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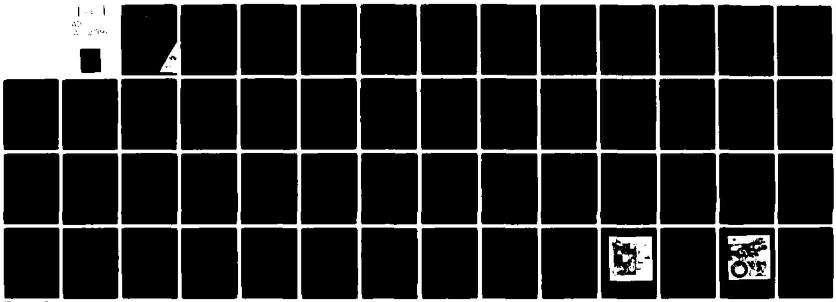

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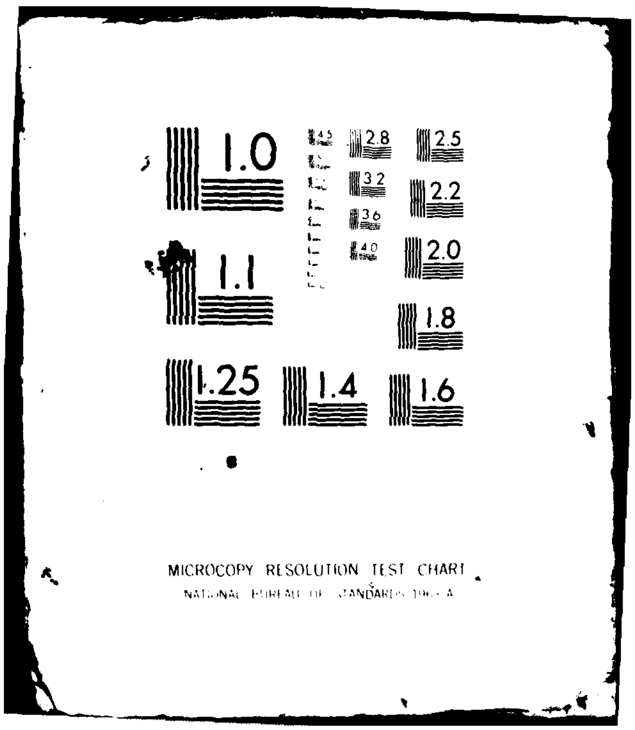
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NAVAL OCEANOGRAPHIC OFFICE REFERENCE PUBLICATION

GUIDE TO COMMON SHIPBOARD EXPENDABLE BATHYTHERMOGRAPH (SXBT) RECORDING MALFUNCTIONS

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AUGUST 1978
REVISED FEBRUARY 1981

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FOREWORD

Accurate and synoptic shipboard expendable bathythermograph (SXBT) data are necessary as input to environmental/acoustic predictions which are provided to fleet units. Since tactical decisions are based on these predictions, erroneous SXBT data may result in misleading acoustic predictions.

This report will aid the system operator in discerning good data from bad data. It describes erroneous SXBT data and simple methods to be employed for rectifying defective SXBT recording equipment.

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER NOO RP-21- Rev.	2. GOVT ACCESSION NO. AD-A112091	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Guide to Common Shipboard Expendable Bathythermograph (SXBT) Recording Malfunctions		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Barry P. Blumenthal Stephen M. Kroner		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Oceanographic Office NSTL Station, Bay St. Louis, MS 39522		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Oceanographic Office NSTL Station, Bay St. Louis, MS 39522		12. REPORT DATE August 1978 Revised February 1981 13. NUMBER OF PAGES 46 (incl 2 appendixes)
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

SXBT System
Temperature Profiles
SXBT Quality Control
Bathythermograph

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Sippican SXBT system is a reliable method of measuring temperatures in the upper few hundred meters of the ocean while underway. The system provides information on local temperature distribution and sonic conditions which assists the Navy in tactical decision making.

This guide has been prepared to aid the system operator in

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20. discerning good data from bad data. It describes erroneous SXBT traces and simple methods to be employed for rectifying the more common problems which may occur with this equipment.

ACKNOWLEDGEMENTS

The authors would like to thank the Sippican Corporation for assistance in identifying probable causes of SXBT system recording malfunctions presented in this publication. We also wish to thank Mr. Alfred Lewando for his many helpful suggestions and Messrs. Robert Cheney and Alvan Fisher who critically reviewed the manuscript. Kay Collins and Jo Ann Lyons provided secretarial assistance.

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TABLE

INTRODUCTION

The U. S. Navy uses the Sippican shipboard expendable bathythermograph (SXBT) system on board its vessels to collect temperature profiles while underway. Accurate SXBT data are required to prepare effective environmental/acoustic predictions for fleet units which rely on these predictions for sensor placement and tactical decisions. Accurate data are also necessary for mapping thermal variability of the oceans and for building and maintaining scientifically accurate historical data files.

This publication is designed to assist the SXBT operator in collecting acceptable SXBT data; it is not an exhaustive study of the SXBT system itself. Recording problems are documented to demonstrate common system malfunctions and the adjustment procedures required to correct the system.

SYSTEM DESCRIPTION

The SXBT system consists of a shipboard recorder, a launcher, and an expendable probe (figure 1). The recorder has a completely automatic cycle initiated by loading the launcher with an SXBT probe. Closing of the launcher breech completes a circuit between the probe and recorder, triggering the recorder into the Check/Run Mode. The calibration temperature (16.7°C/62°F) is recorded on the recorder chart paper for approximately 2 seconds after which the recorder is in Launch Mode (green light illuminates on the lower left front of the recorder).

When the probe is launched and contacts the water, the Measure Mode begins and the chart drive operates for 88 seconds for T-4 probes or 178 seconds for T-7 probes. A continuous trace of temperature versus depth is

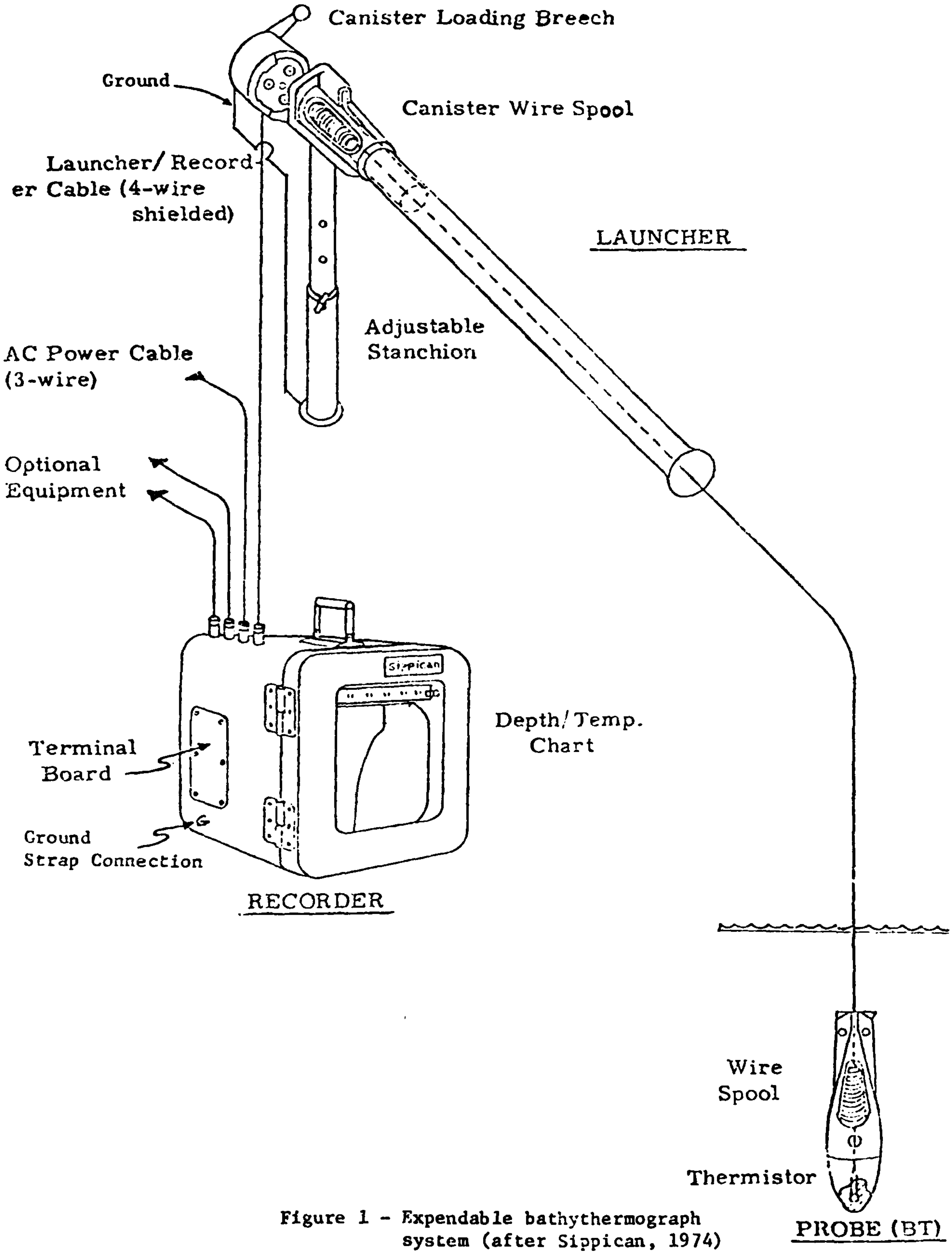

Figure 1 - Expendable bathythermograph system (after Sippican, 1974)

recorded on the chart until the probe wire is exhausted. The cycle is now complete with the recorder in Reload Mode (red light illuminates on the lower right front of the recorder).

The probe, containing the thermistor, functions by a dual-spooling technique. Wire is unreeled from the probe as it drops vertically through the water column; simultaneously, wire is unreeled from a canister in the launcher aboard ship. Changes in electrical resistance of the thermistor due to temperature changes in the water are transmitted to the recorder.

The probe descends at a known rate while the recorder chart drive advances at a constant speed. In order to compensate for the probe's decrease in speed as it loses weight (wire), the vertical divisions of the chart paper are expanded towards the bottom of the chart. Hence, depth can be read directly from the vertical axis of the chart.

Overall system accuracy is $\pm 0.2^{o}C$ ($\pm 0.4^{o}F$) for temperature and the greater of 2 percent or 4.6 m (15 ft) for depth. Temperature measurement error is due to servometer response in the recorder, accuracy of the chart paper, and to a lesser degree to uncertainties in thermistor calibration and wire resistance balance. Depth error is due to launch conditions (launcher distance from sea surface and wave height) and the descent rate of the probe (Dugan and Schuetz, 1977).

OPERATION PROCEDURES

Before launching the initial probe, the system should be calibrated according to the procedures outlined in appendixes A and B. Calibration should be checked daily, whenever the chart roll is renewed, or after

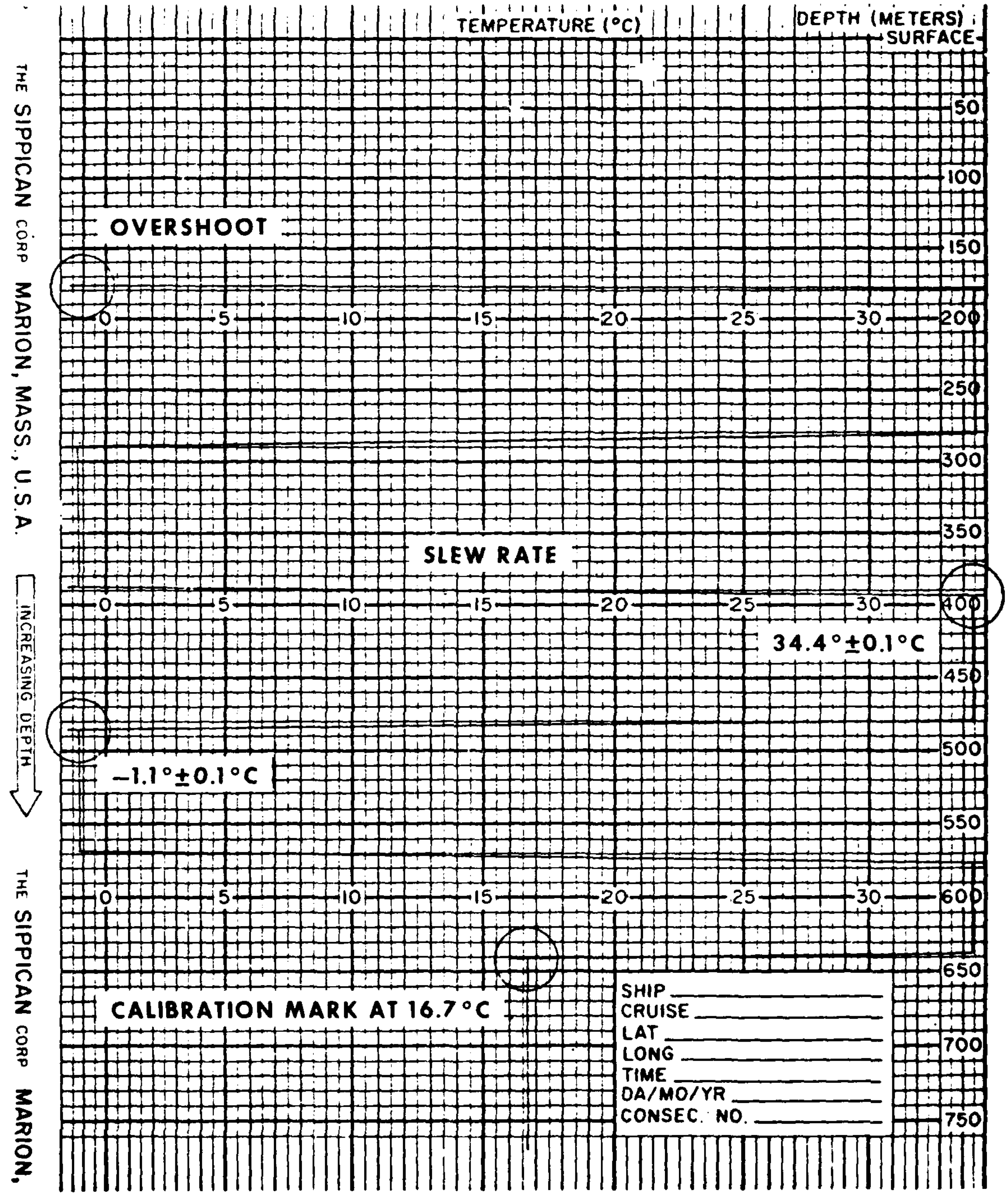

Figure 2 - Calibration check trace

minor repairs. The calibration trace shown in figure 2 indicates the correct high (34.4°C/94°F) and low (-1.1°C/30°F) values and the central check mark at 16.7°C (62°F).

The recorder's chart alignment (depth axis) should also be checked; the stylus should be positioned at the "SURFACE" line. Should the stylus overshoot this line, advance the roll to the next chart. Never reverse the chart drive.

During operation, the chart roll may tend to either slip or pull out of the drive sprocket teeth. In such cases, the plastic chart spool ends should be checked to assure that they are properly fitted into both the feed and rewind rolls. If the condition persists, determine the direction of misalignment in relation to the drive sprocket and adjust the set screws on the spool ends either in or out to properly align the chart roll. Should a malfunction occur during operation, adjustments can be made prior to launch of the next probe. However, the expended canister should not be replaced until shortly before the next drop to protect the launcher contact pins from corrosion.

Specific information, including platform name, cruise number, position, time (GMT), date, consecutive observation number, surface reference temperature, and bottom depth, must be recorded on each trace and in appropriate SXBT logs. Calibration tests must also be dated and timed to assure that, if separated, all traces can later be placed in chronological order by the processing agency for a final data quality check.

SXBT SYSTEM ERRORS

Table 1 lists the most common errors that occur in recording SXBT data. Each error category contains 1) sample SXBT traces, 2) probable cause(s) of the error, and 3) a possible method for correction prior to the next launch. In addition to traces representative of each error category, examples are given of SXBTs taken in shallow water and within oceanic frontal regions.

Obvious malfunctions (wire leaks or breaks, launcher leakage, recorder problems) normally occur in less than 10 percent of launches. However, improper handling of the SXBT probe before launch can lead to a greater number of failures than normal because of wire insulation damage or tangled wire. These failures can be reduced by storing the probes away from extremes of temperature and humidity. Probes should always be maintained in a vertical position with the protective cap down.

While collecting SXBT data, the observer should be aware of expected thermal characteristics of the local operating area. If anomalous features are encountered, the observer should question the validity of the trace(s) and, when in doubt, should be encouraged to launch another probe.

TABLE 1
SXBT RECORDING MALFUNCTIONS

CATEGORY	MALFUNCTION	PROBABLE CAUSE(S)	FIGURES
1	Check mode calibration mark other than 16.7°C (62°F)	Improper calibration; defective servo potentiometer or printed circuit board	3,4
2	Recorder gain set incorrectly	Gain control out of adjustment; faulty electrical connection at launcher	5,6
3	Noise > 0.2°C (0.4°F)	Mechanical/electrical interference; defective servo potentiometer	7,8,9
4	Wire break	Fouling	10,11
5	Insulation penetration	Fouling; wire damage and leakage	12,13,14
6	Wire stretch	Unreeling problems; tangled spool	15,16,17
7	Improper ground or leakage at launcher	Faulty launcher/ground/canister contacts	18,19
8	Doubtful features		20,21

Category 1 - Check mode calibration mark other than 16.7°C (62°F): The calibration marks on figures 3 and 4 are not within specifications. These probes should not have been launched. The system is out of calibration and should be adjusted according to procedures described in appendix A. When the recorder is calibrated to within $\pm$ 0.1°C at -1.1°C and 34.4°C ($\pm$ 0.2°F at 30°F and 94°F), a temperature mark other than 16.7°C (62°F) during the Check/Run Mode indicates a defective servo potentiometer or printed circuit board.

Figures 3 and 4 show a temperature other than the 16.7°C calibration mark; therefore, they cannot be used for accurate thermal analyses nor used as input to historical data files. However, significant acoustical parameters such as general temperature structure, layer depth, and in-layer and below-layer gradients can be determined from such traces.

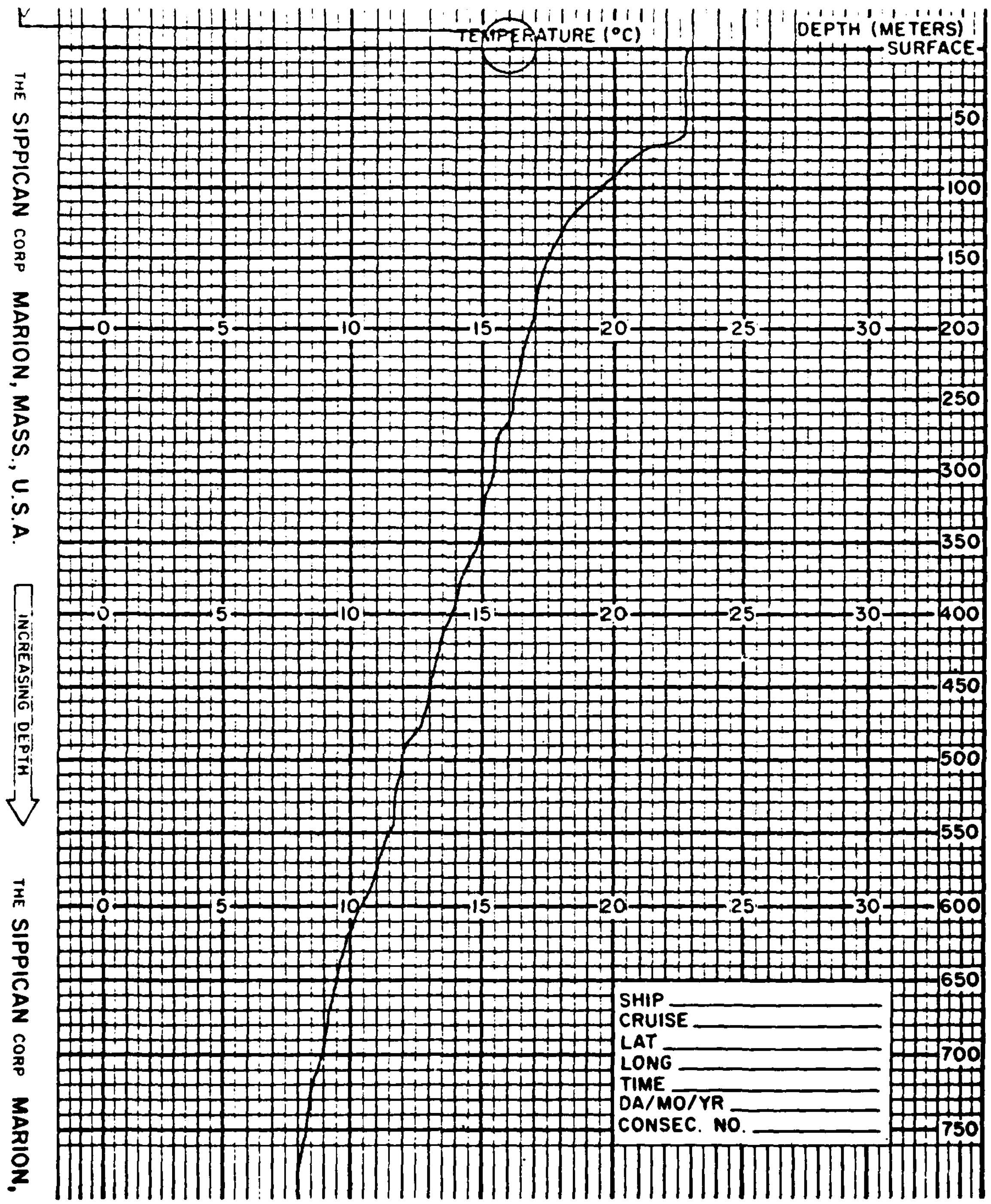

Figure 3 - Check mode calibration mark other than 16.7°C (appears at 16.1°C)

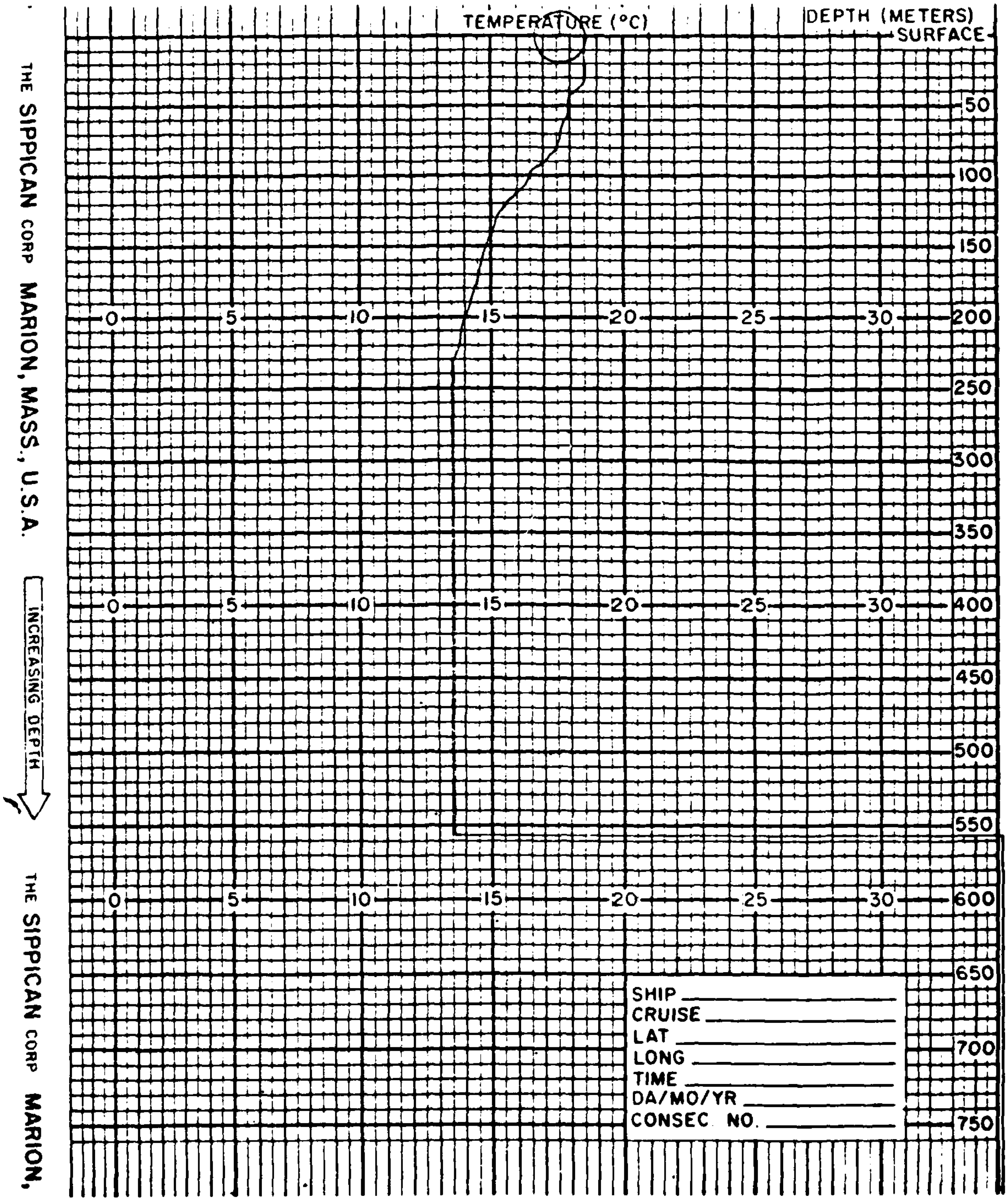

Figure 4 - Check mode calibration mark other than 16.7°C (appears at 17.7°C)

Category 2 - Recorder gain set incorrectly: Gain adjustment controls the stylus slew rate (stylus travel time across the chart) and the amount of stylus overshoot. With low gain setting, stylus response is slow and the trace exhibits a temperature lag most noticeable at the surface (figure 5). The trace is erroneous and should not be encoded. Recorder response to temperature change is slow for the entire trace, and temperature structure cannot be determined accurately. When gain is set too high, the stylus vibrates in the Check/Run Mode and overshoot exceeds the maximum allowable value of 0.5°C (1.0°F) (figure 6). Note: A 5 m negative depth correction must be applied to this trace because of depth offset at the surface.

Gain and overshoot adjustment procedures are outlined in appendix B. If a gain check indicates that no adjustments are necessary, the probable cause of temperature lag is a faulty electrical connection in either the launcher cable or canister head contacts.

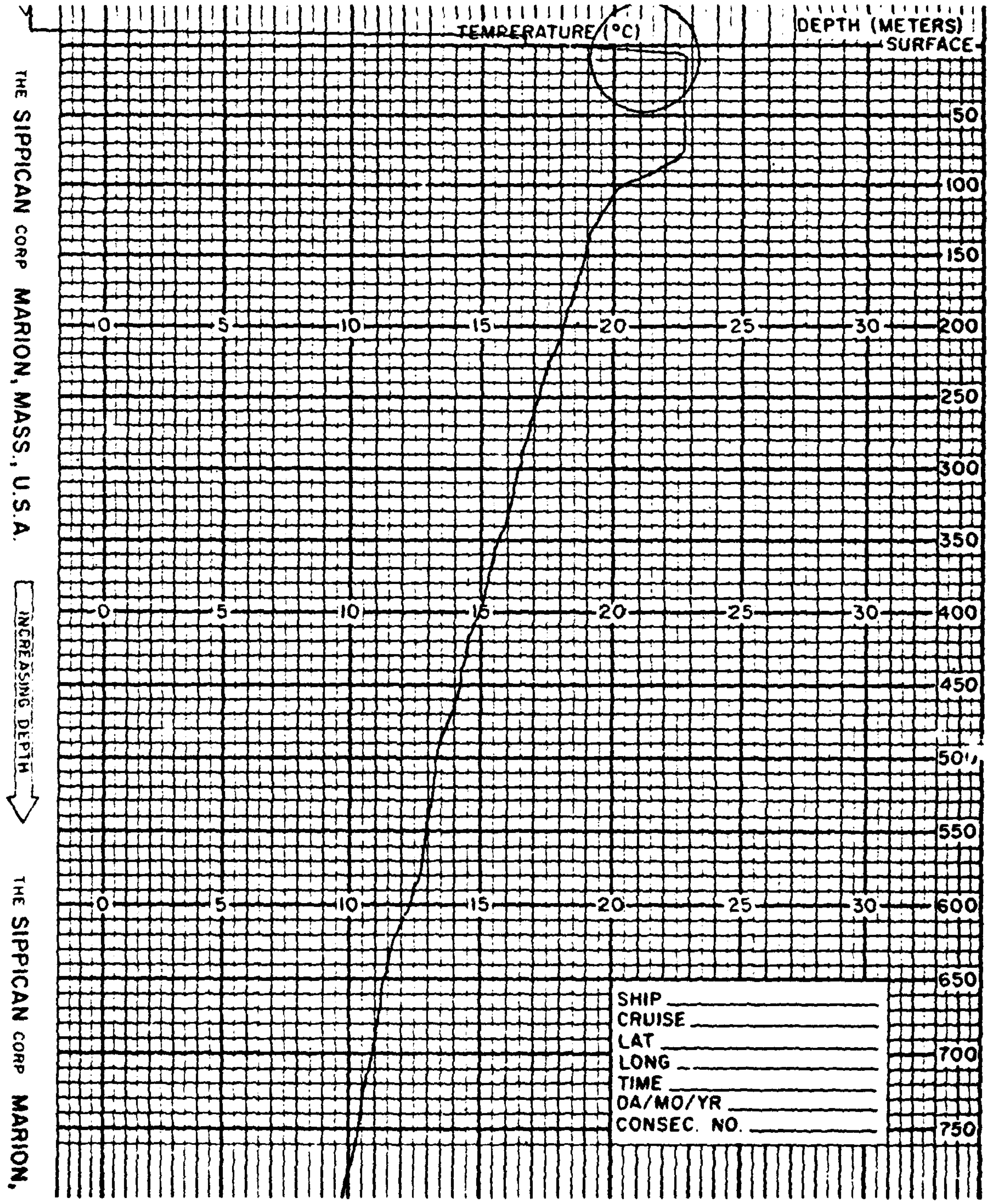

Figure 5 - Recorder gain set too low (stylus slew response slow)

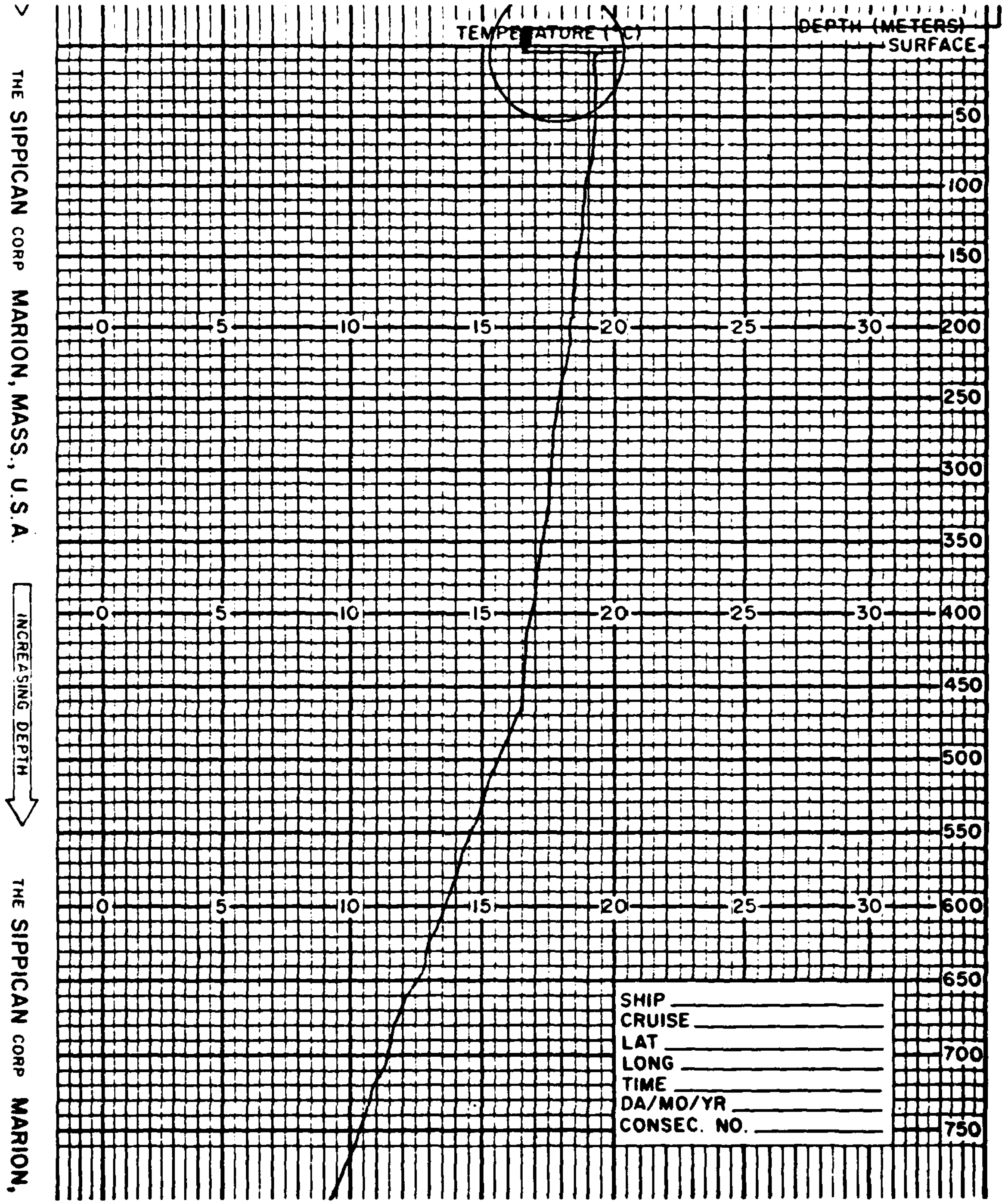

Figure 6 - Recorder gain set too high (stylus overshoots true temp)

Category 3 - Noise > $0.2^{o}C$ ($0.4^{o}F$): Mechanical and electrical interference can influence recorder output. Mechanical noise (e.g., resonant vibration) produces open spiking (figure 7). When spiking is greater than $0.2^{o}C$ ($0.4^{o}F$), interference is greater than the accuracy of the system. The trace is therefore erroneous and should not be encoded. Additional probes should be launched until the problem disappears, because mechanical noise is usually intermittent. When encoding a trace with interference less than $0.2^{o}C$ ($0.4^{o}F$), the noise must be smoothed.

Electrical noise (e.g., interference from the ship's radio) causes symmetrical stylus deflections (figure 8). Since the noise is symmetrical, the trace can be smoothed through the center of the deflections.

Sometimes a "flat" spot occurs in the potentiometer of the recorder. This will cause a vibration at $16.7^{o}C$ ($62^{o}F$) on the trace (figure 9) during both the Check/Run and Measure Modes. As with electrical interference, the trace can be smoothed through the vibration.

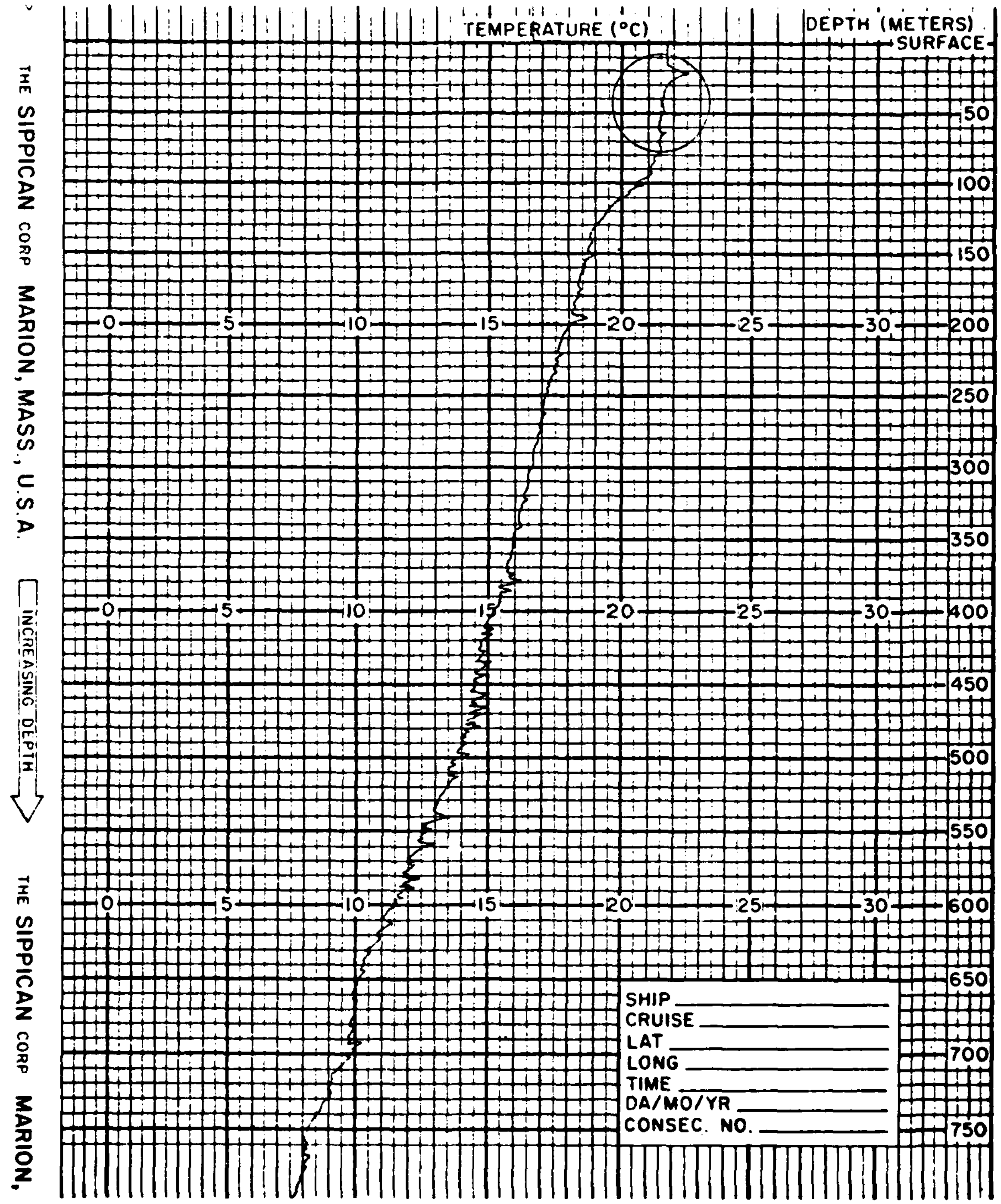

Figure 7 - Noise greater than 0.2°C (external mechanical interference)

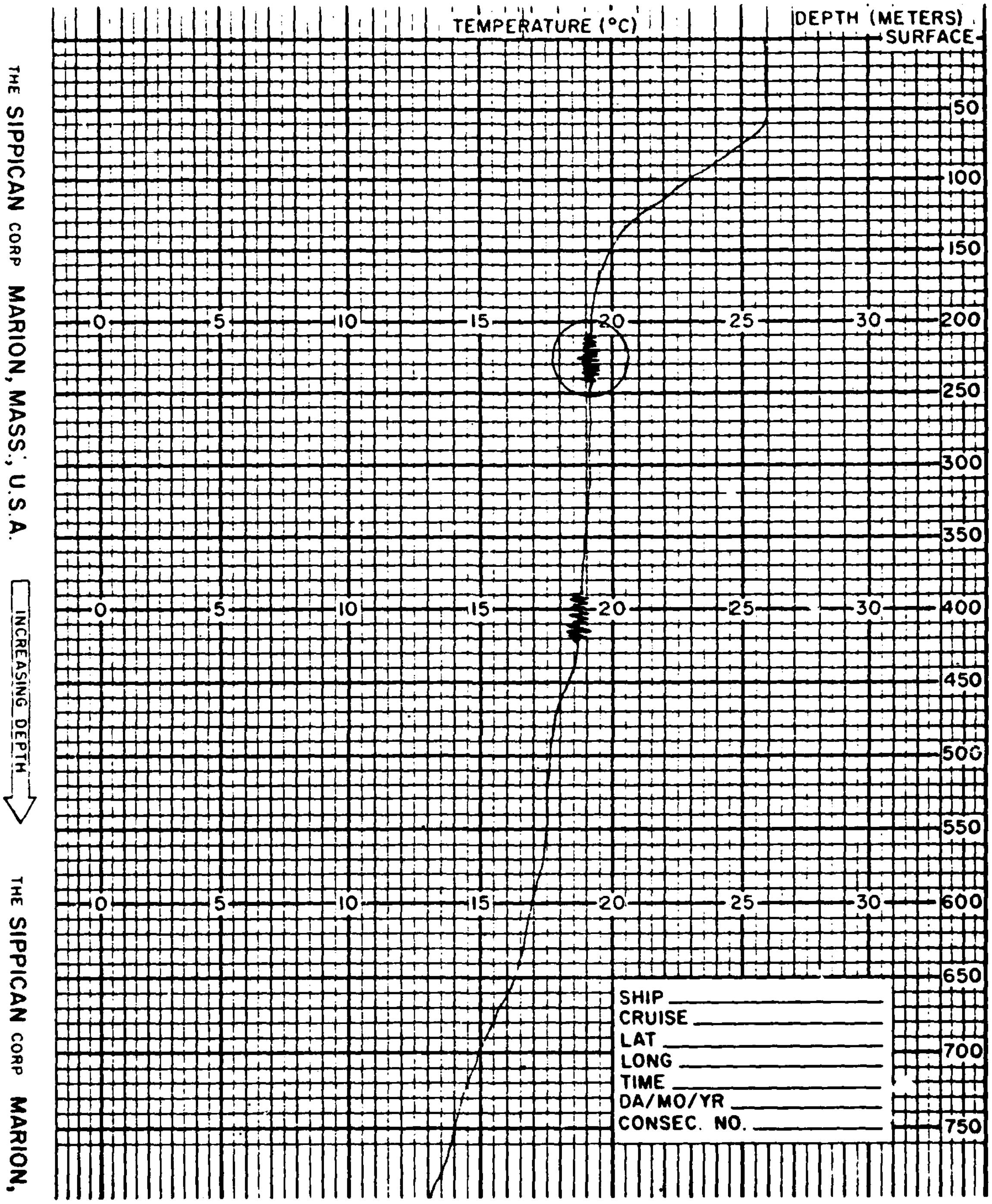

Figure 8 - Electrical noise

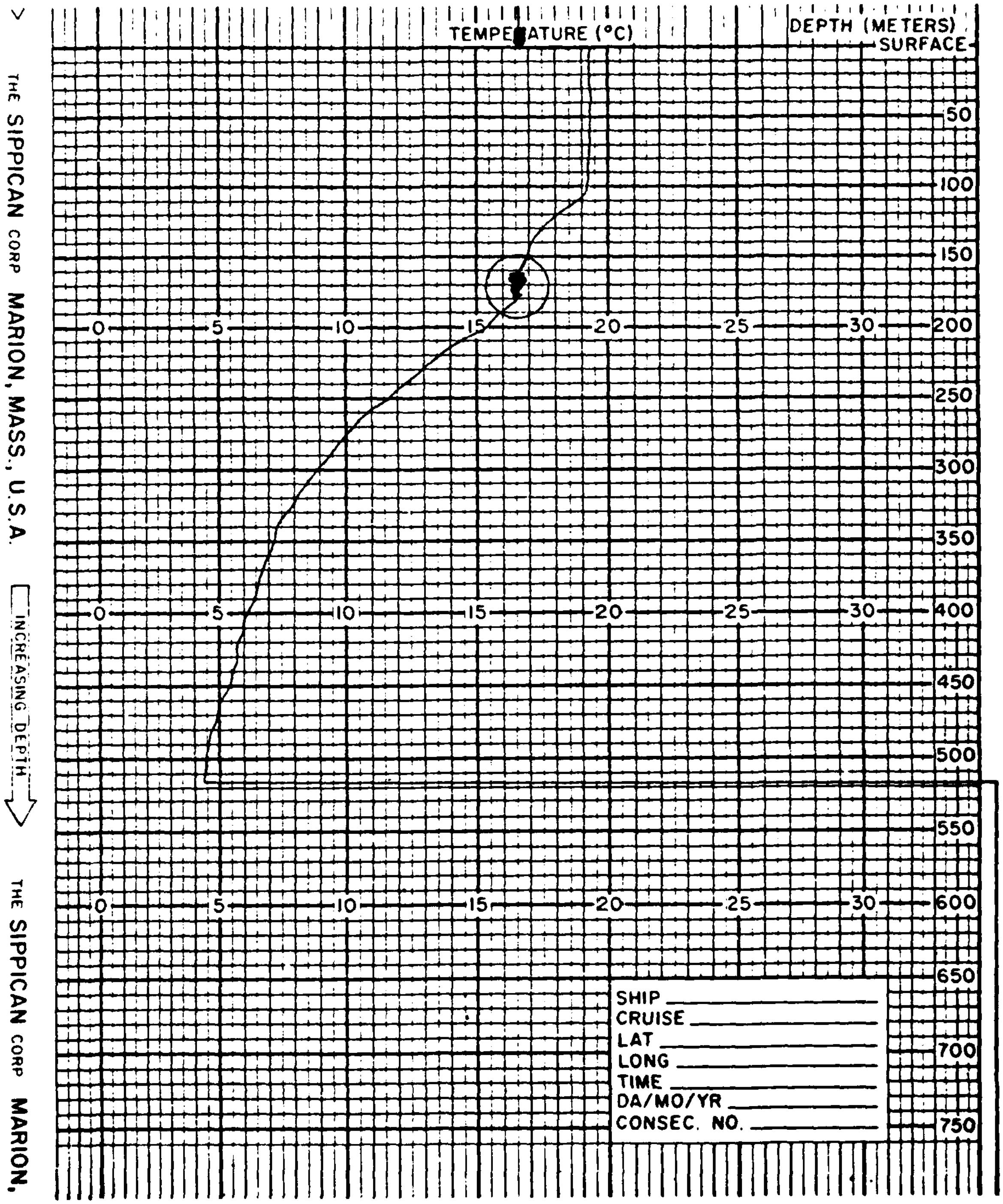

Figure 9 - Servo potentiometer "flat" spot at 16.7^{o}C

Category 4 - Wire break: Figure 10 shows an obvious failure at 535 m. The cause appears to be due to initial wire fouling on the ship (spike to high-temperature side) followed by wire break. This trace is usable to 535 m. In this case, the wire broke from the spool in the launcher and the open circuit caused the stylus to travel off-scale at the low-temperature end. When the wire breaks from the descending probe's spool, the short circuit drives the stylus to the high-temperature end of the scale (figure 11).

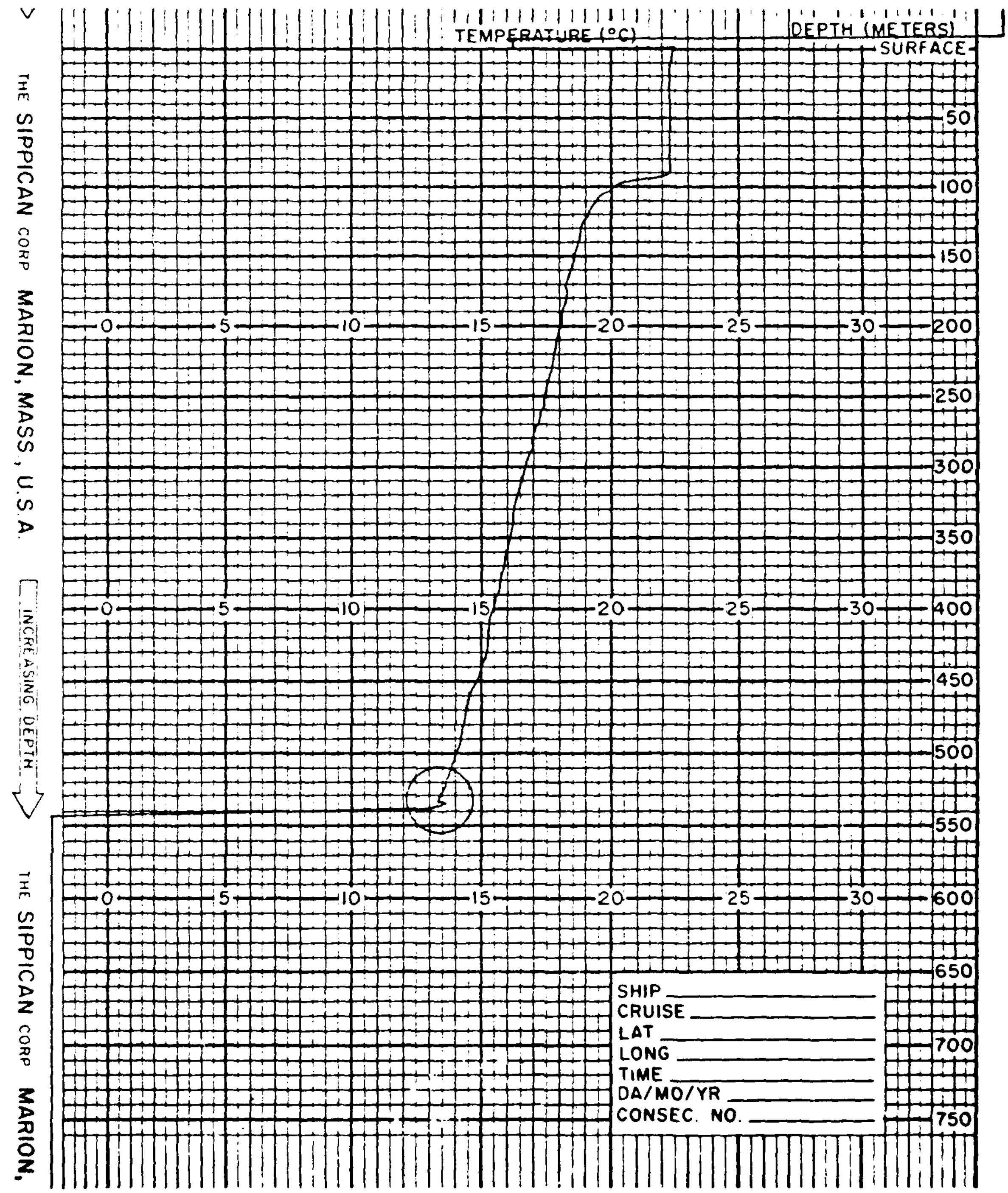

Figure 10 - Fouling followed by wire break at launcher

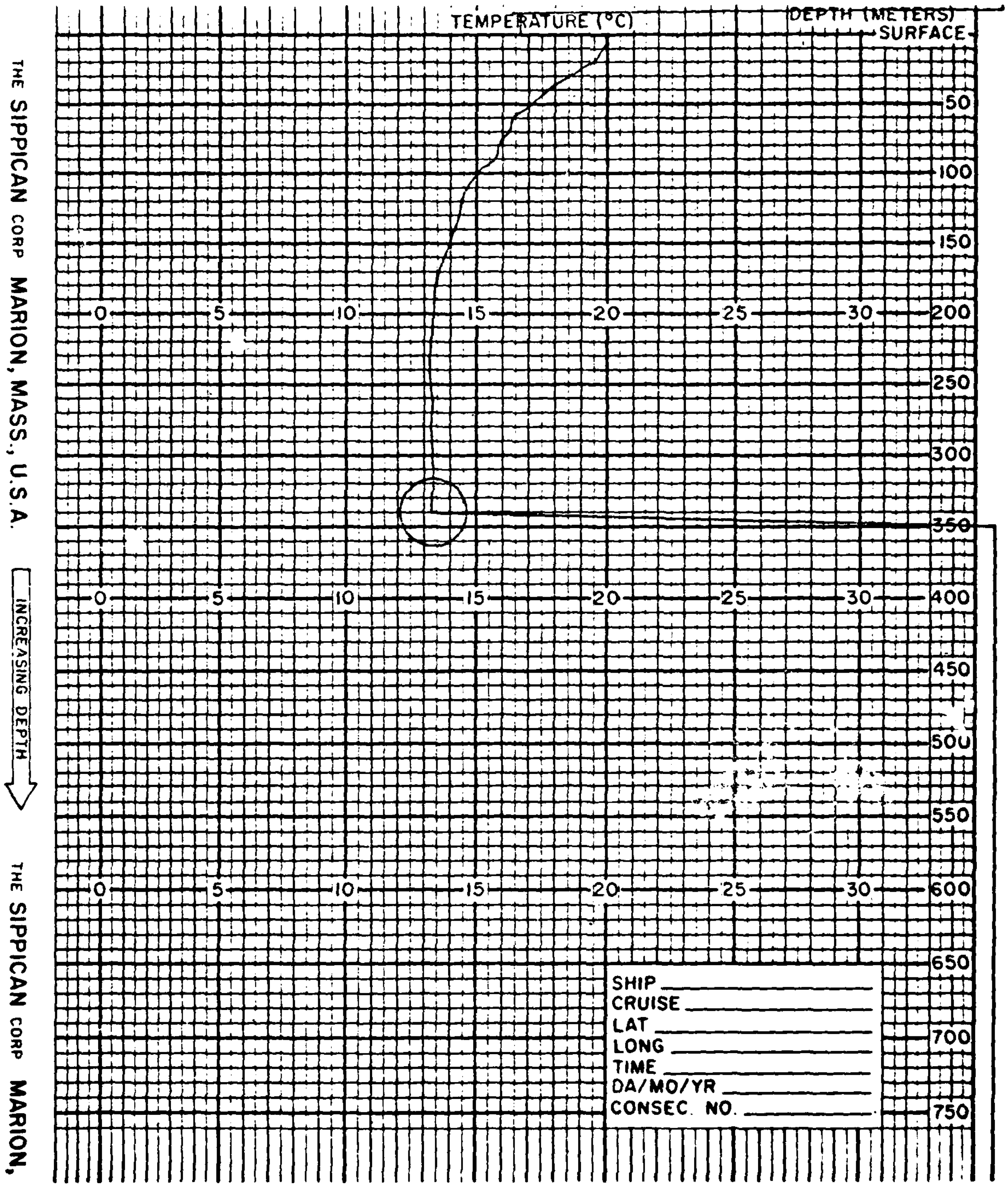

Figure 11 - Wire break from probe spool

Category 5 - Insulation penetration: Several possible causes can lead to wire insulation damage followed by leakage, represented on a trace by a sharp spike toward the high-temperature end of the scale (figures 12 and 13). Two of the most common causes of damage include wire contact with the ship's hull or wire hangup on a metal burr at the open end of the launcher tube. Data recorded below the initial insulation penetration are erroneous even though the insulation damage tends to heal itself through interaction between wire and seawater. However, recovery from the damage is never complete.

Figure 14 displays leakage in one of a probe's pair of wires. This leakage causes a trace to show excessive temperature at depth. Another probe should be launched in such cases.

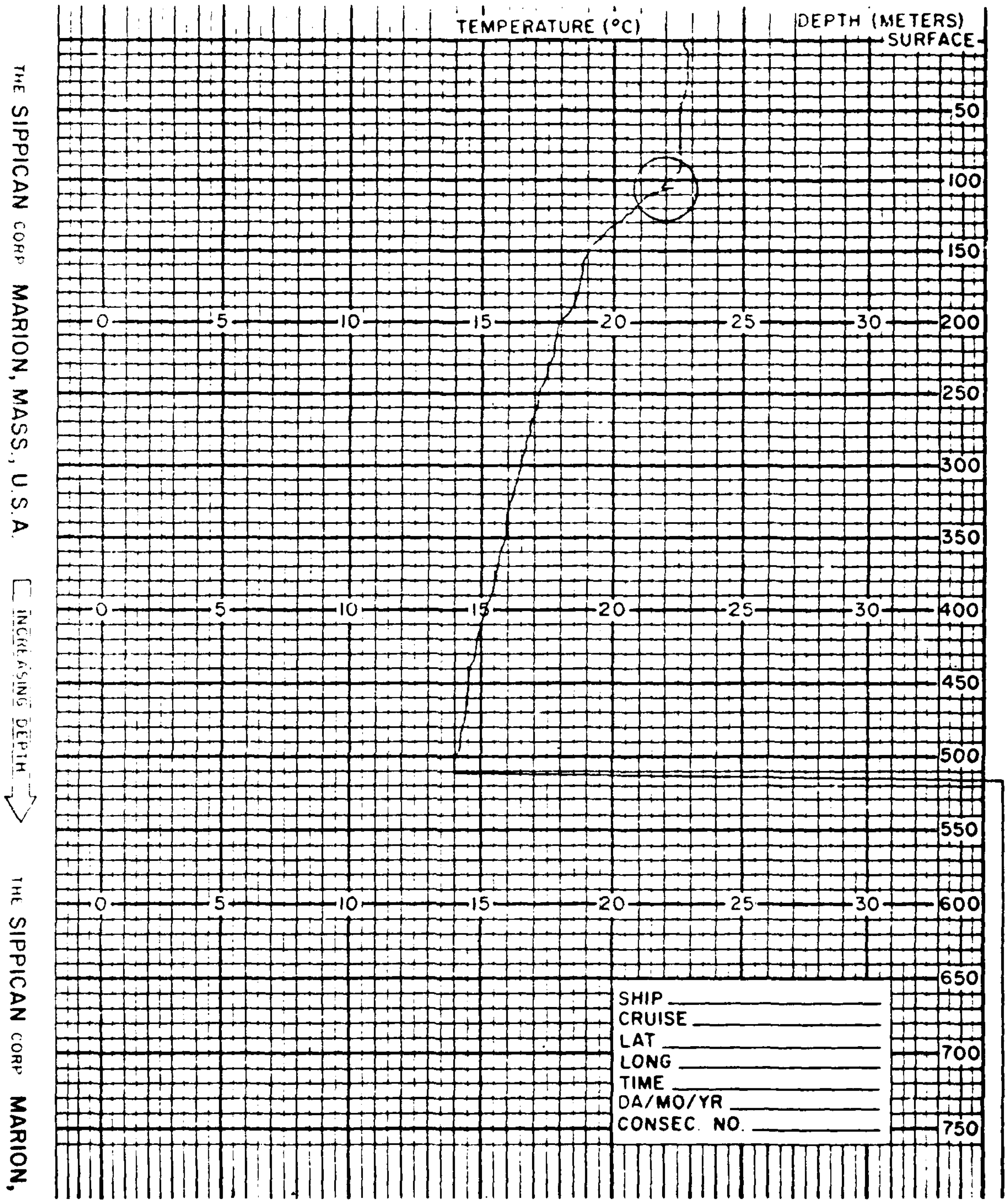

Figure 12 - Wire insulation penetration (at 105 m) with attempt at recovery

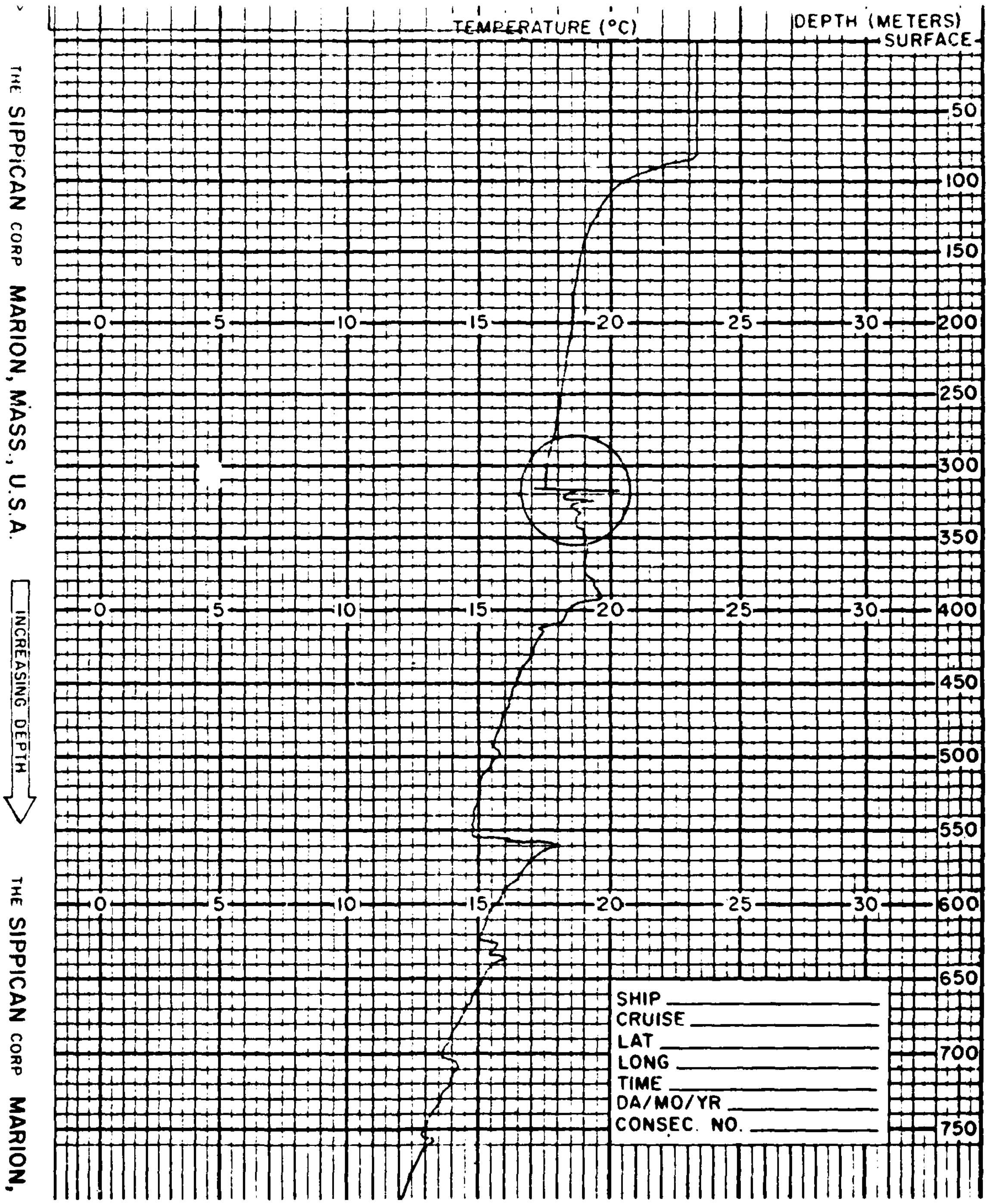

Figure 13 - Wire insulation penetration (at 318 m) followed by continuous leakage

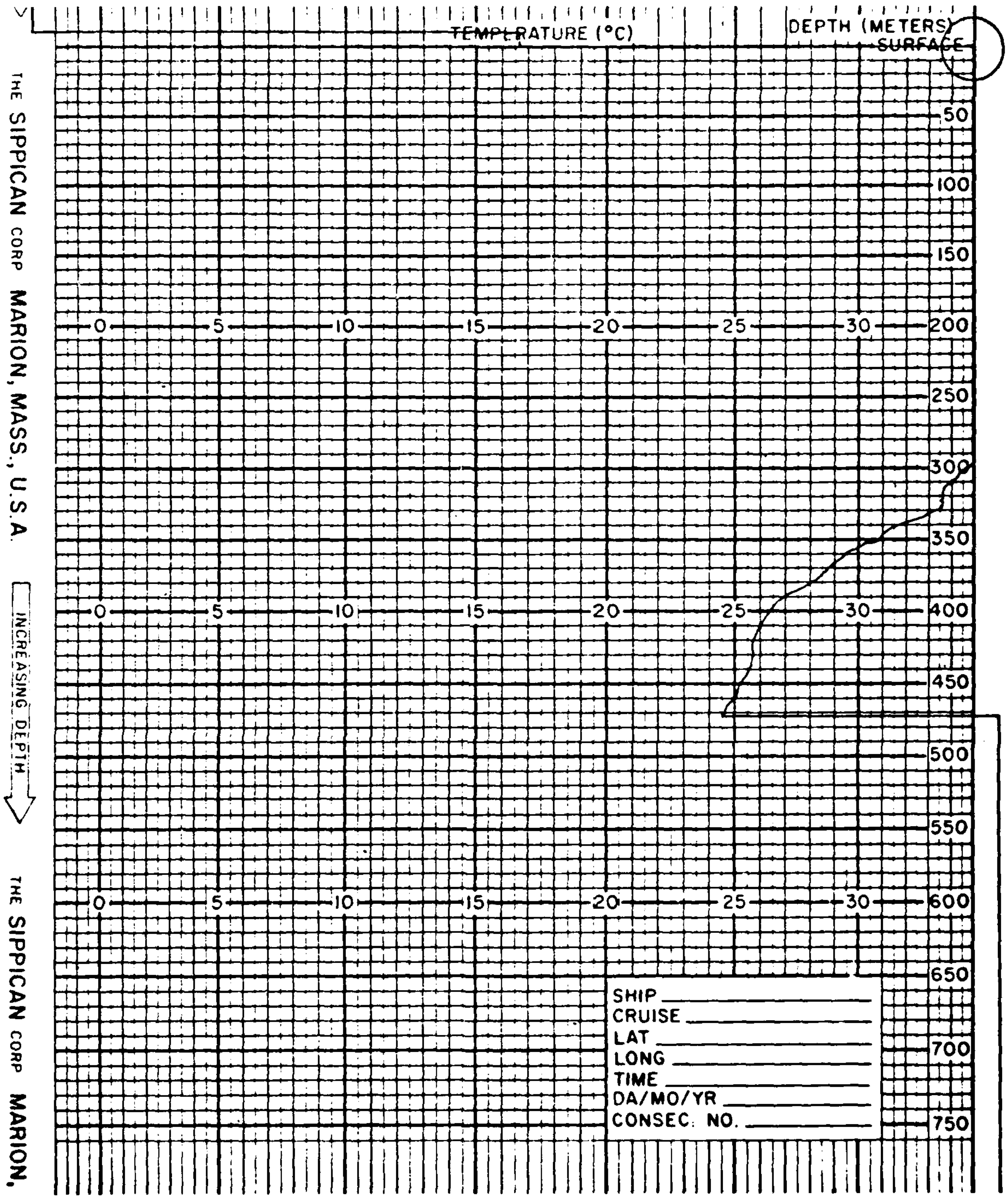

Figure 14 - Wire leakage

Category 6 - Wire stretch: Increased tension due to poor wire unreeling leads to wire stretch. This results in a characteristic bulge to the high-temperature side that can occur at any point in the trace (figures 15, 16, and 17). Data recorded beyond the stretch point are erroneous because of a permanent change in the conductive characteristics of the wire.

Subtle wire stretch within the mixed layer (figure 16) has recently been documented during several oceanographic experiments (Dugan and Schuetz, 1977). These features appear on traces using stock Navy T-4 probes (460 m/1500 ft). This malfunction seriously degrades data quality by affecting the temperature gradient and thickness of the mixed layer. Failure rate in excess of 70 percent has been noted for T-4 probes more than 4 years old.

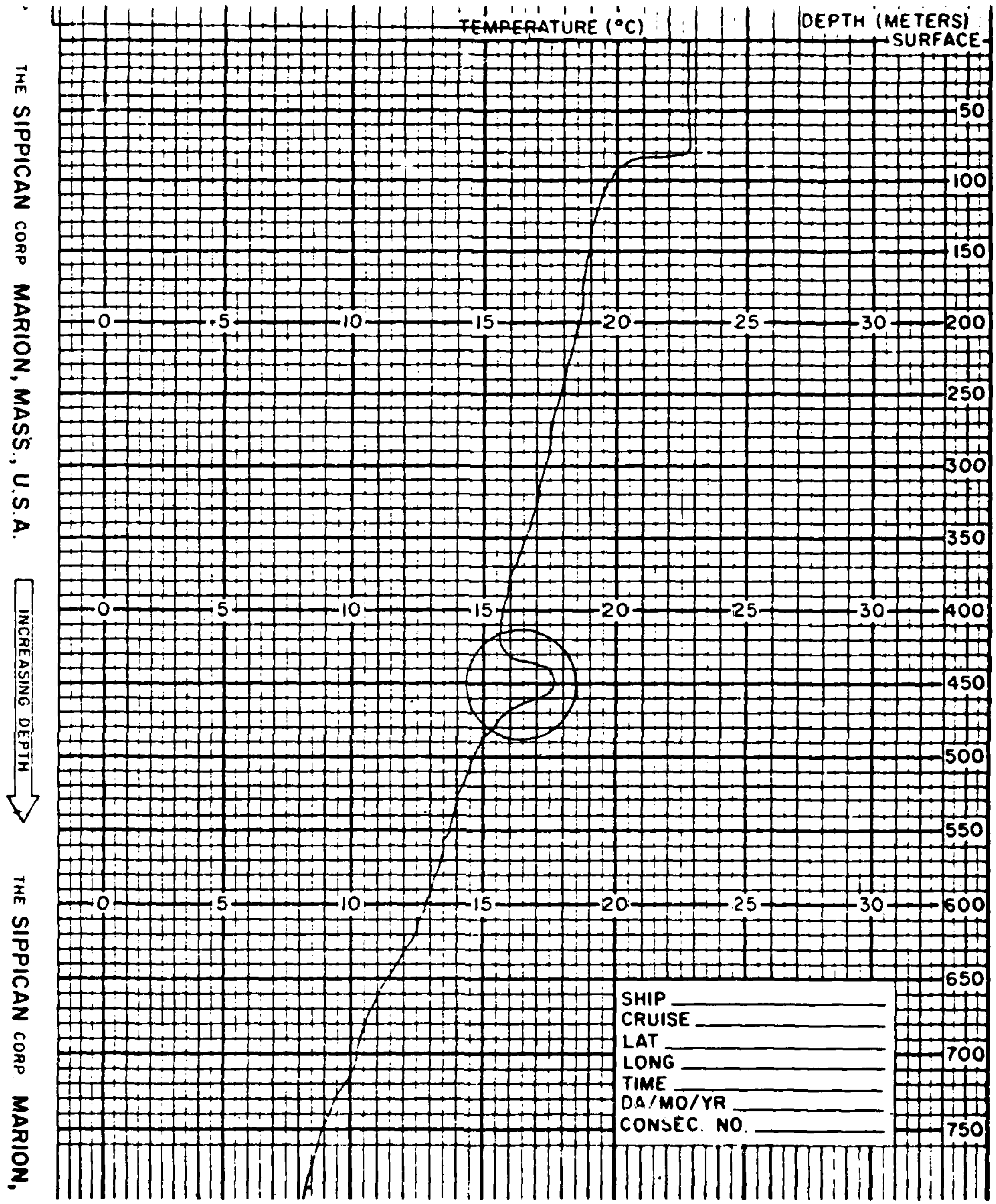

Figure 15 - Wire stretch (good to 405 m)

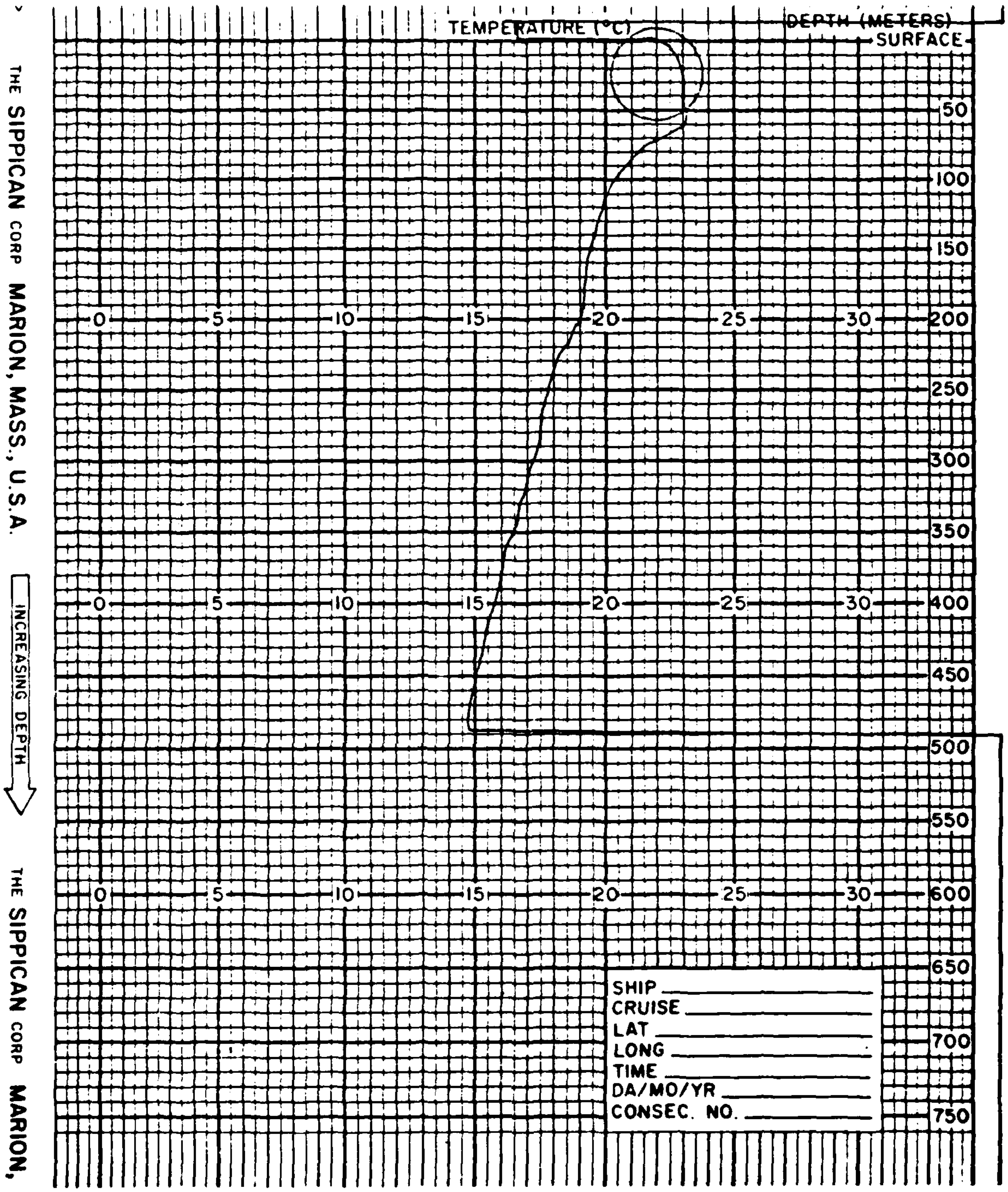

Figure 16 - Wire stretch in mixed layer (trace is no good)

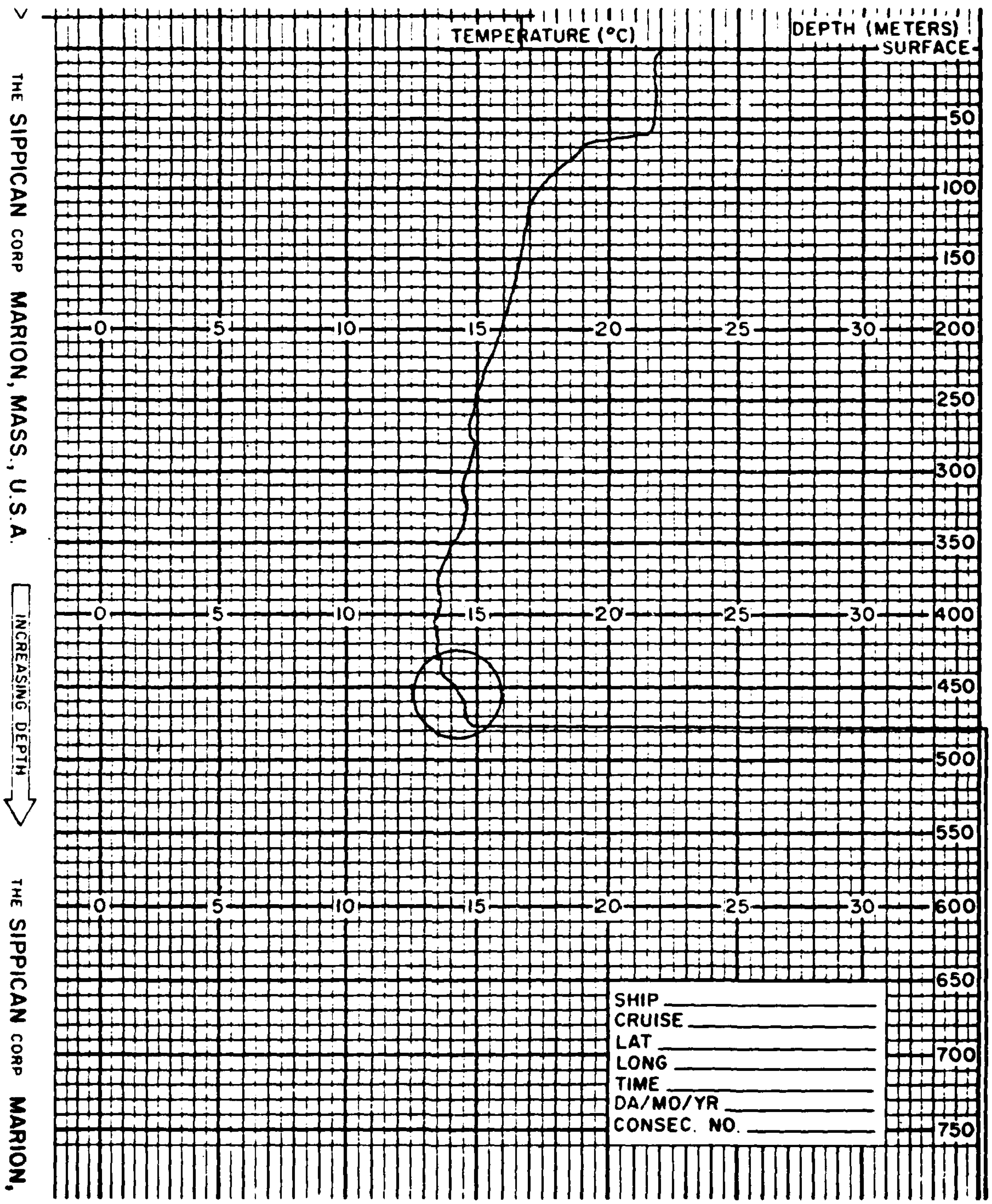

Figure 17 - Wire stretch at bottom of trace resulting in false temperature increase

<u>Category 7 - Improper ground or leakage at launcher</u>: Figures 18 and 19 show the results of a faulty launcher ground and an electrical leakage at the launcher, respectively. Both tr are erroneous. Possible causes for these problems are 1) improper grounding of the deck-mounted launcher, 2) leakage caused by corrosion or moisture at the canister contacts in the launcher breech, or 3) launcher-to-recorder cable leakage. Launcher and ground connections should be checked to assure proper contacts and electrical continuity of the system. The operator is referred to the Sippican Corporation Instruction Manual for the Expendable Bathythermograph System (1975) for adjustment and troubleshooting procedures.

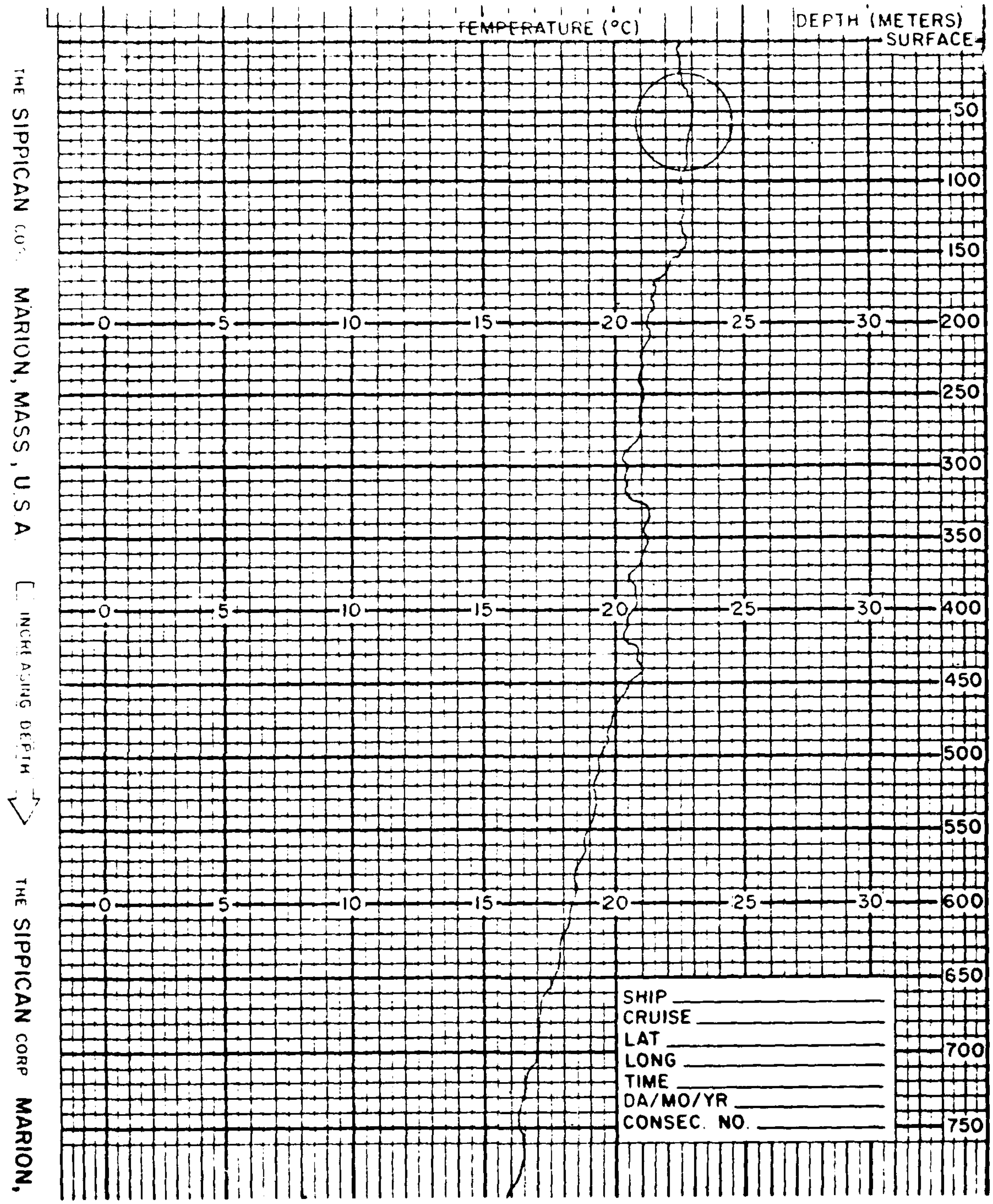

Figure 18 - Improper launcher ground - erratic excursion to high temperature end

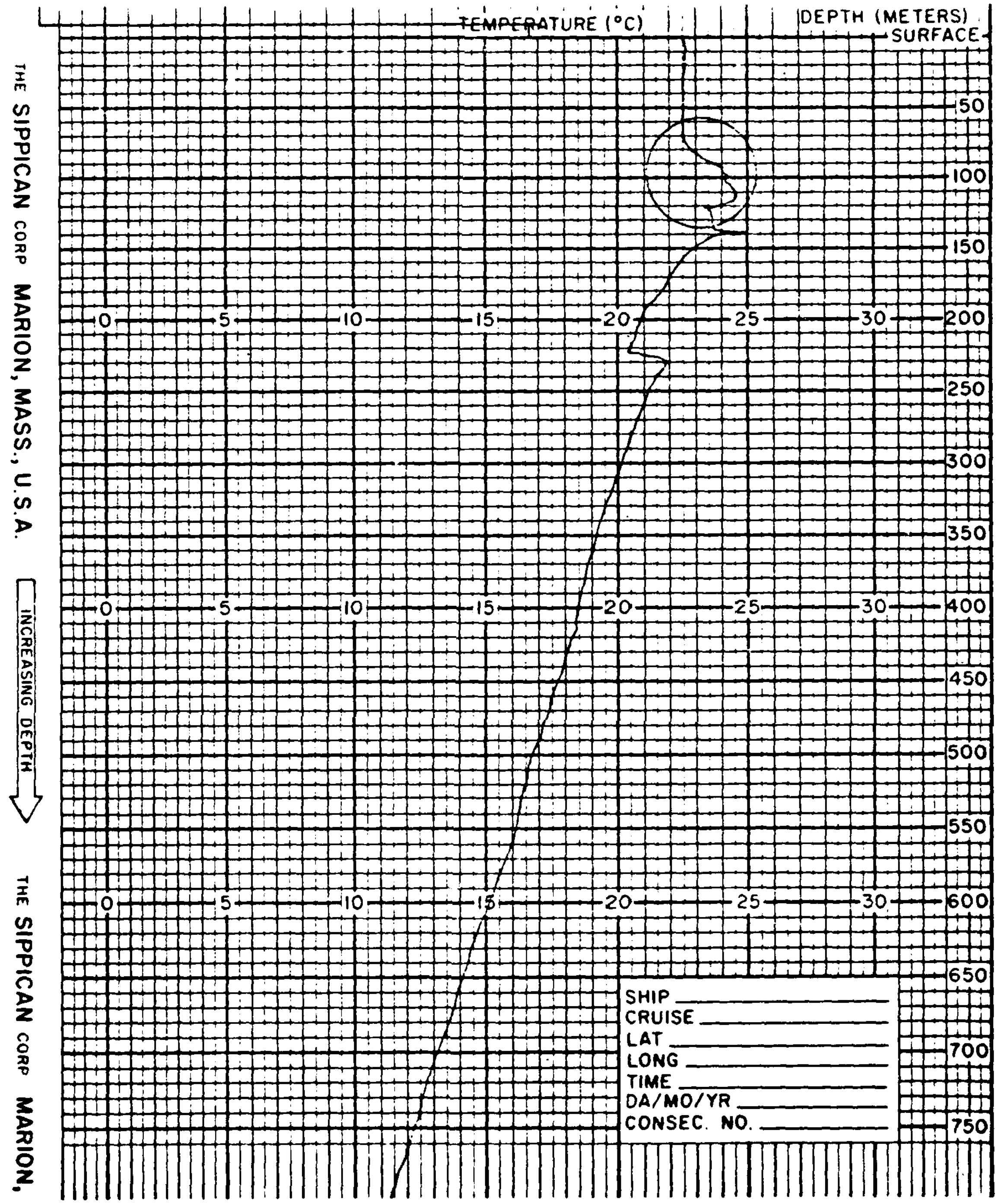

Figure 19 - Launcher leakage (at 65 m)

Category 8 - Doubtful features: Without knowledge of expected oceanographic conditions, an observer can have difficulty discerning good data from bad data. Figures 20 and 21 display features which may or may not be real. Comparison should be made between succeeding traces in the same area to determine if the feature is real. Doubtful features can appear at any point in the trace. Care must be taken, however, in labeling features as doubtful. Variations in thermal structure do exist, particularly in regions of oceanic fronts and eddies, but they can also occur in relatively stable regions.

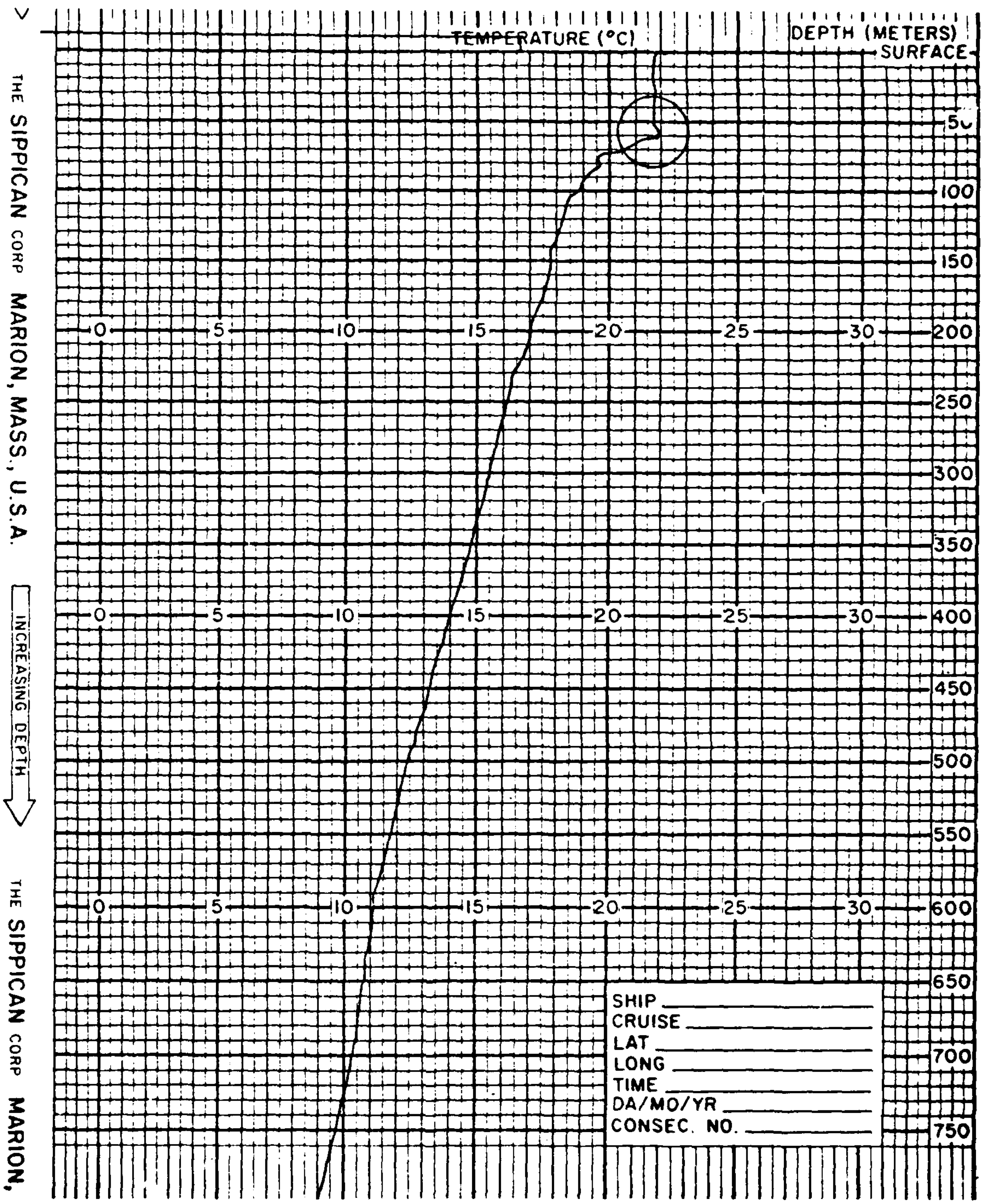

Figure 20 - Doubtful feature within the mixed layer

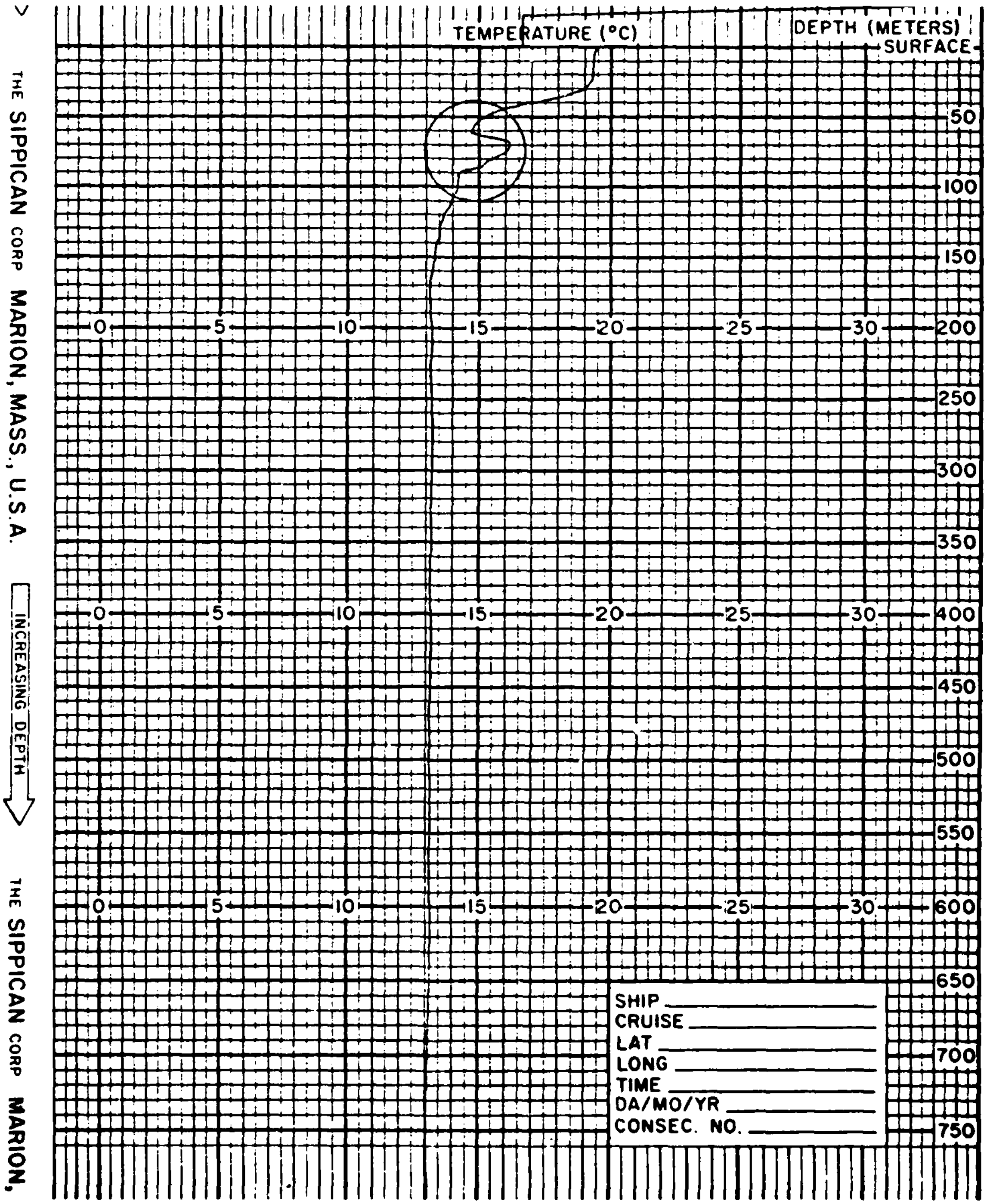

Figure 21 - Doubtful feature within the permanent thermocline

<u>Probe hits bottom</u>: When bottom depth is less than the rated depth of a probe, bottoming occurs (figures 22 and 23). An indication that a probe has hit bottom is given by a small horizontal spike in the trace followed by an isothermal reading. However, little or no spiking may appear if the bottom is soft. In shallow areas, it is important to know the bottom depth so that false data do not result from encoding data below the actual bottom.

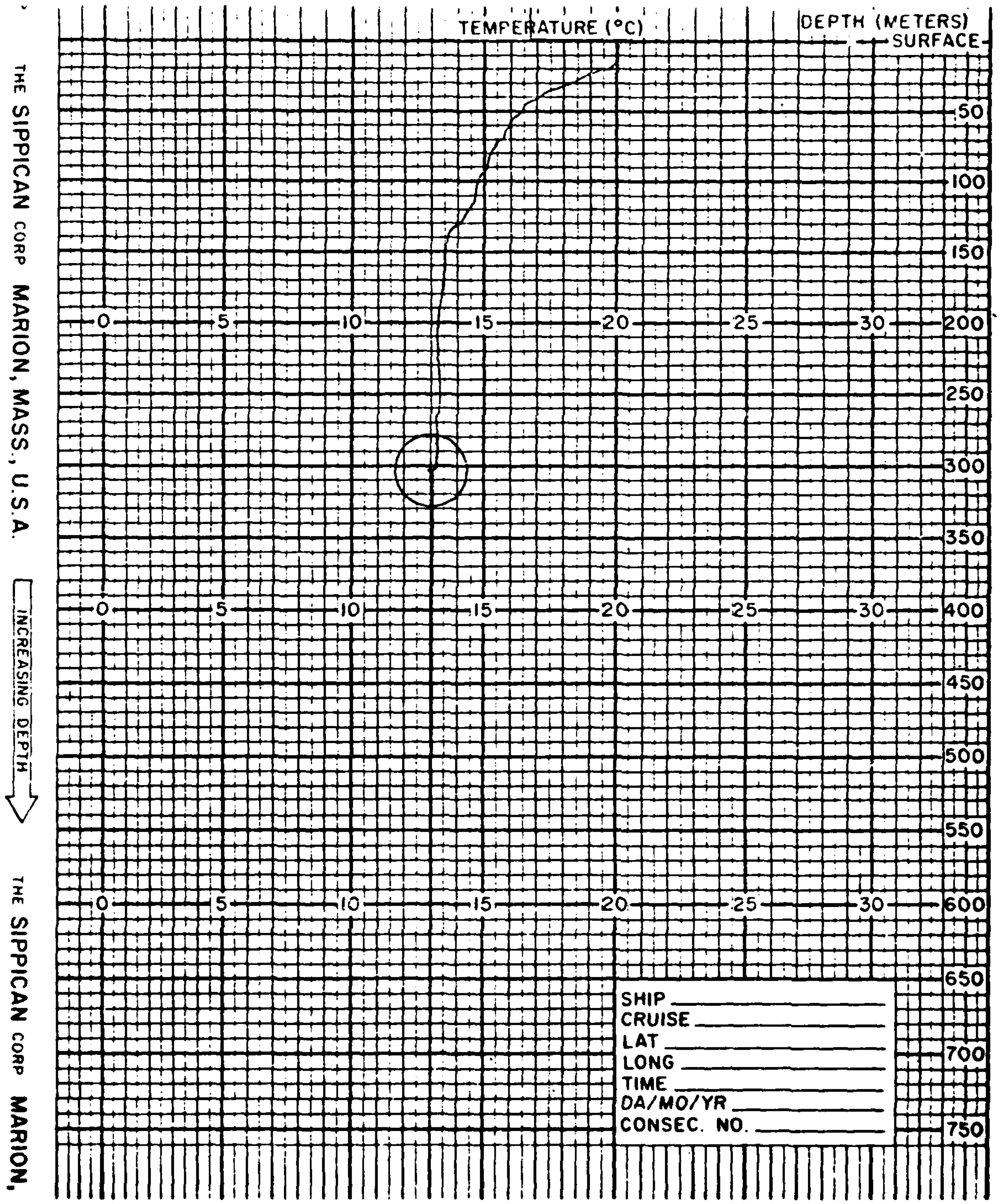

Figure 22 - Shallow drop - bottom spike (at 302 m) followed by isothermal reading as probe lies on bottom

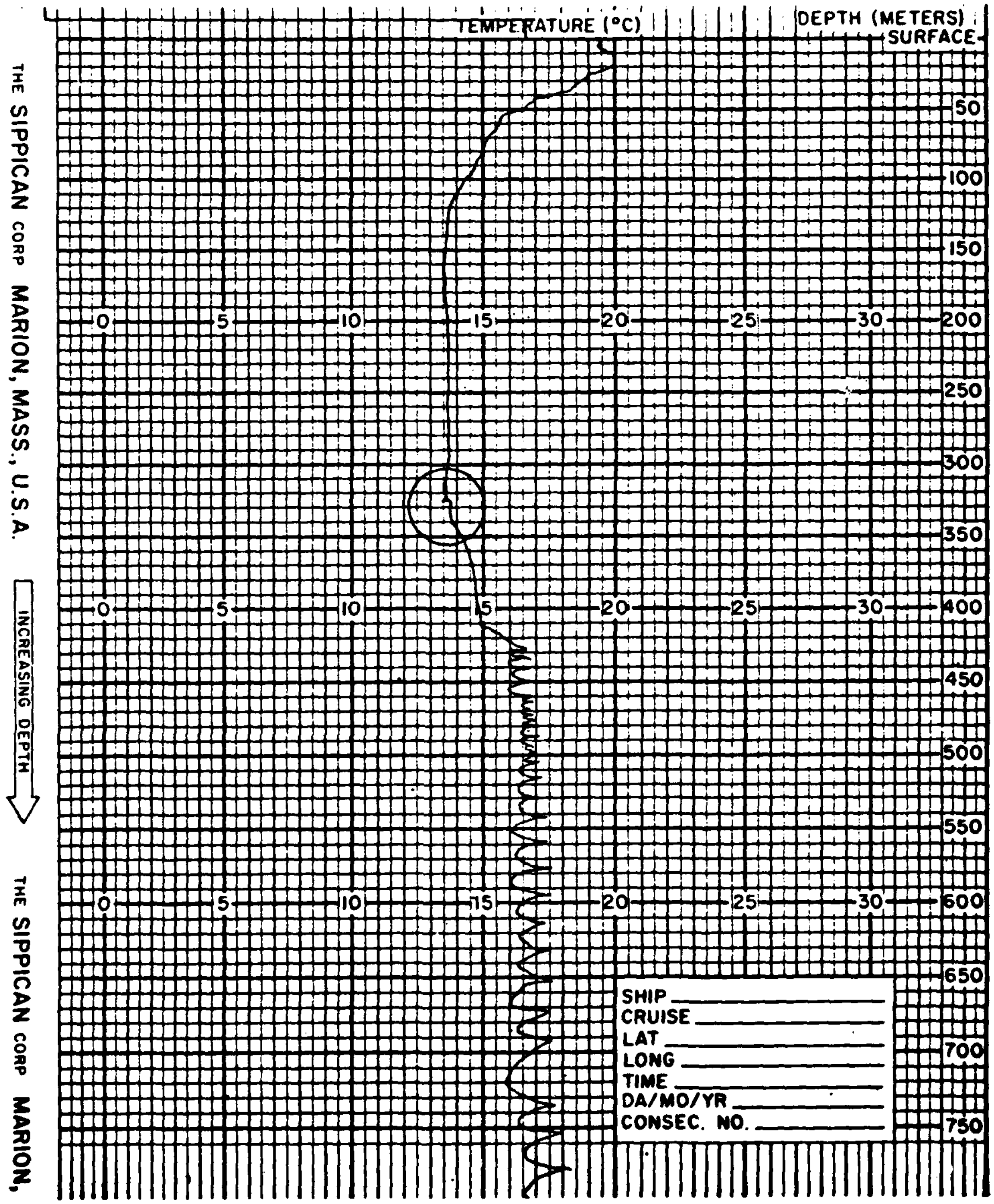

Figure 23 - Shallow drop - bottom spike (at 326 m) followed by wire leakage

<u>Frontal regions</u>: Care must be exercised in determining data quality in the vicinity of oceanic fronts. Proper maintenance and calibration of the system is very important in frontal regions because the temperature structure can vary significantly between SXBT observations. The trace shown in figure 24 was obtained in the Gulf Stream. The trace exhibits a rather large (7^{o}C) temperature inversion caused by entrainment of cold, relatively fresh water from coastal regions. This trace was originally labeled as questionable; however, a nearby SXBT (figure 25) also shows a temperature inversion. These temperature inversions are real. Higher-than-normal probe failure rates should be expected near major oceanic fronts because of increased current shear and turbulence.

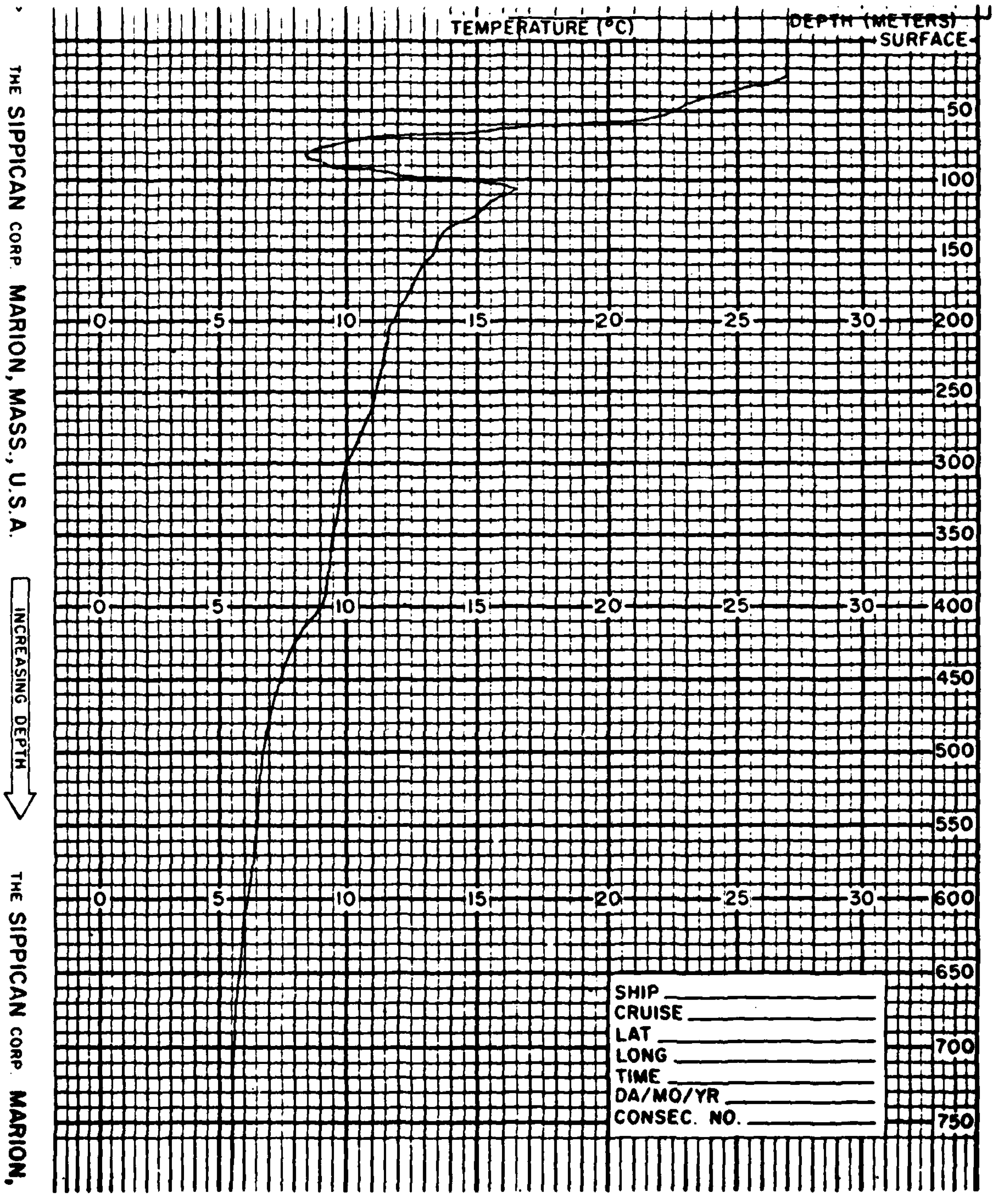

Figure 24 - Frontal region with real $7^{o}C$ temperature inversion

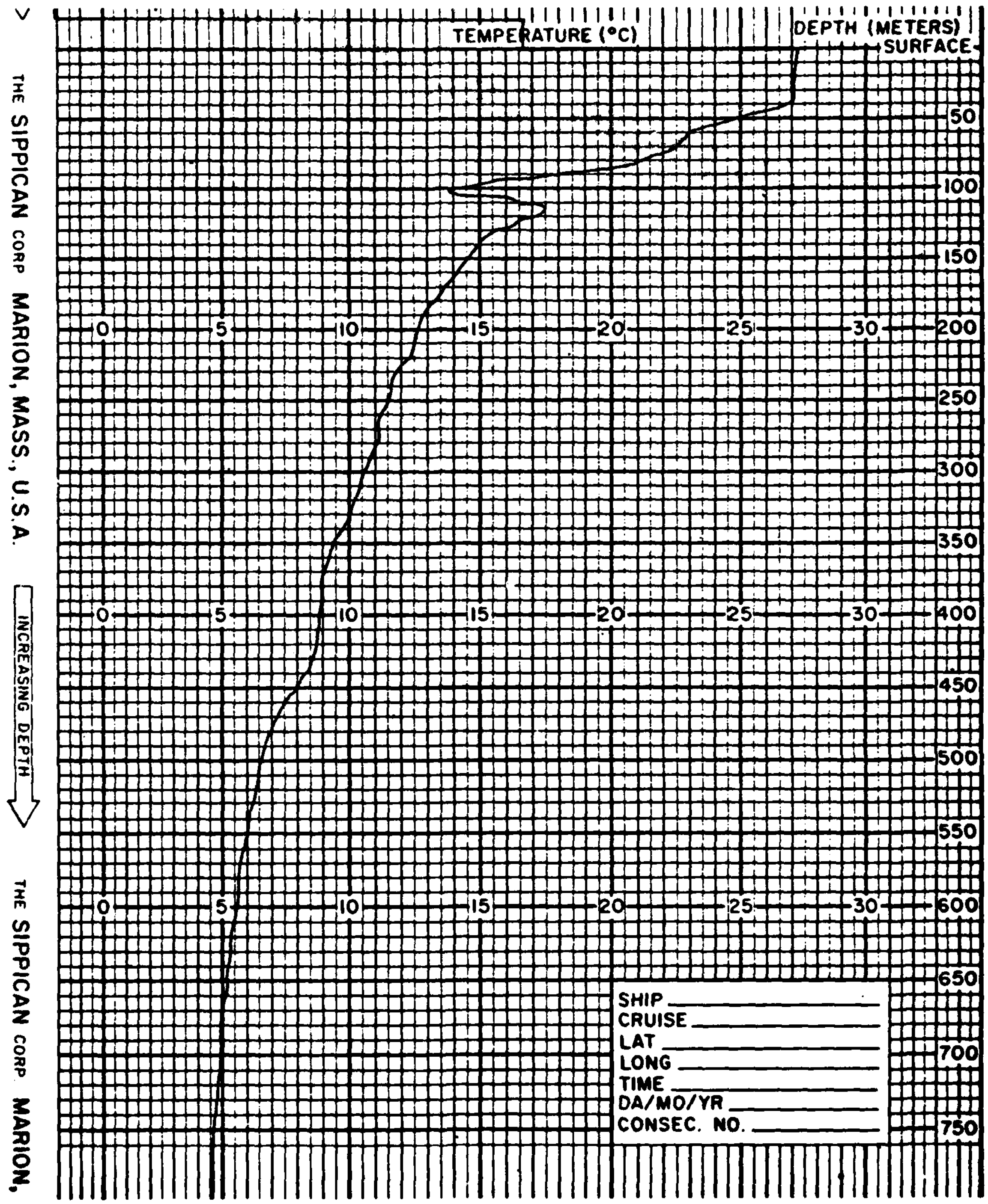

Figure 25 - Frontal region with real $3^{o}C$ temperature inversion

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Sippican Corporation, Instruction Manual for the Expendable Bathythermograph System R-603. Marion, Massachusetts. Revised 1975.

APPENDIX A

RECORDER CALIBRATION PROCEDURES

If a recorder check indicates that the extreme calibration temperatures exceed the specified limits of $\pm$ 0.1°C at -1.1°C ($\pm$ 0.2°F at 30°F and 94°F), the recorder must be calibrated. Calibration is regulated by the servo potentiometer and the printed circuit scan potentiometer (figure A-1). Two separate devices can be used to calibrate the SXBT system to specifications 1) an A2A test canister to be inserted into the launcher or 2) an A-4 XBTester to be connected to the launcher terminal block on the left of the recorder and to the launcher cable. If neither of these testing devices is available, the operator is referred to the instruction manual (Sippican, 1975) for the schematic diagram of the test canister so that the proper circuit can be constructed if electrical resistors are available.

After inserting the test canister or connecting the XBTester, the following steps should be followed in the given order during calibration.

1. Rotate the servo potentiometer to adjust the low-scale temperature to -1.1°C/30°F within the $\pm$ 0.1°C/$\pm$ 0.2°F tolerance limit.

2. The printed circuit scan potentiometer is then adjusted to set the high-scale temperature at 34.4°C/94°F within the same limit by turning the scan potentiometer screw.

3. With the system set in the Measure Mode and with the chart advancing, alternately check and adjus. the servo and scan potentiometers until the temperature values are within specified limits.

4. During a 2-second Check/Run Mode, the recorder should read $16.7^{o} \pm 0.1^{o}C$ ($62^{o} \pm 0.2^{o}F$). If not, the servo potentiometer or a resistor in the printed circuit board is defective.

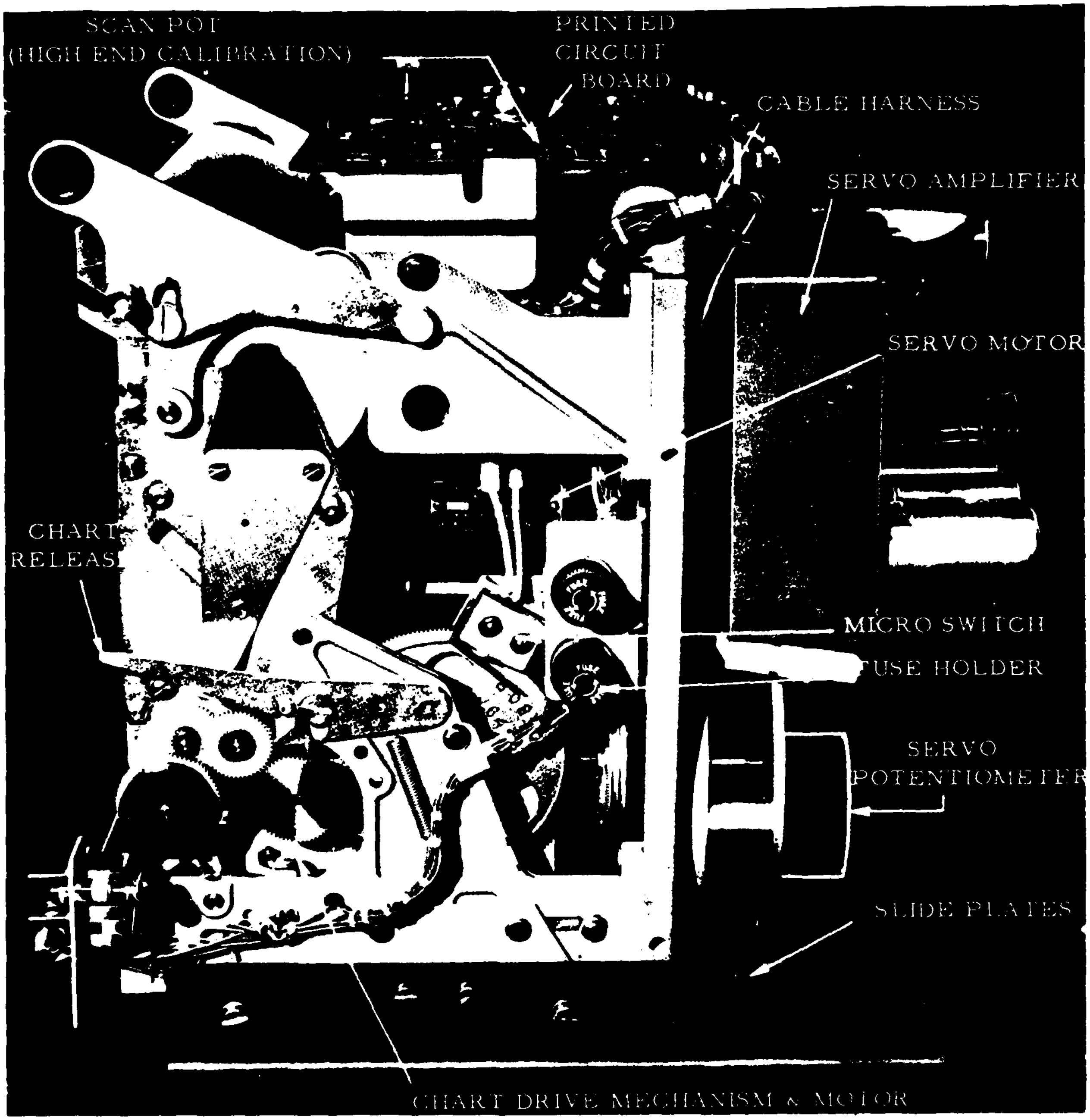

Figure A-1 - Recorder subassemblies, right side (Sippican, 1974)

APPENDIX B

GAIN AND OVERSHOOT ADJUSTMENT

If a stylus slew rate and overshoot check indicates that the recorder gain exceeds the limits for maximum full-scale slew or overshoot, the servo amplifier gain control (figure B-1) must be adjusted.

1. With the system in Measure Mode and with the chart advancing, alternately set the calibration switch (marked 94° - 30°) to the low (-1.1°C/30°F) and high (34.4°C/94°F) temperature ends. Adjust the gain control until the overshoot is between 0.3°C and 0.5°C (0.5°F to 1.0°F).

2. Check the slew rate of the stylus across the chart by again alternately setting the calibration switch to the high and low ends. The slew rate across the chart paper should now be 1.5 seconds or less (approximately 10m). Never overtighten the gain control, because this increases response lag in the stylus.

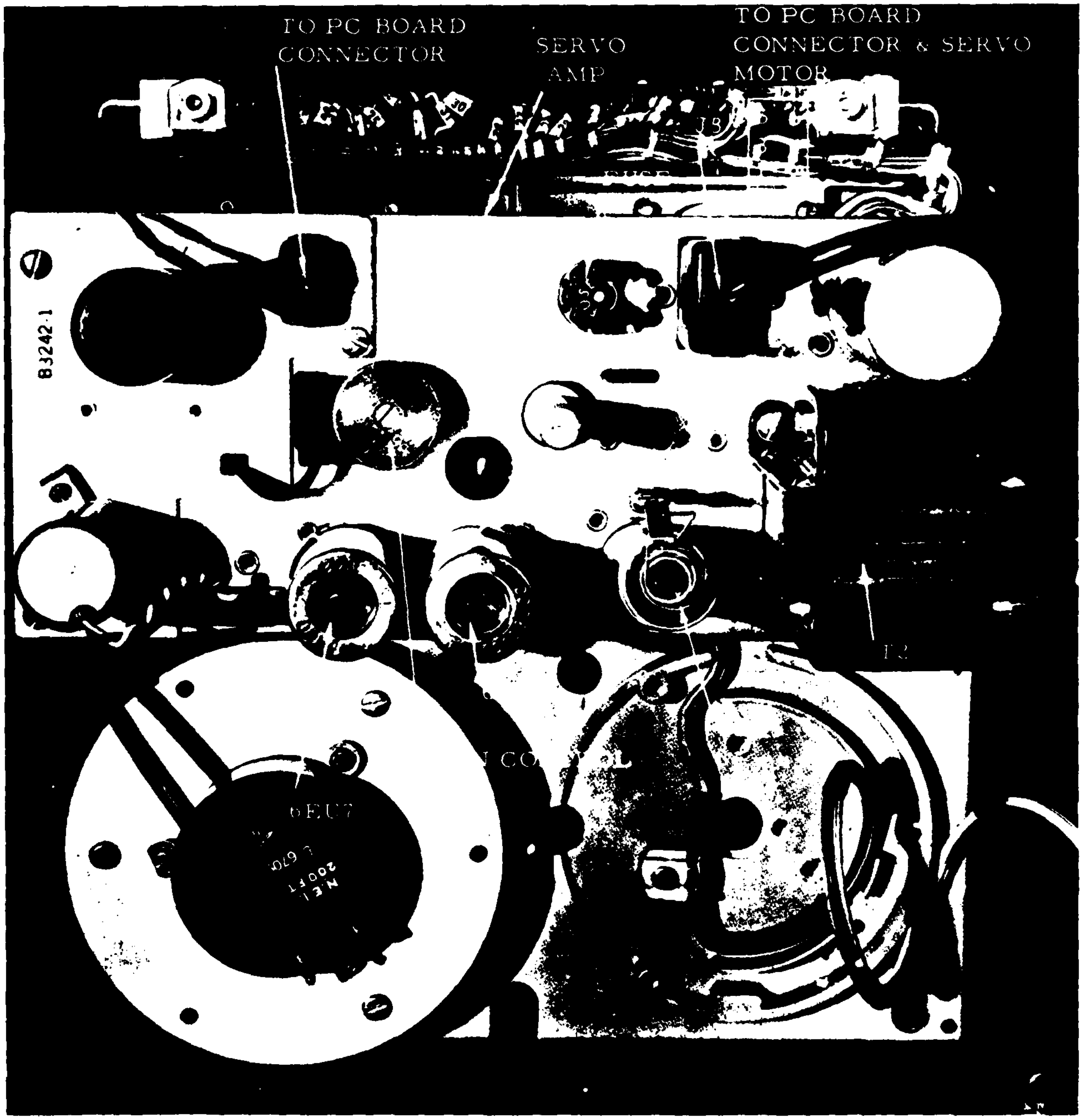

Figure B-1 - Recorder subassemblies, rear view (Sippican, 1974)

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