EXPOSURE

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Volume 4, Number 1

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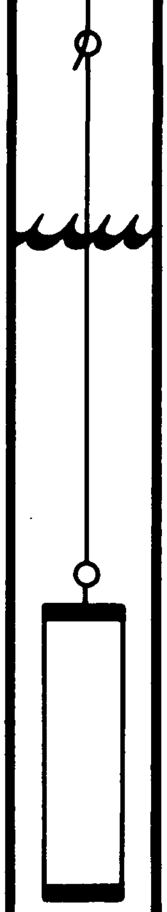
a non-magnetic pressure gauge designed for external face seal mounting

A non-magnetic, all 6Al-4V titanium strain gauge pressure transducer in the shape of a pressure transducer adapter has been designed for Woods Hole Oceanographic Institution by Standard Controls, Inc., of Seattle, for use in VACM's (Vector Averaging Current Meters) and pressure case end caps. They are also used on Webb's (of W.H.O.I.) SOFAR (Sound Fixing and Ranging) floats.

The several features which set this transducer apart from others are (1) it can be screwed into a 7/8-14 threaded hole in an end cap from the outside--the O-ring face seal keeps the threads from getting wet--just as with a Marsh



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Richard L. Koehler
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Figure 1. Front View of Pressure Gauge

Figure 2. Rear View of Pressure Gauge

Figure 3. Outside View of Pressure Gauge Mounted in VACM End Cap

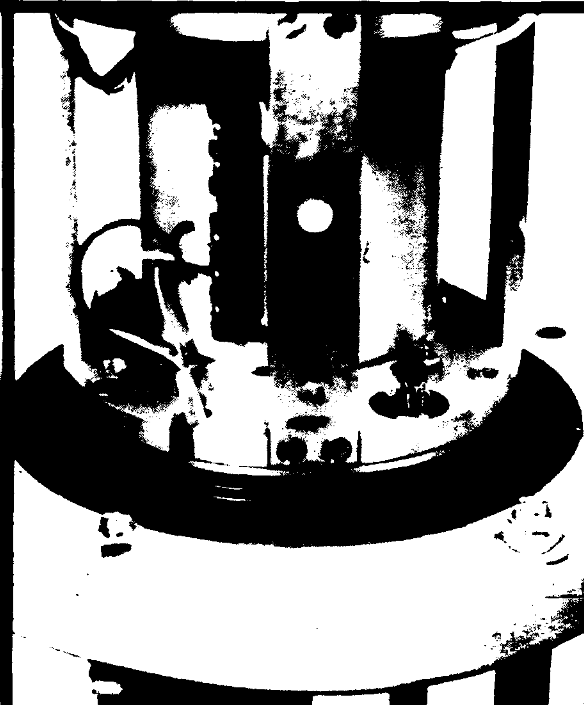

Figure 4. Inside View of Pressure Gauge Mounted in VACM End Cap

Marine connector; (2) the 1/8 in. flare fitting pressure port with O-ring seal (MS33649-2) can be used for calibration after the gauge is screwed into the end cap; (3) the case of the pressure gauge can withstand 10,000 psi, so that if a gauge with a low pressure range is subjected to high pressure and the sensing element (a small cylinder) breaks, the instrument case will not be flooded; (4) it is non-magnetic so it may be used near a vane follower in a VACM; and (5) titanium is immune to corrosion in sea water.

There is a problem of different corrosion potentials between the titanium gauge and aluminum end caps, but it is not as bad as with stainless steel and aluminum. I would welcome a design around this problem. Another caution is that the common mode bridge output is about 0.6 of the input, not 0.5 as one might expect in a strain gauge bridge.

Figures 1 and 2 show the pressure gauge. The length is 2.5 in. overall, the flange is 1.6 in. diameter, and the body is about .76 in. diameter. Figures 3 and 4 show the gauge mounted in a VACM end cap. While the unmounted gauge looks big and ugly, when mounted it looks neat and unobtrusive.

The two most common resistances for the strain gauge are 350 ohm and 1150 ohm, although they can be made up to 2000 ohms. A modest price reduction (e.g. $60) can be obtained by relaxing the specs. The following are the best specs I could get Standard Controls to guarantee:

Sensitivity:
2.5 mV full scale (FS) per volt applied
Thermal zero shift:
.0055% FS/^{o}C max
Thermal sensitivity shift:
.0055% FS/% max
Temperature compensation range:
0^{o} to 40^{o}C
Hysteresis and nonlinearity combined:
±.05% FS max

The Model 211-35-470-(Pressure Dash No.) is 1150 ohms and Model 211-35-530-(Pressure Dash No.) is 350 ohms.

Pressure Dash No.	Pressure Ranges
-01	0-1500 psi
-02	0-2200
-03	0-3000
-04	0-4400
-05	0-5000
-06	0-7500
-07	0-10000

The pressure can be over-ranged 50 percent without damage, so you don't need the exact range. Since the gauges are made to order, you can specify any pressure in the 1500 to 10,000 psi range for the 2.5 mV/V sensitivity.

These gauges are available from Standard Controls, Inc., 2401 South Bayview Street, Seattle, Washington 98144, Telephone (800) 426-0366. Ask for Ted Notman. They cost $480 each with a modest discount schedule for more than one.

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Richard Koehler has been working at the Woods Hole Oceanographic Institution for the past eight years. He has a S.B., S.M., and a Ph.D. in electrical engineering.

Among his developments are the VACM and the Acoustic Dropsonde. He is currently working on an A.C. multiplexing amplifier/converter and new types of current meters.

damped spar drift buoy

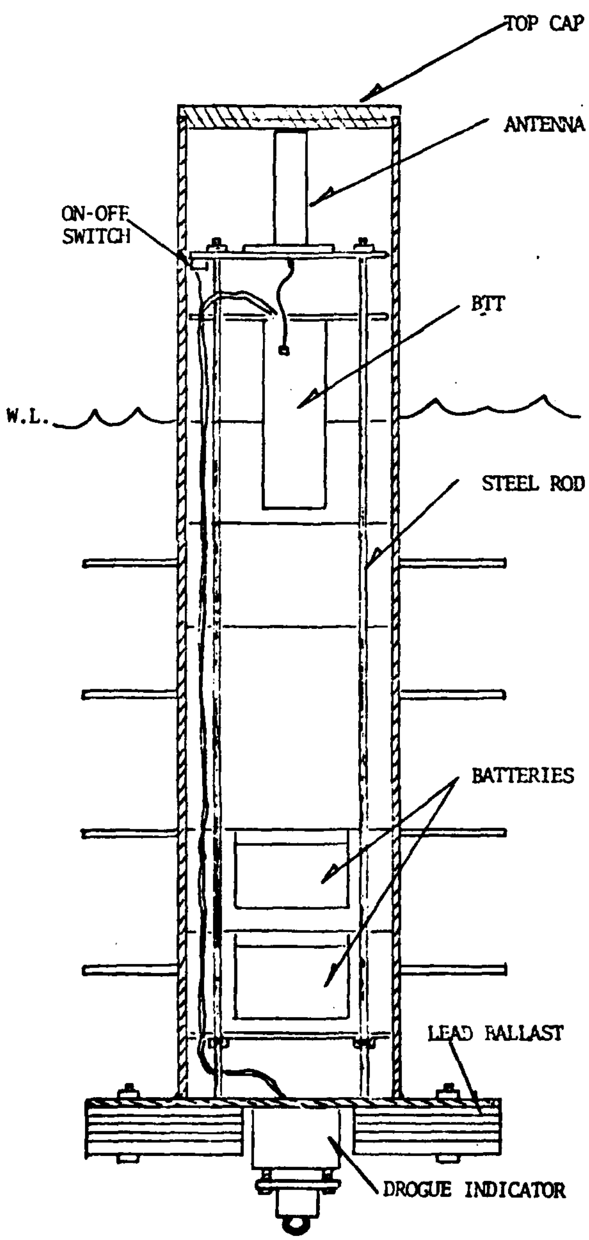
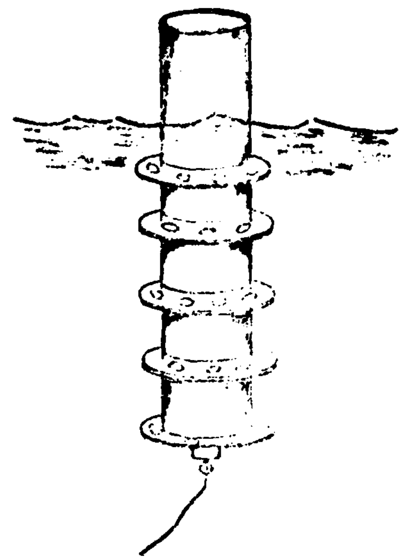


FIGURE 1. DAMPED SPAR DRIFTING BUOY HULL



BUOY DIMENSIONS

Length:	10 ft
Diameter:	15 in
Above waterline:	3 ft
Air weight of hull:	220 lb
Displacement:	586 lb
Reserve Buoyancy:	236 lb

SURFACE AREAS

Above waterline:	6 ft^2
Below waterline:	14 ft^2
Drogue:	600 ft^2

In a recent issue of *EXPOSURE* (Vol. 3, No. 3), H. Daman reported on the drift buoy system developed at Nova University for the NOAA Data Buoy Office (NDBO). At Scripps Institution of Oceanography we have used this type buoy in NORPAX (North Pacific Experiment) with some degree of success. In addition, we undertook the development of a buoy specifically designed to withstand the rigors of the North Pacific winter environment. Both buoy designs utilize the Random Access Measurement System (RAMS) carried aboard the NIMBUS 6 satellite. The result of the drifter buoy development at Scripps is the topic of this brief report.

Figure 1 shows the damped spar hull which we have used in our deployment for the North Pacific. The spar is a single piece of molded fiberglass with 1/2 in. thick walls. It is 10 ft long and has a diameter of 15 in. The water line is 3 ft from the top after ballasting with 250 lb of lead bolted to the bottom, thus providing 240 lb of reserve buoyancy. The damping rings are 27 in. in diameter and are spaced 18 in. apart along the submerged portion of the spar. The rings have 2 in. diameter holes randomly spaced. The damping rings were added to the spar to reduce the natural heave response.

Our experience over the past two years has shown that the hull can, and often is, subjected to a more rigorous environment during shipment then it experiences after deployment. This contingency also impinged on the preference for a regular shaped hull rather than an irregular one which presents a difficult packaging problem when the buoy is shipped to its deployment site. In this sense, one of the most significant tests of our hull's ability to survive was to ship it uncrated, by commercial carrier, from the west to east coast and have it arrive undamaged.

The buoy payload (buoy transmit terminal (BTT), batteries, etc.) is encased in individual urethane blocks 1 ft high and 13 in. in diameter. The individual urethane blocks are pre-drilled to accommodate separate parts of the payload. They are then assembled into a 7 ft long tube with PVC bulkheads at top and bottom by passing three mild steel rods through the package and securing them at both ends. Six-in. standoffs are used on the bottom of this package so there is no danger of damaging the drogue indicator switch wires when the package is loaded into the hull.

Running down the inside of the hull is a 1 in., half-round spine. The foam package has a matching cutout in each of its segments. This serves to both locate the package inside the hull and prevent it from rotating inside the hull after deployment.

The fact that the hull is fiberglass and has a 14 in. inside diameter allowed us to move the antenna inside. We feel we have effectively moved the weakest element from the region of greatest possible stress to a region of essentially no environmental stress. This antenna location has not impaired the antenna's performance. During our deployment in the North Pacific we achieved close to the maximum possible successful transmission during satellite fly-by.

Our drifters have been equipped with the following component parts:

- BTT DCP-1: manufactured by American Electronics Laboratories.
- Antenna: manufactured by Commat Inc.
- Power supply: 9 parallel stacks of Mallory RM-2550 mercury batteries, total capacity 117 A-hr.
- Drogue: surplus 28 ft personnel parachute.
- Drogue indicator: in-house design.

The "drouge indicator" we use is shown in Figure 2. The reed switches which are glassed into the bottom of the hull are normally open. The switch furthest from the magnet will remain closed until the magnet is pulled 1/4 in. away from its unstressed position. A deflection of 1/4 in. results from a load 4 to 6 lb above the load of the 50 lb drogue ballast alone. The switch closest to the magnet will not open until the magnet has moved through its maximum allowable travel, 1/2 in., corresponding to load in excess of 100 lb.

The normal operating mode for the indicator is for the switch furthest from the magnet to be open almost all the time while the second switch remains closed. Under heavy sea conditions the second switch will close occasionally due to the large shock loads incurred by wave pumping. This operation was observed during our recent deployment.

Three types of drogue failures are expected:

1. Drogue system plus indicating mechanism is lost: Both switches will remain open all the time.

2. Drogue line and ballast remain but the parachute is lost: Switch furthest from magnet will open occasionally due to wave action, but second switch would rarely, if ever, open.

3. Drogue line parts: Both switches remain closed.

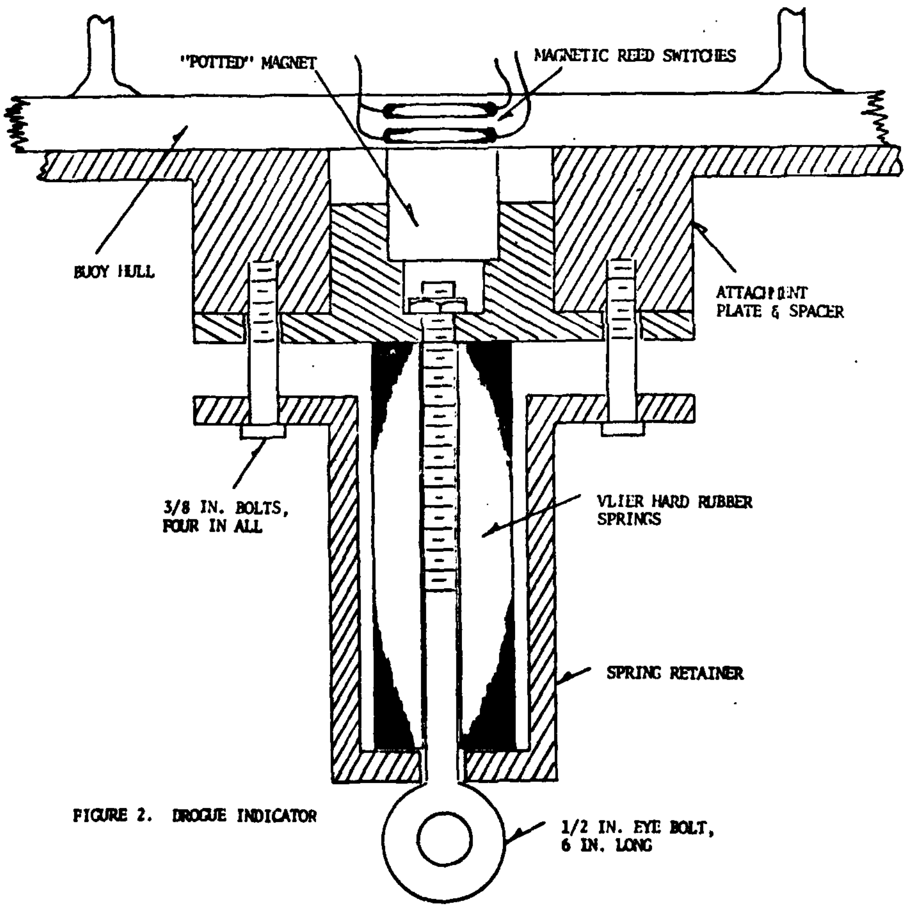


FIGURE 2. DROGUE INDICATOR

EXPOSURE

TABLE OF CONTENTS
VOLUMES 1, 2, & 3
March 1973 to March 1976

a newsletter for ocean technologists

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

The drogue indicator will not yield any information on the condition of the parachute, that is, whether it is fully or partially deployed.

Seven of the drifter buoys were deployed in mid October along 158°W with two at 32°N, two at 34°N and three at 36°N. The following is a summary of system performance during the deployment: The most unsuccessful system component was the drogue system. All drogue systems failed within 30 days of their deployment. The "drogue indicator" which we use indicates that the failures occurred between the drogue and the spar. The drogue line used during this deployment was stranded steel cable. Prior to the deployment, we had anchored a buoy 1/4 mile off the beach for a period of 3 months. The anchor line was a 3/8 in., two-in-one nylon Sampson cord. The decision to use stranded cable instead of the Sampson cord was in response to fears about fish bite as a major problem with the drogue line. This was obviously a poor choice and in future deployment a nylon Sampson cord will be used for the drogue line.

After 70 days we incurred our first electronic system failure. This drifter had been reliably yielding the maximum number of transmissions during satellite fly-by. It was reporting a healthy battery voltage with no signs of fatigue. It abruptly went off the air.

One of our seven drifters was equipped with a carbon-zinc battery pack whose capacity was equivalent to the mercury packs. This drifter reported sporatically for some 117 days. Fixes obtained during this time were unreliable. Prior to going off the air it showed definite signs of battery fatigue with its last reported voltage slightly under 10 volts.

We lost two more drifters after 125 days. In both cases there was a marked drop in the battery voltage reported by the drifters prior to going off the air. The final three buoys are still reporting, as of the time this is written, some 149 days after deployment.

The sudden decrease in battery voltage exhibited by the two drifters, which failed after 125 days, could be an indication of either battery fatigue or a failure mode of the BTT's. The plastic C-Mos used in the BTT's has been known to exhibit a failure where the system continues to function but draws an excessive amount of current. Failure after 125 days represents a 32 percent decrease in the life expectancy of the battery pack based on the average current drain exhibited by these units during testing. In future deployments, we will respond to both contingencies by using more reliable ceramic C-Mos circuits and increasing the capacity of the battery pack.

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hybrid thermo/conductivity system

In research today it is very prudent to have a high-use factor for each piece of instrumentation. The following article describes an adaptation to allow a second use for an Aanderaa RCM-4 current meter, with the conductivity option, as a shipboard thermo/conductivity recorder system that can be installed on most ships in a few hours.

The intent of the adaptation is not to modify the current meter in a way that would prevent its quick return to use as a current meter. If the shipboard thermo/conductivity unit fails, a reserve current meter can be quickly pressed into service to replace it.

Figure 1 shows two of the three components used to make up the thermo/conductivity recorder system. The unit on the left side of the photograph is the bulkhead-mounted recording unit with the seawater cell on top. Off to the right is a readout unit which displays the last recorded values of seawater cell temperature, seawater intake temperature, conductivity, time of day, and the reference word on demand. Readout panel space has been allowed for computed salinity, which is scheduled for future implementation.

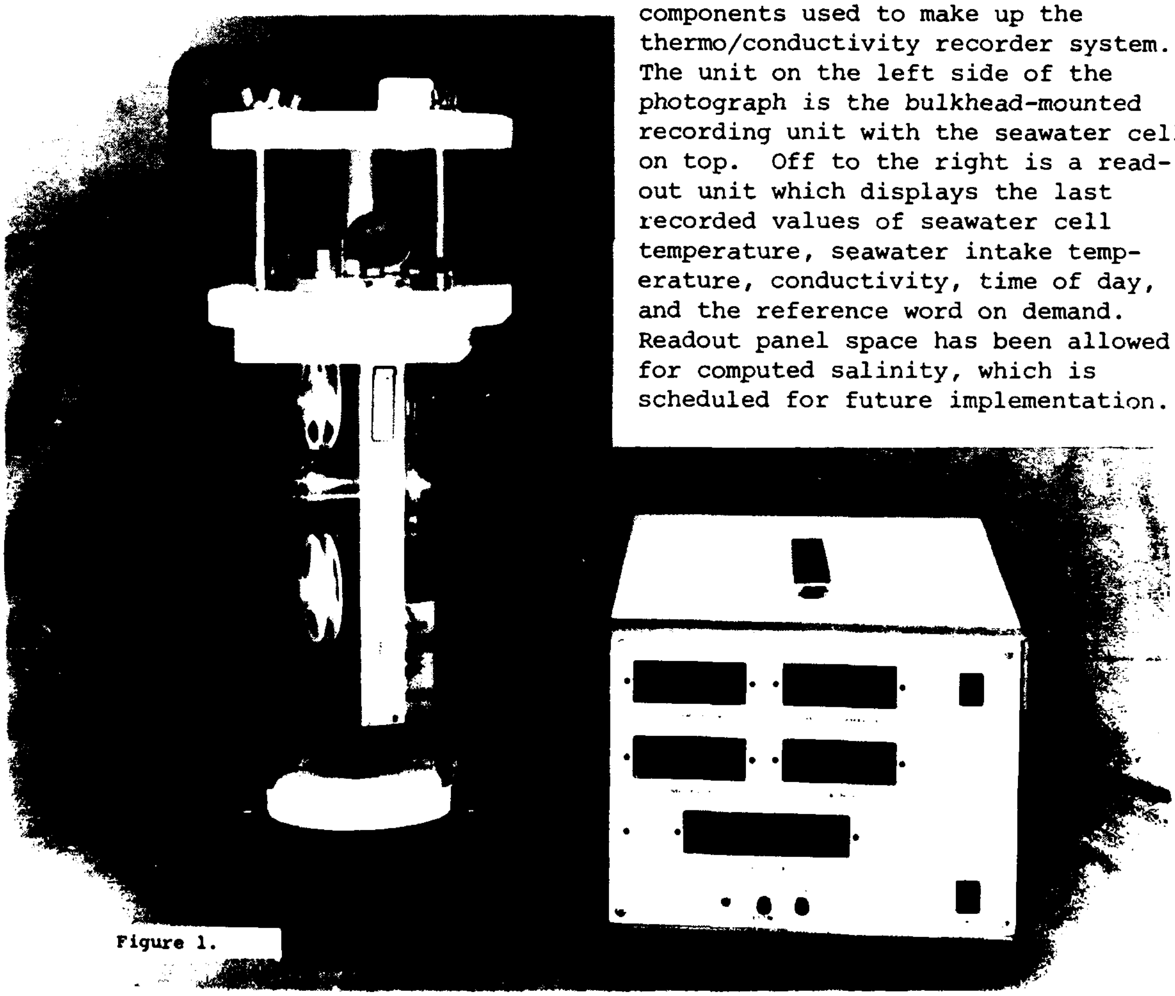

Figure 1.

Time of day is on the readout display, but it is not on the magnetic tape. A component not shown is a thermistor mounted on a pipe plug for insertion into the seawater intake line.

The intake temperature sensor and the bulkhead-mounted unit can stand alone as a thermo/conductivity unit. The readout unit offers the added convenience of real time visual data during the cruise.

Basically, there are no mechanical modifications to the current meter other than removing the rotor bracket and pressure case. The mounting plate supporting the recorder has been machined to use the O-rings on the recorder end cap as the bottom seal for the seawater chamber. Four rods with wing nuts clamp a top cap on a Lucite cylinder with edge seal O-rings to complete the chamber. The seawater is piped into the side of the mounting plate and vented into the chamber directly behind the conductivity cell. Water passes across, and to the top of, the chamber for the outflow.

Figure 2 is an enlarged view of the seawater chamber. The stanchion shown mounted in the top cell cap makes it possible to provide the necessary seal pressure on the recorder end cap to eliminate the need for additionally rigid supports for the recorder body.

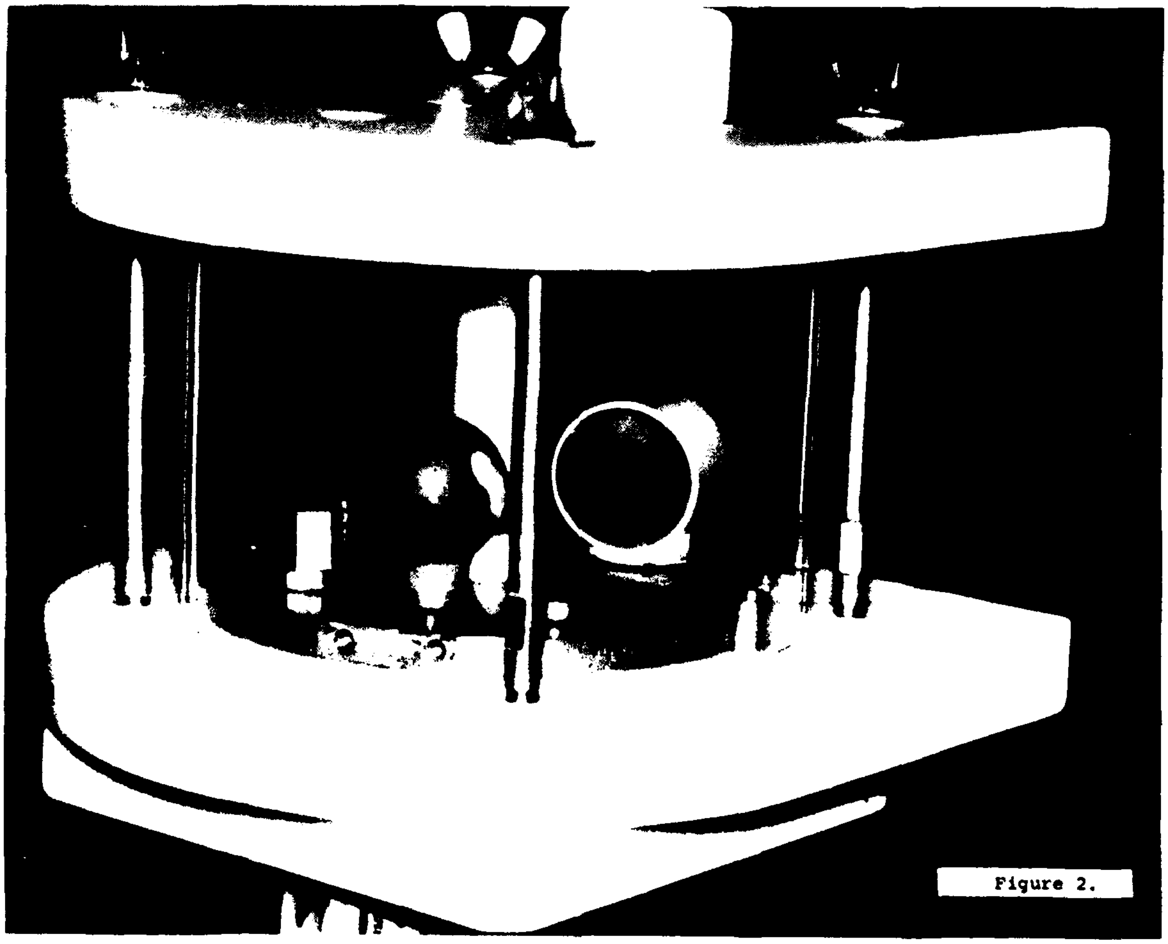

Figure 2.

Another Lucite cylinder is used to protect the recorder from dust and water spills. The cover is quickly slipped off by pulling a retainer pin holding a hinged bottom cover in place. The cover must be removed periodically to replace the magnetic tape and battery.

There are two backing plates. One is used to mount the recorder support ring and the bottom hinged cover. This plate is in turn socketed onto the second plate. A quarter turn of the first plate releases it from the second for removal to a more convenient inspection station. The second plate is fixed to the ship bulkhead.

The schematic of Figure 3 identifies those electrical changes needed to alter the current meter recorder to function as a thermo/conductivity recorder system. All of the circuit modifications are done at the recorder terminals. The first change is adding a bridge circuit for the intake seawater temperature sensor. This sensor is an Aanderaa slow-response thermistor that can be placed 45 m (cable length) from the recorder. The bridge values shown on the schematic have been computed for a temperature range of -2 to 20 degrees C. This sensor output appears in the data word sequence in place of the pressure sensor output.

A second circuit change involves the conductivity range. Two conductivity ranges were chosen: 20 to 40 mmhos and 33 to 53 mmhos. The conductivity range modification nomograph described in *EXPOSURE*, Vol. 3, No. 2, was used to select the resistor values for these ranges. For two conductivity ranges it's generally necessary to select a minimum of four resistor values. Two resistor values each are required for WR5 and WR6; however, for overlapping conductivity ranges, it is

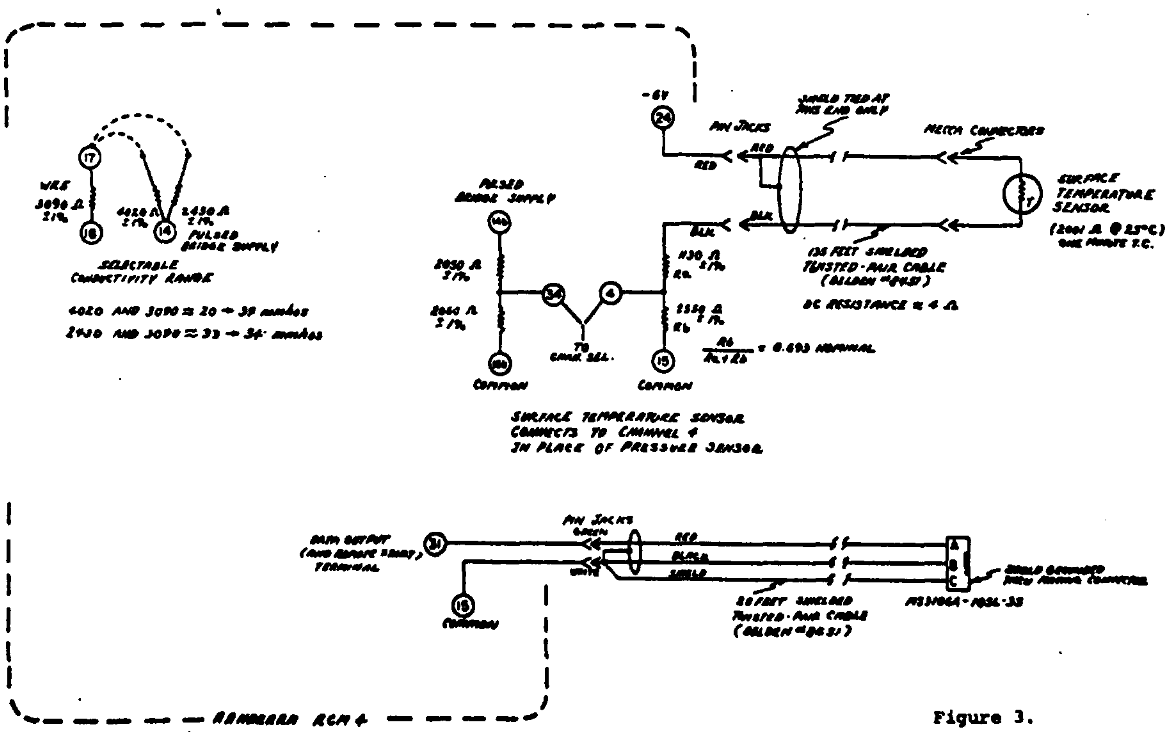

Figure 3.

usually possible to make the resistor value WR5 common to both ranges. The benefit of having only three resistor values is that one resistor value (WR5) stays fixed and permanently connected between terminals 17 and 18 and a simple 3-way switch between terminals 14 and 17 (WR6) allows one to quickly switch conductivity ranges. From the previously published nomograph, the following resistor values were put in the recorder before calibration:

Range 20 to 39.2 mmhos:
WR5 = 3090 ohms, WR6 = 4020 ohms

Range 33 to 54 mmhos:
WR5 = 3090 ohms, WR6 = 2430 ohms

The graph of Figure 4 is a plot of calculated conductivity (using seawater chamber temperature and bottle salinity) vs. digitizer (recorder) bit numbers. By extrapolating from the two lines on the graph, the actual ranges are 20.8 to 41.5 mmhos and 34.8 to 55.5 mmhos for the particular resistors used in this calibration. The resolution for both ranges is 0.0202 $mmhos/cm^2$ for conductivity and 0.018 o/oo for salinity.

The thermo/conductivity recorder was calibrated in the following manner: Approximately 15 gallons of high-salinity water was put in a container above the seawater cell. By gravity flow, the water passed through the seawater cell to another container below. The tubing leading to the seawater cell could be pinched off to stop the flow. This was done whenever the salinity of the supply bath was to be decreased. One or two coffee cans of cooled, distilled water were added at a time to drop the salinity to the next lower level. The readout display was used to determine the flushing time of the seawater cell and for obtaining the digitized scale values. The flow rate through the seawater cell was two liters per minute and the flushing transition time from one salinity to another at this flow rate was 120 seconds.

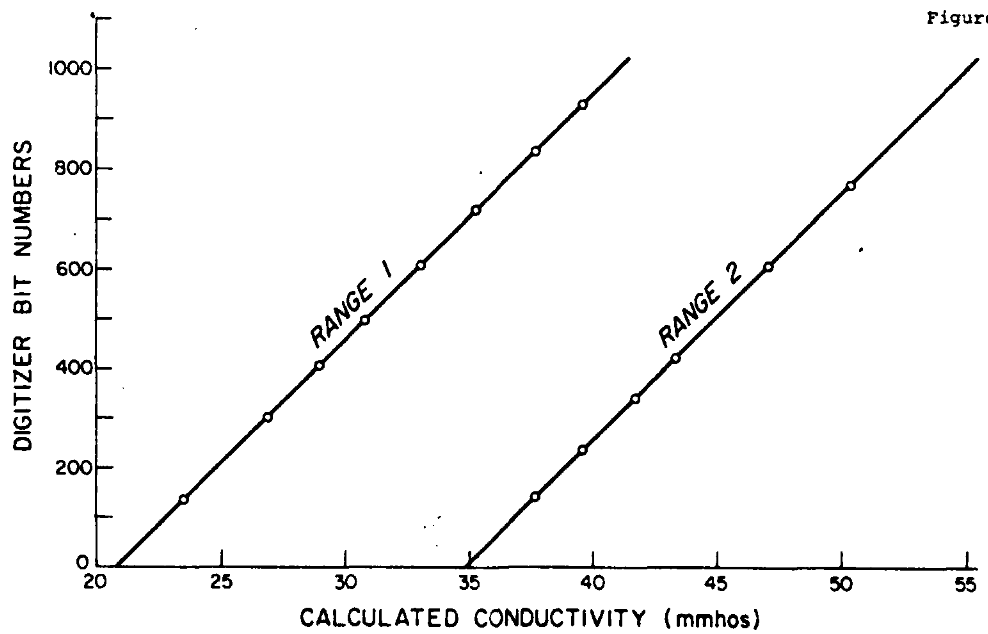

Figure 4.

Bubbles will adhere to the inside of the conductivity cell when the chamber is first filled and these must be removed. An access hole has been provided in the top of the seawater cell to allow the user to mechanically remove any air bubbles trapped in the conductivity cell. An accumulation of bubbles will affect the conductivity reading of the recorder; therefore, the conductivity cell should be inspected regularly for bubbles. It is helpful to have a debubbler in the intake line of the seawater cell.

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CORRECTION:

In the article on "Turbulence Effects On Current Measuring Transducers", by L. Bevins and G. Appell (EXPOSURE Vol. 3, No. 6, page 3), the vertical axis titles of Figure 3 were inadvertently transposed.

TABLE OF CONTENTS

EXPOSURE
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