YSI MODEL 56
DISSOLVED OXYGEN MONITOR
INSTRUCTION MANUAL

Scientific Division
Yellow Springs Instrument Co., Inc.
Yellow Springs, Ohio 45387 • Phone 513-767-7241 • Telex 20-5437

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GENERAL DESCRIPTION

The YSI Model 56 Dissolved Oxygen Monitor (see Figure 1) is intended to provide a record of dissolved oxygen content and temperature in a liquid environment. The information is recorded on a 4"-wide strip chart record. Dissolved oxygen (D.O.) is indicated in milligrams per liter (mg/l) on **0.5, 0-10, 0-20** scales or in air saturation on a **0-100%** scale. Temperature is indicated in **°C** on a **-5** to **+45 °C** scale. The D.O. ranges are appropriately automatically compensated for solubility of oxygen in water and permeability of the probe membrane.

The instrument has a rugged polyethylene case which is rain-tight and weather-resistant. If lost overboard or left in a flooded site, the unit should float for several hours. A storage compartment in the case lid provides space for storing accessories and service items. An external clip is provided for mounting a YSI cable reel and probe during transport. Probes with cables up to 250' long may be used with the Model 56. A 12 volt power outlet is provided to operate a probe stirrer, normally required where sample flow is less than 1 foot per second. The batteries' capacity allows at least 10 days unattended recording. The instrument can be line operated using the battery charger with, or in place of, the removable battery pack.

The D.O. probe uses a Clark-type membrane-covered polarographic sensor with built in thermistors for temperature measurement and compensation. A thin, permeable membrane stretched over the sensor isolates the sensor elements from the environment but allows oxygen and certain other gases to enter. When a polarizing voltage is applied across the sensor, oxygen that has passed through the membrane reacts at the cathode causing a current to flow.

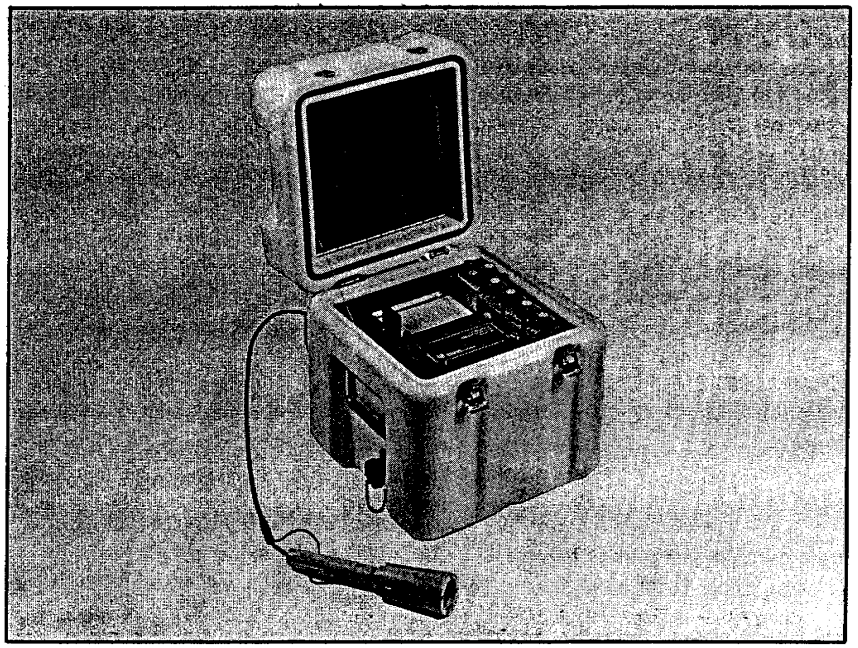

Figure 1 - YSI Model 56 Dissolved Oxygen Monitor

The membrane passes oxygen at a rate proportional to the pressure difference across it. Since oxygen is rapidly consumed at the cathode, it can be assumed that the oxygen pressure inside the membrane is zero. Hence the force causing the oxygen to diffuse through the membrane is proportional to the partial pressure of the oxygen outside the membrane. If the oxygen pressure increases, more oxygen diffuses through the membrane and more current flows through the sensor. A lower pressure results in less current.

SPECIFICATIONS

Instrument

OXYGEN RECORDING: The Model 56 can record in units of mg/l dissolved oxygen in three ranges (0-5, 0-10, and 0-20) and 0-100% AIR SATURATION. When using the dissolved oxygen ranges, linearity is 0.5% of full range. If the instrument is calibrated on **0-10 mg/l** or **0-100%** AIR SATURATION, switching to **0-5** or **0-20 mg/l** can introduce an error of 1% of the reading on the "switched to" range. Supersaturated freshwater samples require special consideration; see comments on Supersaturated Samples in Measurement Notes.

Overall ambient temperature limitations for the Model 56 are -30 to +60 °C; however, instrument accuracy specifications are not guaranteed beyond 0 to 45 °C. With the instrument factory-zeroed at 25 °C, allowable instrument electronic zero offset over the 0 to 45 °C ambient temperature range is 1% for **0-100%** AIR SATURATION or 0.1 mg/l for the **mg/l** ranges.

The probe is preprogramed for automatic temperature compensation for sample temperatures from 0 to 45 °C. Appropriate compensation is automatically provided for mg/l or 0-100% air saturation measurement. Typically the accuracy of the D.O. reading for probe temperatures within ±5 °C of calibration temperature is ±1%. The accuracy is ±3% of the D.O. reading when probe temperatures vary from calibration temperature over the 0 to 45 °C span.

The minimum recorder response time is ½ second with the **FILTER** turned to **OFF** and 18 ± 5 minutes at the maximum **FILTER** setting for the instrument pen to respond 90% to a step change in the D.O. signal.

TEMPERATURE RECORDING: The Model 56 has a range of -5 TO +45 °C with an accuracy of ±0.4 °C plus probe interchangeability. The linearity is ± 0.1 °C over the +5 to +30 °C region. The instrument's temperature scale is nonlinear over the -5 to +5 °C and +30 to +45 °C regions. The fixed time required for the instrument pen to respond 90% to a step change in temperature signal is 1/2 second.

CHART SPEEDS: Chart speeds are **1, 2, 5,** and **10 CM/HR** plus the uncalibrated **RAPID** (~10 cm/min). The worst case chart speed error is ±10 min/day.

BATTERIES:

Type: Two, 6 volt, 8 amp-hour, sealed, lead-acid, rechargeable, cyclical discharge such as Yuasa Nuyper NP8-6M 6V 8.6 AH in series.

Operating Time with Stirrer: Minimum of 10 days with YSI 5695 stirrer.

Battery Charger: YSI 5604 (115 V), YSI 5605 (230 V): Automatic dual mode. The "FAST" light indicates a fast charge and the "ON" light, by itself, indicates a slow charge when only a maintenance charge is needed.

Recharge Time: Nominal 24 hour recharge time.

Battery Charge Indicator: Battery terminal voltage is indicated on the instrument's **0-10 O_2** scale. **0** = 10.5 ±0.1 volts; **10** = 13 ±0.25 volts.

Battery Cut-Off Feature: When battery terminal voltage drops to 10.5 ±0.1 volts, the instrument automatically shuts off until battery voltage is increased to 13 volts or instrument **POWER** switch is cycled through **OFF** with batteries above the cut-off voltage.

Venting: The instrument charger jack serves to vent the enclosure during battery charging.

Line Operation: Instrument and stirrer can be powered continuously by the YSI 5604 or 5605 charger.

EXTERNAL OUTPUT: External output of 0 to 100 mV signal is available at the instrument **OUTPUT** receptacle. This signal is proportional to pen position in **°C, O_2,** and **O_2 & °C** modes. In **ZERO** and **BAT CHK** modes, the O_2 signal is presented.

INSTRUMENT ENVIRONMENT

Ambient temperature range for specification performance: 0 to 45 °C.

Water Resistance: With charger receptacle capped, the instrument is sealed to prevent entry of hose-directed spray.

Desiccant Protection: A removable, reusable desiccant capsule in the instrument storage lid provides protection from condensing atmospheric conditions when the instrument is sealed.

Probe

NOTE: Instrument and probe specifications in this Instruction Manual are based on the use of the YSI 5739 O_2 probe prepared for operation with YSI 5675 Service Kit.

Cathode: Gold.
Anode: Silver.
Membrane: 0.002"-thick FEP Teflon®.
Electrolyte: 0.5 saturated KCL with Kodak Photo-Flo®.
Temperature Sensors: Two, YSI 44004 thermistors; ±0.2 °C accuracy.
Pressure Compensation: Effective 0.5% of reading to 100 P.S.I.
Polarizing Voltage: 0.65 V nominal.
Probe Current: ~ 7.5 microamps in air @ 25 °C, 760 mmHg; less than 0.05 microamps in nitrogen @ 25 °C.
Response Time: 60 seconds to 90% of a step change in D.O. @ 25 °C.
Typical Probe Calibration Stability: ± 3%/week @ 0-30 °C; ± 5%/week @ 30-45 °C.

Accessories and Replacement Parts

YSI 5739 O_2 Temperature Probe for field use. (Use with one of the following cables or with the YSI 5695 submersible stirrer.)

YSI 5740 Cable for use with YSI 5739 O_2 Probe:

YSI 5740-10	10' cable (3 meters)
YSI 5740-25	25' cable (7.5 meters)
YSI 5740-50	50' cable (15 meters)
YSI 5740-100	100' cable (30.5 meters)
YSI 5740-150	150' cable (45.5 meters)
YSI 5740-200	200' cable (61 meters)

YSI 5695 Submersible Stirrer for the YSI 5739 D.O. Temperature Probe and the YSI Model 56 Dissolved Oxygen Monitor. The stirrer comes with attached 50' cable to connect stirrer to instrument (12 VDC power supply) and to connect YSI 5739 D.O. Probe to the instrument. (See Figure 2.)

YSI 5675 Monitoring Probe Service Kit. Includes (30) 0.002"-thick FEP, half sensitivity membranes; KCL solution 30 ml; probe service tool and monitor service instructions for the 5739 probe.

YSI 5945 "O" Ring Pack includes six "O" rings for each type of YSI D.O. probe including the YSI 5739.

YSI 5986 Diaphragm Kit for use with YSI 5739 pressure compensated D.O. probe.

YSI 5601 Probe Storage Clip for storing probe on reel. Cable reel is supplied with all cable lengths greater than 10'.

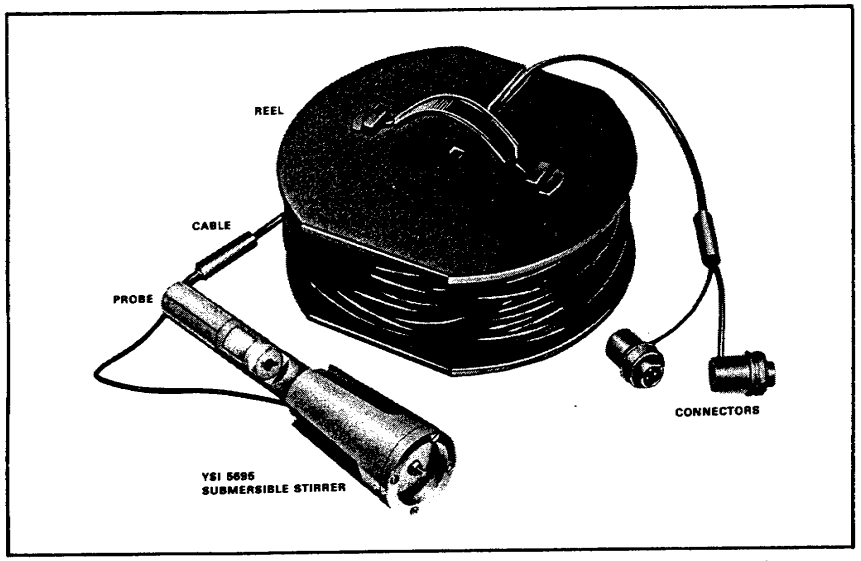

Figure 2 - YSI 5695 Submersible Stirrer with reel and cable.

YSI 5603 Rechargeable Battery Pack for YSI Model 56 instrument (spare).

YSI 5602 Chart Paper, 25 meter roll, for YSI Model 56 Dissolved Oxygen Monitor.

YSI 004612 Desiccant.

YSI 022141 Model 56 D.O. Monitor Service Manual.

YSI 5739 OXYGEN PROBE AND EQUIPMENT

General Description

The YSI Model 56 uses a YSI Model 5739 polarographic oxygen probe. The probe is equipped with a built-in lead weight and automatic pressure compensation.

For user convenience, the probe is equipped with a disconnecting cable to facilitate changing cable lengths and replacing damaged cables or probes. The probe and cable assembly is held together with a threaded retaining nut. The connection is *not* designed for casual disconnection and should only be disconnected when necessary.

To disconnect the cable, unscrew the retaining nut and slide it down to cable to expose the connector. Pull gently on the cable and connector until the connector comes away from the probe body.

To reassemble, inspect the connector and "O" ring for cleanliness. If the "O" ring is frayed or damaged, remove it by squeezing it in the groove causing it to bulge, then roll it out of the groove and off the connector. A replacement "O" ring is supplied with the cable.

Push the connector into the probe body rotating it until the two halves mate. A light coating of vaseline or silicone grease on the "O" ring will make reassembly easier. Air trapped between the connector halves, which may cause them to spring apart slightly, is normal. Screw on the retaining nut, *hand tight only.*

NOTE: If erratic readings are experienced, disconnect the cable and inspect for water. If present, dry out and reconnect, replacing the "O" ring if necessary.

Pressure Compensation

The vent on the side of the probe is part of a pressure compensating system that helps assure accurate readings at great depths of water. Pressure compensation is effective to 0.5% of reading with pressures to 100 psi (230 ft. water). The volume of air trapped under the membrane determines how serious the pressure error will be. To minimize this pressure error proper preparation of the probe is essential. (See OPERATING PROCEDURES.) The system is designed to accommodate a small amount of trapped air and still function properly, but the amount should be kept to a minimum.

The compensating system normally does not require servicing and should not be taken apart. However, if electrolyte is leaking through the diaphragm or if there is an obvious puncture, the diaphragm must be replaced. A spare is supplied with the probe. Using a coin, unscrew the retaining plug and remove the washer and the diaphragm, flush any salt crystals from the reservoir, install the new diaphragm (convolution side in), replace the washer, and screw in the retaining plug. (See Figure 3.)

For Accurate Measurements in Water

A liquid flow of at least 1 foot per second is needed to remove the oxygen-depleted layer immediately outside the membrane created by the constant consumption of oxygen.

The probe's service life and/or calibration stability is determined by several considerations. First is the gradual buildup of silver metal from the anode to the gold cathode. This accumulation requires cleaning off when it becomes thick enough to be visible or is enough to alter the probe's calibration.

Second is the fouling of the membrane's outer surface by its environment. Any deposit which restricts the ability of the dissolved oxygen to reach the membrane surface alters the probe reading. Oil films and oxygen-consuming organisms are the two main causes. Sample agitation and/or more frequent cleaning of the membrane can solve this problem.

The *Half-Sensitivity* membranes included in the YSI 5675 Monitoring Service Kit are recommended for general purpose monitoring use. These units are 0.002" thick. The *Standard* membranes included with the probe, and available in the YSI 5775 Service Kit, are 0.001" thick. In addition *High-Sensitivity* mem-

branes 0.0005" thick are available.

The thicker membranes are recommended because of their greater membrane integrity. A consequence of using thicker membranes is lower O_2 permeability and probe signal current and slower response speed. For most monitoring applications this trade off is desirable. In monitoring applications where faster response speed is required, the standard membranes may be considered.

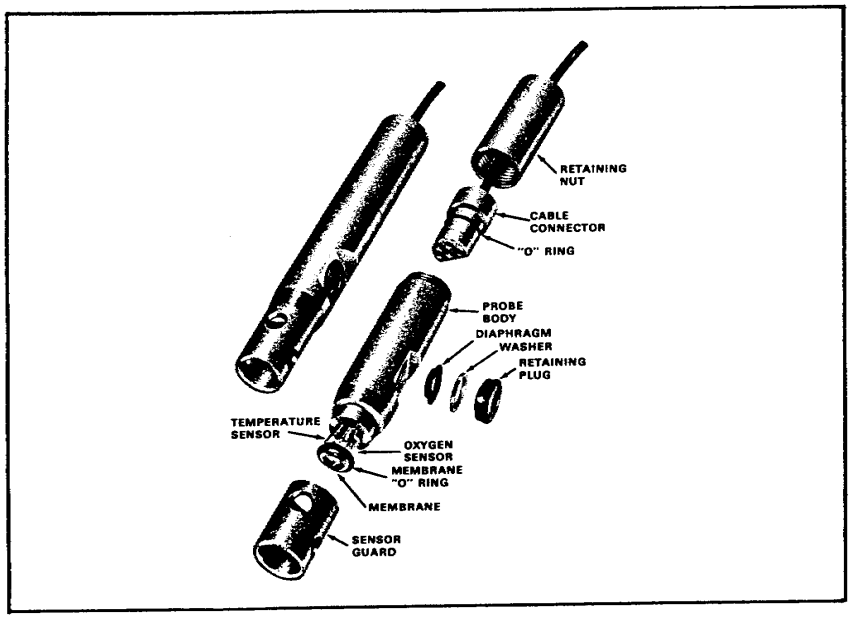

Figure 3 - The 5739 Probe

When data is routinely collected with sample temperatures below 15 °C the low signal current resulting from the use of the half-sensitivy membranes tends to magnify the probe's inherent constant background signal. Using the standard membranes in this situation will decrease the percent error due to the probe's background current.

Theory of Operation

The probe sensor consists of two electrodes wetted with potassium chloride electrolyte and sealed from the environment by an oxygen permeable Teflon® membrane.

A 0.65 supply voltage is applied between the gold cathode (negative) that is positioned directly under the membrane and the central silver anode (positive). The cathode "consumes" any oxygen that is dissolved in the thin layer of electrolyte between the cathode and the membrane. This frees four electrons from the cathode for each molecule of oxygen consumed and produces an electric current passing between anode and cathode proportional to the quantity of oxygen consumed.

The silver anode reacts with chloride ions accepting electrons from the electrolyte to complete the probe's conduction path. Whenever oxygen pressure outside the membrane is greater than zero, oxygen diffuses through the membrane into the probe. The current created by the entering amount of oxygen indicates the environmental oxygen partial pressure. The probe current can be calibrated at the instrument into required measurement units (i.e. % air saturation, % oxygen saturation, or milligrams per liter dissolved oxygen by weight).

Calibration is performed by exposing the probe to a gas or liquid of known oxygen content or known oxygen partial pressure. The 56's recorder sensitivity is adjusted to indicate this value. As a convenient and accurate alternate, the oxygen partial pressure in an air-saturated liquid is equal to the oxygen partial pressure in the saturating air. It follows that the probe/instrument calibration is identical with the probe exposed to either moist air or air-saturated water. The 56 automatically scales for % air saturation units (if % air saturation is pressure corrected for the true barometric pressure) to fresh water mg/l units via the **O_2 RANGE** switch.

YSI 5695 Submersible Stirrer

The YSI Submersible Stirrer (see Figure 2) agitates the sample adjacent to the probe membrane providing a continuous, fresh sample to the probe. The stirrer should be used where a steady sample flow rate of at least 1 foot per second is not provided by existing sample flow.

When a probe is used with the submersible stirrer, the stirrer agitates the sample directly in front of the sensor by means of a rotating eccentric weight which causes the spring-mounted sealed motor housing to vibrate. An impeller on the end of the motor housing flushes the medium across the oxygen sensor. (See sales literature and YSI 5695 Instruction Sheet for further information.)

The YSI 5695, with its 50 foot cable, connects directly to the YSI 5739 probe and provides the cable connection between probe and instrument. Special models with longer or shorter cable lengths are available. 12-volt power for the stirrer is provided by the Model 56 rechargeable battery pack. Stirrer power consumption is approximately 20% of the system load.

OPERATING PROCEDURES

Preparing the Probe

ALL PROBES ARE SHIPPED DRY — YOU MUST FOLLOW THESE INSTRUCTIONS. For optimum monitoring performance, prepare the probe with one of the half-sensitivity membranes included in the YSI 5675 Service Kit. For optimum stability, contour and clean the probe's gold sensing surface with the sanding tool provided in the YSI 5675 Service Kit.

1. Prepare the electrolyte provided in the service kit by dissolving the KCL crystals in the dropper bottle with distilled water. Fill the bottle to the top.
2. Unscrew the sensor guard from the probe and remove the "O" ring and membrane. Throughly rinse the sensor with distilled water.
3. Prepare a new probe for use with the half-sensitivity membrane.
   A. Lightly pencil an "X" across the probe's gold sensing surface. (See Figure 4.)
   B. Wet the specially contoured sanding tool from the YSI 5675 Service Kit with distilled water.
   C. Hold the tool's abrasive face uniformly against the probe's sensing surface (see Figure 5) and slowly twist the tool in a circular fashion until all traces of the pencil mark are erased.
   D. Use the tool to slightly radius the outer edge of the probe face. (See Figure 6.)
   Rinse probe surface with distilled water to remove all particles.

NOTE: If a probe has been in use for some time and the gold cathode appears tarnished or shows a slight silver ring on the inner edge, it should be restored by sanding as described in Step 3.

4. Fill the probe with electrolyte as follows (see Figure 7):

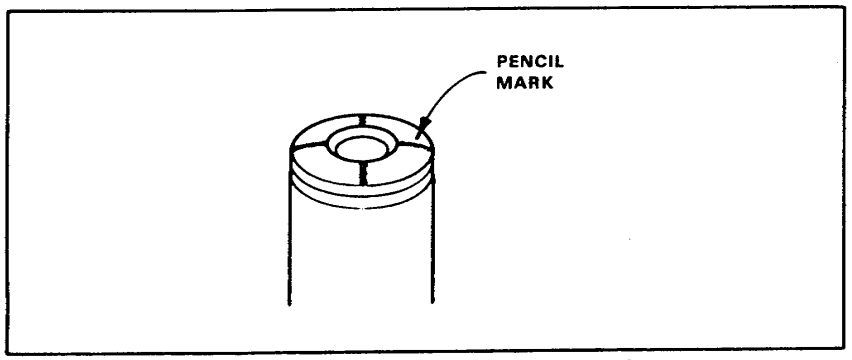

Figure 4 - Penciled X on the probe surface

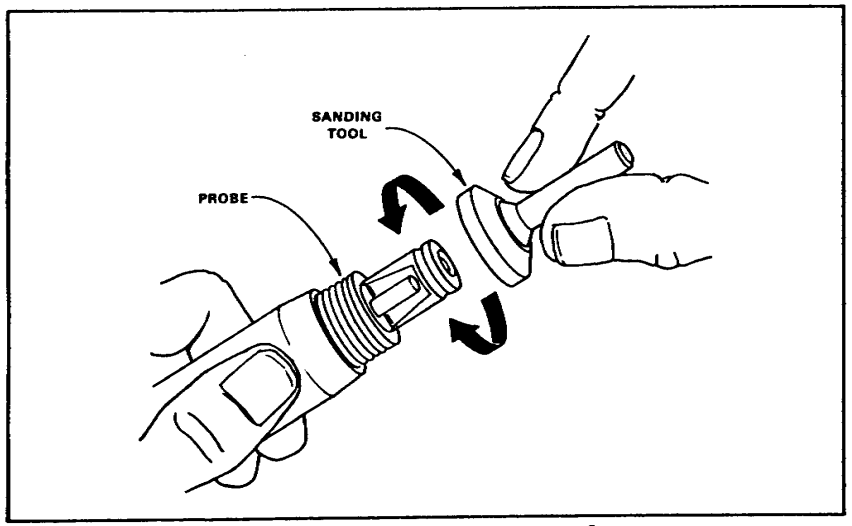

Figure 5 - Sanding the probe surface

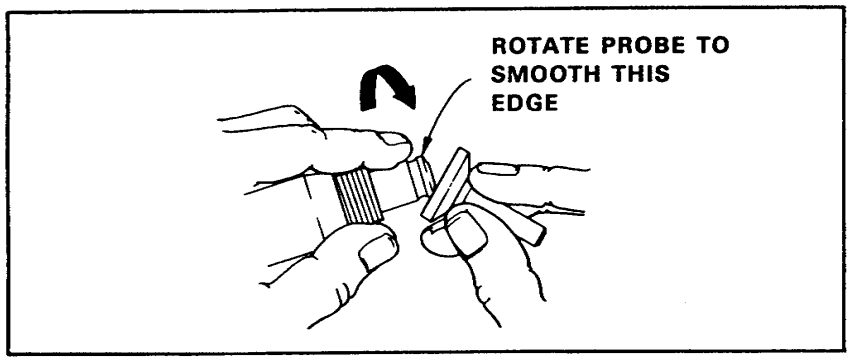

Figure 6 - Smoothing the edge

A. Grasp the probe in your left hand. When preparing the YSI 5739 Probe the pressure compensating vent should be to the right. Successively fill the sensor body with electrolyte while pumping the diaphragm with the eraser end of a pencil or similar soft, blunt tool. Continue filling and pumping until no more air bubbles appear. (With practice you can hold the probe and pump with one hand while filling with the other.)

B. Secure a membrane under your left thumb. Add more electrolyte to the probe until a large meniscus completely covers the gold cathode.

NOTE: Handle membrane material with care . . . keep it clean and dust free . . . touch it only at the ends.

C. With the thumb and forefinger of your other hand, grasp the free end of the membrane.

D. Using a continuous motion, *stretch* the membrane UP, OVER and DOWN the other side of the sensor. Stretch DOWN until the membrane "cap" forms smoothly over the "O" ring groove.

E. Secure the end of the membrane under the forefinger of the hand holding the probe.

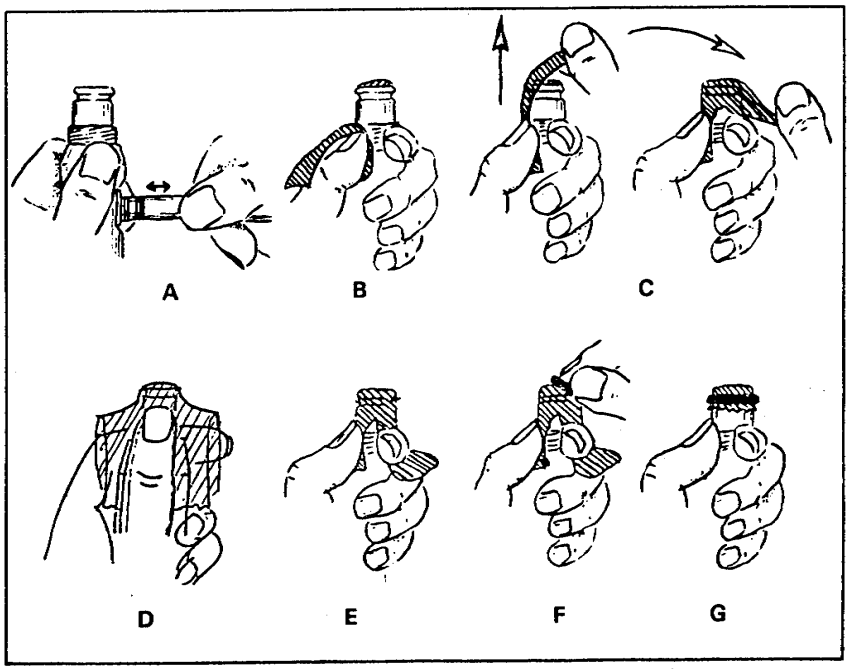

Figure 7 - Putting the membrane on the probe

F. Roll the "O" ring over the end of the probe. There should be no wrinkles in the membrane or trapped air bubbles. Some wrinkles may be removed by lightly tugging on the edges of the membrane beyond the "O" ring.

G. Trim off excess membrane with scissors or sharp knife. Check that the stainless steel temperature sensor is not covered by excess membrane.

5. Shake off excess KCL and reinstall the sensor guard.
6. A bottomless plastic calibration bottle is provided with the YSI 5739 Probe for convenient calibration. Place a small piece of moist towel or sponge in the bottle and insert the probe into the open end. This ensures 100% humidity for accurate calibration and helps protect the probe against drying out in storage.
7. Membranes will last indefinitely, depending on usage. Average replacement is 2 to 4 weeks. However; should the electrolyte be allowed to evaporate and an excessive volume of air form under the membrane, or the membrane become damaged, thoroughly flush the reservoir with KCL and install a new membrane.
8. Also replace the membrane if erratic readings are observed or calibration is not stable.
9. User-prepared electrolyte can be made by making a saturated solution of reagent grade KCL and distilled water and then diluting the solution to half strength with distilled water. Adding two drops of Kodak Photoflo® per 100 ml of solution assures good wetting of the sensor.
10. H_2S, SO_2, halogens, neon, nitrous oxide and CO are interfering gases. If you suspect erroneous readings, it may be necessary to determine if these are the cause.

Gas	Response @ 20 °C
100% Carbon Monoxide	< 1% O_2 response
100% Carbon Dioxide	~ 1% O_2 response
100% Hydrogen	< 1% O_2 response
100% Chlorine	2/3 O_2 response
100% Helium	none
100% Nitrous Oxide	1/3 O_2 response
100% Ethylene	none
100% Nitric Oxide	1/3 O_2 response

Preparing the Instrument for Operation

1. Connect the YSI Model 5739 Oxygen Probe to the receptacle on the side of the case. Tighten the connector finger tight to ensure a proper waterproof seal. If the YSI Model 5695 submersible stirrer is to be used, connect it to the probe at this time.
2. Open case lid.
3. Pull out the chart paper drawer by grasping the handles on either side of the chart paper and pulling up. Check for sufficient paper supply. If additional paper is needed, see section on Chart Paper for proper paper loading.
4. Check desiccant condition if the instrument is to be used in an environment of 70% relative humidity or above. Window in desiccant should be blue in color. If the desiccant appears white, see section on Desiccant Maintenance for desiccant drying.
5. Check battery charge. (See Figure 8.)
   A. Switch **POWER** to **ON** and **PEN INPUT** to **ZERO.** Adjust **PEN ZERO** to read **0** on the **0-10** red scale on the scale plate.
   B. Turn **PEN INPUT** switch to **BAT CHK.** Recharge batteries if the pen will not move or if the pen indicates low battery charge. **10** on the **0-10** red scale on the scale plate is full charge. **0** indicates lack of charge. See section on Instrument Battery for battery charging.

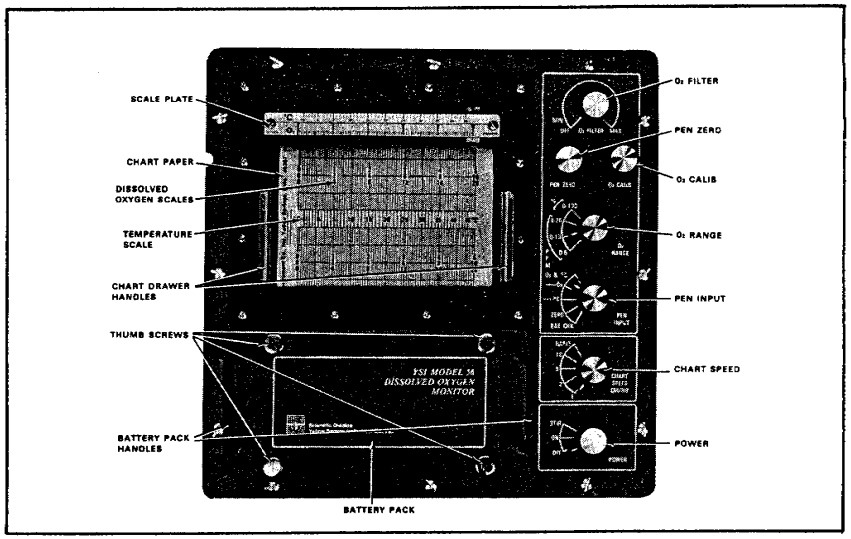

Figure 8 - Model 56 instrument panel

Calibration

NOTE: Each time the probe membrane is changed, adjust the instrument's O_2 **CALIB** knob to compensate for normal variation in membrane characteristics. Likewise, adjust the calibration if the probe is replaced. After data collection, check the calibration to verify that the data is not in error due to probe damage or calibration shift.

Calibration consists of exposing the probe to a known oxygen concentration, such as air or water of a known oxygen content, and then appropriately adjusting the Model 56 reading to match the known sample. The following procedure is based on the air calibration technique. (See Figure 8.)

1. Place a moist sponge or a piece of cloth in the plastic calibration bottle. Loosen the bottle lid about ½ turn and slip the bottle over the probe guard up to the body. Place the probe in a protected location where temperature is not changing or wrap it in a cloth or other insulator.
2. Set instrument:
   POWER to **ON**
   CHART SPEED to **1 CM/HR**
   PEN INPUT to **O_2 & °C**
   O_2 RANGE to **0-100%**
   O_2 FILTER to **OFF**
3. After one minute, adjust the **O_2 CALIB** control to give a full scale dissolved oxygen reading near **10.** Switch **PEN INPUT** to **O_2 & °C.**
4. Wait for the pen to draw straight lines on the chart.

   NOTE: The accuracy of your data is dependent on the accuracy of the calibration. Following a membrane change, probe stabilization may require several hours. For best calibration accuracy allow the probe to stabilize with polarization voltage on overnight.

Once the lines are straight, the probe has stabilized and can be calibrated. If both the °C and O_2 lines are not straight, probe temperature is fluctuating too much. If the °C line is straight but the solid O_2 line continues to change, the probe is not functioning properly. See sections on Preparing the Probe and Maintenance and Service Considerations.

5. To calibrate
   A. Set **O_2 RANGE** to **0-100%**
   B. Switch **PEN INPUT** to **ZERO**
      Set **CHART SPEED** to **RAPID**
      Turn **O_2 FILTER** to **OFF**
      Adjust **PEN ZERO** control to indicate **0** on the **0-10** chart scale.
   C. From Table I look up the Calibration Value for the local true (not "corrected") barometic pressure.
   D. Switch **PEN INPUT** to **O_2** and adjust the **O_2 CALIB** control until the pen traces at the calibration value on the **0-10** chart scale.

      NOTE: If calibrating to read % air saturation, use **10.0** as the calibration value.

   E. Switch **CHART SPEED** control to **1 CM/HR.**

Atmospheric Pressure (mmHg)	or	Equivalent Altitude (ft.)	=	Calibration Value
775		-540		10.2
760		0		10.0
745		542		9.8
730		1094		9.6
714		1688		9.4
699		2274		9.2
684		2864		9.0
669		3466		8.8
654		4082		8.6
638		4756		8.4
623		5403		8.2
608		6065		8.0
593		6744		7.8
578		7440		7.6
562		8204		7.4
547		8939		7.2
532		9694		7.0
517		10472		6.8
502		11273		6.6

Table I - Calibration value

6. The calibration procedure in Step 5 is the most reliable and accurate under most circumstances. However, if a Winkler Titration calibration is preferred, use the following procedure:
   A. Draw a volume of water from a common source and carefully divide it into four samples. Determine the oxygen in three samples using the Winkler Titration technique and average the three values. If one of the values differs from the other two by more than 0.5 mg/l, discard the value and average the remaining two.

   B. Place the stabilized probe in the fourth sample and stir.
   C. Allow the probe to remain in the sample two minutes.
   D. Switch the Model 56 as follows:
      CHART SPEED to **RAPID**
      PEN INPUT to **O_2**
      O_2 FILTER to **OFF**
      O_2 RANGE to **0-5, 0-10,** or **0-20 mg/l** as required to include the titrated D.O. of the sample on the scale.
   E. Adjust the **O_2 CALIB** knob until the pen traces at the value determined in Step A. Probe and instrument are now calibrated.

Monitoring Dissolved Oxygen

With the probe and instrument prepared and calibrated, the monitor can now be set up in a variety of modes to perform various measurements.

1. Probe Placement Considerations
   The probe can be placed directly into moving water that has a flowrate of at least 1 ft per second but not more than 5 ft per second. The probe should be firmly clamped or taped to a rigid wand or pipe to prevent unnecessary wear on the probe cable from constant flexing. Position the probe on the downstream side of the support to protect it from debris. The probe should be attached in such a way as to provide for easy routine servicing. (See Figure 9.)

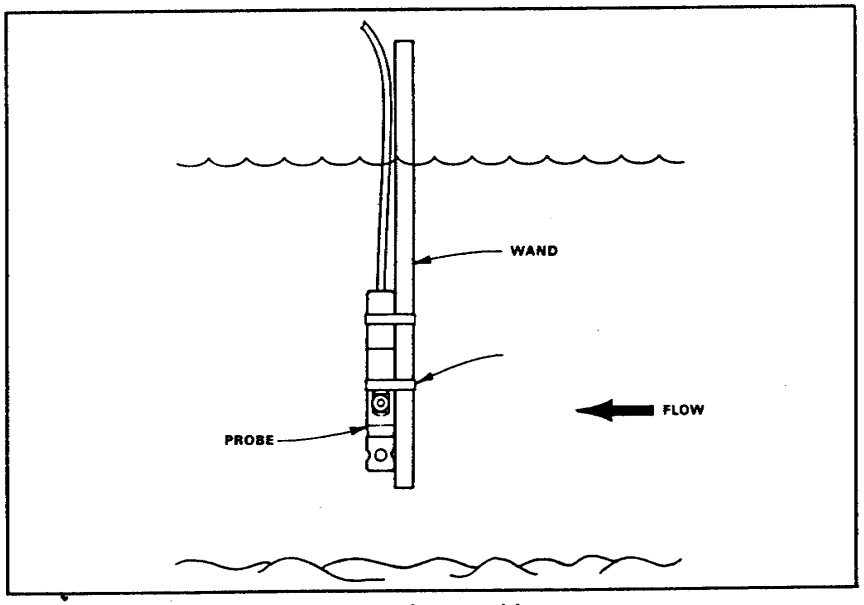

Figure 9 - Probe secured to avoid unnecessary wear

When the flowrate of the water is less than 1 ft per second, the probe should be used with a YSI 5695 Submersible Stirrer. (See Figure 10.) The probe/stirrer can be supported by its cable from the pier (A), boom or float (B), or attached to a wand or pipe (C). A simple probe stand can be used to hold the probe and stirrer above a pool bottom (D).

2. Environmental Considerations
Continuous monitoring with membrane-covered dissolved oxygen probes is not recommended for certain applications

A. Erroneous readings will be made in any environment where the probe's Teflon® membrane will become rapidly coated with oxygen consuming or oxygen evolving organisms. In some cases the YSI 5695 Submersible Stirrer can provide adequate cleaning action due to its high turbulence action.

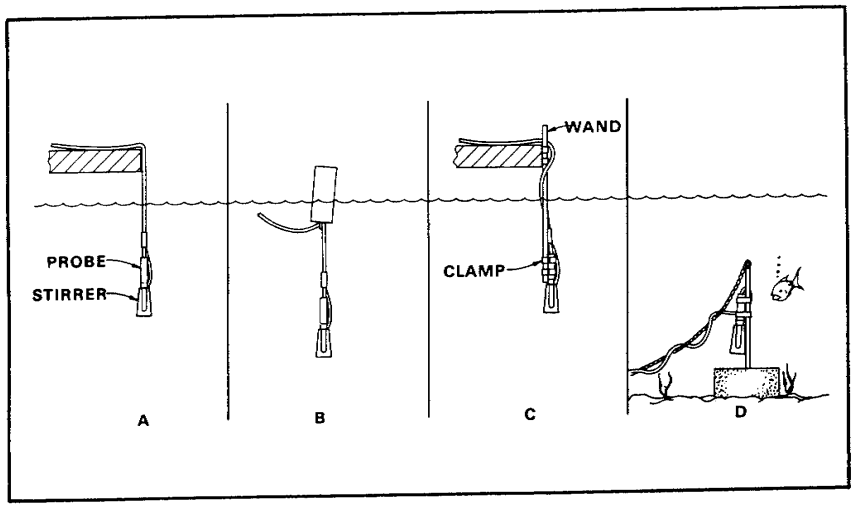

Figure 10 - Using the probe with the submersible stirrer

B. Erroneous readings will be made in any environment where heavy residue may coat the probe's membrane. In such instances, problems generally can be eliminated by more frequent probe service and/or cleaning.

C. Erroneous readings will be made in any environment where dissolved gases are present which will chemically interfere with the probe's electrochemistry. Known interfering gases are H_2S, SO_2, halogens, neon, nitrous oxide and CO. (See list on p. 10.)

D. Also avoid any environment that contains substances that may attack the probe materials. Some of these substances are concentrated acid, caustics and strong solvents. The probe materials that come in contact with the sample include: FEP Teflon®, acrylic plastic, A.B.S. plastic, E.P.R. rubber, stainless steel, epoxy and the polyurethane cable.

3. Instrument Settings. (See Figure 8.)
Position the probe and set the instrument controls as follows:

A. **POWER** to **ON** (**STIR** if the YSI 5695 Submersible Stirrer is used.)

B. **CHART SPEED** to **RAPID**

C. **PEN INPUT** to **ZERO**; adjust **PEN ZERO** to trace a solid line on the chart at **0** on the **0-10** scale.

D. **CHART SPEED** to appropriate speed:
1 CM/HR = 0.24 m/day; **5 CM/HR** = 1.20 m/day;
2 CM/HR = 0.48 m/day; **10 CM/HR** = 2.40 m/day
NOTE: A full roll of paper is approximately 24 meters long.

E. PEN INPUT to appropriate setting:
--- **°C**; pen records temperature only.
— **O_2**; pen records D.O. only.
O_2 & °C; pen records two lines; dashed line is probe temperature and solid line is D.O.

F. **O_2 RANGE** to appropriate D.O. range:
0-5 mg/l **0-20 mg/l**
0-10 mg/l **0-100% AIR SATURATION**

G. If O_2 reading shows rapid fluctuation in your sample, adjust **O_2 FILTER** until pen draws a continuous smooth line. **OFF** position eliminates all filtering.

H. Mark the chart paper with:
1. Time of day.
2. Location.
3. **CHART SPEED** in use.
4. **O_2 RANGE** in use.

I. Close and latch instrument.

Post Data Collection

Following an extended period of operation, the probe's calibration should be checked to ensure data accuracy. See section on Calibration. Note any change from initial calibration on the chart. If the instrument's batteries have been exhausted during operation, the instrument will have shut off automatically. Operation is restored by recharging the batteries and then switching the instrument from **OFF** to **ON**. Probe calibration is not affected by shutting the monitor off or disconnecting the probe, but does require an approximately 15 minute stabilization period upon restoration of power.

MEASUREMENT NOTES

Dissolved Oxygen Measurements in Samples with Unknown or Varying Oxygen Solubility

The **0-100%** air saturation dissolved oxygen range of the YSI Model 56 Dissolved Oxygen Monitor facilitates accurate observation of dissolved oxygen levels for non-freshwater environments.

In applications where the sample's solubility of oxygen is fluctuating, or unknown, dissolved oxygen levels are most accurately recorded as % air saturation or % oxygen saturation. This data can be a useful parameter in itself. Alternately, if information is available regarding the sample's varying oxygen solubility, such as salinity levels, the % air saturation data can be converted to mg/l D.O. units using the % air saturation and temperature data provided by the Model 56.

The % air saturation data is converted to other units of sample dissolved oxygen content by reference to published, or user generated, tables of sample oxygen solubility at 100% saturation at various temperatures. The tabular data is multiplied by the recorded % air saturation data and divided by 100 to determine sample dissolved oxygen content in the desired units.

Table II lists oxygen solubility at 100% air saturation in sea water of varying salinity and temperature.

Temp. °C	Salinity % (PPT)					Difference mg/l Per 1 ‰ (PPT) Salinity
	0	10	20	30	36	
	Dissolved Oxygen mg/liter					
0	14.60	13.7	12.8	11.9	11.3	.091
1	14.19	13.3	12.4	11.5	11.0	.089
2	13.81	13.0	12.2	11.3	10.8	.083
3	13.44	12.7	11.8	11.0	10.5	.083
4	13.09	12.3	11.5	10.8	10.3	.078
5	12.75	12.0	11.2	10.5	10.0	.078
6	12.43	11.8	11.0	10.3	9.8	.075
7	12.12	11.5	10.8	10.0	9.6	.072
8	11.83	11.2	10.5	9.8	9.4	.069
9	11.55	10.9	10.3	9.6	9.2	.066
10	11.27	10.7	10.0	9.4	9.0	.064
11	11.01	10.5	9.8	9.2	8.8	.064
12	10.76	10.2	9.6	9.0	8.6	.061
13	10.52	10.0	9.4	8.9	8.5	.058
14	10.29	9.8	9.2	8.7	8.3	.058
15	10.07	9.6	9.0	8.5	8.1	.058
16	9.85	9.4	8.9	8.3	8.0	.055
17	9.65	9.2	8.6	8.1	7.8	.053
18	9.45	9.0	8.5	8.0	7.7	.050
19	9.26	8.9	8.4	7.9	7.6	.050
20	9.07	8.7	8.2	7.7	7.4	.050
21	8.90	8.5	8.1	7.6	7.3	.047
22	8.72	8.3	7.9	7.4	7.1	.047
23	8.56	8.2	7.8	7.3	7.0	.047
24	8.40	8.1	7.6	7.2	6.9	.046
25	8.24	7.9	7.5	7.0	6.7	.045
26	8.09	7.8	7.3	6.9	6.6	.044
27	7.95	7.7	7.2	6.8	6.5	.044
28	7.81	7.5	7.1	6.7	6.4	.042
29	7.67	7.4	7.0	6.6	6.3	.042
30	7.54	7.2	6.8	6.4	6.1	.042

Table II - Solubility of oxygen in water exposed to water-saturated air @ 760 mmHg

EXAMPLE:

For a recorded sample temperature of 18 °C with 62% air saturation, in sea water of 35 PPT salinity, the calculation would involve looking up the saturation oxygen solubility of sea water at 18 °C and 35 PPT salinity in Table II. The 100% saturation value in milligrams per liter by weight is approximately 7.7 mg/l from Table II.

$$\frac{62\% \text{ air saturation}}{100} \times 7.7 \text{ mg/l} = 4.8 \text{ mg/l}$$

% Oxygen Saturation

By altering the calibration procedure, the YSI Model 56 Dissolved Oxygen Monitor and the YSI Model 5739 D.O. Probe with the YSI 5675 Service Kit can be used to monitor % oxygen concentration in gas or liquid. Calibration is identical to that for % air saturation (see section on Calibration) except that the probe is exposed to pure oxygen and the **O_2 CALIB** control is set to indicate **10** on the **0-10** scale. **10** is then defined as 100% oxygen.

Supersaturated Samples

The Model 56 is designed to measure oxygen concentrations corresponding to 100% of normal air saturation or less. The monitor has some overrange capability on the mg/l ranges for all but the highest probe temperatures. Occasionally, situations arise where the oxygen concentrations being measured exceed the normal capabilities of the monitor . . . such as when high levels of photosynthetic activity are present or when oxygen is being added artificially to the sample.

When greater-than-air-saturated conditions are likely to occur, you can calibrate the monitor such that the measurement ranges are doubled. To do this, follow the calibration instructions in the Calibration section of this manual, except that you must adjust the **O_2 CALIB** control so the pen trace is half the normal calibration value. For example, using the air calibration technique at 760 mmHg atmospheric pressure, adjust the **O_2 CALIB** control so the pen traces at 5.0 (50%) instead of 10.0 (100%). This causes the ranges labeled **0-5, 0-10,** and **0-20 mg/l** and **0-100%** to become **0-10, 0-20,** and **0-40 mg/l** and **0-200%.**

If even higher readings are needed the recorder can be calibrated to 1/4, 1/5, or 1/10 of the standard calibration value (for example, 25, 20, or 10% instead of 100%). You then multiply the range and overrange limits by a factor of 4, 5, or 10, respectively. Be sure to note special ranging on the chart paper at the head of each run.

Instrument Battery

The instrument batteries are housed in a removable battery pack. The pack capacity, when fully charged, is sufficient to operate the YSI Model 56 D.O. Monitor for at least 10 days with stirrer. Spare battery packs may be recharged separately and used to keep a Model 56 in operation indefinitely at a remote site.

- To check battery charge:
  1. Turn **POWER** to **ON.**
  2. Set **PEN INPUT** to **BAT CHK.**
  3. Read battery charge on the **0-10** scale. **0** = full discharge, **10** = full charge.

  NOTE: While charging or for approximately 1 hour after recharging, readings may be above **10.**

  4. If instrument will not function, batteries are discharged.
- To recharge batteries:
  1. Unscrew the large cover on the left side of the instrument case.
  2. Plug the YSI 5604 (115 VAC) or 5605 (230 VAC) battery charger into the exposed receptacle. Red light on the charger will show the batteries are charging. Red light fades out and green light comes on as recharging is complete. Full recharge requires 24 hours.

  NOTE: To recharge batteries without the instrument, plug the YSI 5604 (115 VAC) or 5605 (230 VAC) charger directly into the receptacle on the side of the battery case.

- To remove battery pack
  1. Remove the four bright thumb screws on the instrument front panel.
  2. Grasp the handles on either side of the panel and lift the battery pack straight up.
  3. To reinstall the battery pack, reverse the procedure.

  NOTE: At approximately ½" from full insertion, the pack connector engages. Wiggle the pack to ensure smooth contact. *Do not force.*

- To replace cells within the pack:
  Normal battery life is 100 to 500 full discharges or 2 years. If batteries will not provide 10 days operation or will not accept a charge, they should both be replaced. Replacements are available from:

  Yuasa Battery Corp.
  Santa Fe Springs, CA 90670
  Model No: NP8-6M 6V8.6AH

  Globe-Union Inc.
  Milwaukee, Wis. 53201
  Model No: GC 680

  Power Sonic Corp.
  Redwood City, CA 94063
  Model No: PS-680

  Eagle Picher Industries, Inc.
  Senica, MO 64865
  Model No: CF 6V8

  Elpower Corp.
  Santa Ana. CA 92704
  Model No: EP 685A

Or batteries may be purchased from YSI Service Department.

1. Remove battery pack from the instrument.
2. Remove the six flat-head screws from the side of the pack and lift off the side cover.
3. Lift the cells out of the pack approximately one inch and remove the lead wire contacts.
4. Connect the new cells as shown in Figure 11.
5. Replace the six flat-head screws holding on the side cover.

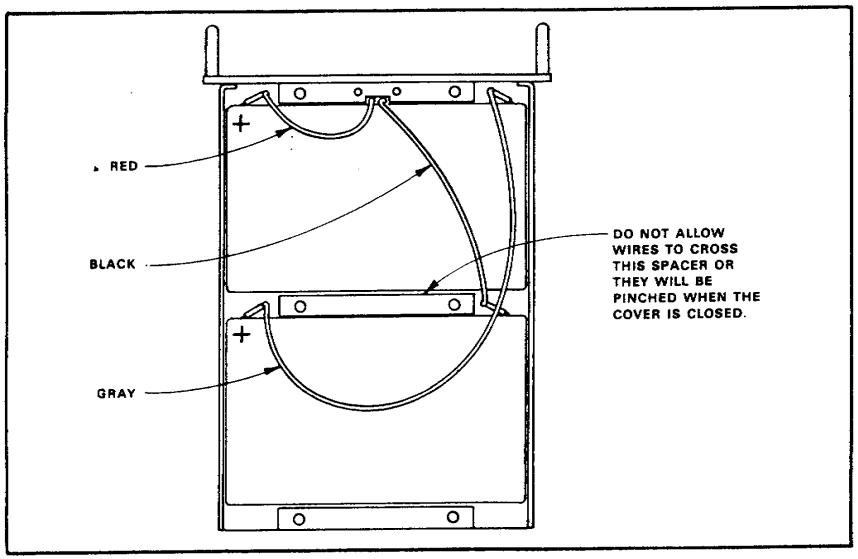

Figure 11 - Connecting the new cells.

6. Reinsert the pack in the instrument and tighten down the thumb screws finger tight.

- Storage:
  The batteries should be fully charged before the instrument is stored. Storage in excess of 6 months without recharging can damage the batteries. Batteries can be stored connected to the YSI 5604 (115 VAC) or 5605 (230 VAC battery charger indefinitely.

- Operating the Model 56 without battery pack in place:
  The YSI 5604 (115 VAC) or 5605 (230 VAC battery charger will operate the YSI Model 56 directly with or without the battery pack installed.

  NOTE: The instrument case is vented when the charger if connected and, therefore, is not watertight.

Chart Paper

- To install the chart paper:
  1. Use only YSI 5602 thermal chart paper.
  2. Remove the chart paper drawer from the instrument by lifting up on the two handles on either side of the chart paper. (See Figure 1.)
  3. Install the chart paper as shown in Figure 12.

     NOTE: If paper roll is too large to install, remove several feet of paper until it fits.

  4. Make sure the chart paper is engaged in the drive teeth and the take-up spool is fully engaged. Slack paper may be taken up by rotating the take-up reel with one finger inserted in its hollow core.
  5. Install the chart paper drawer in the instrument. *Do not force.* If the drawer hangs up half way in, the take-up reel is not fully in place. The drawer should lock in place when installed.

- To remove chart paper record:
  1. Remove drawer.
  2. Tear paper across its width, wind the loose end on the take-up spool and slip the take-up spool from its shaft.

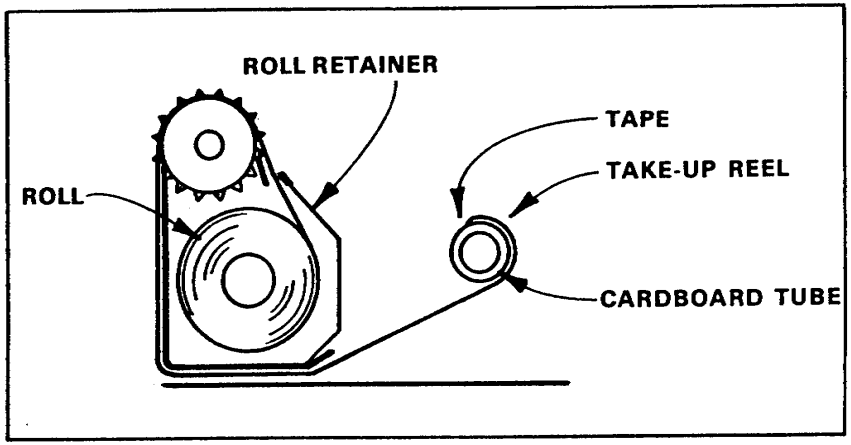

Figure 12 - Installation of chart paper

3. If the paper is almost used up, simply pull out the paper until the end is visible.
4. Install a new roll of chart paper if needed or attach the new end to the remaining chart paper on the take-up reel and reinstall the drawer.

Desiccant Maintenance

The desiccant in the aluminum canister supplied with the YSI Model 56 protects the instrument electronics and chart paper from potential 100% humidity conditions in damp environments. The desiccant comes packaged in a foil bag. Remove the bag the first time the instrument is to be used in over 70% relative humidity environment. The window in the canister should show blue desiccant indicating that it is dry. After several weeks of use, the desiccant will turn white as it picks up moisture. At this time, the desiccant should be placed in a 200 to 250 °F oven for several hours to drive off excess water. When dry, the desiccant is blue and ready for use. Spare desiccant packs are available from the YSI Service Department.

Probe Storage Clip

The Probe Storage Clip is included with the Model 56 Dissolved Oxygen Monitor. It provides for easy storage of the probe on the cable reel. (See Figure 13.) Cable reels are supplied with all cables longer than 10'.

- To install probe storage clip:
  1. Attach the reel in place on the side of the instrument case.
  2. Loosen the two screws holding the probe storage clip to its small white backing plate.
  3. Slip the probe storage clip onto the reel at the slot, positioning it so that the notches in the clip's backing plate align with the horizontal bar of the raised grid on the inside of the reel.
  4. Tighten the two screws securing the probe storage clip in place. (See Figure 14.)

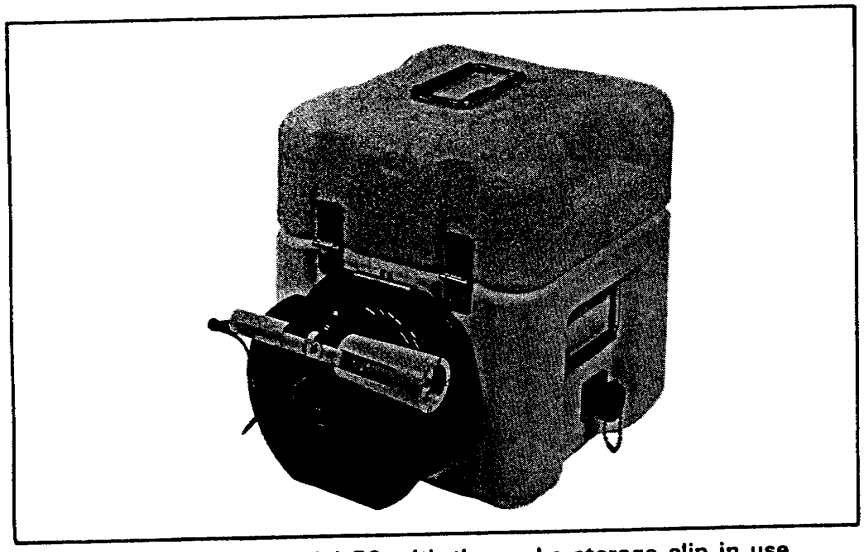

Figure 13 - YSI Model 56 with the probe storage clip in use

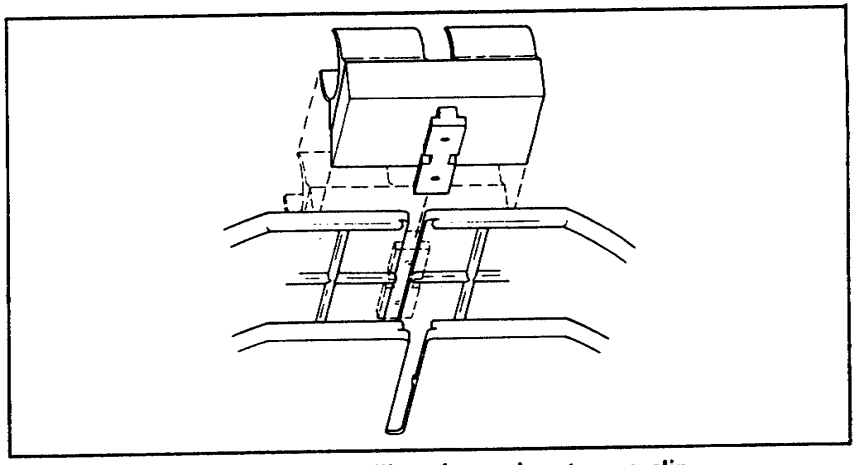

Figure 14 - Installing the probe storage clip

Signal Output

The SIGNAL OUTPUT receptacle on the right of the YSI Model 56 Dissolved Oxygen Monitor provides the user with the ability to connect the instrument to data transmitting devices, alarms, or other signal recording devices. The receptacle connects to a MS 3106R 14S-IP Plug. Pin "A" is positive 100 milivolts with respect to pin "B" when the Model 56 is indicating full scale pen position. At zero pen position, the output in 0 millivolts. Output devices should have at least 5kΩ input impedance to prevent loading the Model 56 circuit.

DISCUSSION OF MEASUREMENT ERRORS

Using the information presented in this section, the worst case dissolved oxygen error for a particular data point can be calculated. Chart speed accuracy and temperature data accuracy are presented in Specifications.

Instrument Component Errors

- Recorder Linearity
  Error = ± 0.5% of full scale of measurement range.
- Range to Range Error
  Switching from **0-100%** to the **10 mg/l** range
  Error = 0
  Switching from **10 mg/l** range to the **0-5** or **0-20 mg/l** range
  Error = ± 1% of reading
- Temperature Coefficient (zero setting)
  Error = ± 0.05% °C of full scale of the measurement range (from 25 °C)

Non-Ideal Probe Behavior

- Background Signal — varies with probe temperature. (See Probe Background Error Chart on page 22.)
- Temperature Compensation Uncertainty
  Error = 0 if readings are taken at the calibration temperature.
  Error = ± 1% of reading if readings are taken with ± 5 °C of the calibration temperature.
  Error = ± 3% of reading, all other conditions

PROBE BACKGROUND ERROR

Error		
mg/l	0-100%	Temp. °C
0.28	1.9	0
0.14	1.2	10
0.07	0.8	20
0.04	0.6	30
0.02	0.4	40
NOTE: Use of the YSI STANDARD membranes reduces these errors by 50%.		

Probe Calibration Uncertainty

- Barometric Pressure Effect
  If normal barometric pressure is assumed (±0.5" or 12 mmHg)
  Error = 1.7% of reading
- Altitude Effect. If altitude is estimated ± 500'
  Error = ± 1.8% of reading

  NOTE: Last two errors are eliminated if accurate true barometric pressure data is available.
- Calibration Drift with Time
  Calibration may drift ± 3% of reading over a 7 day period in 0-30 °C samples. In 30-45 °C samples, it may drift ± 5%. Actual drift during a run can be checked by a post measurement calibration check.

Example of a Typical Error Calculation

The following example represents a typical error calculation for a one week period of data collection.

DATA: Instrument calibrated with a 20 °C probe on the **0-100%** air saturation range, elevation estimated at 2000' ± 500', normal barometric pressure presumed. Readings taken on the **0-10 mg/l** scale. Highest sample temperature 25 °C. Lowest sample temperature 15 °C. Ambient instrument air temperature: from 10 to 30 °C. Error calculated for a reading of: 6 mg/l @ 21 °C.

Description	Calculations		Error mg/l
Linearity	±0.005 X 10 mg/l	=	0.05
Range to Range	zero	=	——
Temp. Coef. (Zero)	(25 °C - 10 °C) X 0.0005 X 10 mg/l	=	0.08
Background	@20 °C	=	0.07
Temp. Comp.	0.01 X 6 mg/l	=	0.06
Barometer	0.017 X 6 mg/l	=	0.10
Altitude	0.018 X 6 mg/l	=	0.11
Drift	0.03 X 6 mg/l	=	+ 0.18
	Maximum Possible Error		0.65 mg/l

It is unlikely that errors will sum to produce the maximum possible error. It is more likely that some errors will oppose others, to produce a statistical error approximating a root-mean-square error of about one-half the maximum possible error, or about 0.3 mg/l.

MAINTENANCE AND SERVICE CONSIDERATIONS

These checks can be made without specialized equipment. A Service Manual for the Model 56 is available from the YSI Service Department.

Checking Probe Performance

1. Speed of Response
   A. Prepare and calibrate the probe.
   B. With probe in air, switch to: **O_2, 0-100%, 10 CM/HR.**
   C. Immerse the probe in a 25 °C O_2-depleted sample.
      (Samples may be prepared by adding approximately 1 gram of sodium sulfite to ½ liter of water.)
   D. A good probe will respond down scale to 10% air saturation in 1 minute.
2. Background Current
   After performing the Speed of Response steps, leave the probe in the depleted sample for approximately 10 minutes. The reading should fall below 1% air saturation.
3. Calibration Stability
   A. Carefully calibrate the probe in moist air with the instrument set at **0-100%, 1 CM/HR** and **O_2**.
   B. Place the probe in the calibration bottle and allow the instrument to operate 24 hours or longer.
   C. A good probe will hold calibration ±2% in 24 hours and ±3% in 7 days.
4. Service: If the probe will not perform properly, it may be due to:
   A. Damaged or wrinkled membrane — change the membrane and retest.
   B. Fouled or silver coated cathode — resurface as per Instructions supplied with YSI 5675 Service Kit and retest.
   C. Fouled anode — soak 24 hours in 3% ammonia (NH_3), rinse with distilled water and retest.
   D. Damaged cable or connector — inspect and replace if needed.

If these steps do not restore performance, the probe may require replacement.

Checking Battery Condition and the Battery Charger

The rechargeable batteries are reusable so long as they can be recharged and will operate the instrument a satisfactory length of time between recharges.

If the batteries will not accept charge, the charger should be checked for proper function.

1. To check the charger.
   Remove the instrument battery pack and operate the instrument directly from the charger. The instrument should function normally and the red and green charger lights switch on and off alternately. **BAT CHK** will read off scale to the right.

2. To check the batteries.

   If the charger is functioning properly, connect it directly to the battery pack. The red charger light should normally come on followed by a green light within 24 hours.

   A. If the green light comes on immediately, open the battery pack and look for loose connections or broken wire.

   B. If the red light stays on for more than 24 hours, look for shorted wires in the battery pack.

   C. If the wiring is in order, but the charger lights indicate an abnormal pattern, the batteries are either shorted or open.

Recorder Service

1. Pen Cleaning.

   The thermal pen on the recorder indicator arm should last the life of the instrument. If the trace becomes weak or disappears, remove the chart paper and inspect the underside of the arm. The small black dot is the thermal pen. Inspect for paper residue and clean with acetone, alcohol, or soapy water on a clean towel.

2. Drive belt tightness

   If the paper feed ceases functioning, remove the paper drawer and inspect the drive belt for tightness. Tighten by loosening one motor mounting screw, rotating the motor, and retightening the screw. Light finger pressure on the belt should deflect it about ¼".

Checking the Instrument Zero

The factory-set oxygen amplifier zero should occasionally be checked for proper adjustment. To check:

1. Remove the membrane from the oxygen probe, flush the probe interior with distilled water and thoroughly dry the probe's cathode surface with a clean towel.
2. Connect the dry probe to the instrument. Adjust **PEN ZERO** to **0** on the **0-5** scale.
3. Switch to **O_2, 0-5 mg/l**; and adjust the **O_2 CALIB** control fully clockwise. The instrument pen should indicate **0** ±1 small division on the **0-5** scale. If the instrument does not pass this test, it should be recalibrated by a trained service technician.

Checking Instrument Automatic mg/l Calibration

The Model 56's automatic translation from the **0-100%** air saturation range to the **mg/l O_2** ranges can be checked as follows.

1. Expose probe to moist air and allow to stabilize.
2. With **PEN INPUT** on **ZERO** and **O_2 RANGE** on **0-100%**, adjust **O_2 CALIB** control until the pen traces at **10** on the chart.
3. Switch **PEN INPUT** to **°C** and read probe temperature.
4. Find the mg/l value for this temperature on Table III.
5. Switch **PEN INPUT** to **O_2** and **O_2 RANGE** to an on-scale **mg/l O_2** range.
6. Read the indicated mg/l value on the chart. It should be the same ±0.1 mg/l as the value determined from Table III in step 4.

Table III - Solubility of oxygen in fresh water saturated with air at 760 mmHg.

Temperature °C	mg/l Dissolved Oxygen	Temperature °C	mg/l Dissolved Oxygen
0	14.60	23	8.56
1	14.19	24	8.40
2	13.81	25	8.24
3	13.44	26	8.09
4	13.09	27	7.95
5	12.75	28	7.81
6	12.43	29	7.67
7	12.12	30	7.54
8	11.83	31	7.41
9	11.55	32	7.28
10	11.27	33	7.16
11	11.01	34	7.05
12	10.76	35	6.93
13	10.52	36	6.82
14	10.29	37	6.71
15	10.07	38	6.61
16	9.85	39	6.51
17	9.65	40	6.41
18	9.45	41	6.31
19	9.26	42	6.22
20	9.07	43	6.13
21	8.90	44	6.04
22	8.72	45	5.95

Source: Derived from "Standard Methods for the Examination of Water and Wastewater"

Lightning Precautions

When used at elevations above average surrounding terrain or beneath towers, etc., this instrument should be operated on internal battery power only, with probe cable kept as short as possible (coiled if necessary). In areas having a high incidence of lightning strikes, avoid metallic tethers or other conducting connections to the case when the probe cable is extended.

WARRANTY AND REPAIR

All YSI products carry a one-year warranty on all workmanship and parts, exclusive of batteries. Damage through accident, misuse or tampering will be repaired at a nominal charge.

If you are experiencing difficulty with any YSI product, it may be returned for repair, even if the warranty has expired. YSI maintains complete facilities for prompt servicing of all YSI products.

YELLOW SPRINGS INSTRUMENT CO., INC.
SERVICE DEPARTMENT
P.O. BOX 279
YELLOW SPRINGS, OHIO 45387, U.S.A.
PHONE: (513) 767-7241
TELEX: 20-5437