

CANADA Centre for Inland Waters  
UNPUBLISHED ~~XXXXXXXXXX~~

HARRISON, E J  
1975

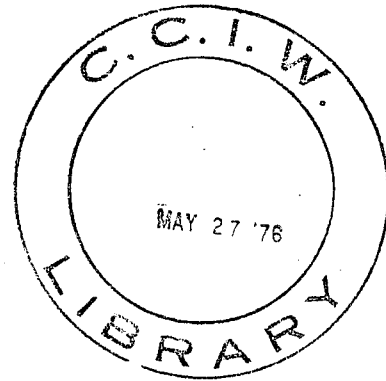
TD  
7  
H376  
1975

Harrison

C.C.I.W.

UNPUBLISHED REPORT

EC-508



DESIGN AND DEVELOPMENT OF "C.A.T.S....  
A NEARSHORE CURRENT AND TEMPERATURE STAFF  
SYSTEM FOR LONGTERM MONITORING OF  
THERMAL-PLUME DYNAMICS"

FEBRUARY, 1975

C. J. Harrison, P.Eng.  
Engineering Services Section,  
Canada Centre for Inland Waters,  
Burlington, Ontario, Canada.

## ACKNOWLEDGEMENTS

Systems such as CATS are the result of a cooperative effort by individuals in a task force formed to carry out specified scientific objectives. The successful development of the CATS system was due to the efforts of the following people.

G. K. SATO	- Scientific Authority
E. J. HARRISON	- Project Engineer
B. P. BRADY	- Mechanical Design Engineer
M. PEDROSA	- Electronic Design Technologist
J. HEIDT	- Mechanical Design Technologist
J. A. BULL	- Data Processing
L. E. BENNER	- Field Operations
J. ROE	- Dive Unit

i

ABSTRACT

A bottom-mounted self-contained system for monitoring surface to bottom temperature profiles and near-bottom vector-averaged current velocity is described. It is intended as an observational tool to assist limnological studies of the extent, intensity and dynamics of power-station thermal-plumes in large lakes. Temperature is measured at one metre depth intervals to typically 30 mC<sup>0</sup> accuracy. Depth accuracy is maintained via secure mounting to a semi-stiff gimbal-mounted rigid staff whose tilt relative to the vertical is measured with a dual-axis tilt sensor. An electromagnetic 2-axis water velocity sensor is mounted 1 metre off the bottom. Self contained electronics digitally averages the two orthogonal sensor outputs over a preselected time interval and converts to resistance values to be read by the data logger. Correct platform alignment is assured through use of an onboard compass. The data logger scans all environmental sensors in 8 seconds and stores this data, together with time, identity, and calibration references, digitally on magnetic tape. Up to 300,000 samples can be stored during the 3-month deployment period allowing prolonged use of the system in winter under ice-covered waters. The system is capable of being monitored in situ from the surface via an expendable cable link. The entire C.A.T.S. system including anchor weighs about 320 kgm. in air and is easily deployed from a relatively small vessel.

LIST OF CONTENTS

<u>SECTION</u>	<u>TITLE</u>	<u>PAGE NOS.</u>
1	INTRODUCTION AND SYSTEM APPLICATION	1
2	GENERAL APPROACH TO CATS SYSTEM DESIGN	2, 3
3	SYSTEM SPECIFICATIONS	4
4	SENSOR COMPLEMENT	5 - 8
5	DATA LOGGER AND DATA FORMAT	9, 10
6	MECHANICAL DESIGN AND PLATFORM CHARACTERISTICS	11
7	PROTOTYPE INHOUSE AND FIELD TEST EXPERIENCE	12, 13
8	EARLY OPERATION OF A DEPLOYED ARRAY IN A THERMAL PLUME	14
9	CONCLUSIONS AND RECOMMENDATIONS	15
10	REFERENCES	16

FIGURES

- (1) Conceptual Sketch of a Prototype CATS System.
- (2) Photoview of First Prototype System.
- (3) Photoview of CATS System.
- (4) System Functional Block Diagram.
- (5) Photoview of Electronics Adapted For Use With The CATS System.
- (6) E/M Current Sensor with Resistive Integrating Electronics.
- (7) Prototype Rotor/Vane Current Sensor With Resistive Integrator.
- (8) Sensor for Temperature, Platform Direction, and Tilt.
- (9) System Data-Logger, and Digital Monitor Unit.
- (10) System Resistive Digital Transfer Function.
- (11) Temperature Sensor: Performance Characteristics.
- (12) Integrating E/M Sensor: Performance Characteristics.
- (13) Integrating Rotor/Vane Sensor: Performance Characteristics.
- (14) Resistive Tilt Sensor: Performance Characteristics.
- (15) Prototype System Being Deployed From 40 ft. Vessel.
- (16) Prototype System: Underwater Photoview.
- (17) Array Deployment Area off Pickering Power Station (Toronto, Lake Ontario).
- (18) Array of 5 CATS Systems Ready For Deployment.
- (19) CATS Systems Array: Operational Performance Record to Date.
- (20) CATS Timer and Power Control PCB Schematic.
- (21) CATS Digital To Resistance Converter PCB Schematic.
- (22) CCIW Integrator PCB Schematic.

SECTION 1:      INTRODUCTION AND SYSTEM APPLICATION

Temperature and current are two fundamental parameters which are important in most limnological studies. CCIW has used a variety of systems and techniques to measure these two variables in many situations and for varied time durations. These systems range from moored Current Meter arrays, fixed Temperature Profiling Systems, Electronic Bathythermographs (EBT) to bucket thermometers, moving sediment and remote sensing techniques. However, none of these existing systems is well-adapted to the task of measuring temperature profiles and current in the nearshore zone (5 to 15 metre depth) for extended periods.

Primarily, such a system is needed to study the dynamics of sinking thermal plumes from the coolant outflows of electricity generating stations. Although the extent of the plume can be ascertained over any given short interval by taking a series of temperature/depth profiles using an EBT from a small craft, the long term behaviour of the plume, over the winter period requires a different solution. Furthermore, it is virtually impossible to get a reliable water velocity measurement from a small craft with current meters lowered over the side. Thus, the need for an array of systems to measure surface to bottom temperature profiles and near bottom current, over several months, in shallow water was identified.

## SECTION 2: GENERAL APPROACH TO CATS SYSTEM DESIGN

The major functional objectives in the design of a CATS system are as follows:-

- a) To measure temperature profiles from surface to bottom with good accuracy and depth resolution of about 1 meter.
- b) To measure near bottom current with good accuracy and threshold of the order of one cm/second.
- c) To measure and store the values for at least 2 months between field servicing, at an interval of 10 minutes.
- d) To withstand the forces of wave action and potential drifting ice cover, the thickness of which is about 1 meter.

The major constraints on the development of the system were the need to minimize expenditures and the short 6 month development cycle, which included the assembly of five complete systems. Capital expenditures were minimized by using as much existing equipment as possible. This constraint made the first choice clear. The data logger and temperature sensors would be the same as those used in the Fixed Temperature Profiling Systems (Ref. 1). These system elements were field proven and available. At that stage there were a number of questions to answer:-

- 1) How should the temperature sensors be mounted to obtain and maintain the necessary depth resolution?
- 2) Which current sensor was best in terms of its sensitivity, threshold and accuracy?

SECTION 2: GENERAL APPROACH TO CATS SYSTEM DESIGN

- 3) How should the system be monitored to ensure correct operation?
- 4) How should the system alignment relative to north be maintained?
- 5) To achieve the endurance and time resolution desired by the research limnologists, a 10 minute sampling interval was necessary. How should the various parameters be averaged over the sampling interval?

To answer the first question it was decided to mount the thermistors on a rigid buoyant staff, so that their positions were fixed relative to each other. To compensate for the induced stresses due to wave forces and possible ice, the staff would be gimbal-mounted to an anchor assembly, which would contain the data logger, batteries and current meter. To eliminate the error due to the tilting of the staff, under wave or ice forces, a two-axis tilt sensor was incorporated in the design. However, due to the relatively high cost of underwater tilt sensors, it was decided to stiffen the gimbal such that only excessively strong forces would tilt the staff significantly from the vertical ( $>10^0$ ) and thereby eliminate the tilt sensor. Stability calculations predicted that water speeds up to 1 metre per second would cause a tilt of only 15 degrees. Finally, to avoid hazard to small craft, and possible damage to the staff due to pack ice, the staff length would be such that it extended to about 1.5m below the surface. A short line, small float and short expendable cable completed the link to the surface. Thus, the system concept stabilised as shown in fig. 1. The corresponding functional block diagram is shown in figure 4, and an early prototype in figure 2.

The design of the individual system components will be described later in the report.



### SECTION 3: CATS SYSTEM SPECIFICATIONS

#### 3.1 TEMPERATURE

- . RANGE : -2 TO 40°C
- . RESOLUTION : 15 mC° (WORST CASE)
- . ACCURACY : + 50 mC°
- . TIME CONSTANT : 4.0 MIN. (WITH BOOT)
- . SENSOR TYPE : FENWAL K-2284 4K-ISO CURVE THERMISTOR.

UP TO 10 THERMISTORS ARE ALLOWED IN THE PRESENT CONFIGURATION, WITH SOME CHANGES, IN EXPANSION POSSIBLE.

#### 3.2 DEPTH

- . RANGE : 0 to 10 METRES
- . RESOLUTION : 1 METRE
- . ACCURACY : + 0.5 m - DEPENDS ON MEASURED WATER DEPTH, MEASURED POSITIONS ON THE STAFF, AND TILT OF THE STAFF.

#### 3.3 TILT (2 AXIS)

- . RANGE : + 45° ON EACH AXIS
- . RESOLUTION : 0.45°
- . ACCURACY : 0.5°
- . TIME CONSTANT : 7 SECONDS (AT 4°C)
- . SENSOR TYPE : HUMPHREY VI 13-0502-1 VERTICAL INDICATOR.

#### 3.4 WATER VELOCITY (2-AXIS)

- . RANGE : + 100 cm/s
- . RESOLUTION : 5 cm/s
- . ACCURACY : + 2% OF OUTPUT OR + 1 cm/sec. WHICHEVER IS GREATER.
- . THRESHOLD : < 1 cm/s.
- . AVERAGING : LINEAR (INDUCED ERROR < .2%).
- . SENSOR TYPE : MARSH-McBIRNEY MM501  
ELECTRO-MAGNETIC 2 AXIS SENSOR AND CCIW  
DEVELOPED AVERAGING ELECTRONICS.

#### 3.5 DATA LOGGER

- . INPUTS : UP TO 24 RESISTANCE INPUTS IN THE RANGE 2.25K  $\Omega$  TO 12.67K  $\Omega$ .
- . SCAN RATE : 6 SCANS/HR. NORMALLY,  
7.5 SCANS/MIN. DURING MONITORING.
- . ACCURACY : + 0.03% (4 $\Omega$  WORST CASE)
- . CAPACITY : 12000 16 SAMPLE RECORDS  
(69 DAYS AT 6 SCANS/HR.)
- . TIME ACCURACY : + 1 MINUTE/MONTH
- . TYPE : EG&G MODEL 775-25 RESISTANCE DIGITIZER.

#### 3.6 PHYSICAL

- . WEIGHT : 320 kg IN AIR (182 kg IN WATER)
- . DIMENSIONS : ANCHOR 1.27m WIDE x 2.3m LONG x 1m HIGH  
STAFF 3 TO 10m LONG.

## SECTION 4:      CATS SENSOR COMPLEMENT

### 4.1    TEMPERATURE SENSORS

Fenwal K2284 thermistors are the CCIW standard slow response high resolution water temperature sensor for field use. The accuracy quoted in Section 3 is obtained through individual calibration, and the long time constant through a neoprene rubber boot, which acts as a thermal mass. The sensors are extremely stable due to the "insulated" rugged construction which has resulted in drifts of less than  $10\text{m}^{\circ}\text{C}$  in many sensors, over several years.

Also contributing to this accuracy is the measurement technique which dissipates less than  $30\mu$  watts of power in the sensor for less than 250 mS during a measurement.

### 4.2    TILT SENSOR

The Humphrey's dual axis vertical tilt sensor uses orthogonal, heavily damped, gimbal mounted, pendulous potentiometers to provide a resistance indication of inclination. The damping is such as to provide a 7 second time constant at  $4^{\circ}\text{C}$ . Data returned from the field for analysis, has shown that the semi-stiff gimbal mounted staff exhibits no significant tilt angle ( $> 10^{\circ}$ ) and no resonance which would cause the possible aliasing using the relatively short time constant.

## SECTION 4: CATS SENSOR COMPLEMENT (Cont'd.)

### 4.3 CURRENT SENSOR

The Marsh-McBirney current sensor used in the system was selected from a survey of 10 major types of sensors. The main criteria for selection were minimum threshold response, maximum accuracy, and output compatible with the digitizer in low flow regimes. Of the sensors surveyed, only 4 offered theoretical thresholds less than 2 cm/sec., the Aanderaa savonius rotor, the Braincon Model 252, the Geodyne 920-3 and the Marsh-McBirney MM501. Neither the Braincon nor the Geodyne were considered because of packaging problems and incompatible pulse type outputs. Thus, the final trade-off was between the Aanderaa sensor and the Marsh-McBirney sensor.

The pros and cons on each side were:

TABLE NO. 1 E/M VS. SAVONIUS CURRENT SENSOR COMPARISON

	Pro	Con
Savonius Rotor Sensor (Fig.13)	<ul style="list-style-type: none"> <li>. extremely low power consumption</li> <li>. excellent workmanship</li> <li>. resistance output on both speed and direction.</li> <li>. speed averaged.</li> </ul>	<ul style="list-style-type: none"> <li>. no averaging of direction</li> <li>. subject to fouling</li> <li>. subject to pumping, due to wave action.</li> </ul>
Electro-Magnetic Sensor (Fig.12)	<ul style="list-style-type: none"> <li>. low speed threshold</li> <li>. good accuracy in low flow</li> <li>. not subject to wave action</li> </ul>	<ul style="list-style-type: none"> <li>. high power consumption (1.5 watts)</li> <li>. voltage output not averaged.</li> <li>. flow effects around cylinder.</li> </ul>

## SECTION 4:      CATS SENSOR COMPLEMENT

### 4.3 CURRENT SENSOR      (Cont'd.)

Both types of sensors were tried in the prototype mooring. To facilitate this, a special configuration of the Aanderaa system was created by Aanderaa (see fig. 7) incorporating a low threshold vane and the standard rotor.

Since the E/M sensor output was not averaged, circuitry was built to average its output (See Fig. 22) and convert the averaged value to resistance (see Fig. 21) to be read by the digitizer. Also, to compensate for the relatively power hungry sensor, duty cycling circuitry (see Fig. 20) was provided to perform active averaging 5 minutes out of the 10 minute sampling interval.

During the prototype mooring several things were noted.

- a) Evidence of pumping action (a common problem with savonius rotors in the near shore zone).
- b) Evidence of vane flopping due to wave action in low flow regimen.
- c) Fouling of the savonius rotor even after only a few weeks in the field and hence, increased threshold.
- d) Confusion relating current direction between the E/M sensor and the Aanderaa vane sensor.

Although at time of writing the last point has not been fully resolved, it was decided that there was sufficient evidence against the savonius sensor for this application, to justify adopting the E/M sensor for further field use. Economically, it was also more reasonable to choose the E/M sensor even though some electronics needed to be built, since the expenditure needed to buy 5 savonius rotor systems was comparable to that required to obtain the necessary averaging electronics. (The E/M sensors themselves were available in house .... ref. 3 ).

## SECTION 4:      CATS SENSOR COMPLEMENT

### 4.3 CURRENT SENSOR (Cont'd.)

The voltage outputs from the E/M sensor were treated in the following way. Firstly, since the sensor tends to be power hungry, a crystal controlled timer, when activated by the digitizer, enables the resistance output for twenty seconds, then shuts down the sensor for four minutes and ten seconds. At this point, the sensor turns on to stabilize for thirty seconds before its outputs are allowed to be integrated. The output is integrated by converting the voltage to frequency, then scaling and counting for a fixed 300 second interval. On command from the digitizer, the output from the counter is used to activate a precision binary resistor ladder, which in turn, is read by the digitizer. Fig. 6 shows the normal voltage-generating sensor with the resistive integrator electronics and its underwater case.

### 4.4 DIRECTION

An indication of direction is provided by an Aanderaa magnetic compass, which is clamped under command from the digitizer to provide a resistance output. The compass is contained in the same case as the E/M sensor averaging electronics and its north aligned with the E/M sensor's + Y axis.

## SECTION 5: CATS DATA LOGGER AND DATA FORMAT

5.1 The selected Data logger (Figure 9) contains:-

- a) 24 channel multiplexor
- b) 12 bit resistance to digital convertor
- c) endless loop digital magnetic tape transport with 3 megabit capacity
- d) quartz crystal clock accurate to within one minute/month
- e) self-contained battery with sufficient capacity to fill the tape at any sampling interval.

A detailed description of the data logger may be found elsewhere (Refs. 1, 2).

### 5.2 DATA FORMAT

The data format is fixed for all CATS systems regardless of the number of thermistors used, the presence or absence of tilt sensor, etc., to simplify the data interpretation. The first 18 words of each record are allocated according to table No. 2. Each word is recorded as 16 bits although, not all the bits are used.

SECTION 5:      CATS DATA LOGGER AND DATA FORMAT

5.2 DATA FORMAT    (Cont'd.)

Table No. 2      DATA LOGGER DATA FORMAT

WORD NUMBER	PARAMETER	NO. OF BITS USED	DIGITAL RANGE EXPECTED (OCTAL)
0	IDENTITY	6	0 to 14
1	TIME	14	0 to 37777
2	REFERENCE	12	3163 to 3164
3	SURFACE THERMISTOR	12	300 to 4500
4	THERMISTOR 2	12	300 to 4500
5	THERMISTOR 3	12	300 to 4500
6	THERMISTOR 4	12	300 to 4500
7	THERMISTOR 5	12	300 to 4500
8	THERMISTOR 6	12	300 to 4500
9	THERMISTOR 7	12	300 to 4500
10	THERMISTOR 8	12	300 to 4500
11	THERMISTOR 9	12	300 to 4500
12	BOTTOM THERMISTOR	12	300 to 4500
13	COMPASS	12	3700 to 6400
14	TILT NORTH	12	3000 to 5200
15	TILT EAST	12	3000 to 5200
16	CURRENT NORTH	12	1100 to 1500
17	CURRENT EAST	12	1100 to 1500

The field tapes are reformatted at CCIW onto 1/2 computer compatible 7-track magnetic tape in BCD format, with a header record added, which contains mooring dates and other ancillary information.

## SECTION 6: CATS MECHANICAL DESIGN AND PLATFORM CHARACTERISTICS

The key features and benefits of the anchor design are as follows (see fig. 3).

- a) Minimum size and weight for ease of handling and deployment (2.26 m x 1.22 m x .61 m length, width and height respectively).
- b) Non ferrous design to minimize interference with on-board compass. The frame is welded aluminum with six cradles which contain cast lead weights, which give a total ballast of 164 kg.
- c) 2 metre separation of staff and E/M sensor plus positioning of anchor such that the staff is at the shoreward end of the assembly yield minimum errors in current direction.
- d) 3 point E/M sensor mounting allows diver levelling of the sensor to minimize current error due to uneven bottom.
- e) Quick disconnect clamps to allow diver servicing of any of the system elements.
- f) Stiff nylon reinforced plastic hose which acts as a semi rigid coupling to the staff to minimize staff tilt except under extreme stress, (ice cover or passing vessels).
- g) Penetrating feet which ensure minimum movement of the anchor during heavy wave action or other disturbances.



SECTION 7:      PROTOTYPE INHOUSE AND FIELD TEST EXPERIENCE

The entire development cycle for this system was limited to six months from system definition (June, 1975) to deployment of five systems. (December, 1975). To obtain an adequate prototype mooring period of about six weeks and allow for the assembly of five systems for field use, only two months was available to design, assemble, and test the No. 1 prototype system. Due to procurement delays, the tilt sensor and the Aanderaa savonius rotor current sensor were not installed on the prototype when first deployed. Refer to fig. 19 highlights and unscheduled events 'A' through 'E'. Two problems show up in this list. Only one (see 'D') was relevant to CATS system design. The diver pluggable electro-oceanics connector was wired in such a way, that upon insertion underwater, the -24V supply was shorted to ground thus blowing a fuse. This fault was simply corrected by changing the contact allocation for that plug on later systems.

The second problem area was in relating the savonius sensor data to the E/M sensor data. When all the alignment data and calibrations were applied, there was still a discrepancy of up to  $45^{\circ}$  between the two sensors. The cause of this anomaly is still under investigation at time of writing.

All other system elements performed as expected. The maximum tilt observed was about  $8.6^{\circ}$ , and that was during "near hurricane" conditions. The other factor which could cause significant tilt was surface ice cover. To study this possibility it was decided to place tilt sensors on one shallow station and one deep one during the first winter moorings.

Based on the first prototype experience, the decision was made to proceed with the assembly of five systems for the winter season, using the E/M sensor.

SECTION 7:      PROTOTYPE INHOUSE AND FIELD TEST EXPERIENCE (Cont'd.)

One other change was made. It was the opinion of some members of the task force, that rotational shift of the anchor, due to wave forces was possible. Thus, an on board compass was added at that point to monitor any rotation. The original anchor was fabricated from steel angle and steel plate for weight; however, this type of construction was incompatible with the use of a magnetic compass. Thus, the construction of aluminum and lead as described in Section 6 was adopted. As well as allowing correct operation of the compass, the revised anchor design made the system components light enough to be handled by only two men.

SECTION 8:      EARLY OPERATION OF A DEPLOYED ARRAY IN A THERMAL PLUME

Five systems were deployed off the Pickering Nuclear Generating Station in Lake Ontario in December, 1975. The sensor complement and location is shown, for each station in figure 17, and a photoview of the five systems in figure 18. A complete list of problems/failures is given in Table No. 3, for the field preparation and first measurement periods.

Of the problems observed thus far, only three required action or further investigation. The first is in regard to the compass clamping circuit. The loading effect of the added compass on enabling circuit in the E/M current sensor assembly was underestimated. The same circuit was used to enable the resistance ladder for the averaged E/M outputs and for the compass clamp. After the moorings were in the field for a few weeks and the battery pack weakened, the overloaded enable circuit causes unreliable readings in some cases. This fault was corrected during mid-season refurbishment by providing added buffering to the clamping circuit.

The second problem is possible unreliable operation of a few reed switches in the resistance ladder at low temperatures, and low supply voltages. This situation will be corrected by a simple temperature test during incoming inspection to reject marginal parts.

The final problem is possible drifting of E/M sensor outputs and significant changes to the sensor calibration. This phenomena is under investigation. Its exact definition and recommended remedial action are forthcoming.

SECTION 9:     CONCLUSIONS AND RECOMMENDATIONS

The CATS system in its present configuration provides a viable means of obtaining nearshore temperature profiles and current data for extended periods. The system is relatively small and easily deployed from a relatively small vessel. It is completely modular and fully diver serviceable. Routine system monitoring can be performed at the surface from a small launch, using a battery operated monitor package.

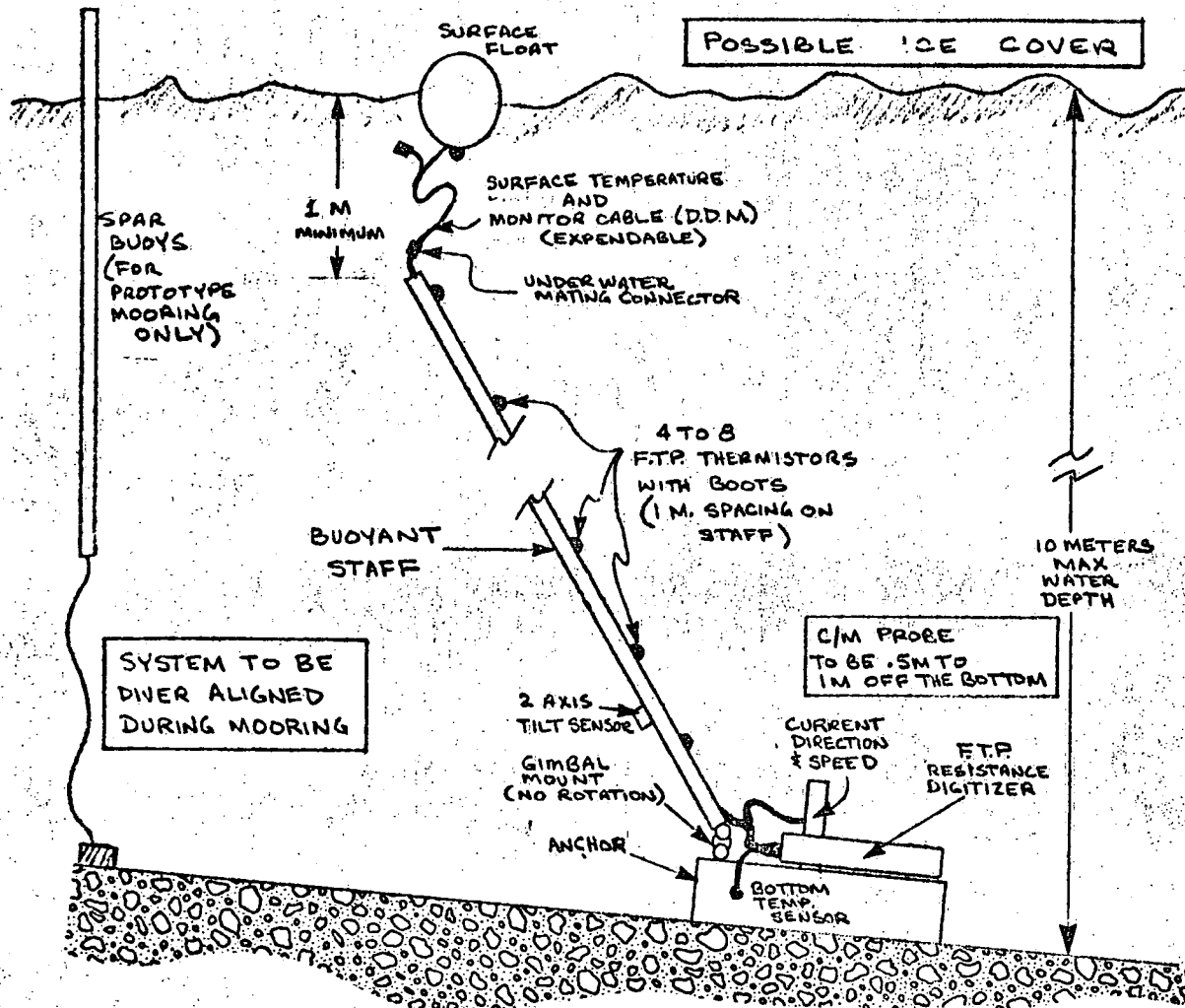
Although the temperature measuring part of the system is highly reliable, (97% data return) some limited work as described in the previous section should be completed to ensure the same degree of reliability on the current measuring side, (81% data return) of the system.

Finally, because of the system's modularity, many configurations are possible. For example, more than one current sensor assembly could be used with the system by making only a few simple wiring changes. Similarly, a different data logger or battery pack could be used, by simply making a different patch cable for the new module.

It is recommended that the CATS system be considered as a basis for future nearshore applications.

SECTION 10:    REFERENCES

- (1) Harrison, E. J. and Watson, A. S.  
Development and Performance of the CCIW Fixed Temperature  
Profiling System - CCIW - ES-500, 1972.
- (2) E.G.&G., Tape Recorder Resistance Digitizer, Model 775-25  
Instruction Manual TM71-188, May, 1971.
- (3) "Handbook Notes for MM-501 Electro-magnetic Sensor"  
Marsh-McBirney, Washington, 1973.
- (4) "Tests on Geodyne Laboratory Digitizer,  
Model A710" N.O.I.C. Fact Sheet IFS-70-002  
National Oceanographic Instrumentation Centre,  
Washington, D.C.
- (5) J. Blanton, ERDA - USA cites Jon Scott,  
Brookhaven National Laboratory for comparison  
in technique.



# PARTS LIST

PART NO.	DESCRIPTION	QTY.
----------	-------------	------

## SYSTEM SPECIFICATIONS

- TEMPERATURE:  $-2^{\circ}\text{C}$  TO  $25^{\circ}\text{C}$   
10 MC° RESOLUTION  
30 MC° ACCURACY  
3 MIN. TIME CONSTANT
- CURRENT SPEED: 2 CM/SEC TO 50 CM/SEC  
1 CM/SEC RESOLUTION  
 $\pm 1$  CM/SEC ACCURACY
- CURRENT DIRECTION: 0 TO 360°  
5° RESOLUTION  
 $\pm 5^{\circ}$  ACCURACY
- TILT SENSOR:  $\pm 45^{\circ}$  RANGE  
5° RESOLUTION  
22° ACCURACY
- ENDURANCE: 60+10 DAYS  
10 MINUTE SAMPLING INTERVAL



Environment  
Canada

Environnement  
Canada

Canada Centre  
for Inland Waters

Centre Canadien  
des Eaux Interieures

## TITLE TEMPERATURE STAFF SYSTEM FOR SINKING PLUME STUDIES (ARD-009) (CONCEPT SKETCH)

DESIGNED BY ERIC H.	CHECKED BY	APPROVED BY
DRAWN BY E. HARRISON	CHECKED BY	DRAWING NO. SKE-5038B
SCALE APPROX. 1" = 1 M.	DATE JUNE 10/75	SHEET / OF /

NO.	DATE	DESCRIPTION	DRWN. BY	APPD. BY
		REVISION		

UNLESS OTHERWISE SPECIFIED	
TOLERANCE ON THREE PLACE DIMENSIONS	$\pm$
TOLERANCE ON TWO PLACE DIMENSIONS	$\pm$
TOLERANCE ON ANGLES	$\pm$
EXTERNAL CORNER CHAMFER	.015 - .025
INTERNAL CORNER RADIUS	.010 - .020
SURFACE FINISH	AA MICRO IN.
MATERIAL SPECIFICATIONS	

FIGURE 1

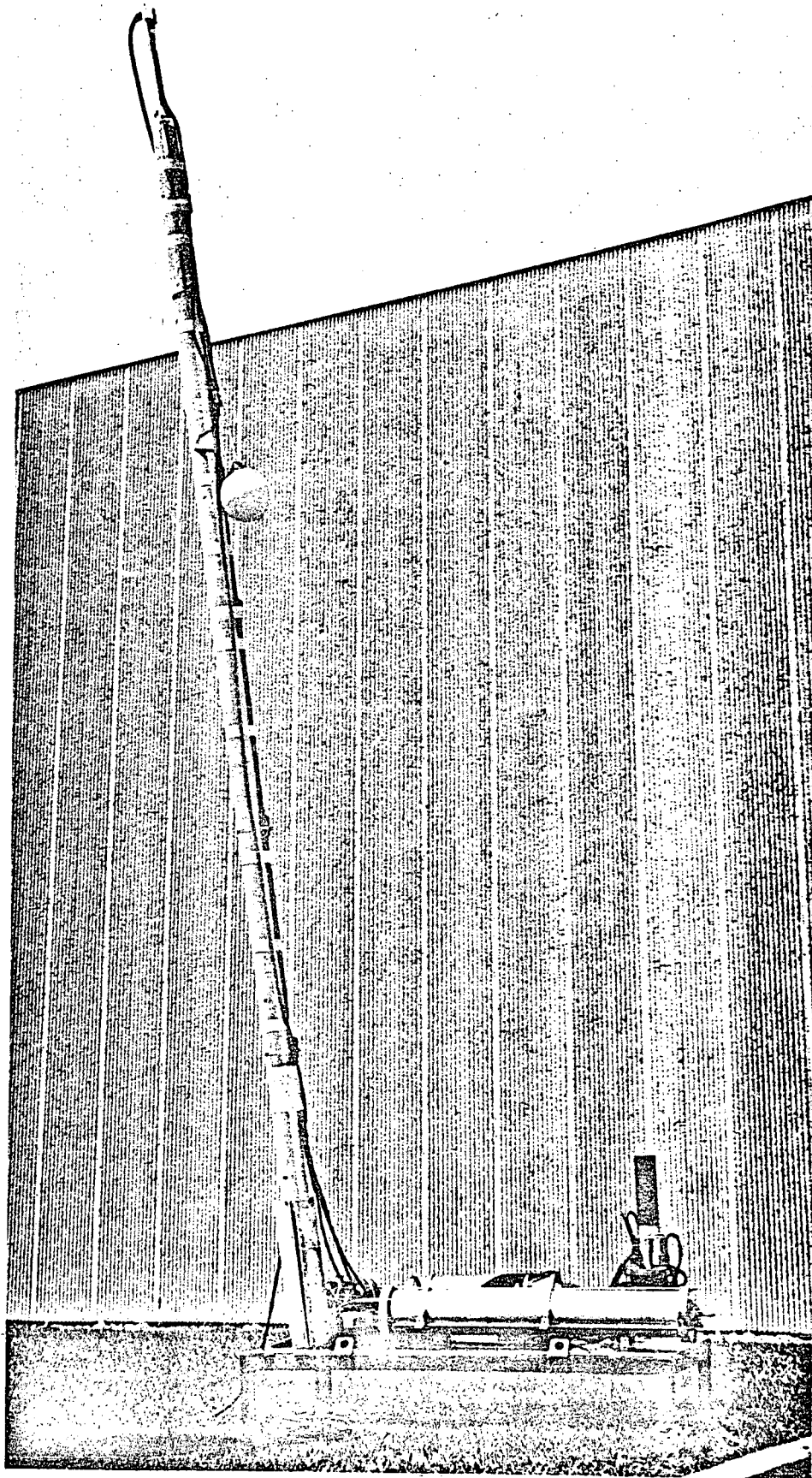


FIG. 2 PHOTOVIEW OF FIRST PROTOTYPE  
CATS SYSTEM

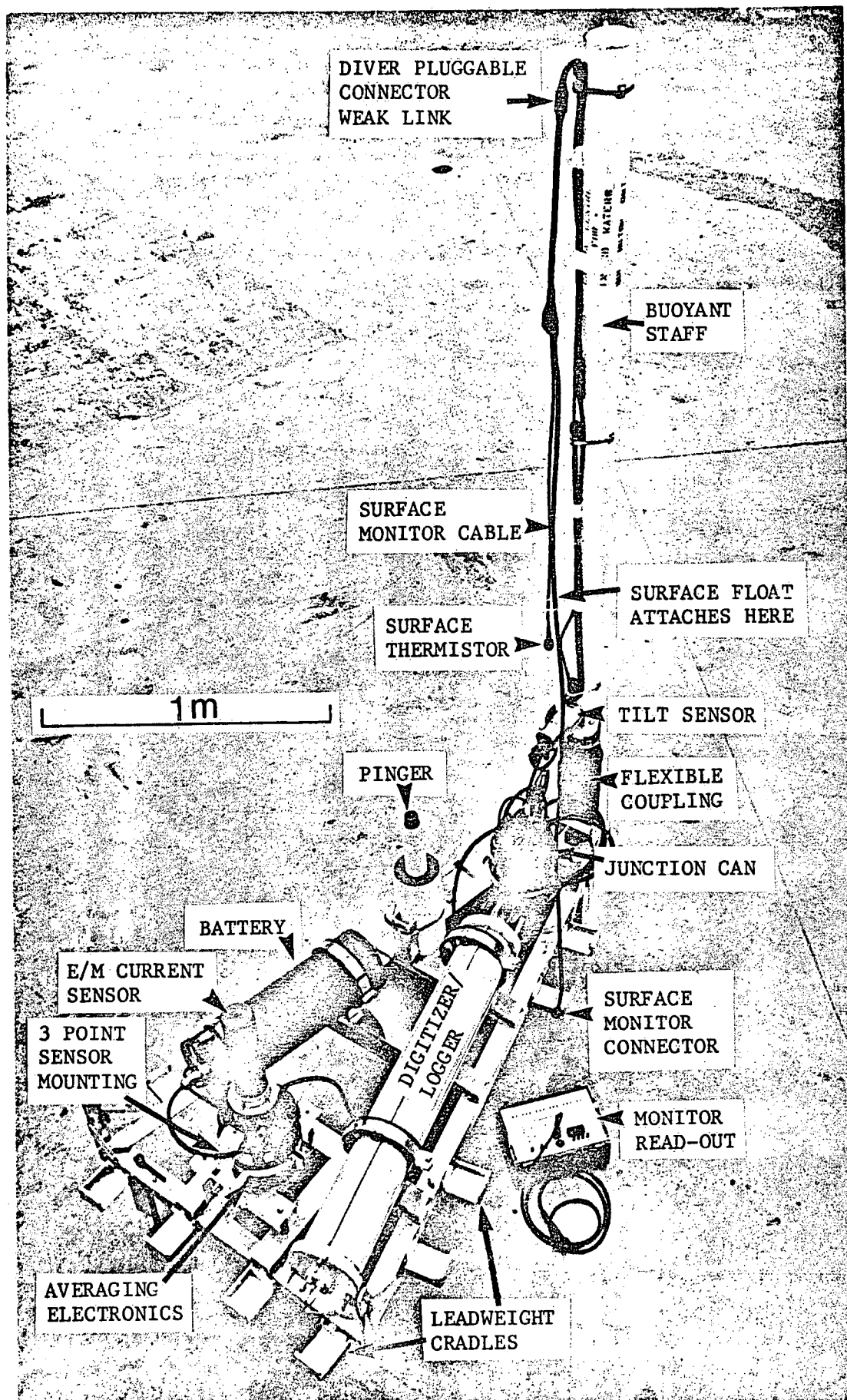
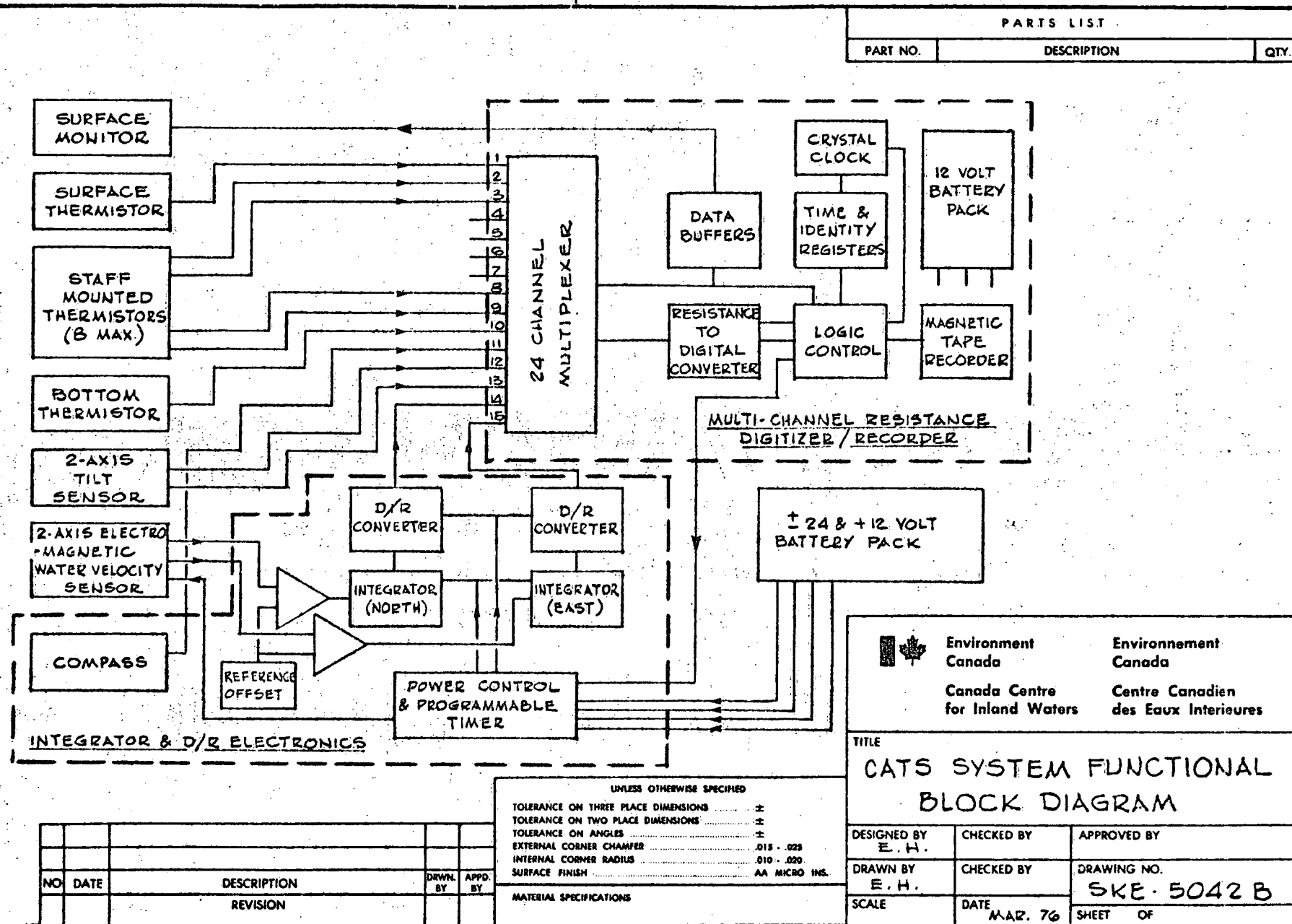


FIGURE 3 PHOTOVIEW OF A PROTOTYPE CATS SYSTEM





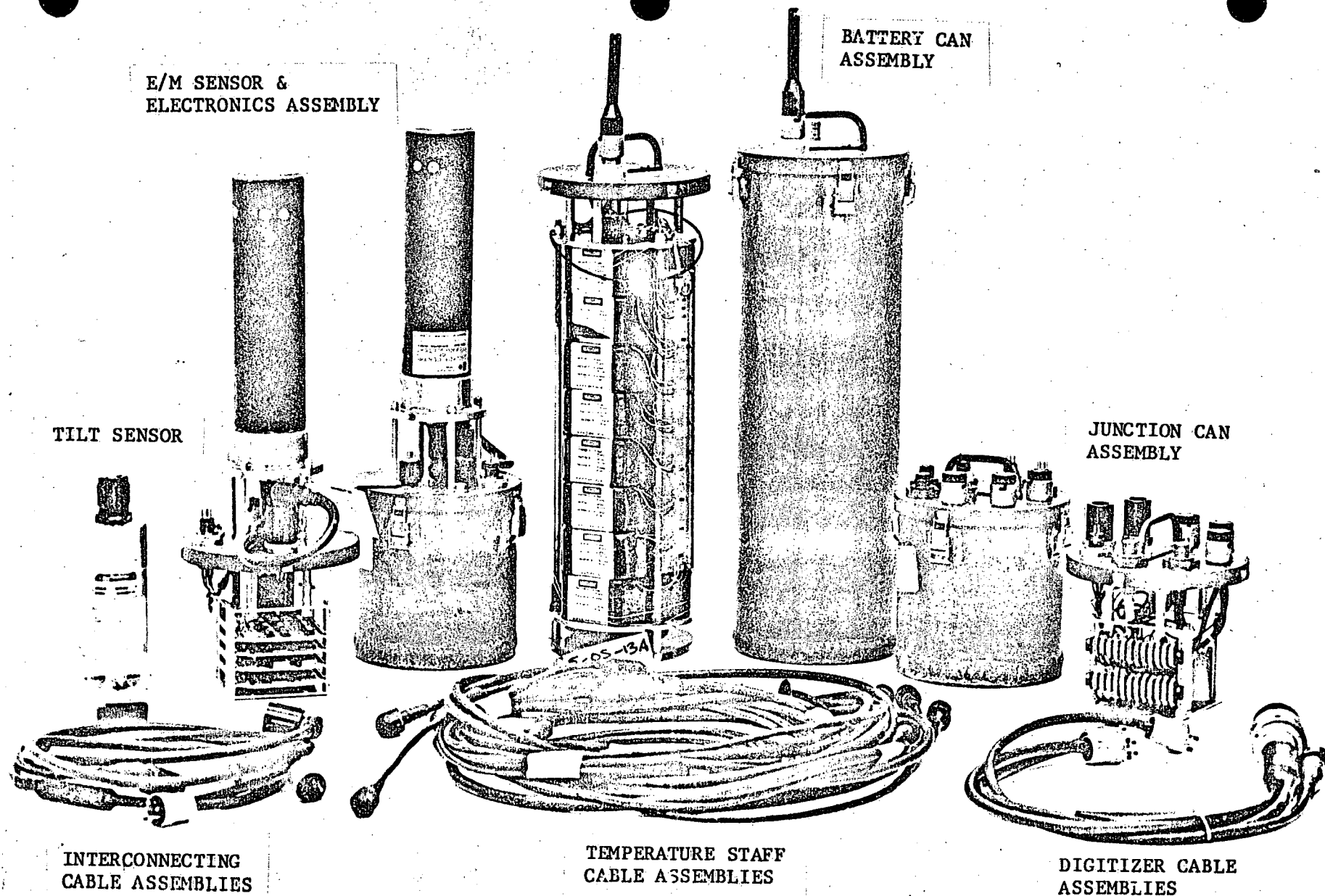


FIGURE 5 PHOTOVIEW OF ELECTRONICS ADAPTED FOR USE WITH THE CATS SYSTEM

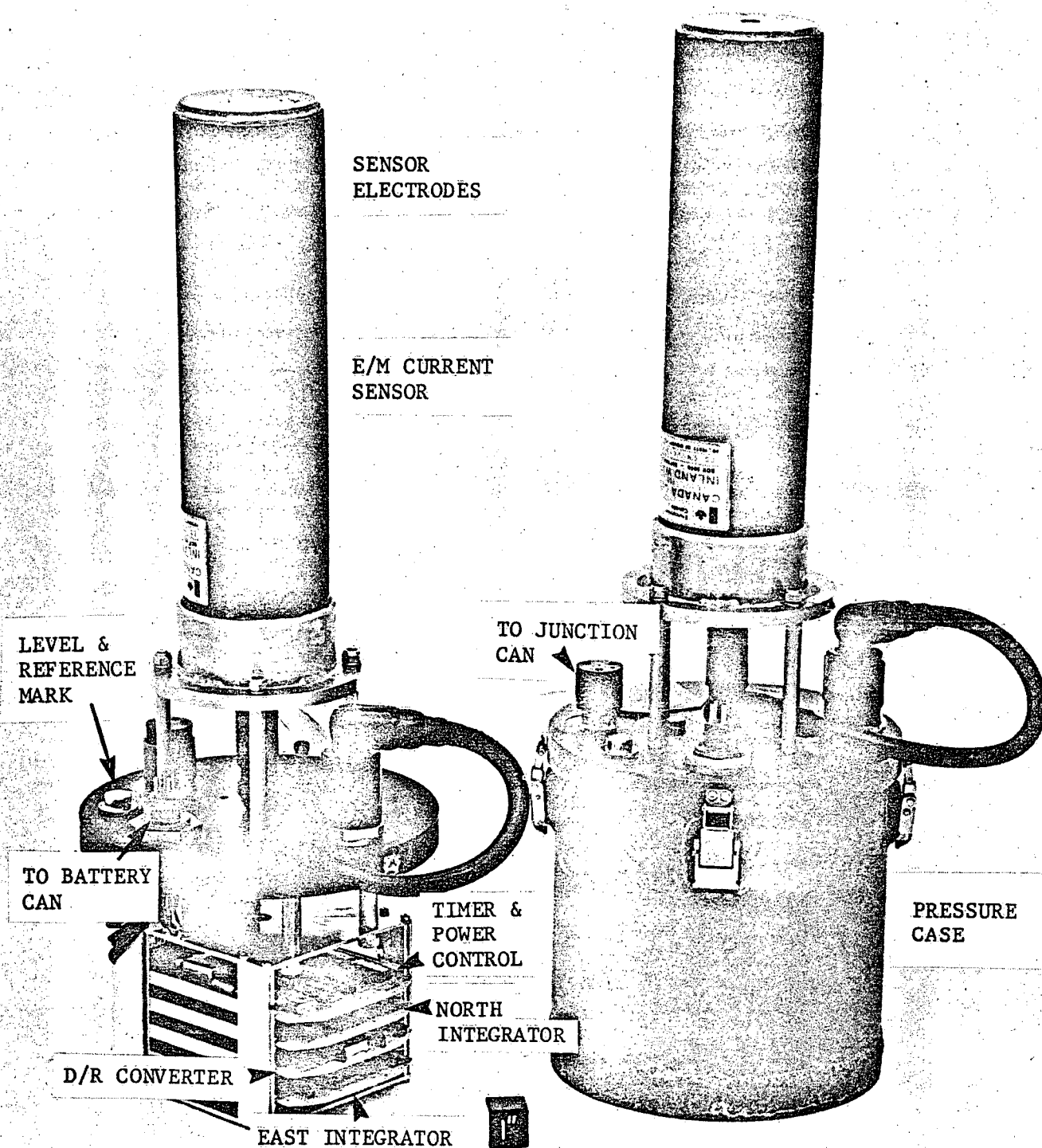


FIGURE 6 E/M CURRENT SENSOR WITH INTEGRATING ELECTRONICS

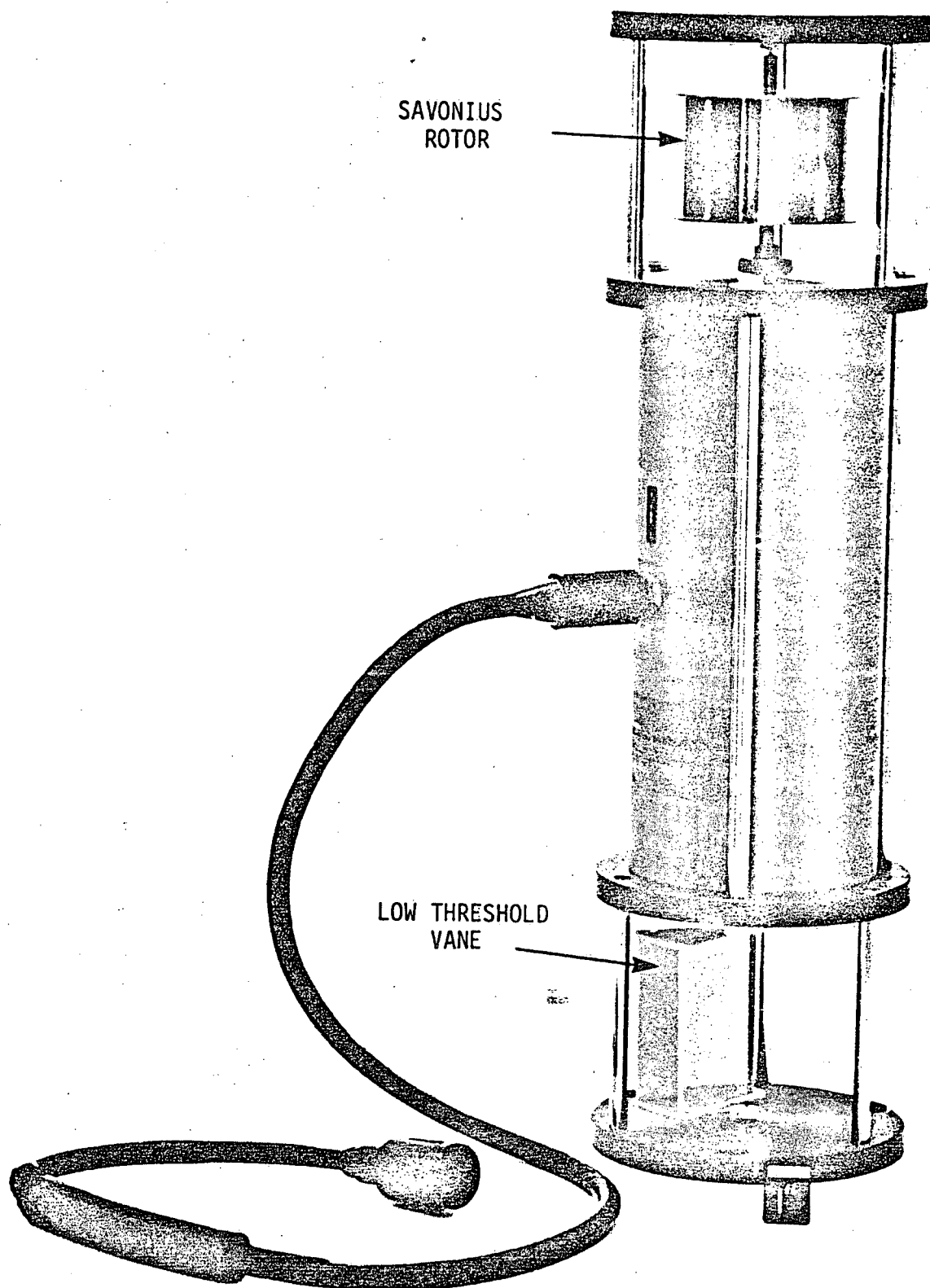
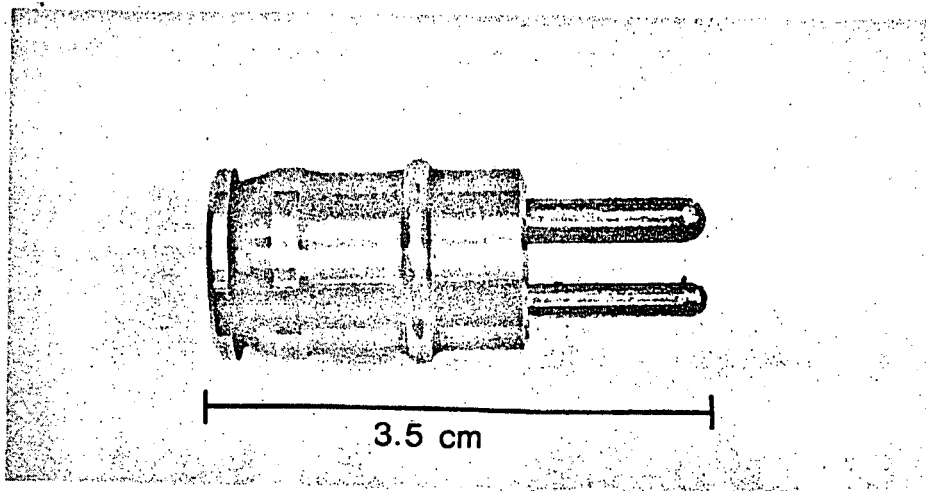
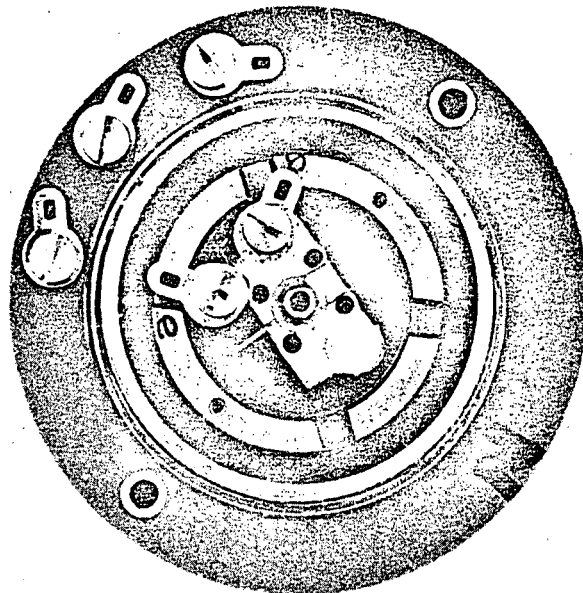


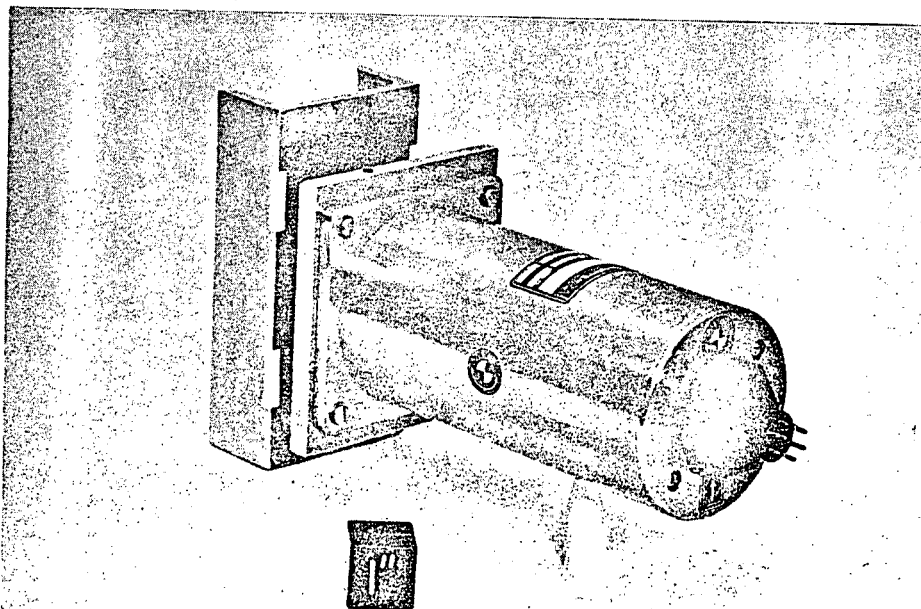
FIG. 7 PROTOTYPE ROTOR VANE CURRENT SENSOR  
WITH RESISTIVE INTEGRATOR



THERMISTOR

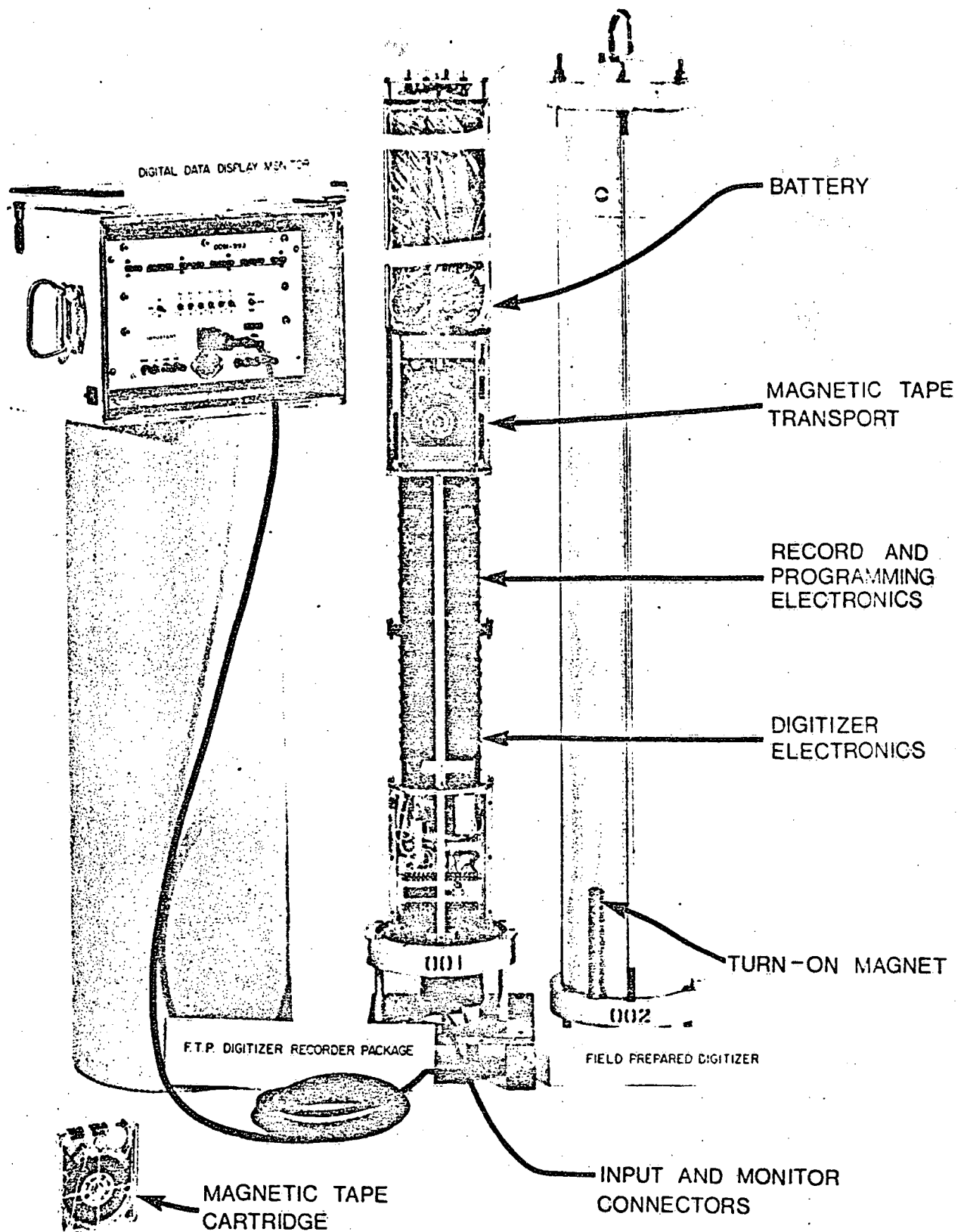


RESISTIVE  
MAGNETIC  
COMPASS



TWO AXIS PENDULOUS  
TILT SENSOR

FIG. 8 SENSORS FOR TEMPERATURE, PLATFORM  
DIRECTION AND TILT



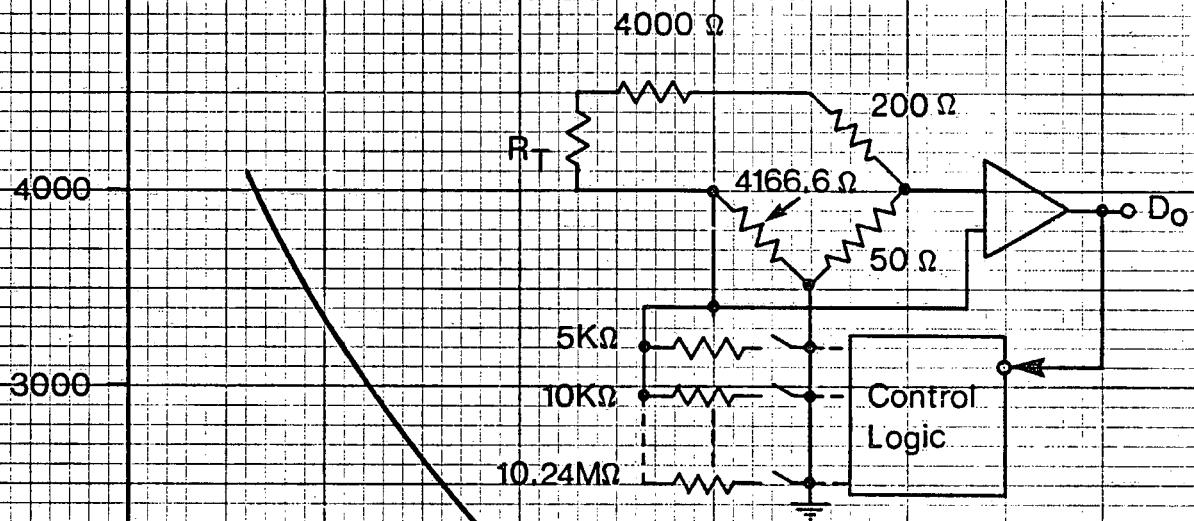
FTP DIGITIZER / RECORDER PACKAGE  
WITH THE DIGITAL DISPLAY MONITOR

FIGURE 9

# E.T.P. RESISTANCE DIGITIZER TRANSFER FUNCTION

## BASIC MEASUREMENT CIRCUIT

OUTPUT DIGITAL NUMBER ( $D_o$ )



EQUIPMENT ERROR  $\pm 1$  BIT

$$D_o = 2^{11.5000} \left[ \frac{4}{R_T + 4000} - \frac{1}{4166.6} \right] \pm 1$$

INPUT RESISTANCE  $R_T$  (IN OHMS)  $\times 10^3$

FIGURE 10

C.C.I.W. REPRESENTATION FOR THE  
4K ISO-VALUES:

$$R = 4002e^{3384(1/T - 1/298.16)} + 87.6 - 1.48T - 0.17T^2 + .0035T^3$$

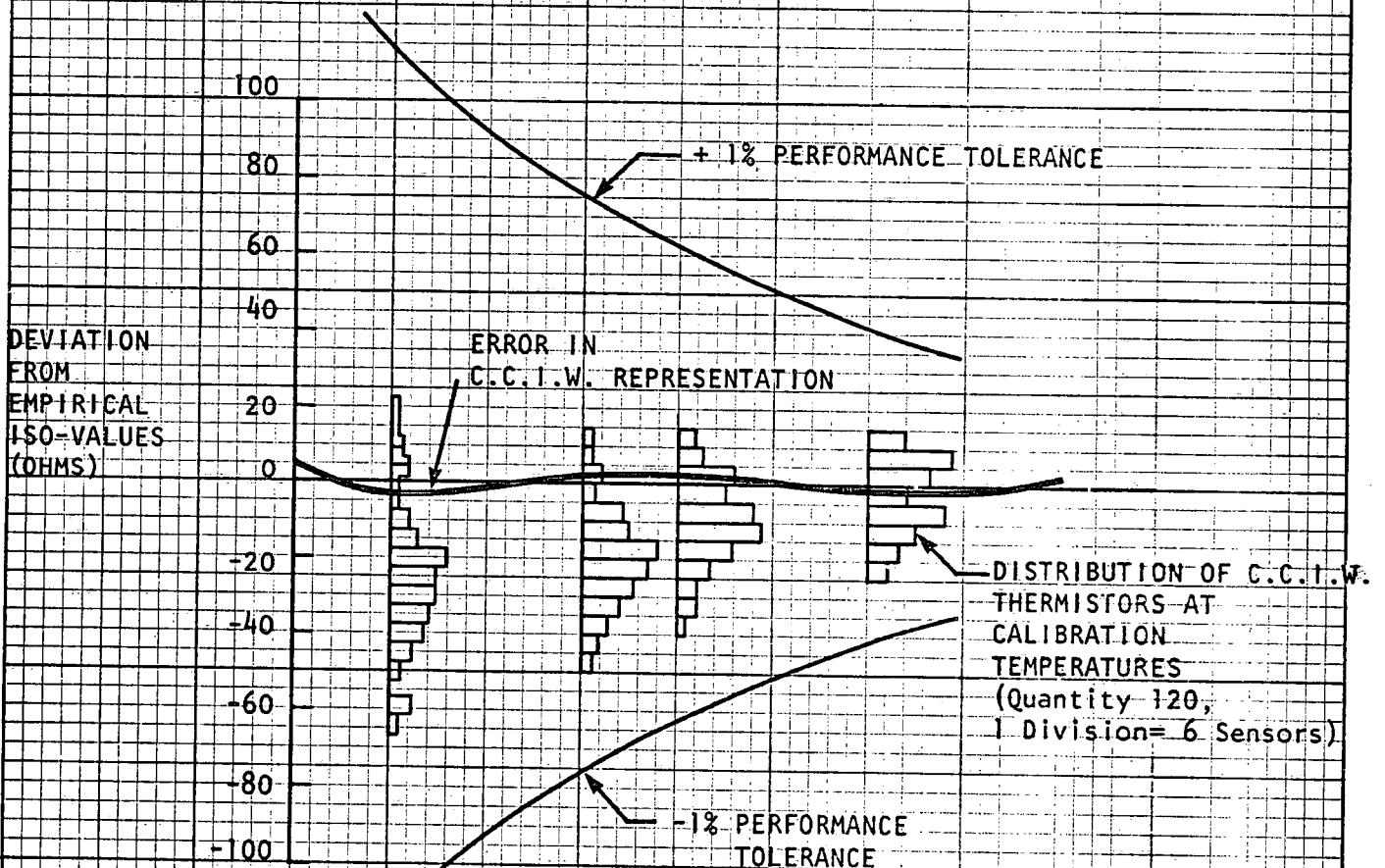
THERMISTOR  
RESISTANCE  
(K OHMS)

4K ISO-CURVE

± 1%

TEMPERATURE (°C.)

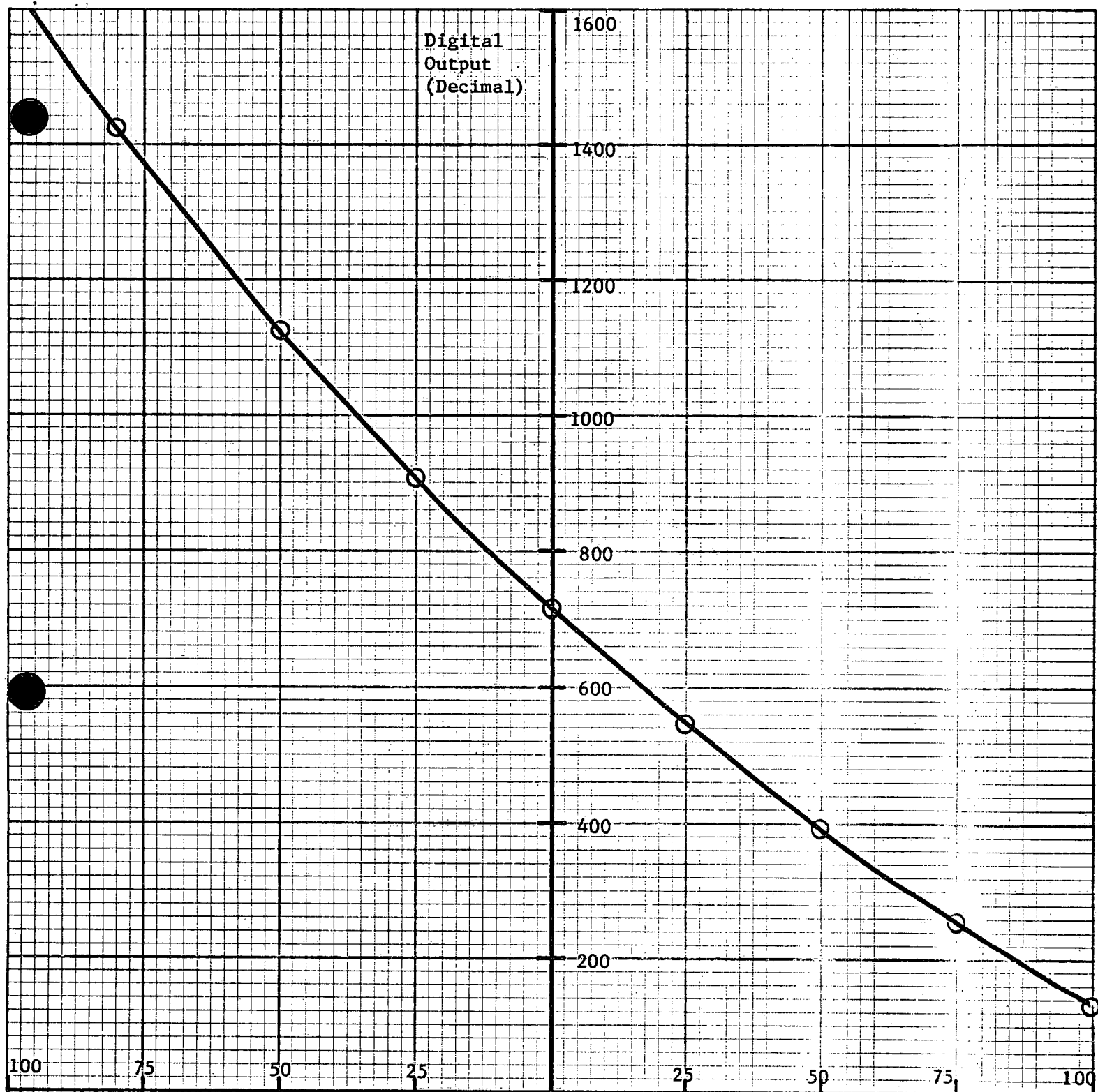
DESIRED CHARACTERISTIC OF THE F.T.P. SYSTEM TEMPERATURE-SENSOR



VARIATIONS AND TOLERANCES FOR C.C.I.W.'S THERMISTOR POPULATION

FIGURE 11





+U or -V

INPUT SPEED COMPONENT- $C_x$  or  $C_y$   
(cm/sec)

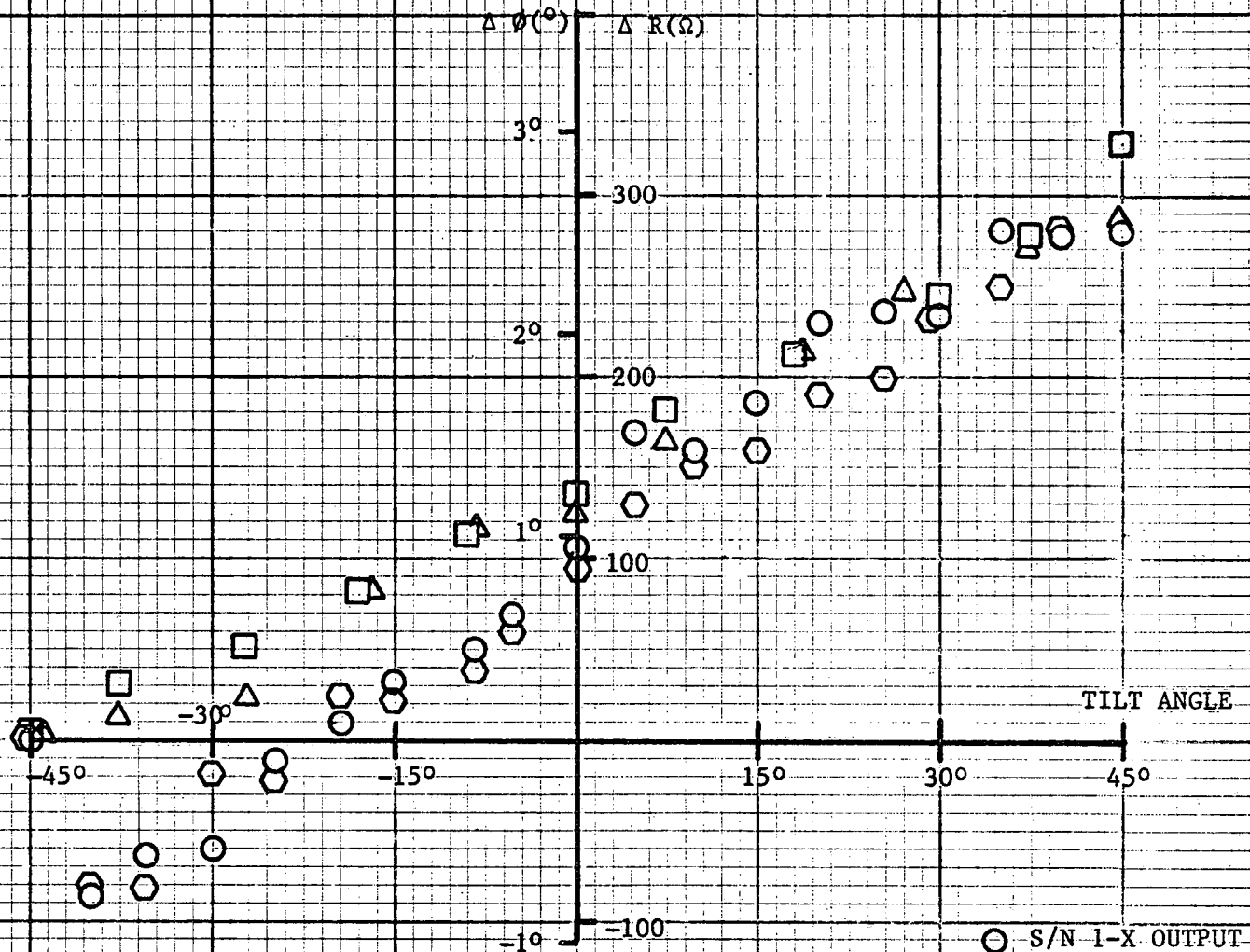
+V or -U

$$\text{DIGITAL OUTPUT FOR X} = - \left( \frac{2^{12} \cdot 10^4}{29.3C_x + 12900} \right) - 2458$$

$$\text{DIGITAL OUTPUT FOR Y} = + \left( \frac{2^{12} \cdot 10^4}{29.3C_y + 12900} \right) - 2458$$

FIGURE 12

TRANSFER FUNCTION  
FOR ELECTROMAGNETIC  
VECTOR AVERAGING  
WATER VELOCITY SENSOR



NOTES

1. PLOT SHOWS DEVIATION FROM THE IDEAL TRANSFER FUNCTION

$$R = 5000 \left( \frac{\phi}{45} + 1 \right)$$

2. SENSITIVITY IS 111Ω/DEGREE

- S/N 1-X OUTPUT
- ⬡ S/N 1-Y OUTPUT
- S/N 2-X OUTPUT
- △ S/N 2-Y OUTPUT

FIGURE 14

CALIBRATION DATA FOR  
CATS TILT SENSORS  
(HUMPHREYS VI13-0502-1)

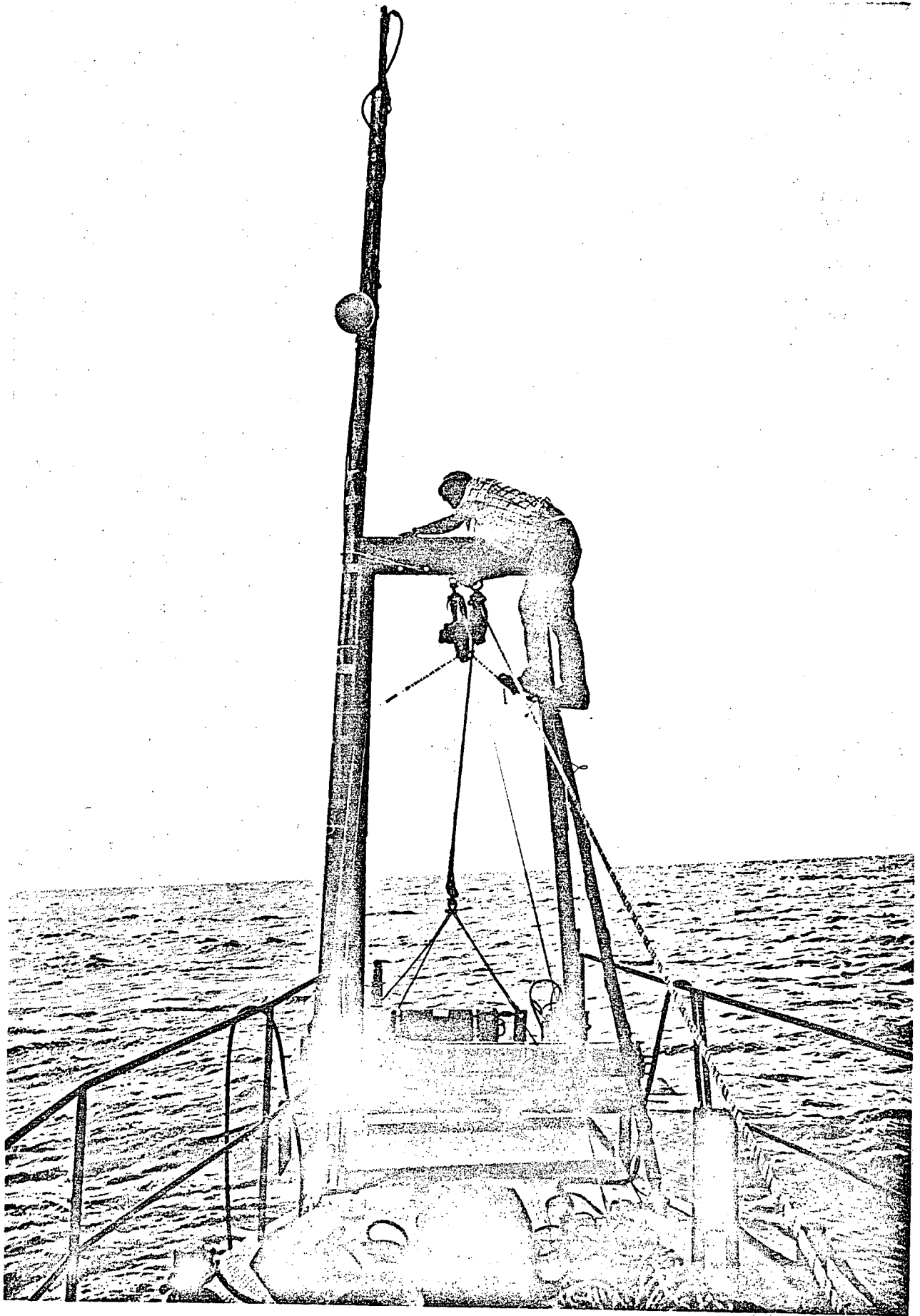


FIG.15 PHOTOVIEW OF FIRST CATS PROTOTYPE  
BEING DEPLOYED FROM A 40 ft. VESSEL

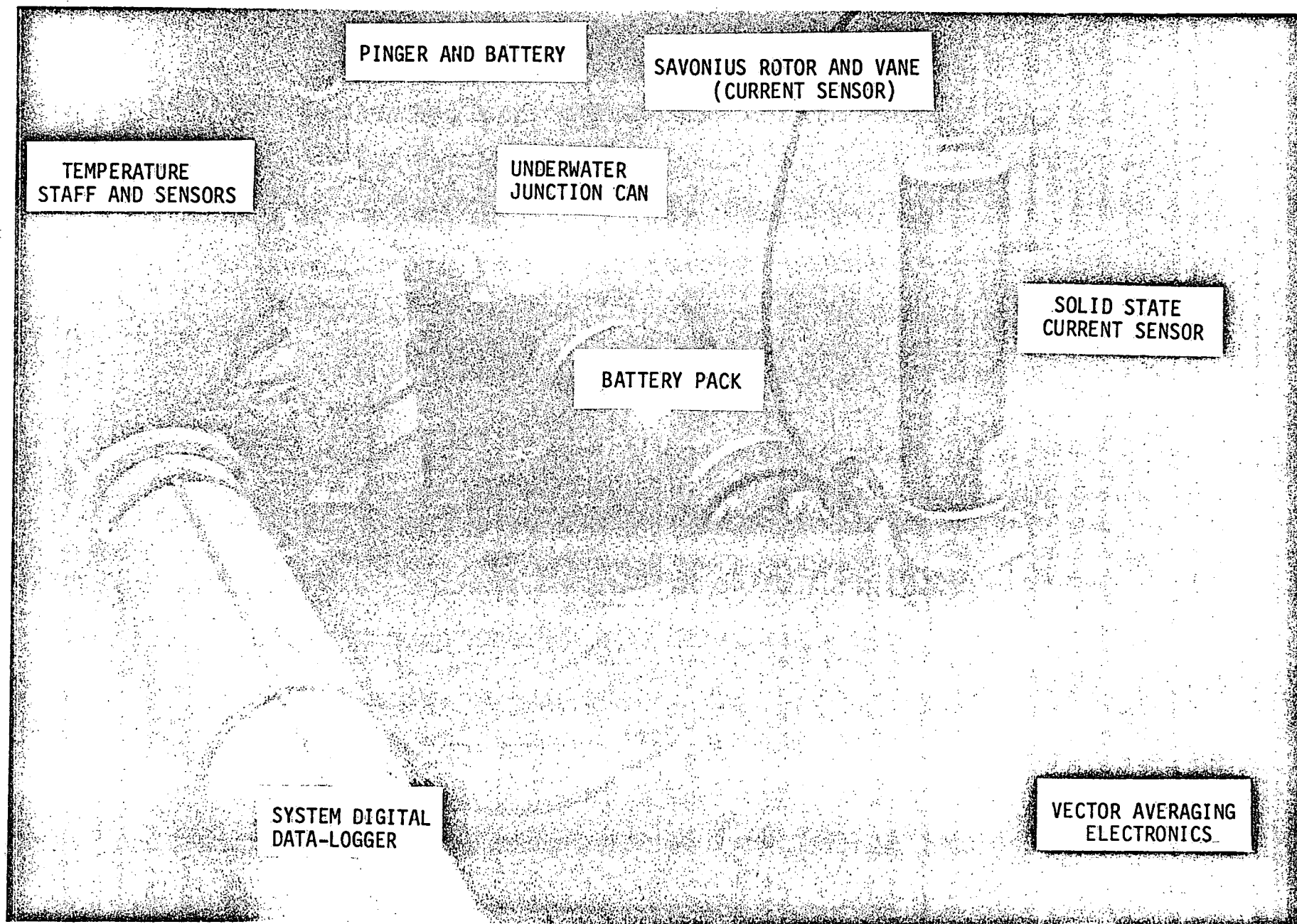


FIG. 16 UNDERWATER VIEW OF FIRST PROTOTYPE CATS SYSTEM

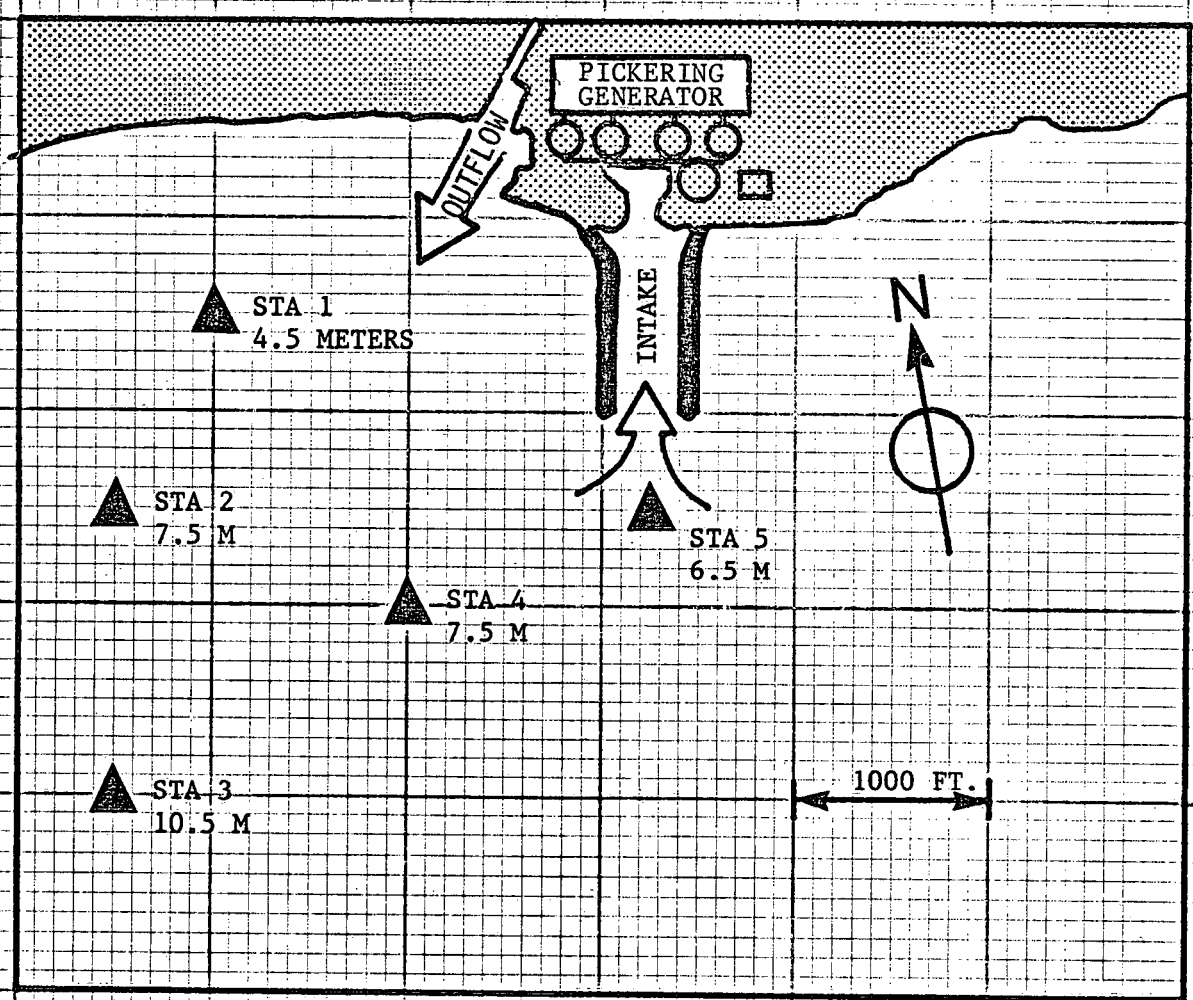
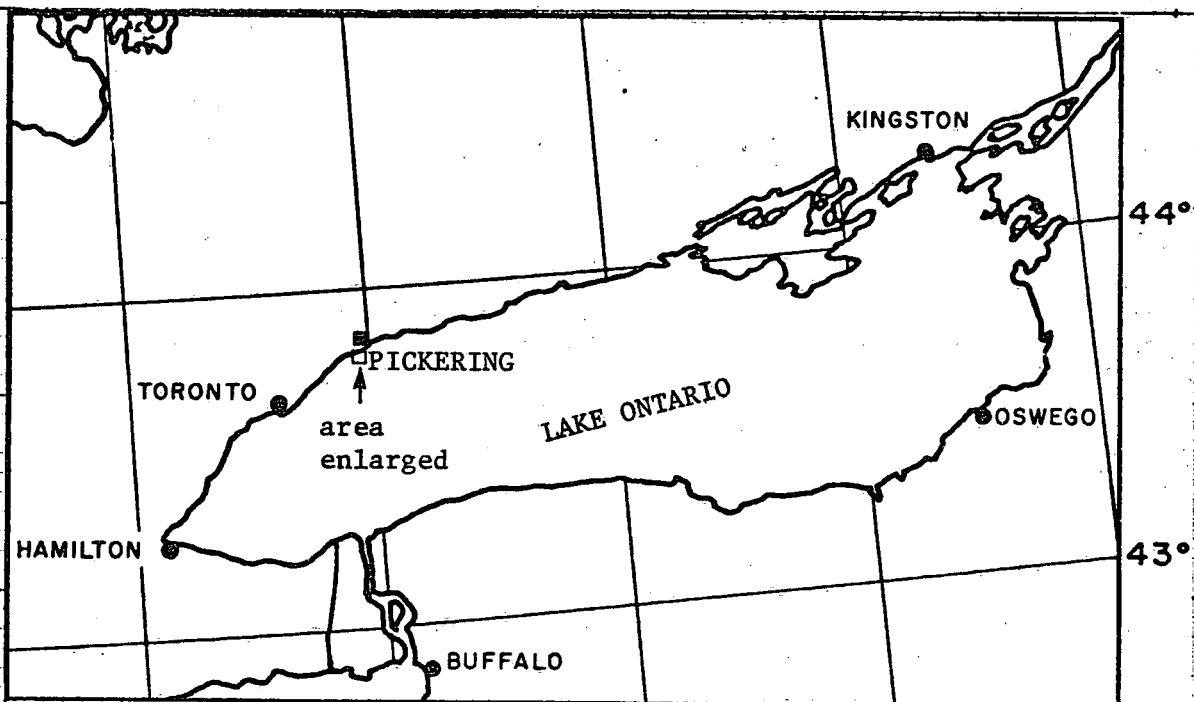


FIGURE 17  
ARRAY DEPLOYMENT AREA  
OFF PICKERING POWER STATION  
(TORONTO, LAKE ONTARIO)

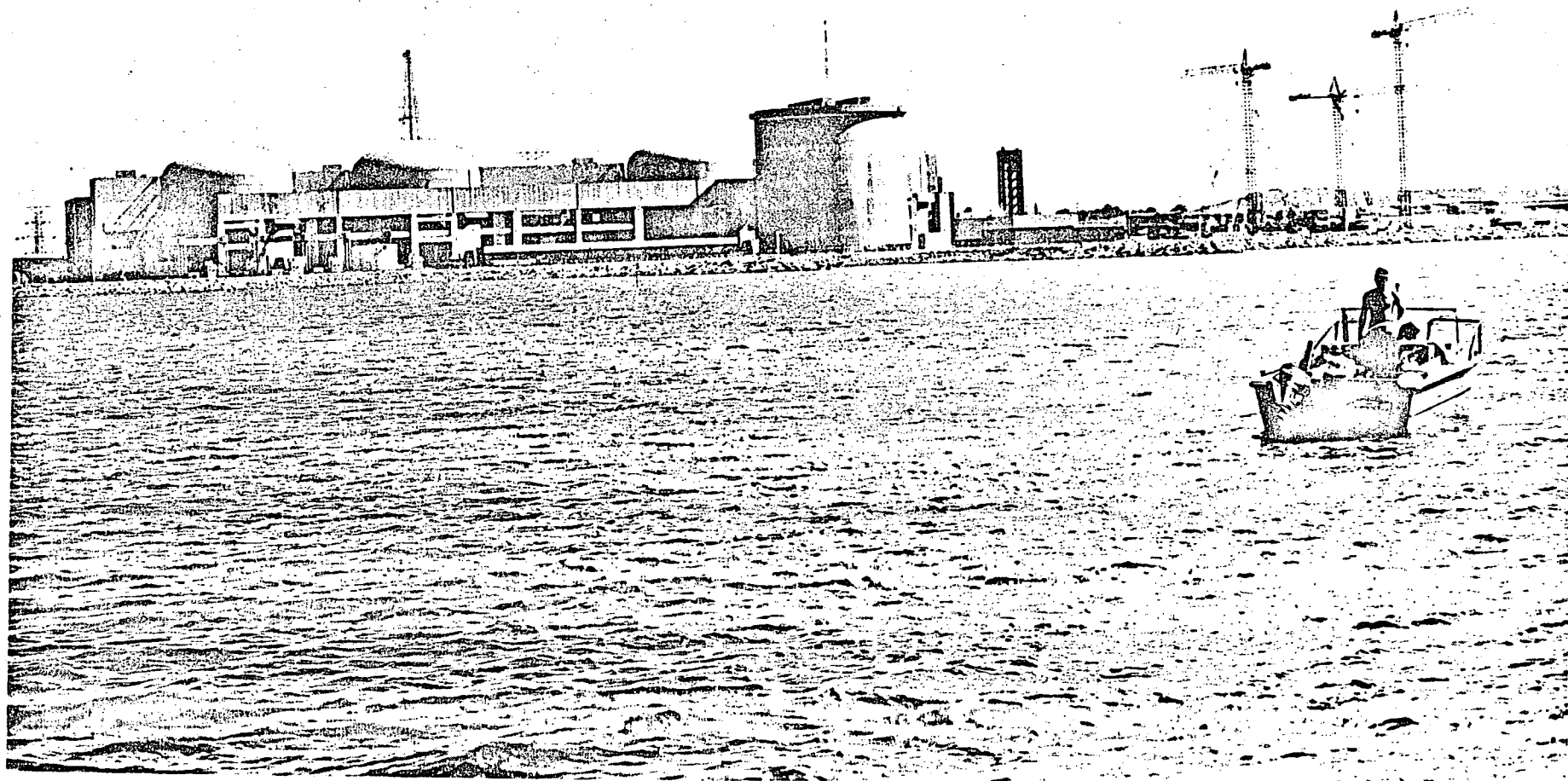


FIG.17B PHOTOVIEW OF ACTUAL DEPLOYMENT SITE CONDITIONS



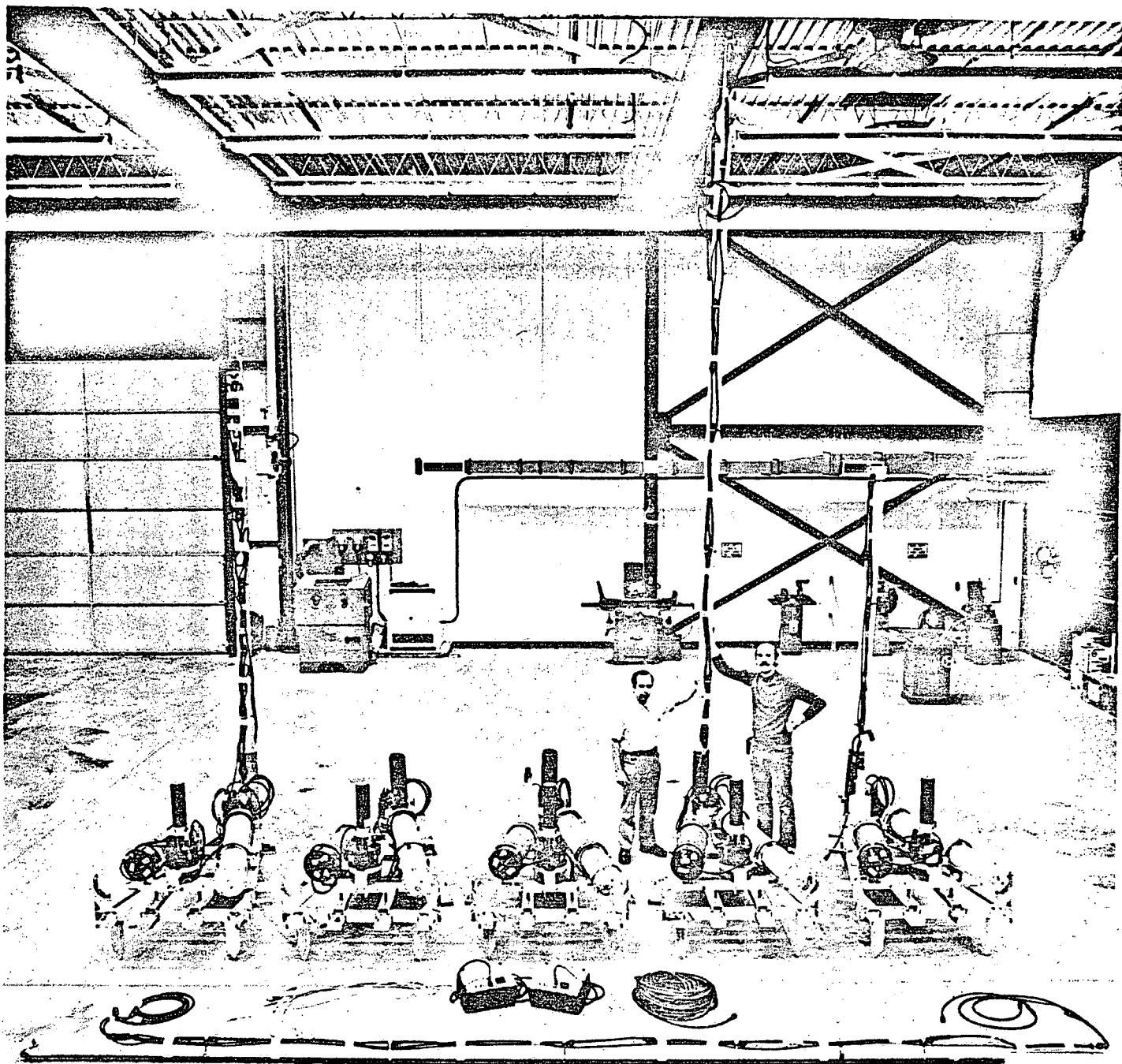


FIG. 18 ARRAY OF 5 CATS SYSTEMS READY FOR DEPLOYMENT

# C.A.T.S. SYSTEM PERFORMANCE RECORD 75/76

1975

1976

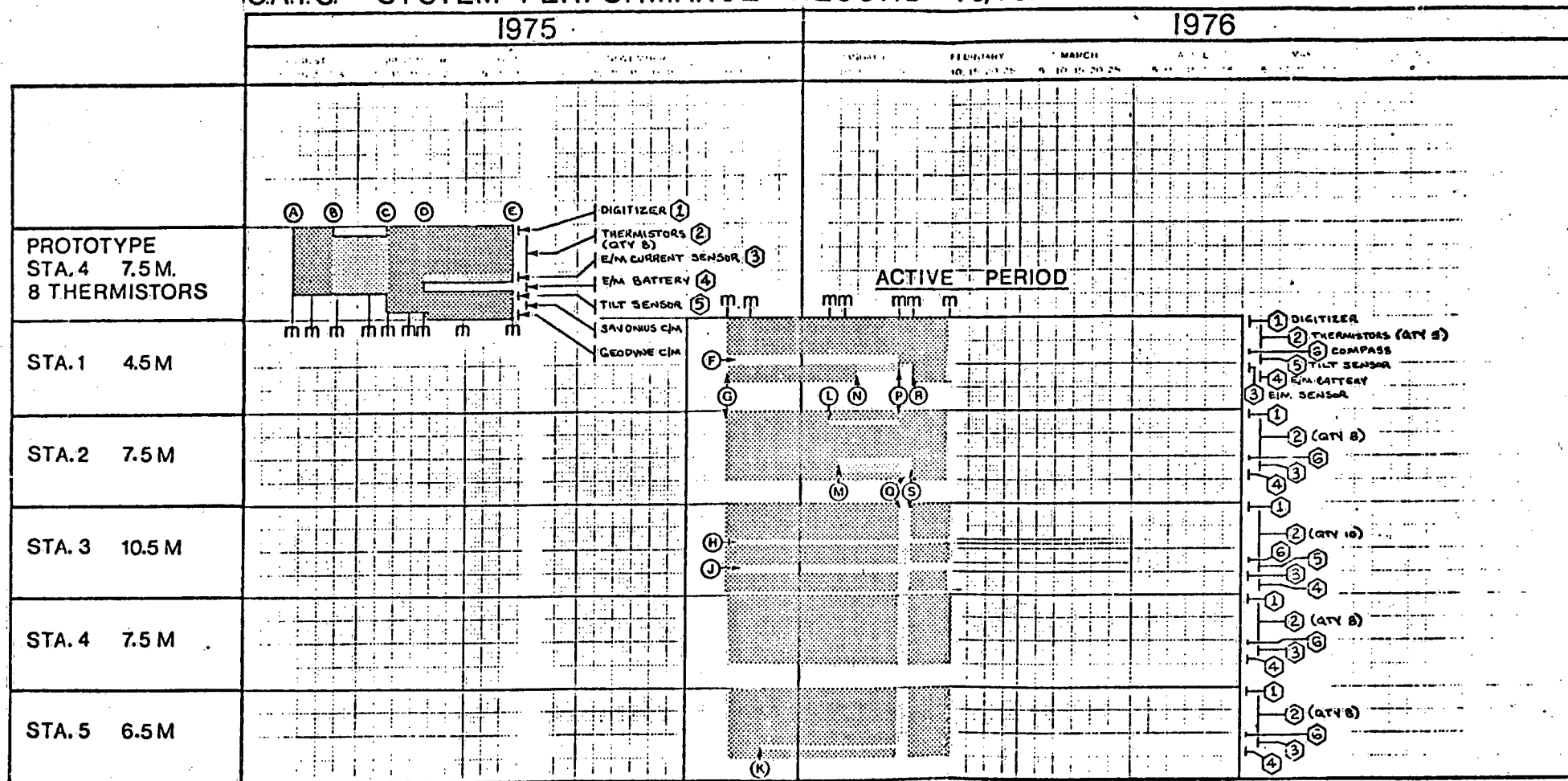
	1975	1976
	<p>August 10 15 20 25</p> <p>September 5 10 15 20 25</p> <p>October 5 10 15 20 25</p> <p>November 5 10 15 20 25</p>	<p>January 10 15 20 25</p> <p>February 5 10 15 20 25</p> <p>March 5 10 15 20 25</p> <p>April 5 10 15 20 25</p> <p>May 5 10 15 20 25</p>
PROTOTYPE STA. 4 7.5 M. 8 THERMISTORS	<p>Diagram of Prototype STA. 4 showing sensor locations A, B, C, D, E and components 1-5.</p>	<p>ACTIVE PERIOD</p>
STA. 1 4.5 M	<p>Diagram of STA. 1 showing sensor locations F, G, L, N, P, R and components 1-5.</p>	<p>1 DIGITIZER 2 THERMISTORS (QTY 5) 3 COMPASS 4 TILT SENSOR 5 E/M BATTERY 6 E/M SENSOR</p>
STA. 2 7.5 M	<p>Diagram of STA. 2 showing sensor locations M, O, S and components 1-6.</p>	<p>1 2 (QTY 8) 3 4 6</p>
STA. 3 10.5 M	<p>Diagram of STA. 3 showing sensor locations H, J and components 1-6.</p>	<p>1 2 (QTY 10) 3 4 6</p>
STA. 4 7.5 M	<p>Diagram of STA. 4 showing sensor locations and components 1-6.</p>	<p>1 2 (QTY 8) 3 4 6</p>
STA. 5 6.5 M	<p>Diagram of STA. 5 showing sensor locations and components 1-6.</p>	<p>1 2 (QTY 8) 3 4 6</p>

GOOD DATA RECORDED  
 SYSTEM ELEMENT OPERATIONAL  
 BUT NO DATA RECORDED DUE  
 TO SOME OTHER CAUSE

M-MONITOR



# CAT.S. SYSTEM PERFORMANCE RECORD 75/76



GOOD DATA RECORDED  
 SYSTEM ELEMENT OPERATIONAL  
 BUT NO DATA RECORDED DUE  
 TO SOME OTHER CAUSE

M-Monitor

HIGHLIGHTS AND UNSCHEDULED EVENTS TO FEBRUARY, 1976

- A. INSTALLATION OF FIRST PROTOTYPE MOORING LESS TILT SENSOR AND AANDERAA C/M. 19 August, 1975
- B. DIGITIZER SHUTS OFF WITH DATA TAPE FULL DUE TO FALSE TRIGGERING BECAUSE OF WATER IN SURFACE MONITOR CONNECTOR. (DIGITIZER WAS MODIFIED TO ELIMINATE PROBLEM). 25 August, 1975
- C. NEW DIGITIZER, AANDERAA C/M AND TILT SENSOR INSTALLED. UNDERWATER PHOTOS TAKEN. 9 September, 1975
- D. GEODYNE C/M INSTALLED NEARBY AND E/M C/M BATTERY REPLACED. NEW BATTERY FAILS (BLOWN FUSE) IMMEDIATELY, E/M C/M BECOMES INOPERATIVE. 19 September, 1975
- E. PROTOTYPE SYSTEM RECOVERED. 14 October, 1975
- F. TILT SENSOR (S/N 2) DELIVERY LATE. TO BE INSTALLED DURING MID PERIOD REFURBISHMENT. 11, 12 December, 1975
- G. ALL 5 SYSTEMS INSTALLED INCLUDING THE SPARE SYSTEM.
- H. THERMISTOR SENSOR No. 7 O/C DUE TO CABLE FAULT (OCCURRED AT MANUFACTURER). 1 December, 1975
- J. TILT SENSOR READINGS BECOME ERRATIC 13 December, 1975
- K. E/M SENSOR CHANNEL X (EAST/WEST) GAINS 20 CM/SEC OFFSET. 21 December, 1975
- L. EXPENDABLE SURFACE CABLE CONNECTION PARTS, THUS DISABLING SURF. THERMISTOR AND ABILITY TO MONITOR SYSTEM. 8 January, 1976
- M. COMPASS CLAMPING BECOMES UNRELIABLE DUE TO OVERLOADED DRIVE CIRCUIT (FAULT CORRECTED DURING REFURBISHMENT). 11 January, 1976
- N. LEAKING BATTERY MODULE CAUSES APPARENT E/M SENSOR FAILURE. 15 January, 1976
- P.& 5 DIGITIZERS, 5 E/M BATTERIES, AND 4 E/M SENSOR ASSEMBLIES  
Q. REMOVED, FOR REPAIRS AND/OR REFURBISHMENT 2 SPARE DIGITIZERS IMMEDIATELY INSTALLED AT STATIONS 1 AND 2. TILT SENSOR AT STATION 1 INSTALLED E/M CURRENT SENSOR ASSEMBLY REMAINS AT STATION 4. 27 January, 1976
- R.& 3 DIGITIZERS, 4 E/M SENSORS AND 5 BATTERY PACKS RE-  
S. INSTALLED. 30 January, 1976

# CATS PERFORMANCE STATISTICS TO 27 JANUARY 1976

	<u>MOORING PERIOD 47 DAYS</u>					<u>OVERALL AVERAGES</u>
	<u>1-STA 10A</u>	<u>2-STA 11A</u>	<u>3-STA 12A</u>	<u>4-STA 13A</u>	<u>5-STA 14A</u>	
1. SYSTEM ELEMENT WORKING DAYS.	79%	89.8%	84.4%	100%	94.6%	89.6%
2. PER STATION SCIENTIFIC DATA RETURN	93.3%	88.3%	91.7%	100%	91.9%	93.0%
3. TEMPERATURE DATA RETURN	100%	94.4%	90%	100%	100%	96.9%
4. CURRENT DATA RETURN	76.6%	66%	100%	100%	61.7%	80.7%

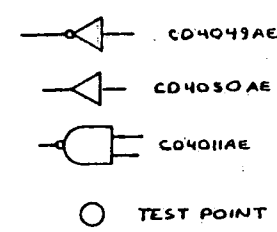
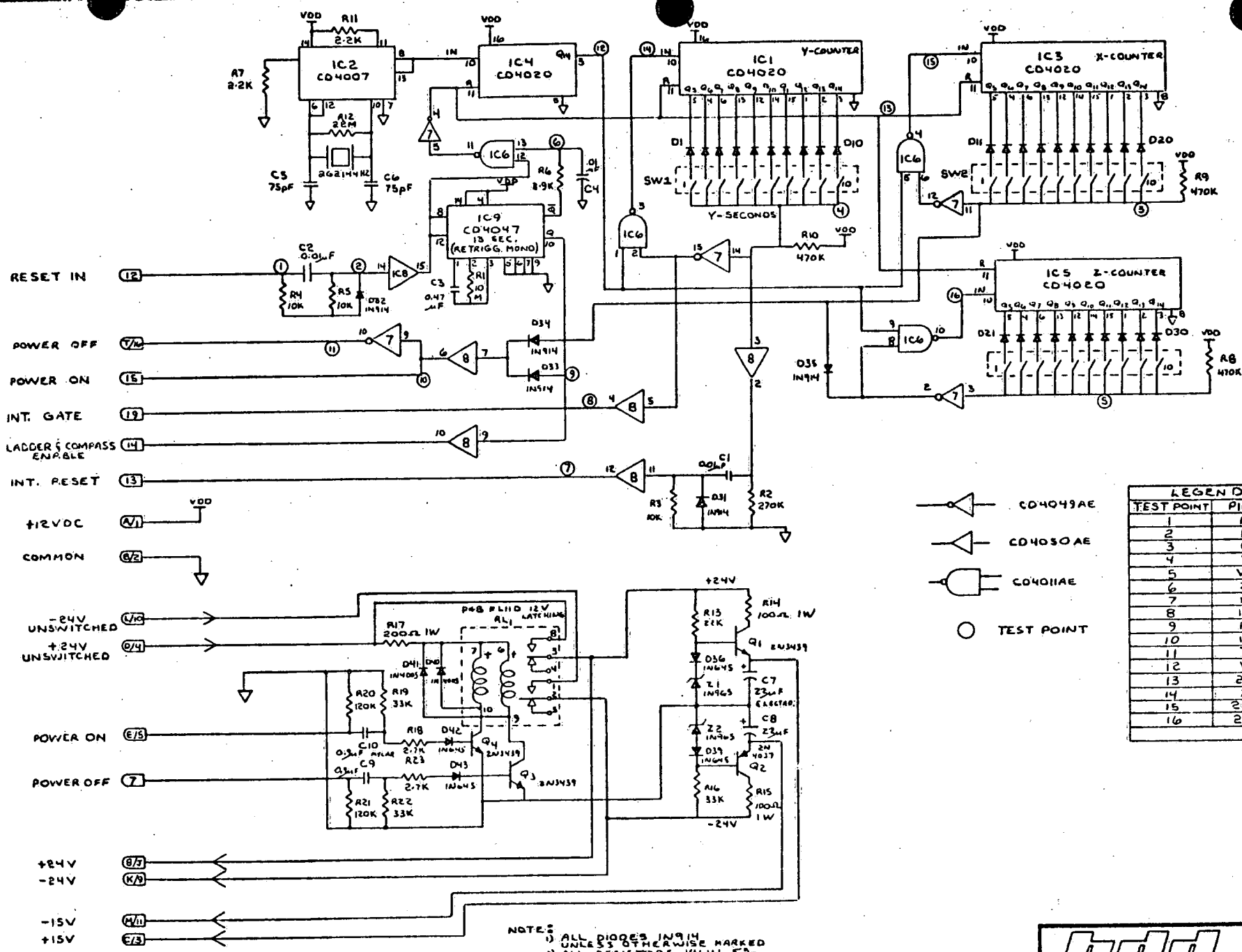
## SOURCES OF SCIENTIFIC DATA LOSS

1. SURFACE MONITOR CABLE CONNECTION PARTING (L)	.91%
2. MANUFACTURING FAULT IN CABLE ASSEMBLY (H)	2.04%
3. BATTERY MODULE LEAKING (N)	.96%
4. E/M CURRENT SENSOR FAILURE (K)	1.66%
5. DESIGN ERROR IN COMPASS CLAMPING CIRCUIT (M)	<u>1.48%</u>
TOTAL:	<u>7.05%</u>

NOTE:  
OF THESE LOSSES, ACTION HAS BEEN TAKEN TO PREVENT FUTURE  
OCCURRENCES OF 2 AND 5.

Eric Harrison,  
Engineering Services Section,  
23 February, 1976.

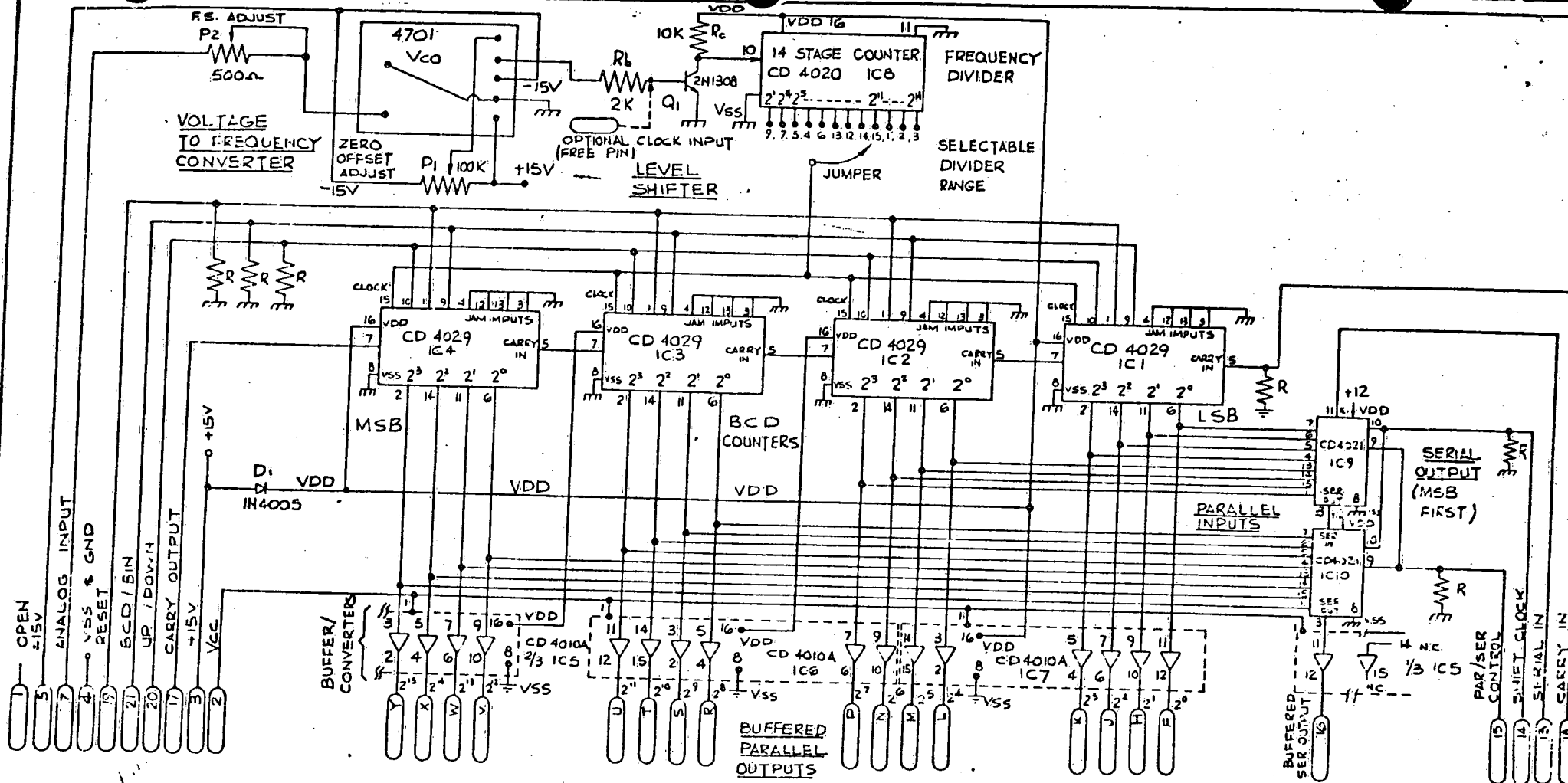
FIG 20 CATS TIMER & POWER CONTROL  
SCHEMATIC



LEGEND	
TEST POINT	PIN
1	12
2	H
3	U
4	V
5	W
6	Z
7	13
8	19
9	R
10	15
11	T
12	Y
13	20
14	X
15	22
16	21

NOTE:  
1) ALL DIODES IN 914  
UNLESS OTHERWISE MARKED  
2) ALL RESISTORS 1/4W 5%  
UNLESS OTHERWISE MARKED

SCALE	NTS	APPROVED BY	EXAMINSON	DESIGNED BY	GLR
DATE	12/15/75			REVISED	
REGULATOR PROGRAMMABLE CONTROL TIMER					
SINKING PLUMBS					
DRAWING NUMBER SKE-541C					



# NOTES:

1. CONNECT VCC LINE (Pin 2) TO THE DESIRED BUFFER OUTPUT VOLTAGE LEVEL (VCC ≥ VDD) VCC CAN BE CONNECTED TO VDD BY JUMPER ON THE PCB.
2. R = 100K TO 500K OHMS
3. IC5, IC6, IC7 CAN BE CD 4050; NO VCC REQUIRED (Not level converters)

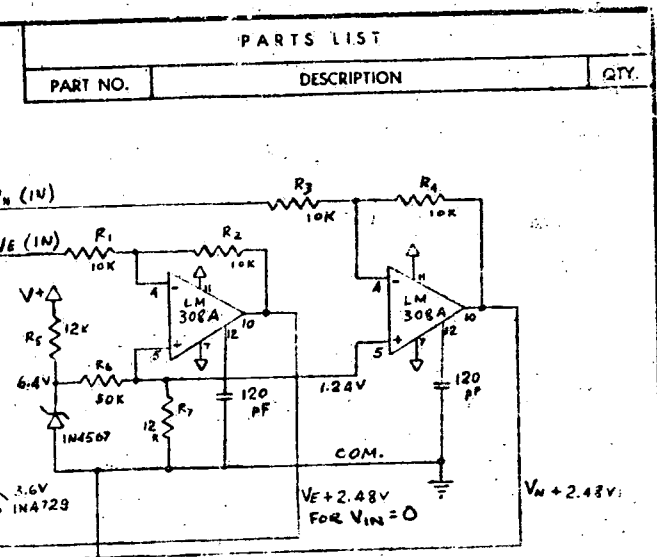
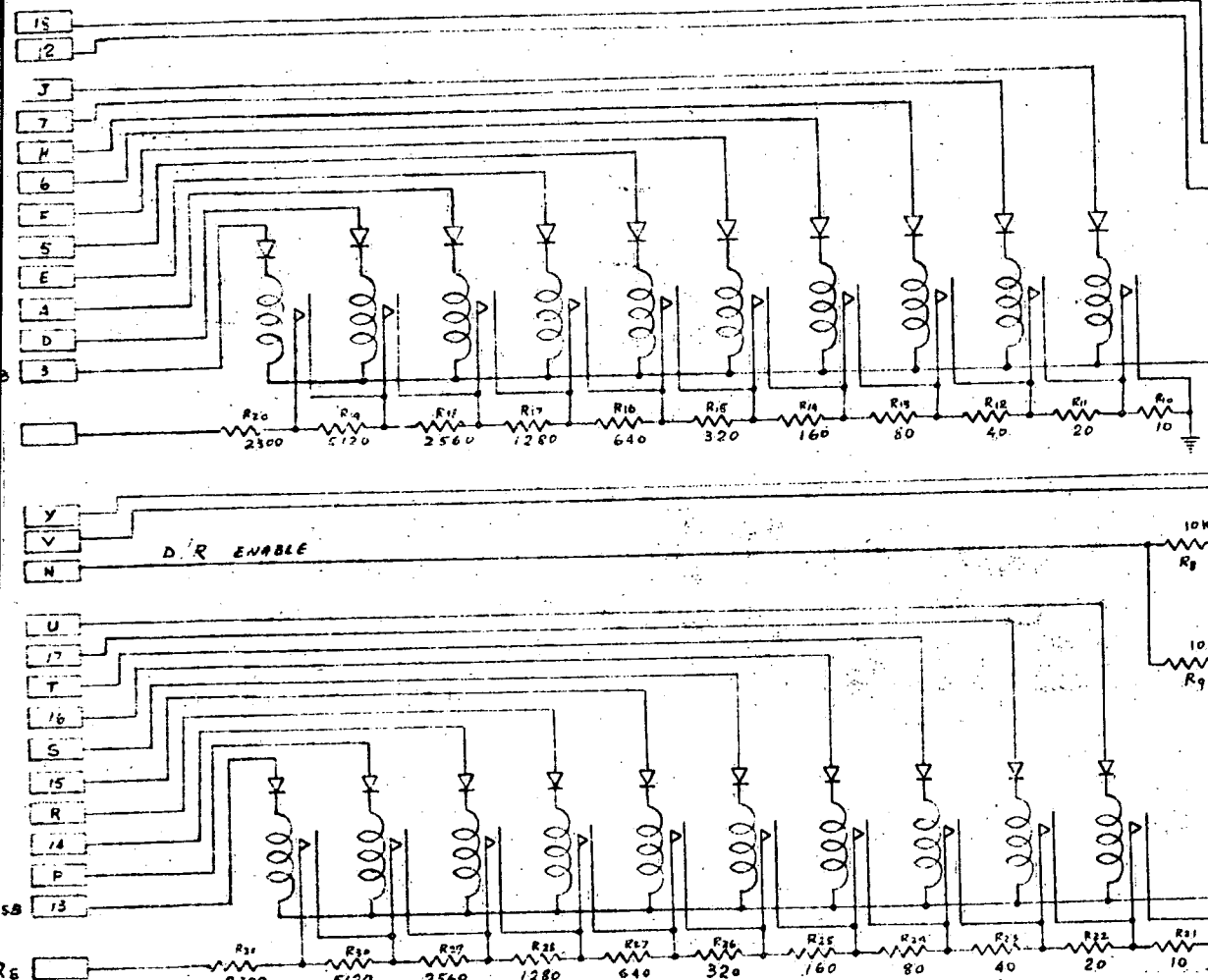


Environment  
Canada  
Canada Centre  
for Inland Waters

Environnement  
Canada  
Centre Canadien  
des Eaux Intérieures

TITLE CCW DIGITAL INTEGRATOR  
PRINTED CIRCUIT CARD SCHEMATIC  
DIAGRAM FIGURE F-4

DESIGNED BY JV	CHECKED BY	APPROVED BY
DRAWN BY F	CHECKED BY	DRAWING NO. 1907-12
SCALE	DATE 2012	SHEET OF



- NOTES:
1. ALL DIODES 1N914
  2. ALL RELAYS FRB2013H (CLARE)
  3. RES.  $R_1$  &  $R_9$  5%  $\frac{1}{4}$  W
  4. RES.  $R_0$  &  $R_{12}$  &  $R_{21}$  &  $R_{23}$  1%
  5. RES.  $R_{13}$  &  $R_{15}$  &  $R_{24}$  &  $R_{26}$  0.1%
  6. ALL OTHER RES. 0.01%

Environment Canada  
Canada Centre for Inland Waters

Environnement Canada  
Centre Canadien des Eaux Interieures

TITLE SINKING PLUME STUDIES  
BUFFERS AND DUAL DIGITAL TO RESISTANCE CONVERTER

DESIGNED BY E. H. / M. P.	CHECKED BY S. C. / A. L. / A. M.	APPROVED BY
DRAWN BY M. P.	CHECKED BY	DRAWING NO. SKE - 5108
SCALE NTS	DATE 2/9/75	SHEET OF

NO.	DATE	DESCRIPTION	REVISION

UNLESS OTHERWISE SPECIFIED	
TOLERANCE ON THREE PLACE DIMENSIONS	±
TOLERANCE ON TWO PLACE DIMENSIONS	±
TOLERANCE ON ANGLES	±
EXTERNAL CORNER CHAMFER	.015 - .025
INTERNAL CORNER RADIUS	.010 - .020
SURFACE FINISH	AA MICRO INS.
MATERIAL SPECIFICATIONS	

FIGURE 21

ENVIRONMENT CANADA LIBRARY BURLINGTON



3 9055 1016 7473 6

10107

10107

