by unauthorised persons, or the serial number is missing.

PROCEDURE FOR SERVICE
If you feel that this equipment is in need of repair, please re-read the manual. Sometimes, instruments are received for "repair" in perfect working order. This can occur where batteries simply require replacement or re-charging, or where the electrode simply requires cleaning or replacement.
TPS Pty. Ltd. has a fine reputation for prompt and efficient service. In just a few days, our factory service engineers and technicians will examine and repair your equipment to your full satisfaction.

To obtain this service, please follow this procedure:
Return the instrument AND ALL SENSORS to TPS freight pre-paid and insured in its original packing or suitable equivalent. INSIST on a proof of delivery receipt from the carrier for your protection in the case of shipping claims for transit loss or damage. It is your responsibility as the sender to ensure that TPS receives the unit.

Please check that the following is enclosed with your equipment:

- **Your Name and daytime phone number.**
- **Your company name, ORDER number, and return street address.**
- **A description of the fault. (Please be SPECIFIC.)**
  (note: "Please Repair" does NOT describe a fault.)
- **either $12 for return freight for units under warranty,**
- **or $20 to cover inspection costs and return freight.**

(These amounts are not applicable to full-account customers.)

For out-of-warranty units, a repair cost will be calculated from parts and labor costs. If payment is not received for the additional charges within 30 days, or if you decline to have the equipment repaired, the complete unit will be returned to you freight paid, not repaired. For full-account customers, the repair charges will be debited to your account.

- **Always describe the fault in writing.**
- **Always return the sensors with the meter.**

If you did not receive a Warranty Card, please photocopy or tear off the bottom half of this page, fill in the details and send to:

T.P.S. PTY. LTD.
4 JAMBEROO STREET,
SPRINGWOOD, BRISBANE,
AUSTRALIA, 4127.

Fill in purchase details for your reference. (Retain this section).

Model No: _____ Serial No: _____

Purchase Date: _____ Dealer: _____

Send this section to TPS

Customer: _____ Position: _____

Company/Division: _____

Address: _____

City: _____

Post Code: _____ Country _____

Phone No: _____ Fax No: _____

Model No: _____ Serial No: _____

Purchase Date: _____ Dealer: _____

Comments: _____

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