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ABSTRACT

A Recording Instrument Package or RIP was a completely self-contained bottom-mounted observatory designed to record digitally, on magnetic tape, the average spectrum of underwater ambient noise once an hour for one year. A recovery system was incorporated which was initiated by a coded acoustic signal sent from the recovery vessel. The RIPs were designed to characterize the seasonal changes in under-ice acoustic ambient noise in channels of the Canadian Arctic Archipelago.

This report discusses the electronic and mechanical design and describes the installation and recovery of the units in the Arctic.

TABLE OF CONTENTS

LIST OF FIGURES

Page

FIGURE

RECORDING INSTRUMENT PACKAGE (RIP)
FOR LONG TERM UNDERWATER MEASUREMENTS
IN THE ARCTIC

INTRODUCTION

Five Recording Instrument Packages or RIP's were designed and constructed at the Defence Research Establishment Pacific. Each RIP was a completely self-contained bottom-mounted observatory designed to record digitally, on magnetic tape, the average spectrum of underwater ambient noise once an hour for one year. A recovery system was incorporated which was initiated by a coded acoustic signal sent from the recovery vessel. The RIP's were designed to characterize the seasonal changes in under-ice acoustic ambient noise in channels of the Canadian Arctic Archipelago where "typical" ice conditions would be encountered.

Automatic measurement systems such as RIP are particularly attractive for use in the Arctic. Surface ships can operate for only a small portion of the year. Cables from the water to the shore are unreliable and very expensive. Long-term manned stations, either on shore or on the ice, are difficult logistically, and tend to be unattractive to scientific personnel. The RIP units were designed specifically for acoustic ambient noise measurements, but the concept and the mechanical package could be used for a large range of underwater measurements.

In August of 1967 the five RIP's were installed on the bottom of channels in the vicinity of the Queen Elizabeth Islands in locations shown in Figure 1. One year later, in August of 1968, four of the five units were recovered using an acoustic interrogation method. The mechanical packaging and the recovery system were completely successful. The RIP in Northern Baffin Bay, which was lost, was ploughed off its site by an iceberg aground in 1410 feet of water. An initial survey of results showed that the noise spectra available amounted to about one third of expectations, based on the perfect operation and recovery of five RIP's. Other than the loss of the unit in Baffin Bay, there were a variety of component failures, the most serious being in the underwater connectors, which resulted in the premature termination of recording. The units recorded good coverage of the previously unmeasured fall and early winter conditions and enough winter and spring information to confirm our earlier detailed short term measurements. A first look at the data has revealed how complex are the relationships between the surface weather and the spectra of ambient noise and has shown that a great effort will have to be exerted to present in a meaningful way the vast amount of information recorded.

The construction and design of the five Remote Instrument Packages at DREP was the logical result of several years of field expeditions into the Arctic to measure under-ice ambient noise spectra in the winter, spring and summertime. The results of this field work are described in detail in references 1, 2, 3 and 4. A few general observations can be made which were the determining factors in the design of the RIP's. In the winter and springtime, under areas of fast-ice, the noise spectra exhibit a dependence on air temperature and wind. Decreasing air temperatures create surface cracks in the cold, brittle sea-ice. The resulting impulses, when acoustically summed at a hydrophone in the water, produce a non-Gaussian noise with a spectral peak in the vicinity of 100 Hz. Wind noise as observed during air-warming when ice-cracking is not occurring, exhibits a nearly white spectrum in some cases and is Gaussian in character. Spectra from ice-cracking and wind are shown in Figures 2 and 3 which were reproduced from Reference 3. In the RIP design, the median frequencies of the octave-bands used to define the spectra were chosen with the ice-cracking noise spectra of Figure 2 in mind. Another important factor was the necessity for a large dynamic range with a requirement not only to record noise with rms spectral densities changing by as much as 50 db but also to include a generous allowance for high crest-factors to prevent system limiting in the presence of highly impulsive noise. At times, the noise levels are extremely low, necessitating the use of a sensitive hydrophone.

The elapsed time between the initiation of the RIP project and the installation of five RIP's in the Arctic was a short 15 months. During this time the aesthetically neat conception of an RIP as a weighted buoyant sphere with the battery pack serving as an anchor degenerated into the clumsy but nevertheless functional device shown in Figure 4 being lowered over the side of CCGS LABRADOR in Viscount Melville Sound.

RIP Description

Figure 4 shows the general configuration of an RIP unit. The main pressure cases were constructed of fourteen inch seamless steel pipe. Two independent battery packs were set vertically in opposite corners with the recovery winch and the hydrophone in the other corners. The electronics case lies horizontally and provides a volume of three and a half cubic feet. The complete package weighs 2100 pounds in air, 1100 pounds in water and measures approximately five feet square by three and one half feet high. The system was designed for immersion depths of 2000 feet and for continued submergence of up to two years. Corrosion resistance was supplemented by zinc anodes.

Figure 5 shows diagrams of the installation and recovery operations. The RIP was lowered to the ocean bottom by a cable with a specially designed release. For recovery,a coded acoustic command signal initiated the firing of an explosive bolt which in turn released the float shown on the left of Figure 4. The float pulled a light polypropylene line to the surface which then was used to pull up a steel cable. The entire unit was raised with the steel cable. Although the electronics for the recovery system were contained in the main electronics case, it was an independent system having only the hydrophone in common with the

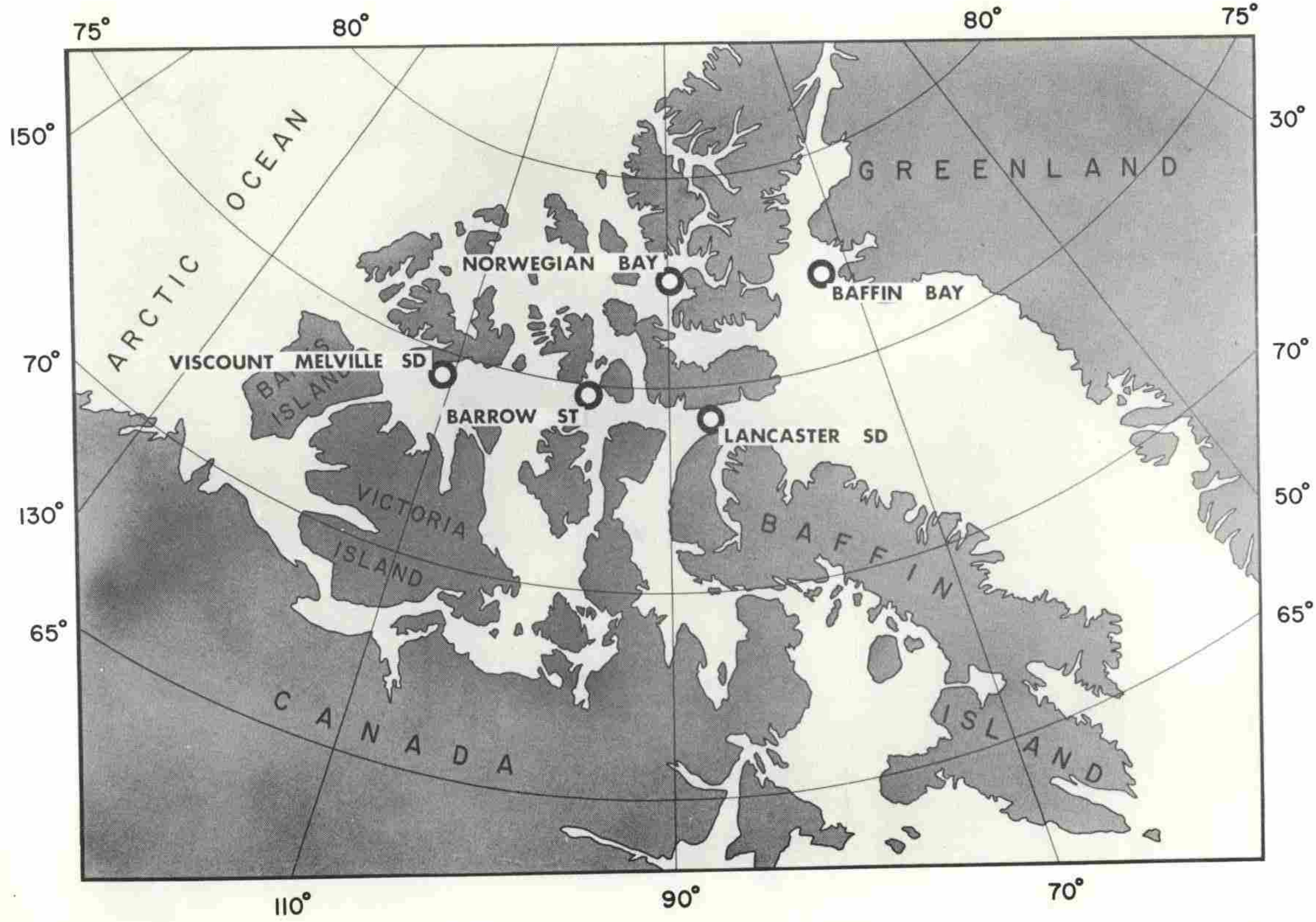

Figure 1: Positions of the five RIP units installed in 1967

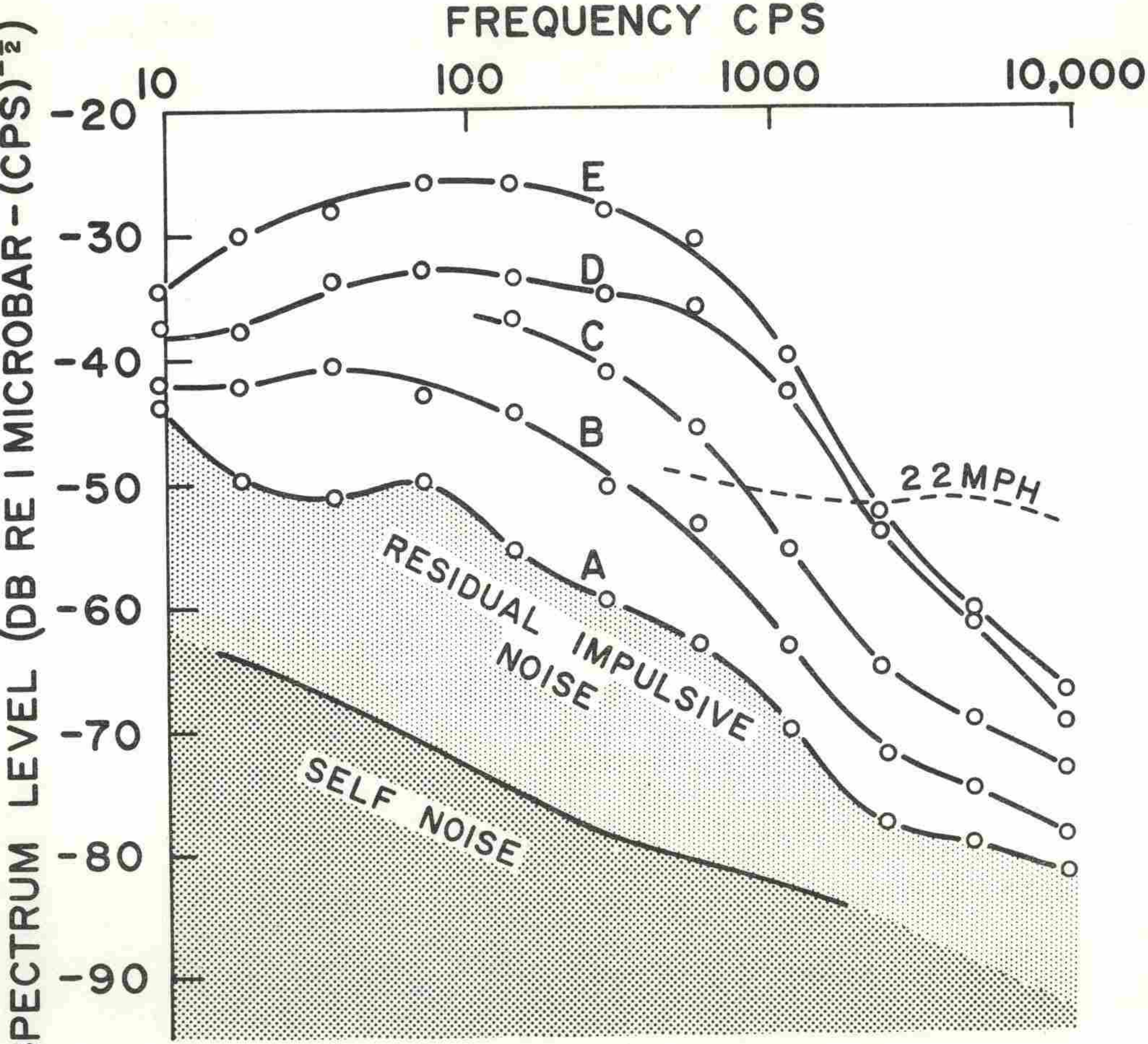

Figure 2: Noise spectra under shore-fast ice due to impulsive ice cracking

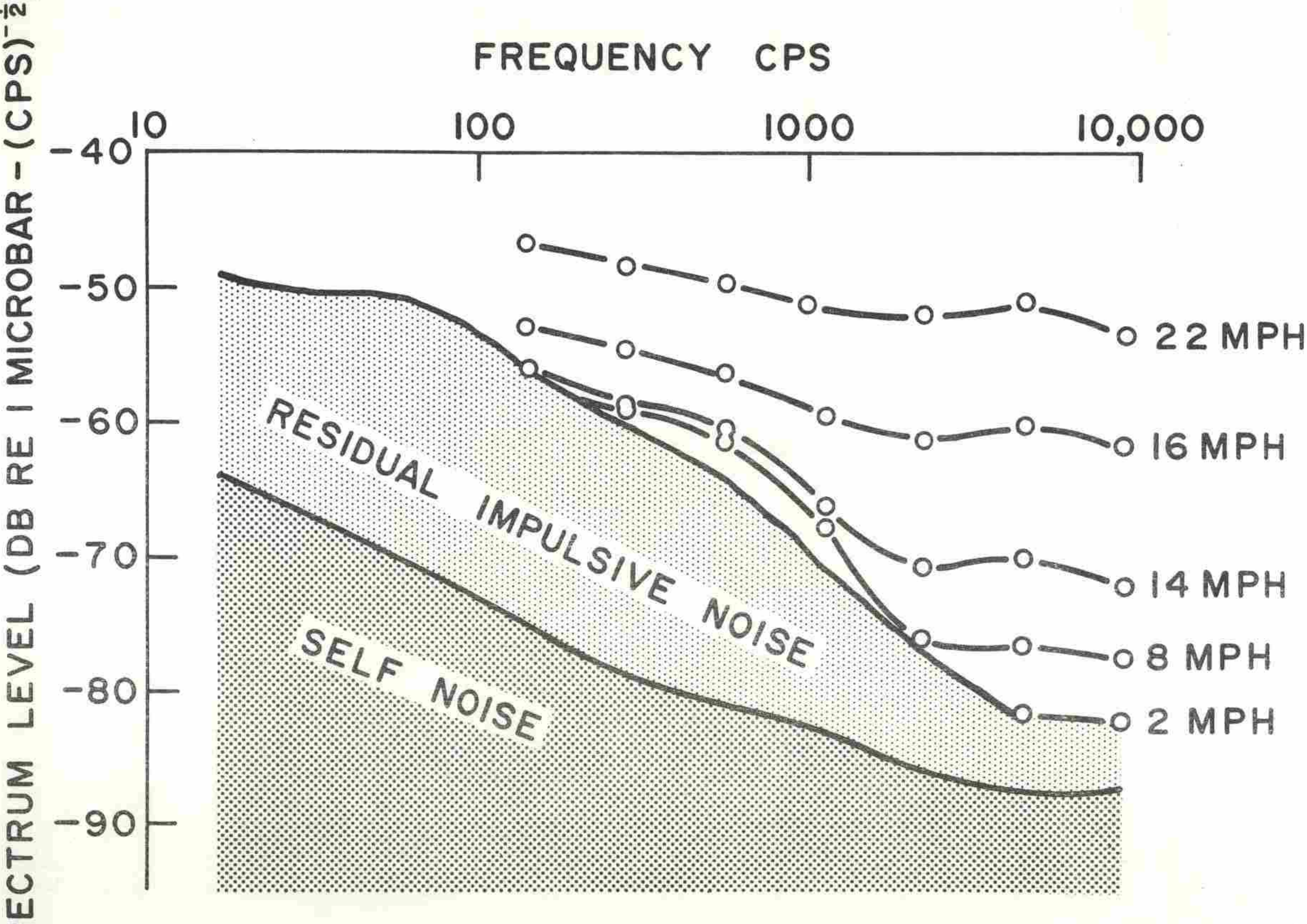

Figure 3: Noise spectra under shore-fast ice generated
by surface wind.

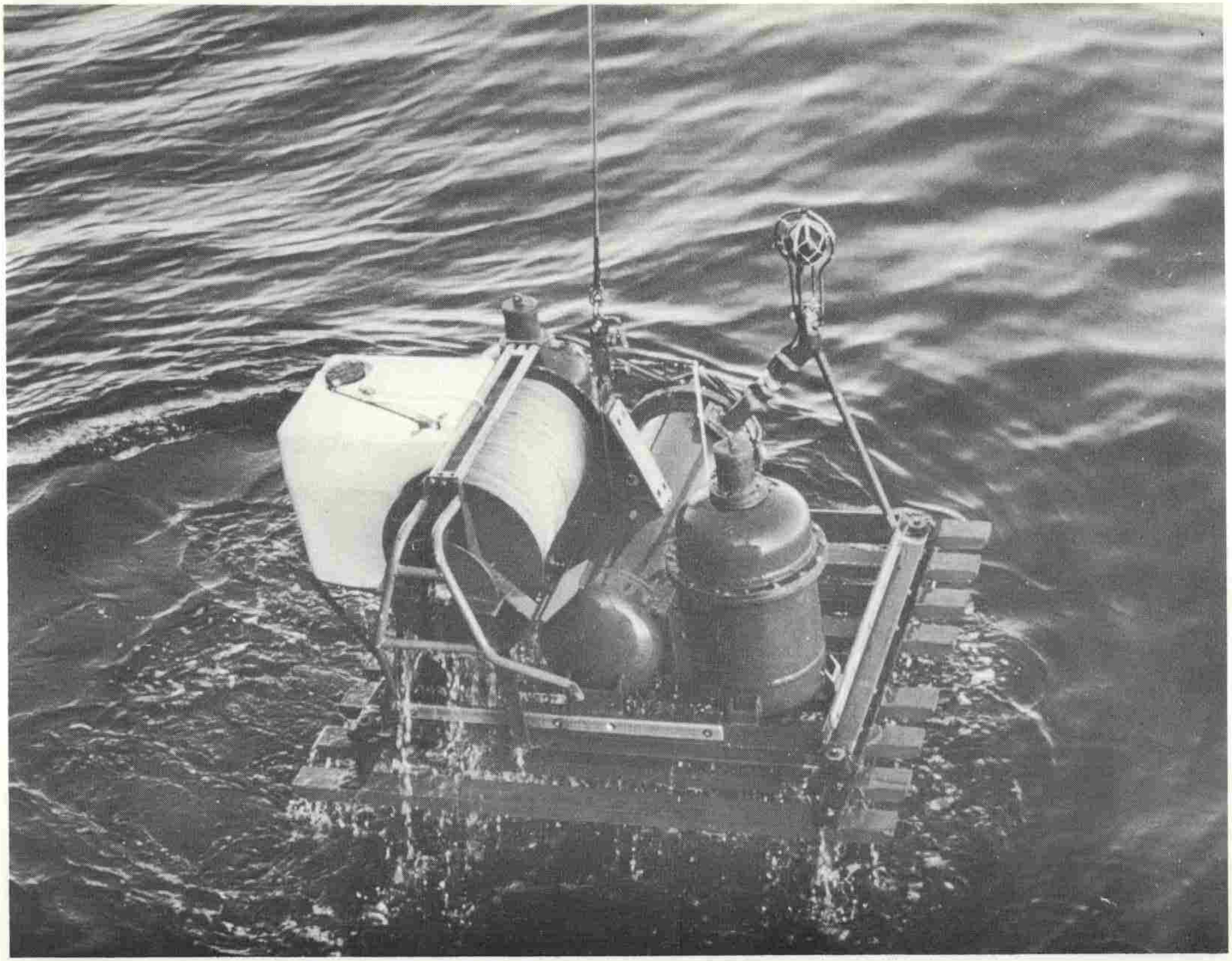

Figure 4: An RIP unit being lowered from CCGS LABRADOR.

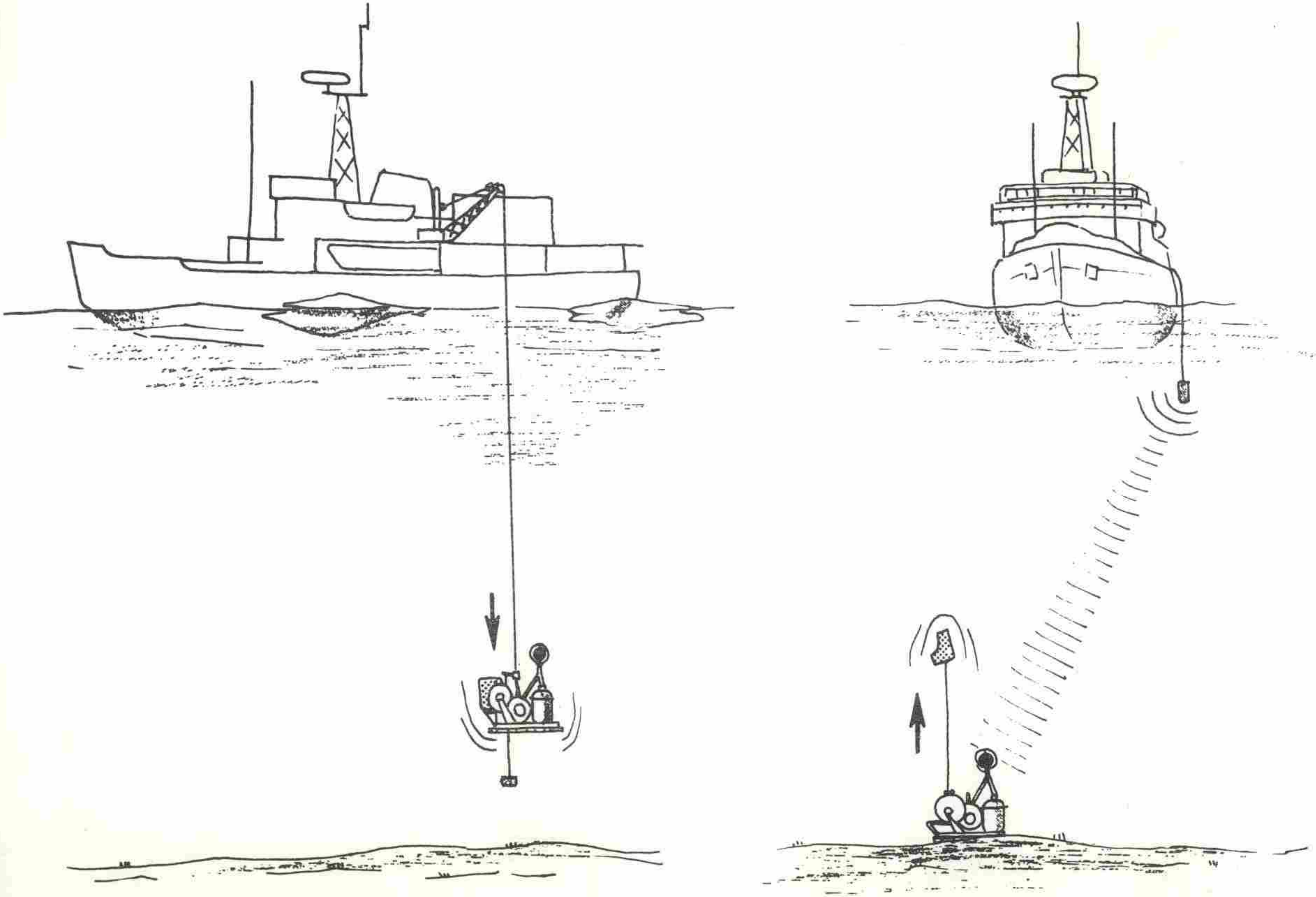

Figure 5: Sketches showing the installation and recovery of an RIP unit.

electronics used for processing the ambient noise. The RIP as described so far can be regarded as a general purpose recoverable instrument package. For our particular application, an electronics system was installed to measure and record acoustic ambient noise.

The electronics system was designed to record the average level of six octave bands of noise. These levels were recorded once an hour for one year on digital magnetic tape with an IBM format suitable for direct computer entry. System timing was provided by an "Accutron" watch movement driving switch contacts. A redundant analogue system, independent of the digital system, recorded the average level of one octave band of ambient noise on a chart recorder. The main battery packs used cheap carbon zinc "dry" cells and provided power for one year. The recovery system had a separate battery supply with capacity for three years. The extended life of the recovery system and of the corrosion protection was specified in anticipation of heavy ice which could have prevented the icebreaker from reaching an RIP site after one year.

The following sections describe some of the details of the electronic and mechanical design.

ELECTRONIC SYSTEM

Requirements

The design of any unattended measuring system requires prior knowledge to guide the choice of system parameters. A "worst case" for ambient noise under sea ice appeared to be described by DREP measurements made under mid-winter conditions (Ref. 3). This suggested that the RIP units should have a dynamic range of 50 db, with the ability to handle crest-factors of at least 10. The ambient noise was very impulsive and analysis had shown the need of long averaging times, of greater than one minute. An intuitive explanation of this requirement is that the averaging time must include a large number of impulsive events so that no one extra event significantly alters the average. For the RIP units an averaging time of four minutes was chosen.

The ambient noise spectra are fairly smooth and the spectrum can be defined adequately by octave-band analysis with measurements every second octave. The RIP unit made measurements in 6 octave bands: 10 to 20 Hz, 40 to 80 Hz, 150 to 300 Hz, 500 to 1000 Hz, 2 kHz to 4 kHz and 8 kHz to 16 kHz.

The earlier short term measurements had shown the noise to be relatively stationary over a period of twenty minutes, but there were usually significant changes over a period of 3 hours. This meant that the octave bands could be sampled sequentially in time, and we chose to repeat the measurements every hour.

Block Diagram

A block diagram of the measurement electronics is shown in Figure 6. Given the above-mentioned requirements, the form of the instrumentation was set by the following decisions:

1. To record a simple average of the sound pressure rather than the desired root mean square of the sound pressure.

2. To use a Bulova TE-16 timer for all system timing. This consists of an "accutron" watch movement driving mechanical switch contacts.

3. To record the data digitally in an IBM format suitable for direct entry into a PB250 computer.

The ambient noise sound pressure signals were received on a spherical barium titanate hydrophone manufactured by the Defence Research Establishment Atlantic and with a sensitivity of -76 db re 1 volt per μbar. The signals were fed into an FET preamplifier and from there to a parallel bank of six octave-band filters. The 10 to 20 Hz filter was active, the others passive. The "accutron" timer controlled electronic switches which selected a particular filter output by applying power to the

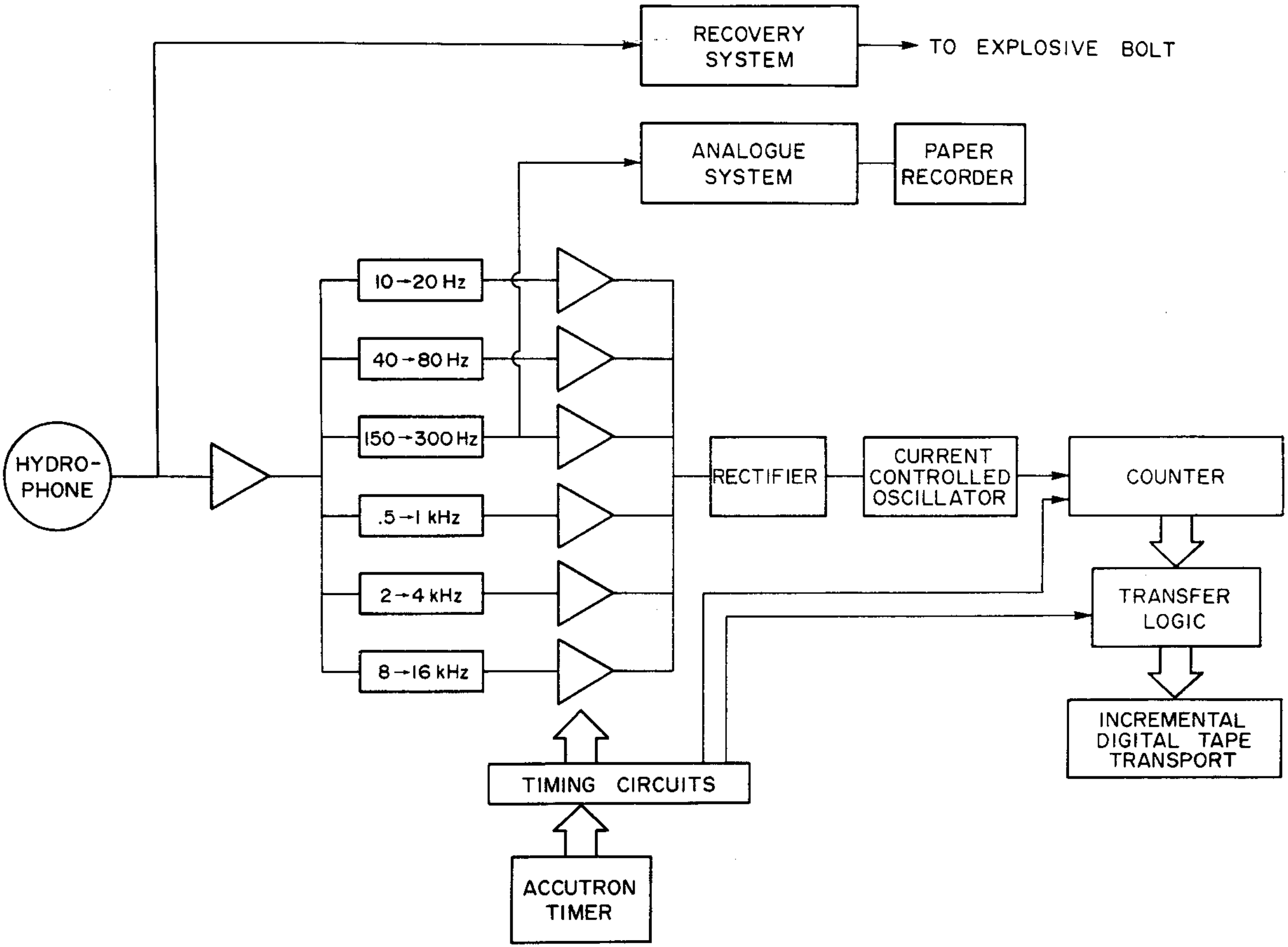

Figure 6: Block Diagram of RIP Electronics

appropriate amplifier following the filter. Designers used to high-speed sampling should pause to consider the leisure allowed by averaging times of four minutes duration separated by dead times of one minute. The noise signals were rectified and used as inputs to a current-controlled oscillator (ICO). The pulse repetition rate of the ICO was of a frequency corresponding to the average amplitude of the noise signal. The dynamic range of the system was set primarily by the rectifier circuit. The input-output relationship between the preamplifier input and the ICO output is shown in Figure 7. The pulse repetition frequency at the output of the ICO was counted by a micrologic counter for a four minute period. The counting served to integrate the signal and to perform an analogue-to-digital conversion. At the end of a particular four minutes interval, the most significant 12 bits of the count were written on digital magnetic tape in a standard IBM format (NRZ1 recording, 7-track, 200 bpi). The incremental tape-transport was controlled by micrologic gates; an interrecord gap was inserted once a day.

As an expression of a lack of faith in digital systems, one channel of analogue recording was included. The output of the 150 to 300 Hz filter was used to drive a logarithmic amplifier which fed a Rustrak paper chart recorder. The analogue system was activated for four minutes every hour.

The recovery electronics was a completely separate system manufactured by Research Manufacturing Corporation which incorporated minor modifications made by DREP.

The following sections describe selected portions of the electronic system design. There will be no attempt to give a complete description of the electronics or to discuss design at the circuit level. The basic design aims were to keep the system as simple as possible in the interests of reliability. The design, from original conception to completed prototype, took five months and this was accomplished by using standard techniques as much as possible.

This report will dwell on the problems and deficiencies, but it should be kept in mind that the RIP design was basically very successful. The main problem areas concerned the purchased components, which included the timer, the tape transport, and the underwater connectors.

System Errors

The major systematic error arose from the decision to measure a simple average of the rectified ambient noise-pressure rather than the desired rms of the noise pressure. The first and second moments of the rectified signal are related by the amplitude distribution function of the noise, and for the under-ice ambient noise the amplitude distribution function is known to be highly variable. If a system is calibrated for

Gaussian noise, then the errors are a maximum for the highly impulsive ice-cracking noise. Errors were calculated using samples of ambient noise recorded in the springtime and these showed that errors of up to 3.8 dB can occur. These errors occur from imputing rms values to measurements which are actually simple averages and are in addition to any errors in the measurement of the simple average. These systematic errors were accepted since the requirements of high dynamic range, low power consumption, and simplicity, were incompatible with the measurement of true rms values. Note that the impulsive nature of the noise made the large dynamic range necessary on an "instantaneous" basis, and AVC or a stepped gain system was considered impractical. The impulsive nature of the noise meant that our readings were always low. A change in the calibration scales would allow the maximum error to be expressed as plus or minus 1.9 dB.

In retrospect, the decision to measure simple averages still seems reasonable, although the latest circuit techniques of stepped gain systems (Ref. 11) would have to be examined carefully.

The analogue system was carefully calibrated and much of the nonlinearity indicated in Figure 6 could be removed in processing if it seems desirable.

Further errors were introduced by the timing system. The clock itself was very good (3 minutes per month) but the readings were affected by the interval between contact closures, nominally four minutes apart. The specifications quote a maximum error of 5% but there are indications that timing errors were worse than this. These timing errors are percentages of the value measured, not of full scale value.

In summary, the major source of error was the systematic error introduced by measuring a simple average when an rms value was desired. From prior knowledge these errors were always negative, the measured value being lower than the actual value, and will be a maximum at low acoustic frequencies during noisy periods.

Timing

All the timing was based on the Bulova Model TE-16 timer. This unit consisted of an accutron watch movement driving mechanical contacts which, functionally, were rotary switches. One wafer provided a separate contact for each minute of the hour. A second wafer provided a separate contact for each hour of the day. These contacts were used to control the supply voltages applied to the various circuits. The quality of the contacts was not suitable for switching low-level signals. Switching transients were avoided by inserting a time delay between the operations of turning on the supply voltages and opening the gate of the counter. The model TE-16 timer is small, accurate, consumes negligible power, and

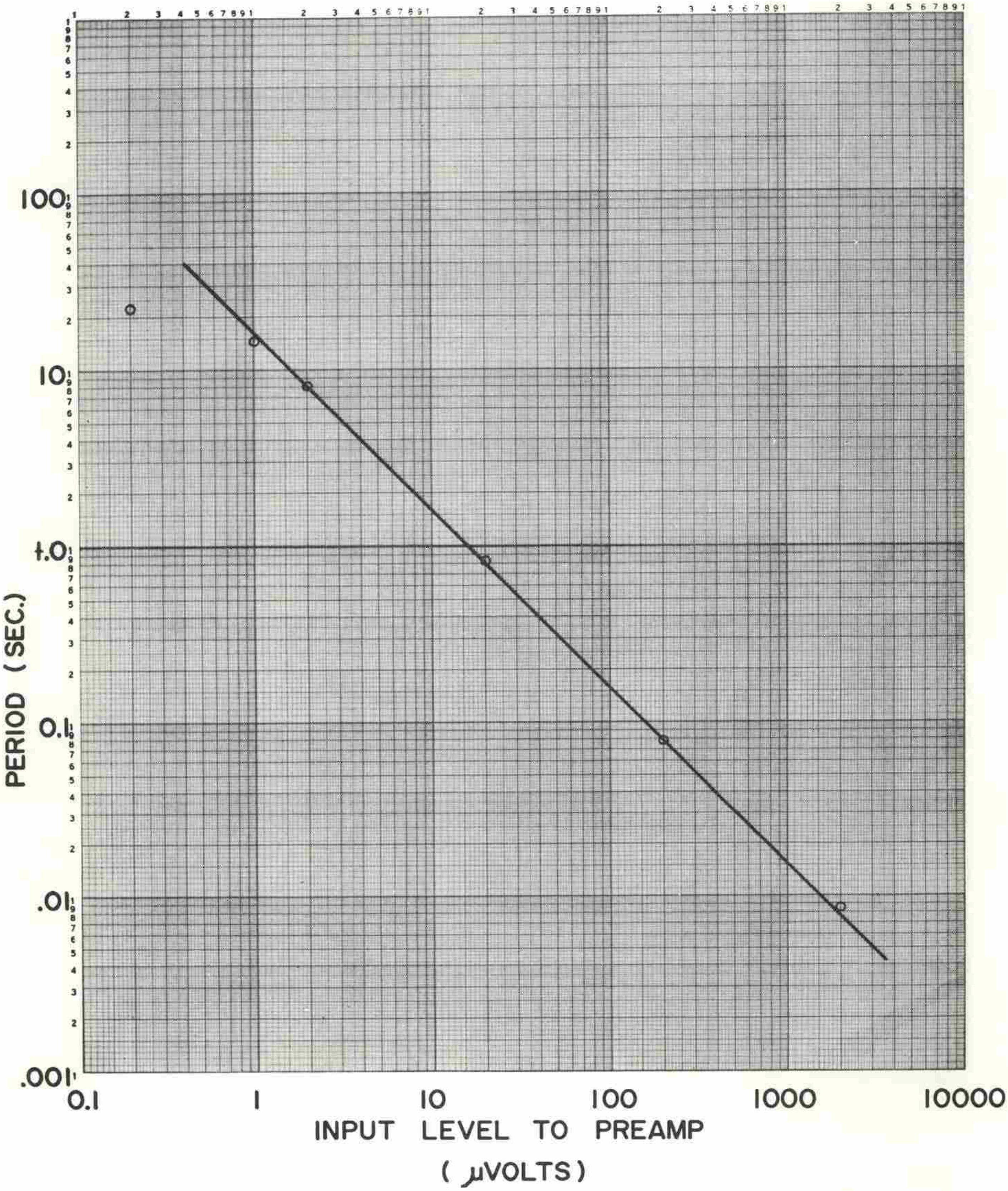

Figure 7: Relationship between the noise input to the preamplifier and the frequency output of the current controlled oscillator. The line represents a linear relationship.

allows for very flexible timing arrangements. Unfortunately the contacts were unreliable over the time periods required by an RIP unit. The power input to the timer is very small, so that the switch contacts must operate with low contact pressure. As a consequence, the unit is very susceptible to any contact contamination. The reliability of the clock movement itself was very good but the reliability of the switch contacts was poor over the 18-month period of interest. After approximately twelve months of operation there was a complete failure of some of the switch segments.

Figure 8 shows a portion of the timing system. Switch contacts on the timer were used to set and reset direct-coupled transistor flip-flops of the PNPN type (Ref. 5). The flip-flops supplied dc power to the appropriate circuitry. The advantage of the PNPN structure is that it consumes negligible power in the "off" condition. Smooth switching occurred if some form of contact closure occurred within the prescribed minute-switch segment.

The timer was one of the weak points in the RIP design. There was, however, no commercially available alternative which did not require vastly more power and complexity.

Recovery Electronics

The recovery electronics were purchased from Research Manufacturing Corporation of San Diego. It is an underwater acoustic system which responds to frequencies between 14 kHz and 15 kHz. A coded underwater acoustic signal, consisting of the presence of two tones and the absence of a tone of intermediate frequency, triggers an electronic switch which is then used to fire an explosive-bolt. A block diagram of the receiving system is shown in Figure 8. The main ambient-noise hydrophone was also used to sense the recovery signals. An amplifier/clipper drives three high Q resonant circuits and a simple logic gate detects the presence of two frequencies and the absence of an intermediate frequency. The receiving system was purchased in the form of electronic boards and the only changes made were the replacement of all electrolytic capacitors with tantalum electrolytics and the replacement of the output relay with a transistor switch. In our application the recovery system was powered with two mercury batteries of the Mallory wound-anode type, which operate satisfactorily at temperatures of $0^{\circ}C$. Each battery had the capacity to power the recovery electronics for 18 months, the two batteries being isolated from each other with diodes. The mercury batteries were placed in the main electronics case and therefore were not affected by the connector problems which plagued the main battery system.

The recovery system was reliable during testing and during operation. The testing was carried out in an area of heavy shipping and there were no false triggerings. The range for interrogation seemed to be more a function of sound conditions in the water than of transmitter power. The command transmitter package was used as supplied by REMCO. The transmitter sends one frequency at a time and switches back and forth between the two command tones. One-shot circuits in the detectors "hold" the code. This switching scheme avoids the deleterious non-linear effects inherent in the amplifier and clipper combination. In the channels of the Arctic Archipelago, a ship's navigation is usually excellent so that the recovery system was not required to work over a distance of greater than a mile. The filters used to pass the code frequencies were slightly temperature-dependent; however, the Arctic seas act as an excellent constant-temperature bath.

Main Power Supplies

The main power source was a series-parallel combination of "number six" cells of the common Leclanche or carbon-zinc type. The cells were a special MWA grade developed by Union Carbide for very high capacity at low discharge rates. Each cell was rated at 85 ampere hours at $70^{\circ}F$ and 55 ampere hours at $32^{\circ}F$, in each case with a continuous 17 ma current drain. Individual cells were purchased and wired into batteries at DREP. Each cell was jacketed with a plastic bag to inhibit the effects of leakage, and then the battery was potted in microcrystalline wax.

The analogue electronics ran on 22 volts while the micrologic required 3.5 volts. These voltages were supplied by electronic regulators from the nominal battery voltages of 36 volts and 6 volts. The battery system was designed to discharge each cell to 1.0 volts in 13 months.

The batteries were divided into two identical halves, with the two halves isolated from each other by diodes. This meant that catastrophic failure could take place in either half and the system would still operate for six months.

The carbon-zinc cell is often regarded as cheap and nasty, but with the MWA grade cell on low discharge rates, the watt hours per pound and the watt hours per cubic inch are very competitive with more expensive power systems. The main disadvantages are that the cells must be protected with a pressure case and that they evolve hydrogen and water vapour during their discharge.

Digital System

The digital portion of the RIP was designed using RCTL micrologic (Resistor-Capacitor-Transistor-Logic) of the Texas Instruments series SN51A. This was the only low-power integrated circuitry available at that time. Discrete components were used in the design of one-shot units for millisecond and second timing. Integrated circuits were chosen primarily for reasons of reliability and there were no integrated circuit failures in the RIP program. A disadvantage was the high power consumption of

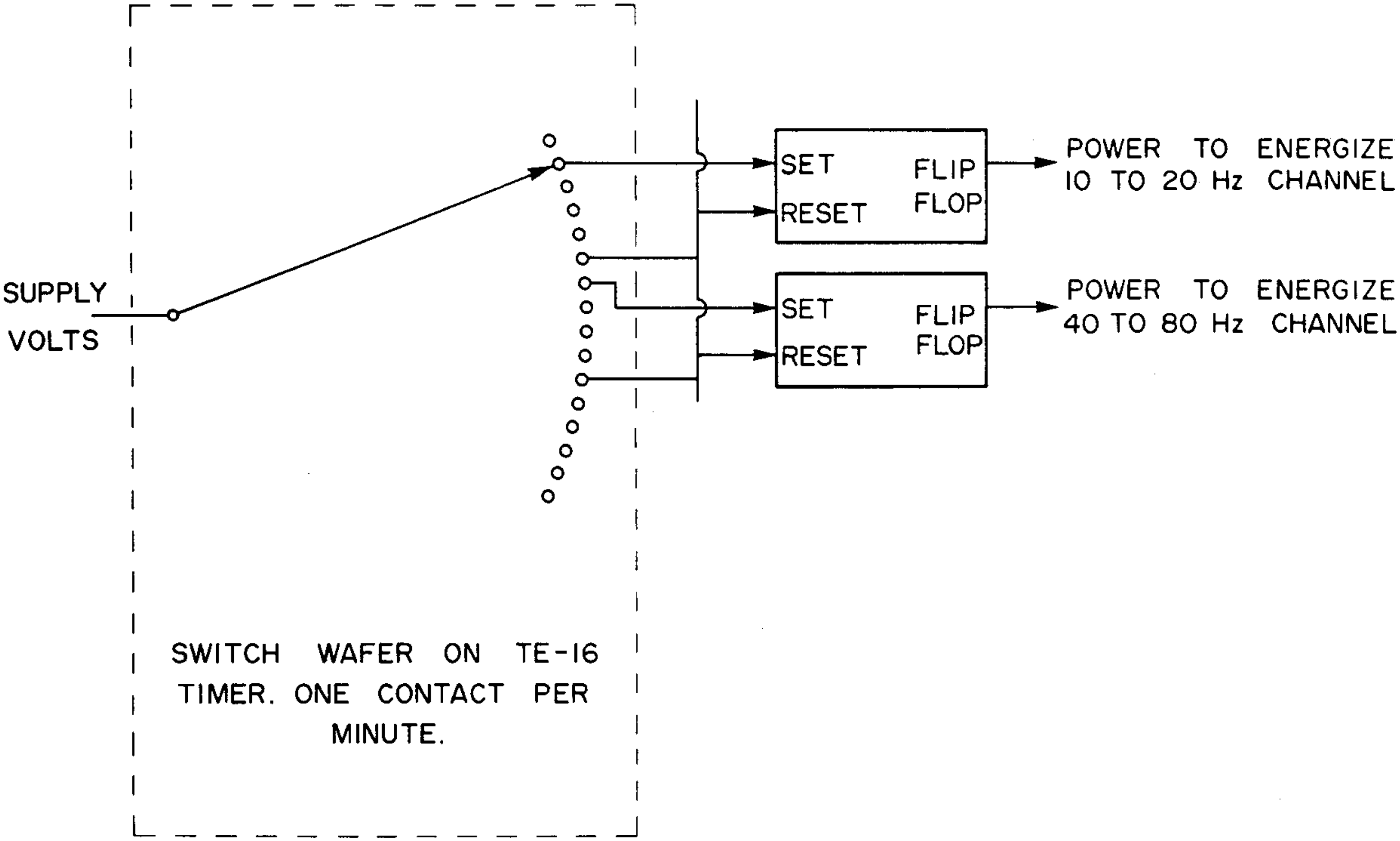

Figure 8: A portion of the timing system showing how the minute contacts were used to switch flip-flops.

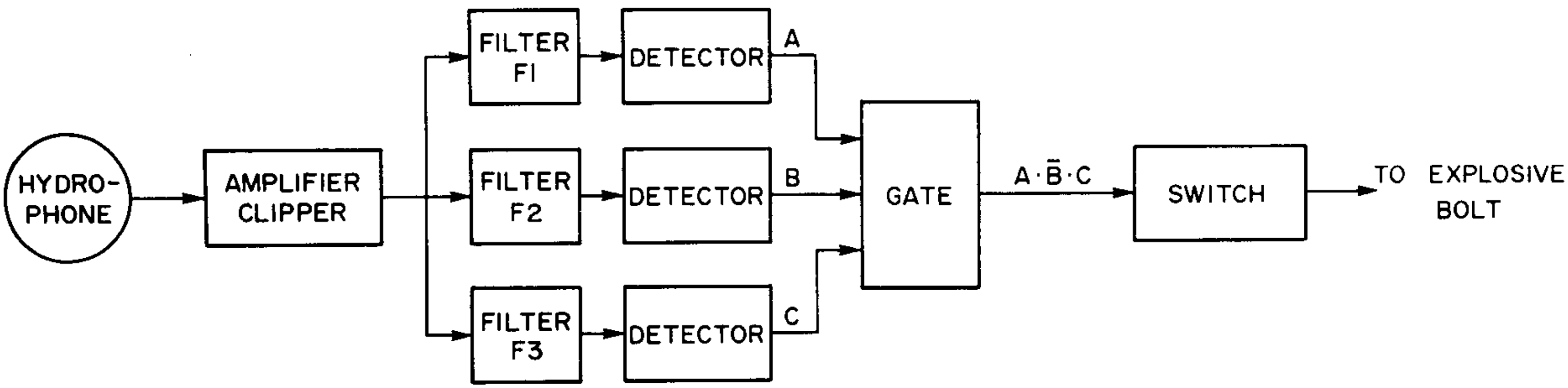

Figure 9: Block Diagram of receiving portion of recovery system.

the integrated circuits. Circuits using discrete components could have used less power than was used by the SN51 series. Additional advantages of the micrologic were their small size and, considering construction overhead, low cost. This type of application, where low power drain and reliability are very important and speed is not a consideration, would seem natural for a digital system based on magnetic elements. DREP did not have any experience with magnetic systems and a more conventional design was used to shorten the development time.

Figure 10 shows a block diagram of the RIP digital system. The 13-bit counter was used to integrate the frequency output of the current-controlled oscillator (ICO) for a four-minute period, and the counter simultaneously effected an analogue to digital conversion. The remainder of the system was used to write the data on digital tape in standard IBM format. This meant breaking up the twelve-bit data word into two six-bit bytes and generating appropriate parity bits. A 7 bit tape register was required for non-return to zero (NRZ1) recording and since it remained on, it was a major power drain. A power control system ensured that most of the logic circuitry was switched off most of the time.

DREP's "in house" PB250 computer operated with an 18-bit word so that it was convenient to write a byte of zeros between each RIP data sample. An inter-record gap was inserted once a day.

One problem was encountered in the micrologic design when a high fan-out flip-flop was required to drive the clock input of another flip-flop. The clock input had a capacitive coupling which leaked, typically 10-60μA. Unfortunately the sink provided by the SN51A high fan-out flip-flop was through a diode. The result was that, when the output of the flip-flop was supposed to be zero volts, it actually increased to about 0.6 volts, which was sufficient to upset the operation of gates which operated from the same point. A resistive load to ground provided a suitable sink for the leakage current, but reduced the fan-out capacity. A more recent series, SN51B, replaces the diode with a saturating transistor having a lower voltage drop.

The digital electronics worked very well and was very reliable, in strong contrast to the incremental tape transport described in the next section.

Digital Tape Recorder

The primary method of recording data was on digital magnetic tape on an incremental tape-deck. This unit is shown in Figure 11. It is compact and has attractive specifications but, as delivered, none of the five transports was capable of moving tape. A variety of mechanical faults and failures suggested poor workmanship, or a lack of adequate testing, or both.

Some examples were:

1. Tape-drive jamming.
2. Sticking of the take-up control arm which permitted the tape to advance but not to be taken up on the reel.
3. Unwanted gaps of several tape characters occurred because of erratic operation of the take-up motor cam assembly. Excessive pull on the tape resulted when the take-up arm came up against the edge of the take-up reel.
4. A capstan head was rubbing the guide-pillar next to it and jamming.
5. Pressure pads holding the tape against the head became unglued and caused jamming. These were removed.
6. Some grub screws on the main drive shafts were loose.
7. In all recorders, movement of the take-up assembly pushed against and moved the leads from the head coils.

The head current was specified as 0.6 mA per track, but the heads that were actually supplied required 2.5 mA and consumed considerably greater power with NRZ1 recording. The capacity of the tape reel was rated at 250 feet of 1 mil tape; even by mathematical calculation this was not possible. The reel held 180 feet of 1 mil tape or 120 feet of 1.5 mil tape. It was decided to use 1.5 mil tape because no certified computer tape of 1 mil thickness was available. This allowed just enough tape for a one-year operation.

The RIP time scheduling was such that the selection of a replacement recorder would have meant postponing the RIP installation for a year, so the various flaws were repaired or accommodated. A basic problem which could not be repaired was the large and variable skew produced by the tape deck.

The end result was that the data were recoverable, but only at the expense of modifications to the playback transport.

<u>Paper Chart System</u>

The output of the 150 to 300 Hz filter was fed through a logarithmic amplifier, rectified, and recorded on a Rustrak recorder for four minutes each hour. Once a day the recorder was run for one minute with a grounded input to make a timing mark. Samples of the paper chart record are shown in Figure 12. This analogue system was developed for an earlier measurement system (Ref. 6) and three sets of equipment were in existence at the start of the RIP program. The paper record is almost a

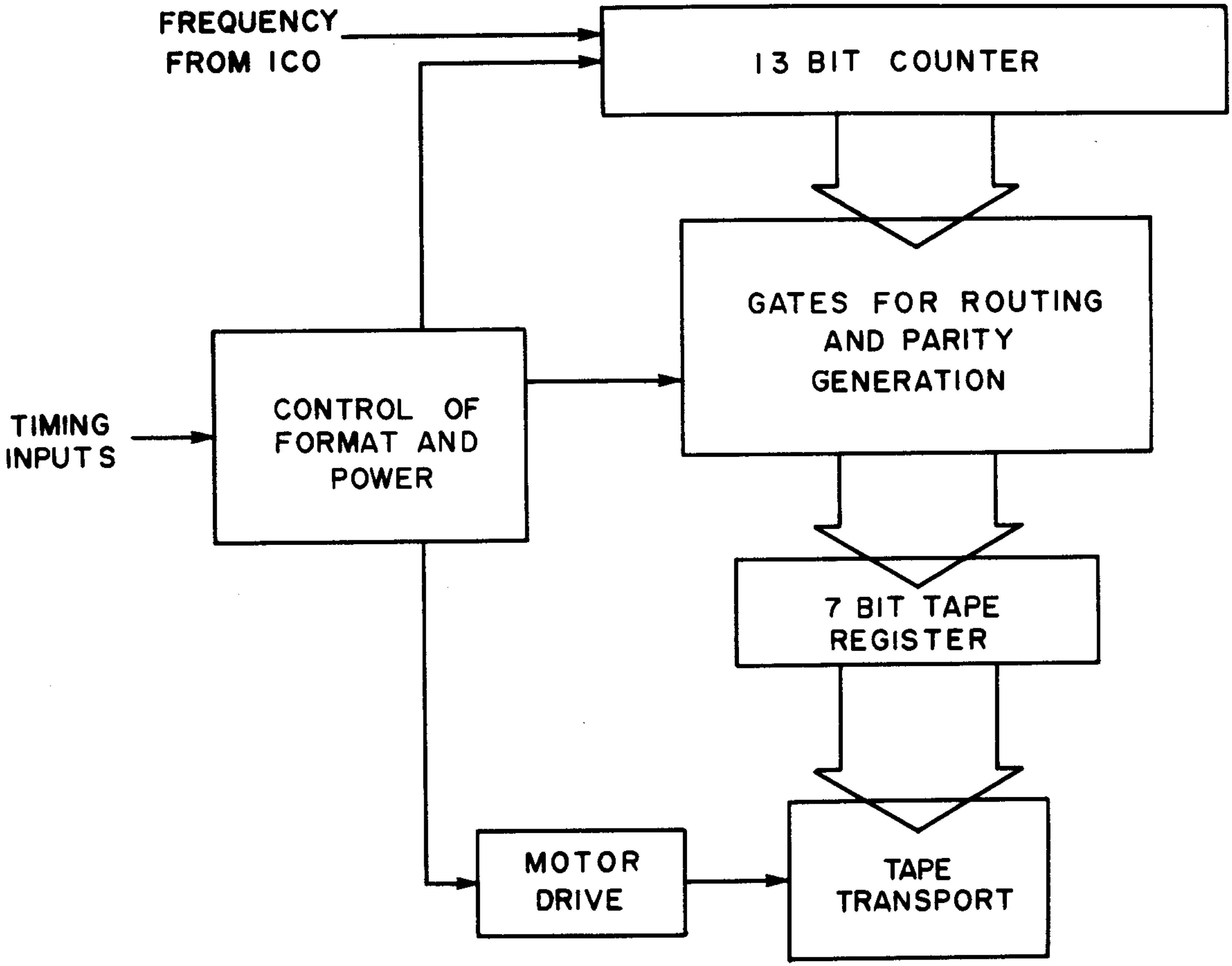

Figure 10: Block diagram of the RIP digital system.

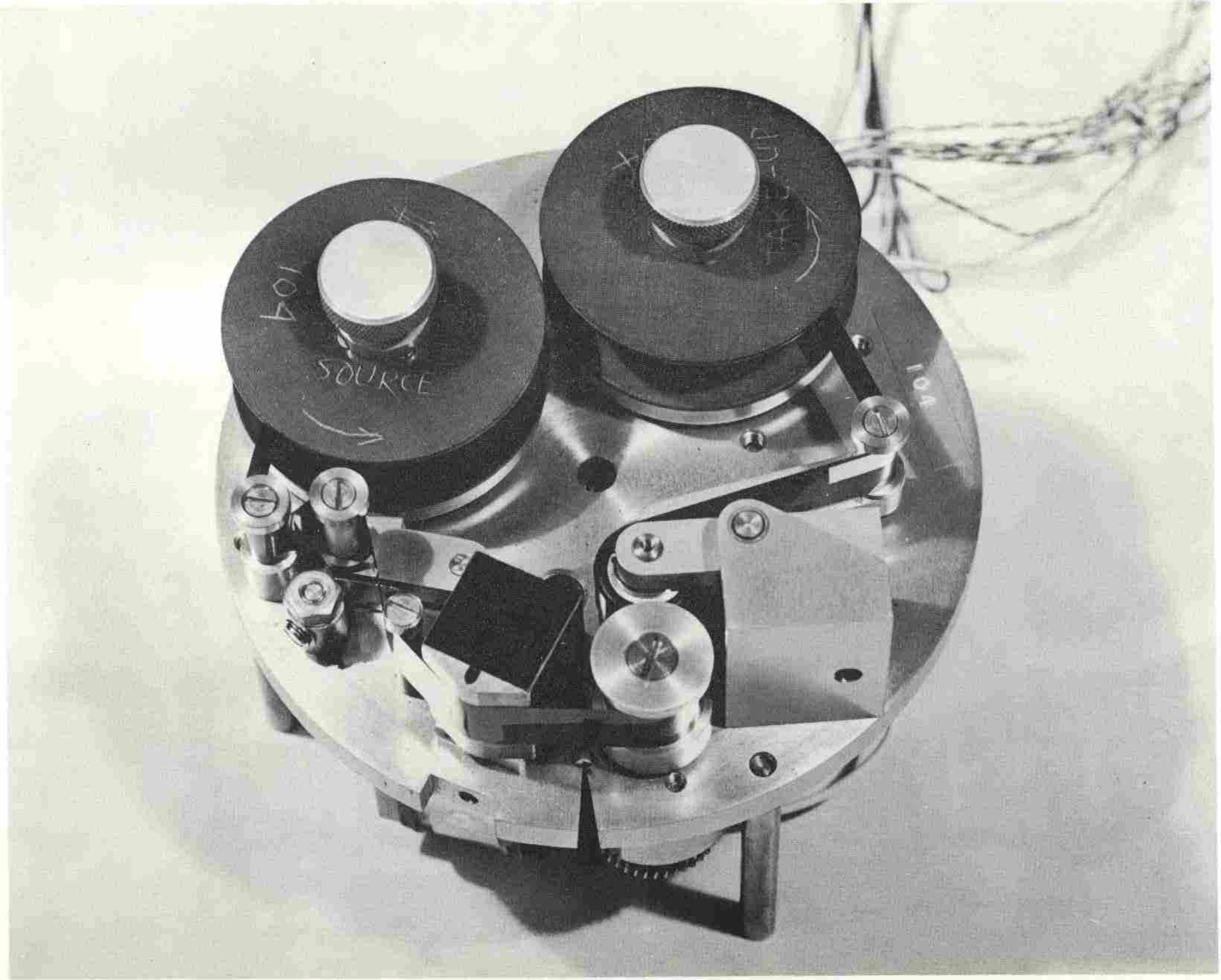

Figure 11: Digital Incremental Tape Transport. The scale is given by the half inch magnetic tape.

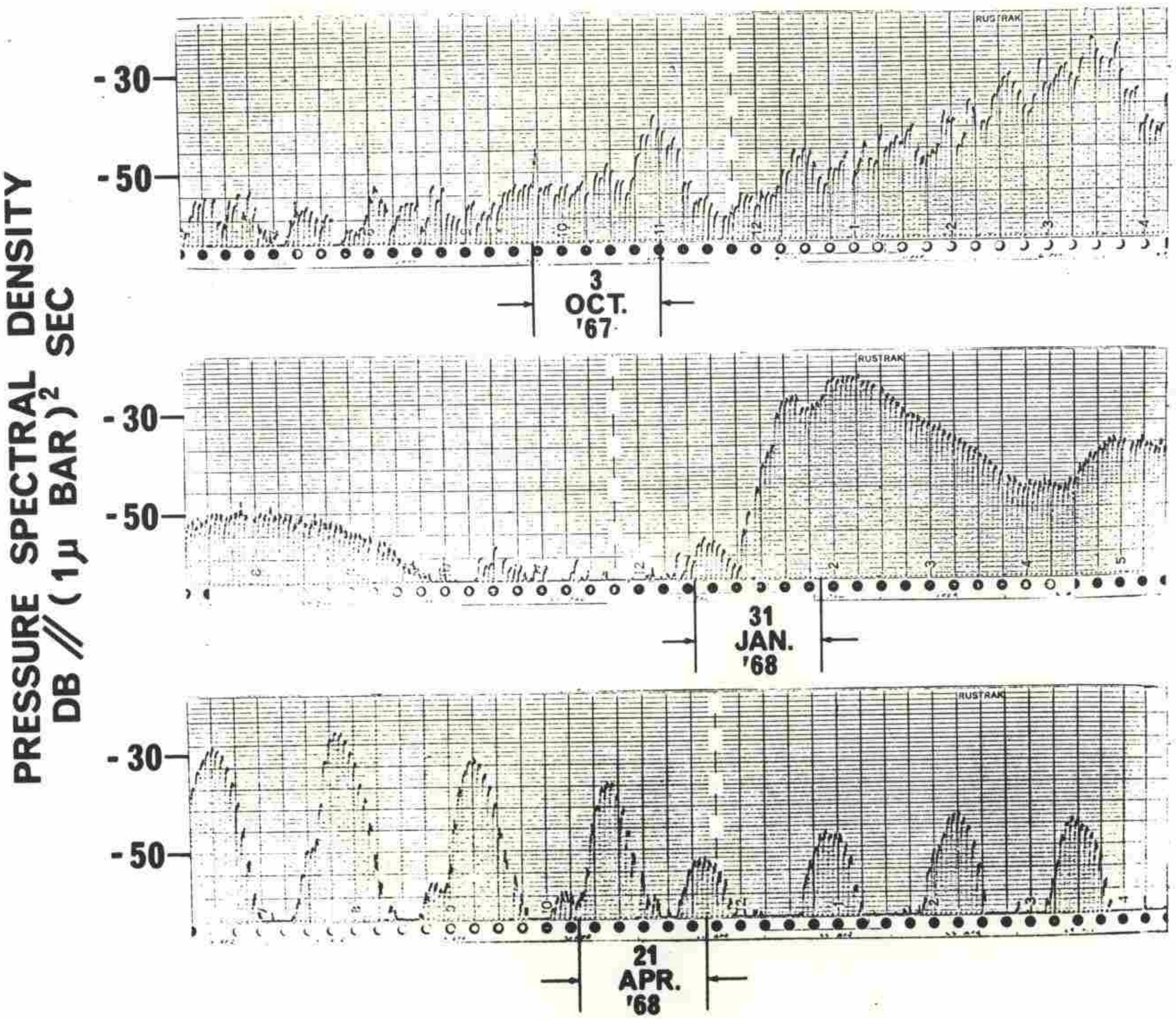

Figure 12: Selected samples of ambient noise in the 150 to 300 Hz band recorded on a Rustrak recorder.

repeat of part of the data recorded on the digital system. The difference was that the paper chart recorded the average of the instantaneous logarithm of the noise signal while the digital system recorded a simple average of the rectified noise. In theory the difference in these two averages should give an insight into the impulsiveness of the noise. Our motivations, however, were simply "reliability through redundancy".

The Rustrak recorder was sealed in a lead box for acoustic noise isolation. The recorder was not running while the digital system was making measurements.

Electronic Construction

The electronics chassis is shown in Figure 13. The electronics boards were bolted on both sides of three steel panels 29" by 9½". One of these panels formed the center web of an I beam structure and the other two panels were hinged on the outside of the I beam. The electronics boards were laid out with all their components and wiring on one side of fibreglass boards as shown in Figure 14. This meant that every component and connection was readily accessible without unbolting any of the electronics boards and without using any connectors. There was a deliberate attempt to avoid all forms of pressure contact. The only switch contacts were in the Accutron timer and the only connectors were the underwater connectors joining the pressure cases. Perhaps there is significance in the fact that two of our major sources of failure were in the Accutron contacts and in the underwater connectors.

The electronics boards used normal layouts with a moderate component packing density. The volume required for the electronics had to be specified early in the development program and the board space was about twenty per cent more than was actually used. The electronics system could obviously be reduced in volume by at least a factor of two without resorting to heroic measures such as cordwood packaging. This procedure would not have reduced the overall size and weight of the RIP unit significantly. It is certainly convenient to have a big chassis and it can lead to greater reliability.

The integrated circuit flat-packs were welded to printed circuit boards, but all the logic interconnections were hand-wired. DREP does not have an "in house" printed circuit capability so that hand-wiring was used throughout the system in order to achieve a short construction lead time.

All solder connections were carefully inspected and the standard of workmanship of the DREP technicians was excellent, but a major worry was still the dreaded "cold joint". Several cold joints were uncovered during testing and unfortunately one showed up after installation in the Arctic.

The construction standards were normal for Arctic field equipment. These included teflon insulated wires, kinks in all component leads, and tantalum capacitors where electrolytic capacitors were required. Plastic cased transistors were used without trouble. Reliability information available since the time of the RIP design indicated that metal cased transistors should be used for future designs. Rudimentary shock-mounting was provided by isolating the electronics chassis from the main case with strips of foam plastic.

The form of construction used for the RIP electronics was very satisfactory and would be used again if the low component packing density was acceptable.

Calibration and Testing

In addition to the original laboratory calibrations, the RIP system provided two calibration measurements every hour. Each hour, after the six samples of ambient noise were written on tape, the 360 Hz frequency from the Accutron oscillator was counted for a period of one minute and the twelve least significant bits were written on tape. This calibration acted as a check on the timer and on the digital system. Following this, the 360 Hz output voltage of the Accutron was attenuated to a known level and used as a calibration input to the rectifier-ICO combination. A normal four minute measurement was made of this calibration signal.

One difficulty with a self-contained system, such as an RIP, is in testing a completely assembled system. Our solution was to provide a small access port in the end-cap of the main instrument case to permit the RIP to accept a multi-pin Cannon connector and test cable. An external monitor could sense the inductive "kicks" from the tape-recorder head and permitted a printer to output a replica of the data being written on the tape. A small sensitive microphone inserted through the access port monitored the mechanical operation of the tape deck. The monitor system was connected for at least 24 hours immediately prior to lowering an RIP to the sea-floor. The recovery system was tested using a small light bulb in place of the explosive bolt.

Underwater Connectors

Cables were required to connect the main instrument case to each of the battery cases as well as to the hydrophone and to the explosive bolt. Each of these cables was terminated with connectors manufactured by Vector Cable Co. in Houston, Texas (type RM mating to bulkhead connectors type XSG).

These connectors were chosen because they had been very satisfactory in other DREP designs and also because they did not have any exposed metal parts and should have been free of corrosion problems. In the field these connectors failed after periods of from three to eleven months. The manufacturer claims that the failure was caused by a migration of moisture through the neoprene on the RM cable connector. A new

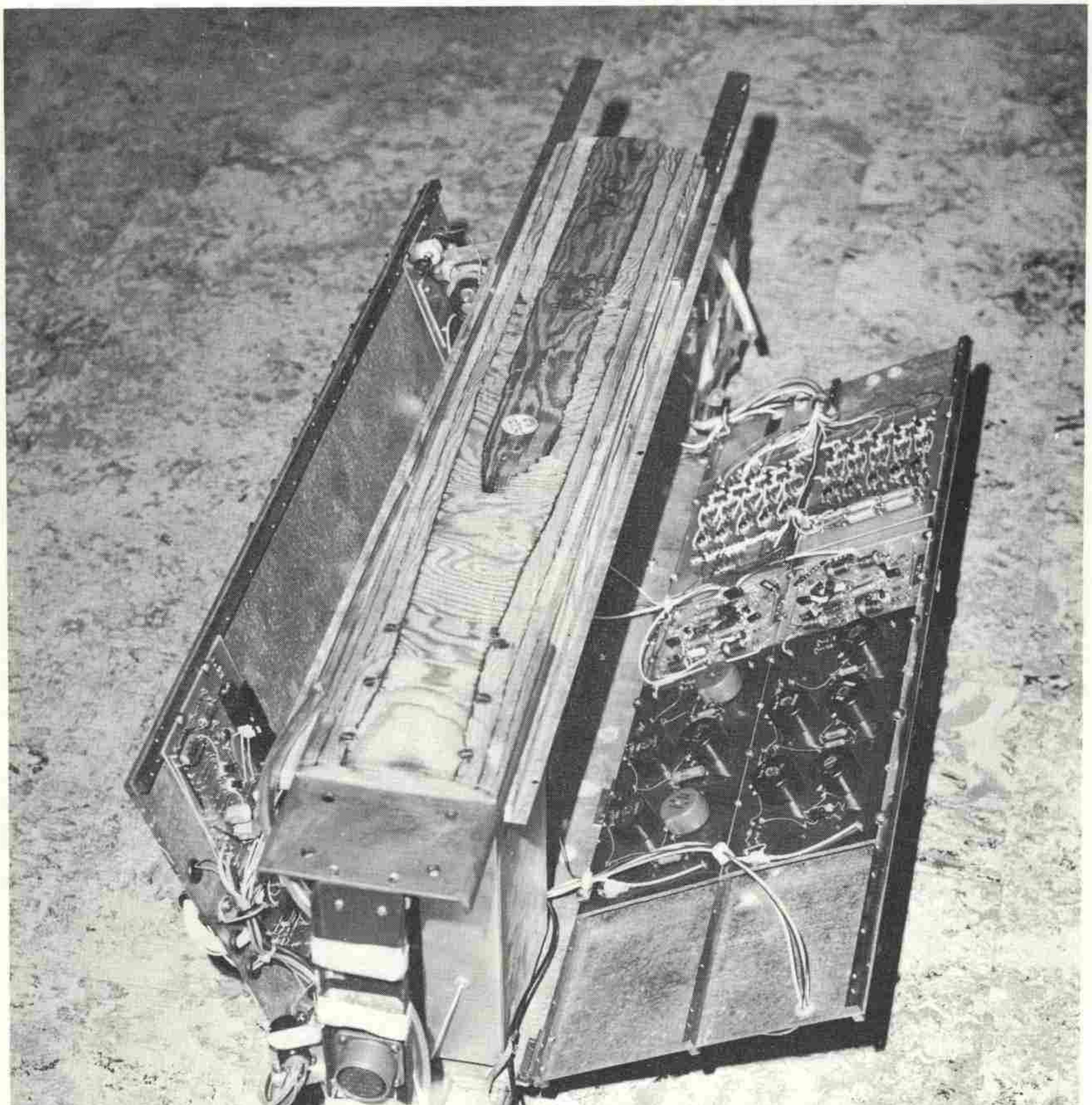

Figure 13: The electronics chassis with the hinged panels opened for servicing. The end connector allows system test through a port in the pressure case.

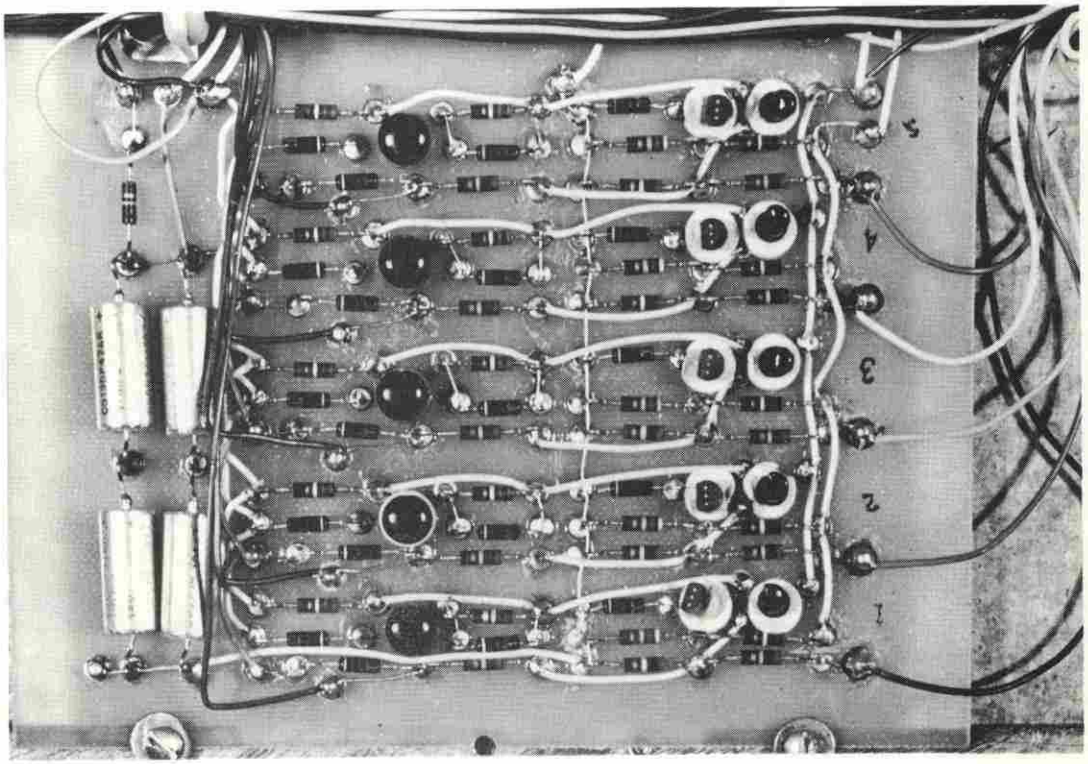

Figure 14(a): Discrete Component Construction.

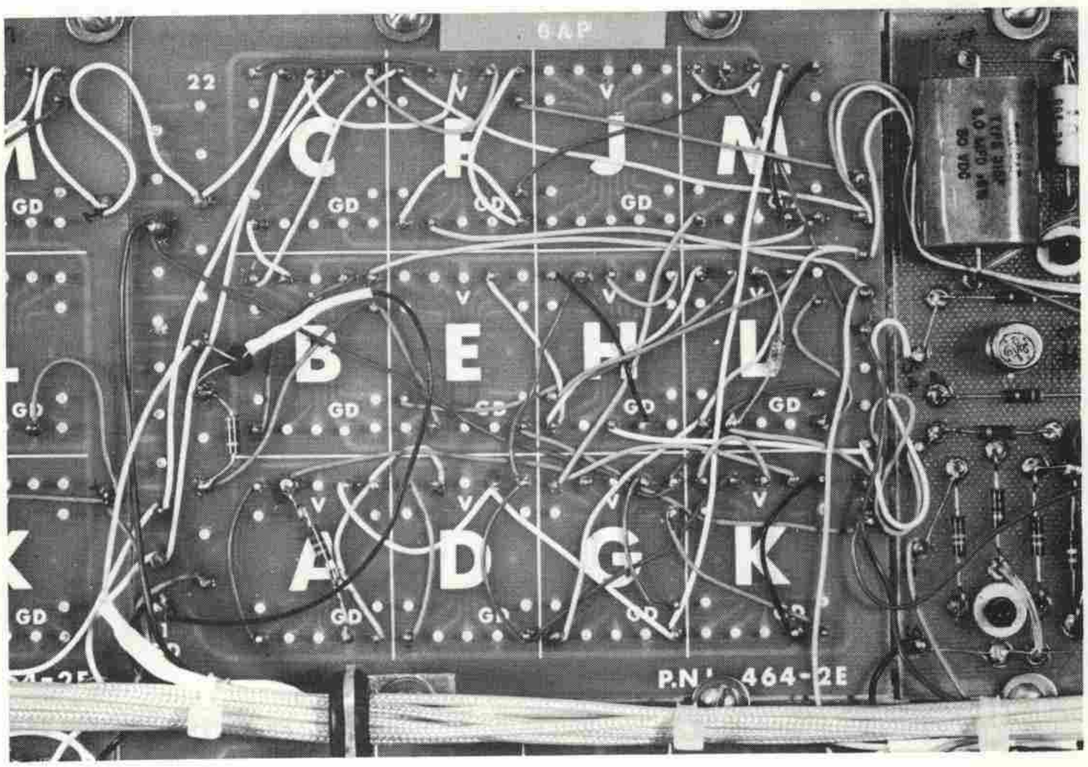

Figure 14(b): Integrated Circuit Construction. "Flat Packs" are welded on the opposite side of the board.

neoprene compound is now being used. There still remains a suspicion of capillary action but in any case, the effect was that salt water entered the connector and corroded off the pins where they entered the plastic bulkhead connector. Figure 15 shows a photograph of a new four-pin XSG connector and one from an RIP package. Except for those pins carrying positive battery voltages the cathodic protection of the main case also protected the connector pins. The RIP connector shown in Figure 15 was used for battery voltages and the two positive pins are corroded off while the two negative pins are in good condition. The effect was to disconnect the batteries from the instrumentation. The recovery system was not affected since the leads to the explosive bolt were active only when the bolt was fired.

MECHANICAL DESIGN

The primary requirements of the mechanical system were:

1. To develop a self-contained bottom-mounted system capable of recovery from 2000 foot depths.

2. To produce pressure cases suitable for depths to 2000 feet which would survive submergence for periods of up to two years.

3. To keep the design simple enough for rapid fabrication and cheap enough that sufficient units could be produced to allow for the attrition expected in Arctic operations.

There were, of course, a host of minor specifications such as the ability to cope with bottom slopes up to 30^{o} and the elimination of any possible sources of acoustic noise.

Several arrangements were considered initially including a spherical buoyant container for both the batteries and electronics, or alternatively, a similar container for the electronics only, but with an expendable battery pack to be used as the 'anchor'. The arrangement selected finally was one using cylindrical non-buoyant containers with an independent float to be released on command. This simplified the construction, the selection of materials, and the solution to the corrosion problems.

Materials

Steel was used for the battery cases, electronics case, winch drum and supports, main frame, and the radio beacon and dye pressure cases. Monel was used in critical areas where corrosion could affect reliability, such as in winch bearing journals, the winch shaft, fittings on the float, the explosive bolt and the hydrophone guard. Syntactic foam was used for the recovery float and lumber for the expendable sub-base, which was attached to the main frame with four magnesium bolts.

Main Pressure Cases

Two independent battery packs were used in each RIP unit, set vertically in opposite corners of a square frame, with the recovery winch and the hydrophone in the other corners and the electronics case lying horizontally in the middle. The three cases were fabricated of lengths of fourteen-inch outside diameter by half-inch wall seamless steel pipe with the corresponding pipe caps at each end. Since the full diameter of each case was required for loading the contents, special flanges were butt welded to the cap and to the pipe and the flanges were provided with double "O" ring face seals. Figure 16 shows the flange arrangement. All these main butt welds were of

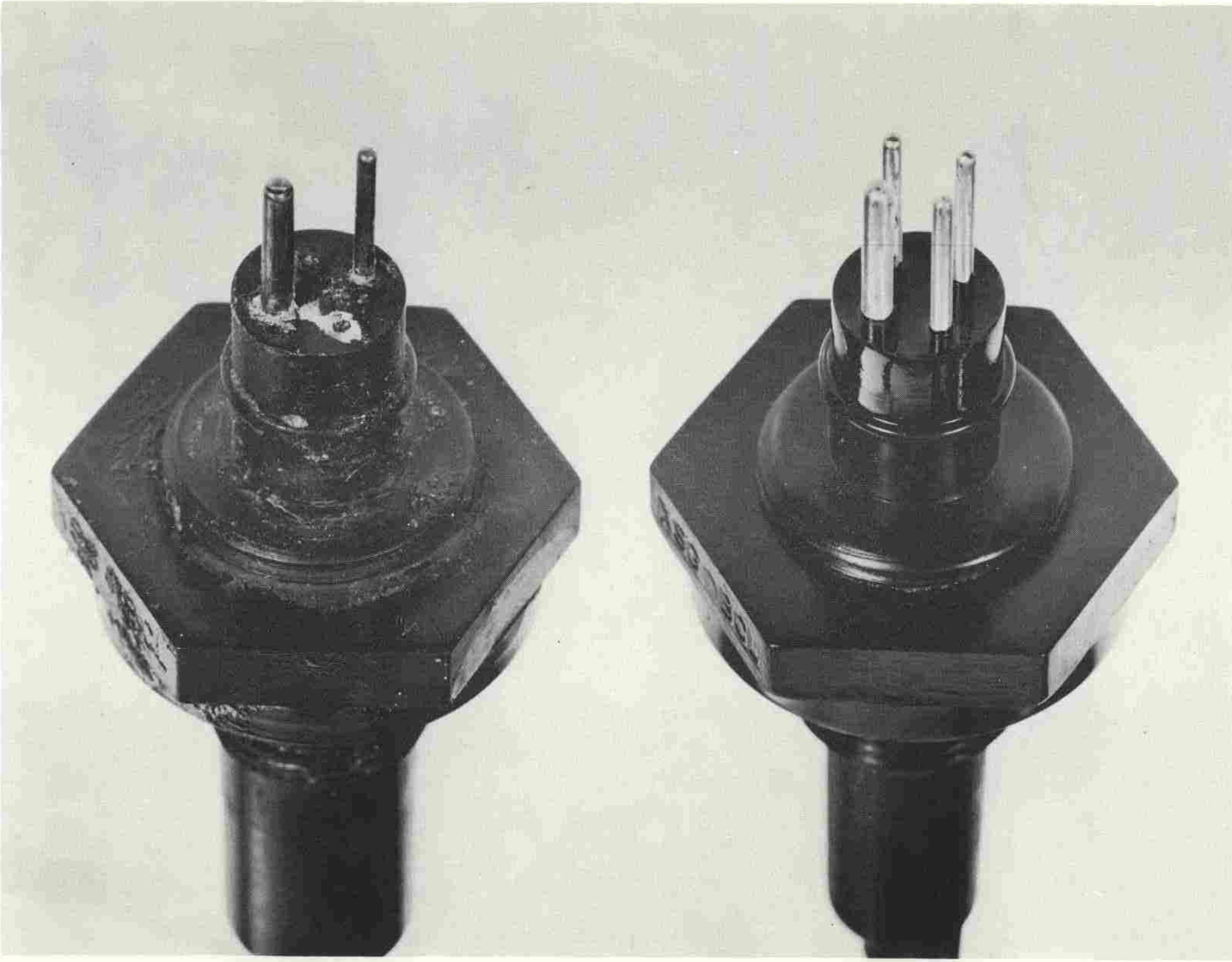

Figure 15: A new XSG four pin connector and an identical connector from a recovered RIP unit.

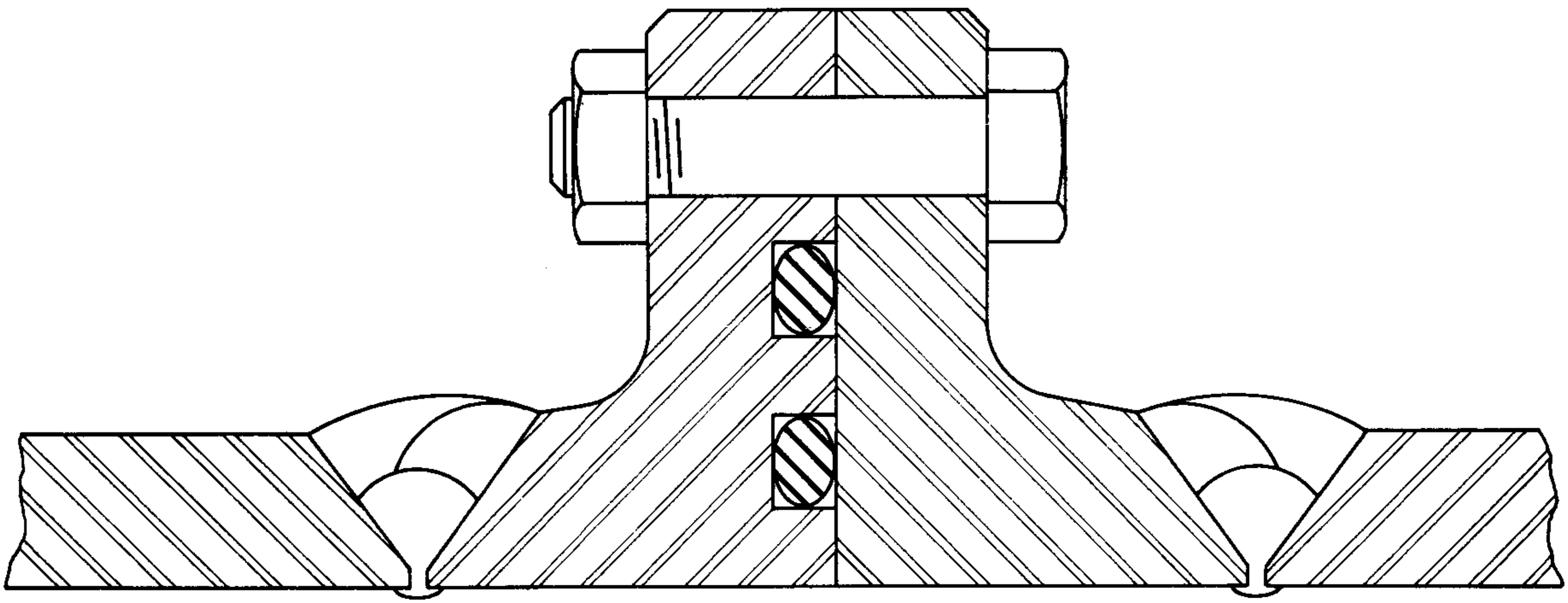

Figure 16: The flange arrangement for the main pressure cases which were constructed from 14-inch pipe.

the "single-vee" type and were X-Rayed to ensure their integrity. The "O" ring grooves and mating faces throughout the RIP units, including main cases, dye cases, radio-beacon cases, explosive bolts, and the mating faces for the bulkhead Marsh and Marine connectors, were all machined to the maker's recommendations for size and given a 32 microinch surface finish. Where-ever possible, double "O" rings were used and incorporated in face type seals. Dow Corning silicon stopcock grease was used on assembly, and care was taken to avoid the use of excess grease to prevent the occurrence of an hydraulic lock between the two "O" rings. Proper mating of the flanges was checked with feeler gauges after torqueing all bolts.

In view of the wide variation in calculated stresses given by different formulae for cylindrical pressures vessels subjected to external pressure, and also because of the variations in the shape, and hence stresses, in the end caps, a proof test was made on the first electronics case by lowering it in seawater to a depth of four thousand feet. This was twice the design operating depth. No leakage occurred but an inward permanent set of .002 to .003 inches occurred in the flat end plate which carried four Marsh and Marine connectors. This weakness was corrected by increasing the plate thickness.

Winch

The steel recovery line and the pilot line attached to the float were wound on a free-wheeling winch. The small net buoyancy of the float gave only a limited torque to rotate the winch, so that close attention had to be paid to the winch bearing design. It was not considered practical to use sealed anti-friction bearings or even those of the sleeve-bronze type, because of possible seal leakage after an extended immersion in seawater, especially at the design depth of two thousand feet. Seal friction could also have been significant unless pressure balanced seals were used.

Figure 17 shows the details of the bearings employed. The spherical journals eliminated the effects of any misalignment from either the bearing housings in their supports or from shaft deflection. This feature enabled the bearing supports to be welded in position rather than shimmed and bolted. In-line boring of the bushings after assembly was not possible.

The combination of monel running on teflon was selected to combat corrosion and provide a low friction bearing which would be satis-factory with seawater lubrication, in the event that the lubricant used leached out after prolonged immersion. The monel journals were machined and polished to approximately a four microinch surface finish. The teflon bushing was machined with a special twin blade cutter to provide automatically the desired wide diametral clearance of 0.015 ins. End float of 0.020 ins was individually set in each unit by machining the spacer between the journal and locking collar. Finally, a grub screw embedded against a suitable relief on the shaft was used to prevent rotation of the journal on the shaft.

In testing the winch and float assembly it was found that when the float reached the surface, overrunning of the winch drum occurred due to its inertia. This overrunning could possibly cause a fouling of the pilot line. To prevent this condition, a simple paddle wheel was added to the outer end of the winch shaft to limit the ascent rate of the float. Further tests showed that drum rotation was limited to less than one turn with the paddle wheel fitted.

Retrieve Line

To minimize the weight and size of the retrieval system the smallest wire-rope size was used, consistent with the inclusion of a generous safety factor to allow for possible deterioration due to corrosion. A non-rotating type of rope was initially considered, in order to reduce the chances of kinking. It was not practical to include swivels in the line. The advantage of this type of rope did not appear to justify its use, in view of its substantially reduced ultimate strength. The rope finally selected was of one-quarter inch diameter, 6/19 IWRC construction, 115/125 grade galvanized wire. The rope was filled in the stranding and in the closing operations with Texaco Crater 5X, a bituminous base corrosion inhibitor. The specified minimum ultimate strength of 5,900 lb was exceeded in all tests on samples cut from each end of each individual rope. Two thousand three hundred feet of wire rope was used on each RIP. Experience has since shown that this length would actually be insufficient for an operating depth of two thousand feet.

Polypropylene rope was selected for the pilot line rather than nylon for several reasons. First, the strength of the poly rope agreed substantially with the makers' specifications, whereas the strength of the nylon was inconsistent and well below specifications, as tested. Second, the drag on the float could be minimized by using a polypropylene rope with a density less than unity, as opposed to nylon rope with a density slightly greater than one. Finally, the polypropylene rope was available in a single braided construction which enabled a relatively simple splice to be made between the polypropylene and wire ropes. This splice consisted of a 'Chinese Finger' about six feet in overall length. The six external strands of the wire rope were staggered over a distance of about three feet and all cut ends were soft soldered to produce a tapered section ending with only the independent wire rope core. This core was then threaded inside the 1/4 inch diameter poly rope for a distance of six feet, the end of the poly rope then being locked with three separate bindings of 'Dialcord' overlaid with a waxed linen thread. The final result was a completely flexible splice with no abrupt changes in its cross section, and having a maximum size very little larger than the one quarter inch diameter wire rope. Several tests were made on these splices and none failed at less than

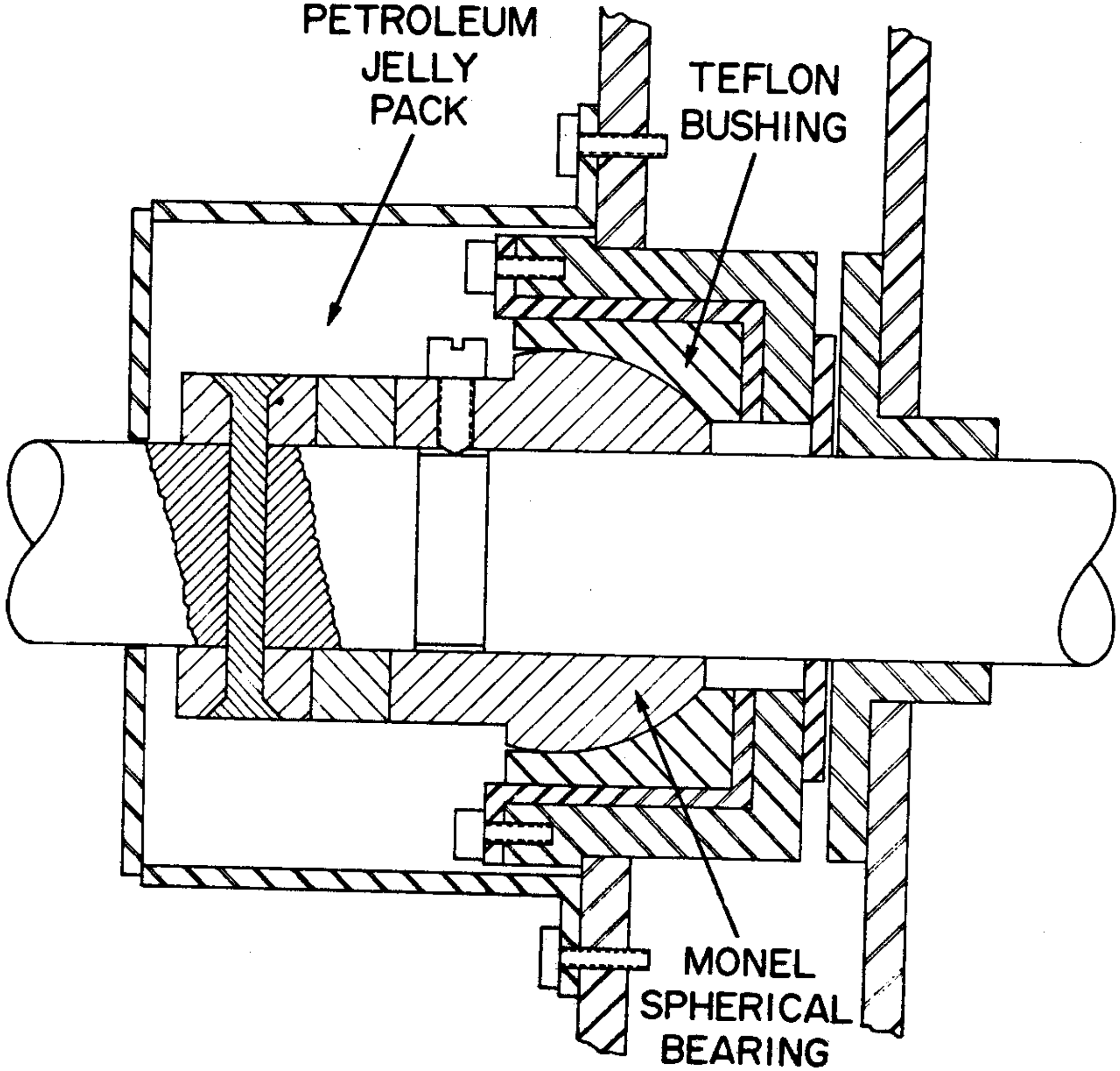

Figure 17: Details of the bearings on the winch shaft of the recovery system.

95% of the poly rope strength. In order to increase the recovery safety factor while lifting the wire rope to the surface and at the same time to provide the maximum length of pilot line, two sizes of poly rope were used. On recovery it was anticipated that the float could be submerged due to line drag from ocean currents unless an excess of length were provided in the pilot line. Fifteen hundred feet of one quarter inch poly rope was used and the winch drum was then filled to within half an inch of the top of the flanges with three sixteenth inch poly rope. By filling the winch drum to this depth it could be locked against rotation by the float. About four thousand feet of this smaller 3/16 in. rope was used on each RIP.

Float

Syntactic foam was used for the float not only because of its very low water absorption over long periods, but for its ability to be cast and machined in relatively complex shapes, and for its shock resistance (from the explosive bolt release). The shape of the float shown in Figure 18, was dictated first by the necessity of keeping the float well below the level of the hydrophone to avoid acoustic interference, and second,by the separation requirement from the RIP unit. It was essential to permit an unobstructed separation for seabed slopes of up to thirty degrees from the horizontal. Finally it was essential that the float arrive at the sea-surface in an attitude rotated at least ninety degrees from its stored position. This rotation was necessary to activate a mercury switch which turned on the power supply to the radio beacon transmitter embedded in the float.

Three sides of the float were machined at 15 degrees from the vertical, to assist in its separation, and a lip was provided to bear against the poly rope on the drum to prevent the drum from rotating prior to the release of the float. Also included were a pair of shallow grooves machined in its base to engage two pipe supports. This combination gave, in effect, a three point float mounting and by using shallow groove angles the chances of a locking or wedging action were minimized.

To help protect the float from the shock wave from the explosive bolt a three inch thick pad of rubberised "horsehair" was inserted in a recess cut in the base of the float. As it was possible for cracking of the float to occur when the explosive bolt was fired, the float anchor connected to the polypropylene line, was joined to a monel rod running completely through the float to a large monel plate at the base.

Suitable recesses were machined for the radio beacon and dye-marker cases, and a groove made for the folded radio antenna. The positions of these were arranged to increase the stability of the free-floating attitude of the float. Abrasion protection was provided for the exposed section of rope between the anchor point on the float and the winch drum by enclosing this section in 'Tygon' tubing.

A net buoyancy of just over fifty pounds was provided by each float, using foam with a density of 38 to 40 pounds per cubic foot made of micro-glass spheres in preference to phenolic. The rough blocks were cast by the 3M Company in Minnesota, and were then machined in the dockyard at Esquimalt. Some cracking occurred during machining, apparently due to residual stresses in the material from the casting process. Wherever substantial cracks appeared a fully threaded monel rod was screwed into the float normal to the crack for reinforcement. To increase the visibility of the float on the sea-surface, a 'Daglo' orange finish was applied and sealed with a coat of clear epoxy.

Explosive Bolt

An attempt was made to purchase "off the shelf" explosive bolts for this application, but the available materials were not suitable for prolonged immersion in seawater so that an 'in-house' design was initiated. From the point of view of corrosion and relatively low cost, monel is an ideal material. It is not as susceptible to crevice corrosion as most stainless steels, but unfortunately its ductility created a new problem. Monel will elongate thirty percent or more before fracture, whereas explosive bolts require a brittle material.

Many configurations of explosive bolt were tested; most resulted in 'birdcaging' without separation, until eventually a very narrow neck was made with heavy sections on both sides adjacent to the cavity containing the explosive. By adjusting the position of this neck axially along the explosive seismocap* an optimum position was found. Figure 19 shows details of the bolt assembly. A non-shattering separation was required to prevent damage to adjacent equipment, in particular the polypropylene pilot line on the winch. In this respect at least, the ductility of monel had a definite advantage. It was found during testing that any eccentricity in the neck affected the manner in which separation occurred. A concentricity tolerance of 0.005 inches was established between the bore and root of the vee groove and was controlled by observing simultaneous readings of dial gauges arranged to contact the vee-groove root and the bore wall below the groove. A set screw, 3/8 in diameter, NF, suitably drilled to accommodate the electrical leads to the seismocap was used to absorb the bulk of the energy in the operating section of the bolt. Shouldered keyhole slots were made in both the RIP frame and the retaining plate on the float to enable the unit to be fitted without tools after arming. Fitting was facilitated by the use of knurled gland nuts and adjusting nuts. Eleven bolts were tested in the final configuration and all of these separated satisfactorily.

Dye Marker and Radio Beacon

Assistance in locating the float after surfacing was considered desirable if not essential so that a dye marker and a radio beacon were fitted to each of the floats. Many types of dyes were tested for visibility

*CIL Trade name

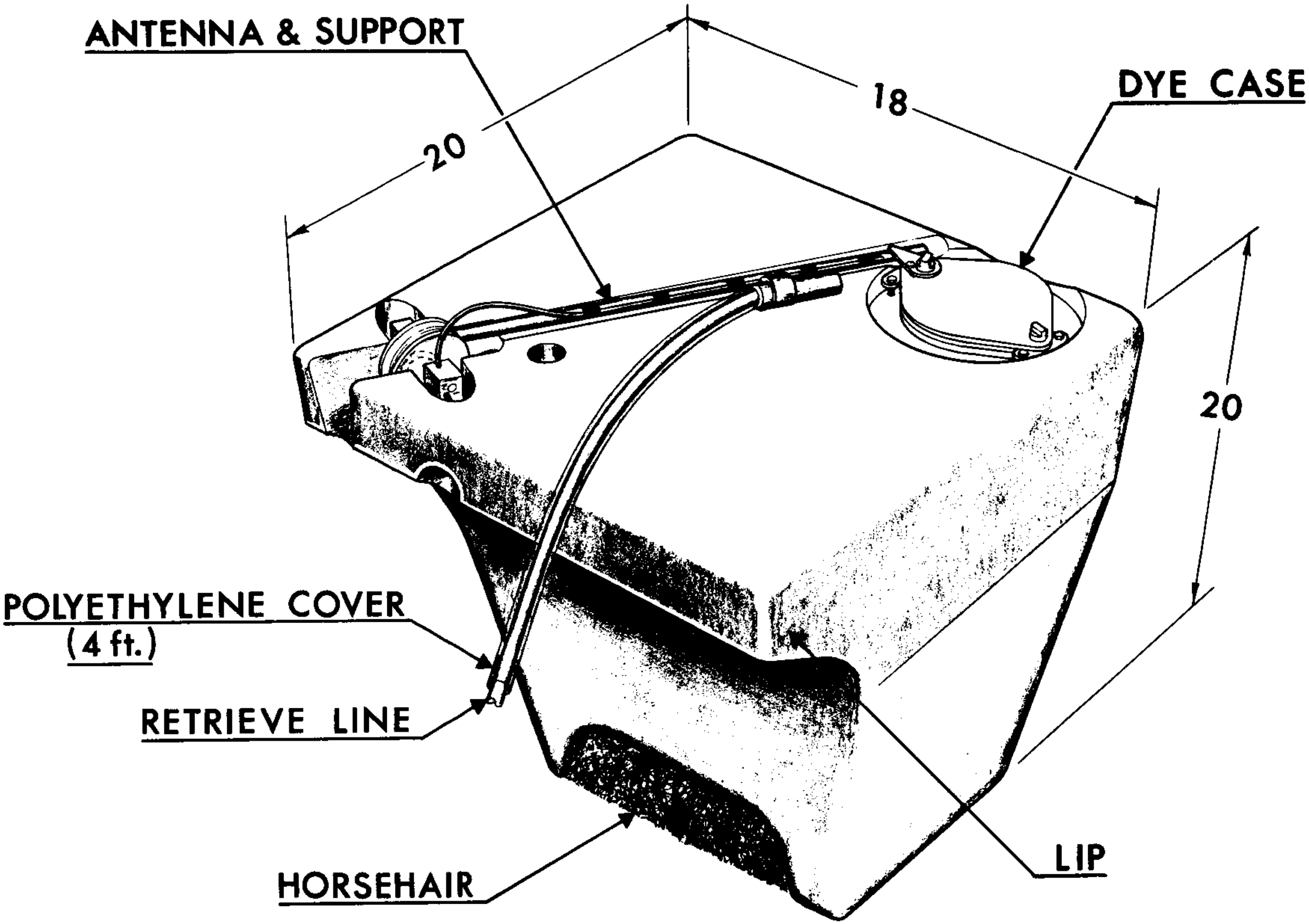

Figure 18: The syntactic foam float.

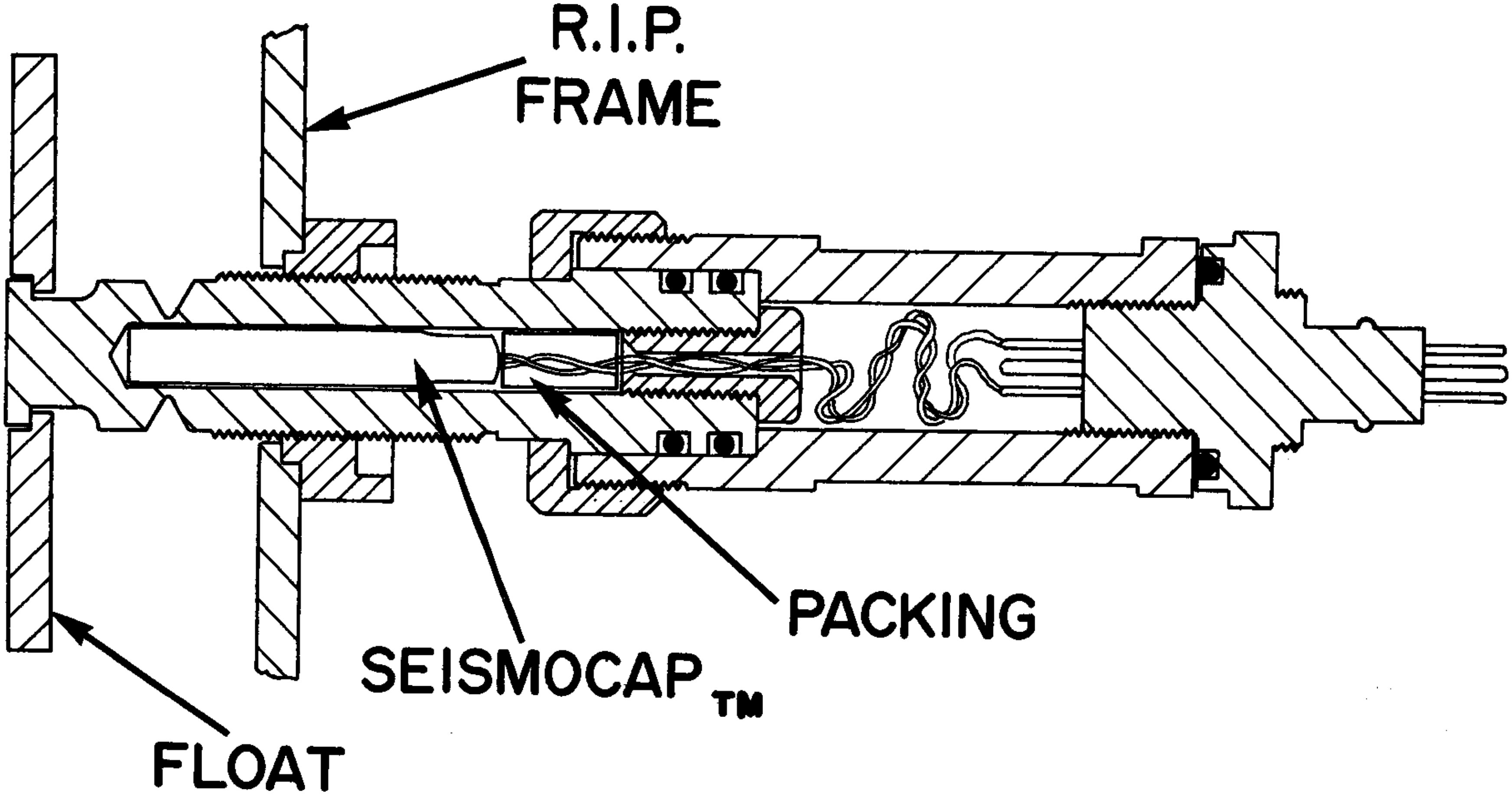

Figure 19: Explosive Bolt

by observations from aircraft, and the dyes were tried as a water-mix, an oil-mix, and dry, with dyes released at the surface and at various depths. The best results were obtained with dry torpedo-marker dye released at the surface. Such a mark from about one ounce of dye was readily visible for at least a mile from a height of 1000 ft, subject to the sun angle and the direction of observation, and to some extent the sea state. As the weight of both the dye and radio units would subtract from the buoyancy of the float, these were kept to a minimum. Thin wall steel cases were employed for both, using single "O" ring seals and a special swaged base closure, shown in Figure 20. Hemispherical bases were tried but the weight advantage did not appear to justify the extra machining required. A simple closing die was made to fold a 0.025 inch wall lip, turned at the bottom of the cylinder, by axial force only. Subsequent pressure testing to produce a collapse of the cylindrical section failed to disturb this seal.

Some form of positive ejection of the dye was found necessary, otherwise a hard cake of wet dye was formed at the neck of the case which inhibited the further distribution of the dye. A spring-loaded plunger was fitted with a tube to allow seawater to replace the dye as it was ejected. To ensure reliability in opening the dye cases, springs were fitted to force their lids off at a depth of between fifty and sixty feet below the surface. The lids were retained initially by two magnesium bolts which were designed to corrode away completely in sea water leaving hydrostatic pressure alone to hold the lids in position. To delay dye ejection until the recovery float reached the surface, a salt block was fitted in the tapered neck of the cap. This block was reinforced with a detachable metal disc to carry the pressure exerted by the dye ejection spring.

Similar construction was used for the radio beacon cases, except that simple lids with single pin Marsh and Marine bulkhead connectors were employed. A mercury switch in each beacon case was actuated by the rotation of the float through 180 degrees upon its separation from the RIP. A small fibreglass fishing-rod tip was used to support the antenna, and was freed when the lid came off the dye case. A twisted surgical rubber tubing loop was fitted to erect the antenna but unfortunately after a year in the stressed condition, the rubber assumed a permanent set and failed to erect the antenna.

Release Hook

Several methods were considered to place the RIP units on the seabed in the Arctic in depths approaching two thousand feet. Free fall was not immediately eliminated, as it is conceivable that some form of speed limitation could be employed to provide a soft landing in the correct attitude. A line looped through the unit to be removed after emplacement was rejected due to the vulnerability of the hydrophone and the distinct possibility of fouling the slack side of the line. A number of commercially made release hooks are available, but the majority of these are of the no-load release type. Premature release due to ship's motion would have been disastrous if a hook of this type were used.

The release hook shown in Figure 21 was therefore designed, and provided a positive fastening to the RIP independent of load, until it could be triggered to a 'no-load' release condition. This triggering was accomplished by means of a suspended weight attached to a spring-loaded arm which, in turn, engaged a locking plate for the main load supporting pin. The length of the lanyard supporting the weight was set at about ten feet to give ample time for actuation at a reasonably fast lowering rate. When the weight hit the seabed the spring-loaded arm and locking plate returned to their upper positions and friction alone retained the main supporting pin. Thus when the RIP reached the seabed and the load in the lowering line was removed, the spring-loading automatically disengaged the main pin. A safety catch was provided for positive engagement of the locking plate while the unit was being handled over the ship's rail in case the weight accidentally fouled the rail. Conical faces on both sides of the lifting eye, with an included angle of 178°, ensured disengagement of the pin in spite of any errors in machining either in the eye itself or the release hook. The materials used were a hardened and ground steel pin, a bronze body, a steel arm and a ground steel locking plate.

The release hook was tested at 50% overload for some fifty drops and performed satisfactorily. To prevent damage to the hydrophone by the hook after release an elastic link was fitted in the bight of the lowering line near the hook to raise it well clear of the RIP, immediately upon its release. A load cell on the ship's lowering boom was used to indicate a sea-bottom contact so that the winch operator would know when to stop paying out and would thus avoid possible fouling by an excessive length of line. The triggering weight was made expendable to avoid any possible damage to the hydrophone.

Corrosion Protection

Many types and combinations of protective greases were tested on specimen materials immersed in running seawater and on a sample main case flange immersed in twenty feet of seawater for ninety days. Results from these tests showed that ordinary vaseline gave the best protection, mainly because of its adherence to the metal surfaces. It was therefore decided to assemble all the main case seals with silicon stopcock grease on both "O" rings and to use vaseline on the metal surfaces from the outer "O" ring to the outside of the flanges. This procedure was also adopted for the other "O" ring seals, on both the tops and bottoms of the dye cases and radio beacon cases. The winch bearings, however, presented a different problem, due to the minimal lubricating properties of vaseline. In view of the low rubbing speeds and relatively light loads in these bearings it was considered that corrosion protection was more important than good lubrication. Consequently, these bearings were also fully packed with vaseline. All bolts, studs and exposed machined surfaces were also coated with vaseline.

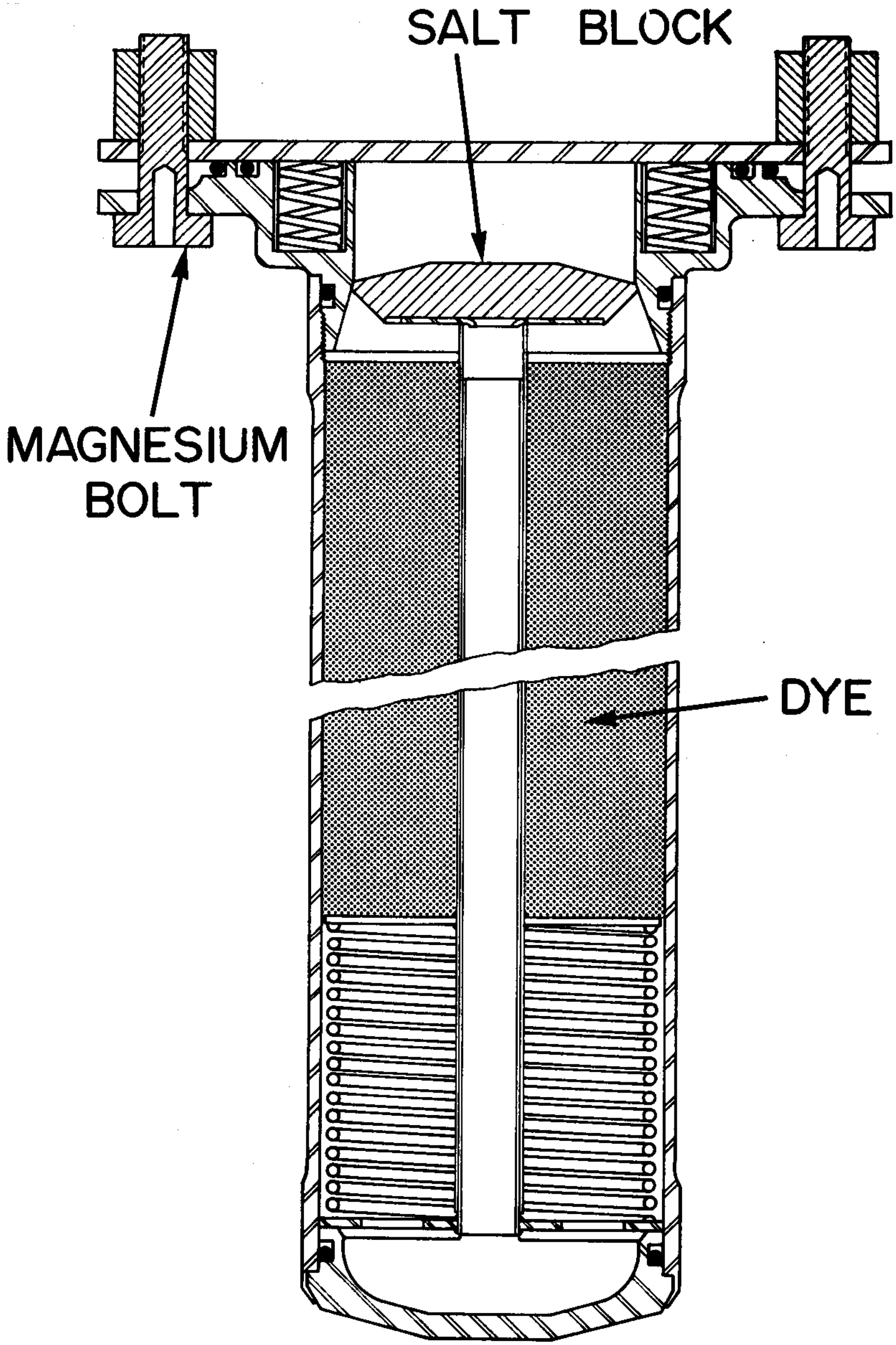

Figure 20: Dye Case fitted to the RIP float.

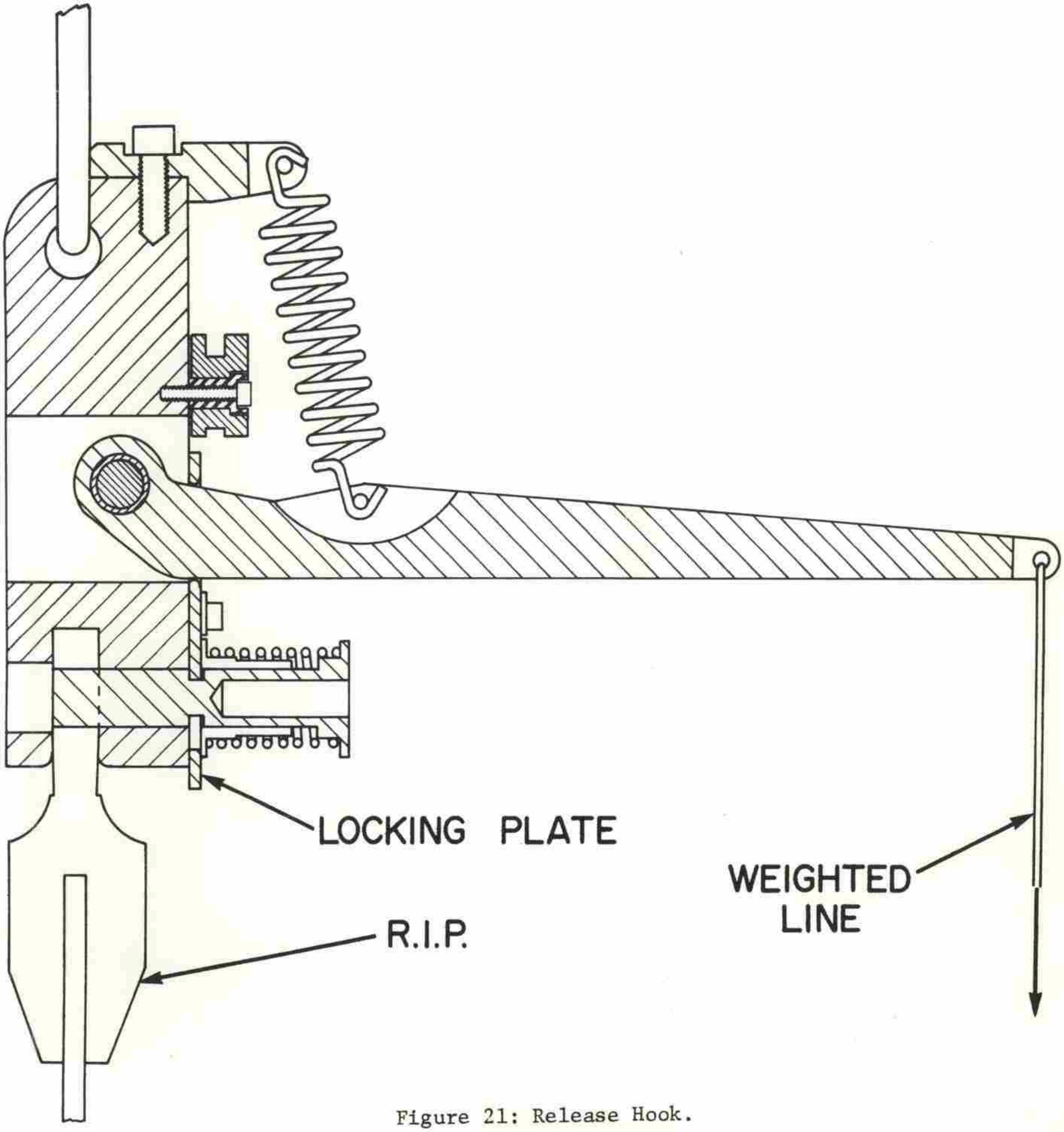

Figure 21: Release Hook.

The steel parts of the whole assembly were protected by the standard procedure adopted for ship hulls; that is by sandblasting to the bare metal, followed by one coat of wash primer, five mills of aluminum vinyl, and two coats of vinyl cuprous oxide anti-fouling paint (Ref. 7). Zinc anodes, in strip form, were attached to the angle-iron base and additional anodes were fitted to the winch drum (Ref. 8). To ensure good electrical contact between the anodes and all the respective parts, all anode retaining bolts were tack-welded in position. One additional small anode was fitted in the float to protect the dye and radio beacon cases. The size of anodes fitted was designed to give protection for a minimum of two years.

Results

In the four units retrieved no leakage was found in any electronics or battery pressure containers nor in the radio beacon cases. The dye system operated satisfactorily in each recovery, indicating that the dye containers remained intact. Opening of the main cases revealed bright metal over almost the entire machined surface of the flanges. Figure 22 shows the flanges on a battery case after a year's submergence.

The anti-fouling paint was effective in preventing marine growth. The hydrophone and its monel protective mounting were not painted and one of the units developed marine growth in this area, as shown in Figure 23.

Inspection of the bearings from all four winches showed the journals to be indistinguishable from new, indicating the effectiveness of the vaseline in this application.

When the RIP's were being installed on the sea-bottom, some difficulties were experienced with the release hook because of ship's drift. Apparently the triggering weight dragged over the seabed and maintained tension in its supporting lanyard. By raising the RIP and relowering it faster this difficulty was overcome.

After a year's immersion, a tensile test was carried out on a section of the recovery wire rope from one of the winches. The result was an ultimate strength of 6,000 lbs, which was identical to the figure obtained from the same rope when new.

The general mechanical condition and appearance of the units when recovered was remarkably good. The condition of the painted steel surface, monel parts, syntactic foam and anodes all indicated that a minimum life of two years could be expected.

INSTALLATION AND RECOVERY

The Department of Transport icebreaker CCGS LABRADOR was used for the installation task during the period 15 August to 20 September, 1967. RIP locations had to be in water depths of less than 2000 ft, on reasonably hard sea-bottoms, and close enough to land-falls to permit use of radar-transponders on the shore as navigational aids. Figure 1 shows the location of the RIP's as of 20 September, 1967. One RIP was originally intended to be installed at the junction of Eureka Sound, Nansen Sound and Greely Fiord, between Axel Heiberg and Ellesmere Island. The bottom contours turned out to be precipitous and the bottom material extremely soft between pinnacles and, as a consequence, an alternate site was chosen. To ensure that the ship could return to within a one-half mile radius of an RIP position, the ship's radar was used as the main navigational aid. When a unit was released, a series of photographs of the radar PPI was taken to preserve the image of the shore-echoes and the echoes from two radar transponders which were set beforehand on carefully identified landmarks. The transponders, two Alpine* X-band units, were essential navigational aids in the Norwegian Bay, Viscount Melville and Barrow Strait sites where the land was low-lying and where the sea-ice masked a poorly defined shoreline. At other sites, hard echoes from cliff-edges made their use unnecessary.

Briefly, the sequence of operations for a RIP installation was as follows:

1. RIP final checkout on route to a site.

2. Careful echo-soundings to determine bottom contours and bottom density from echo character.

3. Bottom cores to confirm bottom hardness.

4. Helicopter used to set out radar transponders (See Fig. 24).

5. RIP lowered to the bottom, its depth being monitored with the ship's echo-sounder and the winch meter-wheel.

6. Release of RIP confirmed by winch load-cell and then PPI photographs taken.

7. Radar-transponders recovered.

One year later four of the five RIP's were recovered, again using the CCGS LABRADOR. For this voyage, the deep submersible PISCES I was flown by a Canadian Forces C130 Hercules to meet LABRADOR at Thule, Greenland. Amongst the various tasks assigned PISCES I (Ref.9) was recovery of an RIP should its acoustic release system fail. This facility was not required but the future design of similar sea-bottom remote stations should consider alternative recovery schemes using DSV's.

*Trade name.

Figure 22: A battery case opened after a year's submergence.
Note the bright clean condition of the flanges.

Figure 23: Marine growth on the unpainted hydrophone and monel mount of the RIP unit in Lancaster Sound. Note the lack of growth on the painted portions of the unit.

Figure 24: Radar Transponder installed by ship's helicopter.

Other than the complete loss of the RIP in Baffin Bay by the plowing of its site by a grounded iceberg, the natural hazards included the presence of heavy seas in ice-free Lancaster Sound, 10/10ths ice cover in Norwegian Bay and moving ice-fields in Viscount Melville Sound. Heavy seas and moving ice-fields are problems which can be dealt with by waiting for the weather to moderate and by being prompt. Of particular interest was the recovery of the RIP in Norwegian Bay, which during the latter part of August 1968 was covered with crack-free 10/10ths one-year ice about 5 feet thick. There was little, if any, ice movement. After the LABRADOR had broken a path over the RIP site, and following the re-emplacement of the radar transponders, an empty fuel drum with a radar reflector attached was set on to the ice as a marker. The next three hours were spent using LABRADOR to break up the ice in a 1/4 mile diameter area, the object being to create numerous ponds and cracks in which the RIP recovery float or its dye could be observed.

The recovery proceeded as follows:

1. PISCES I was made ready to submerge, complete with a rope tether for safety, should the acoustic interrogation fail.

2. The interrogating transducer and a listening hydrophone were lowered over the LABRADOR's stern; the interrogating signals were transmitted and the explosion of the explosive-bolt heard through the listening hydrophone system.

3. Observers were stationed on the ship's bridge with binoculars and a radio tuned to the submerged buoy's radio beacon and two more observers were aloft up-sun in a helicopter.

4. Approximately 15 minutes from detonation time, the dye-marker was seen streaming into a small pool and cracks 300 yds off the LABRADOR's beam.

5. LABRADOR got under way and gently split the floe under which the RIP float was perched; with the float in sight a boat hook was used to haul the polypropelene recovery line aboard, followed by the float.

6. The RIP was then winched to just under the surface at which time a diver examined the unit for biological specimens and then attached the ship's boat-crane to execute the final lift onto LABRADOR's deck.

DESIGN ASSESSMENT

Perhaps the most concise assessment of the RIP design is a brief summary of the performance record of the five units.

Unit One was installed on 17 August 1967 in Lancaster Sound. On 22 November, 1967, a failure in the underwater connectors disconnected the battery cases from the instrument case and recording ceased. The unit was recovered without difficulty on 11 September, 1968.

Unit Two was installed in Baffin Bay in 1410 feet of water on 19 August, 1967. It did not respond to interrogation but since an iceberg was aground on the spot at the time of the attempted recovery, it was almost certainly lost through ice action.

Unit Three was installed in Norwegian Bay on 23 August, 1967. On 27 March, 1968, a failure in the underwater connectors terminated recording. The unit was recovered on 18 August, 1968 in spite of ten-tenths ice cover in the area.

Unit Four was installed in Barrow Strait on 8 September, 1967. The ice-breaker was drifting badly during installation and the rough treatment required to obtain release uncovered a cold joint in the electronics. No useful records were obtained but the unit was recovered without trouble on 26 August, 1968.

Unit Five was installed in Viscount Melville Sound on 5 September, 1967. The contacts on the Accutron timer became erratic in May of 1968 and then recovered in early August. The underwater connectors failed in mid-August. The unit was recovered on 30 August, 1968 with some difficulty caused by large drifting floes of polar ice.

The mechanical design and the recovery system were completely successful. No leaks occurred in any of the pressure cases and the recoveries were without incident except for drifting ice. The only problems in this area were difficulties in releasing the units from the lowering cable when lowering from a drifting ship, and unreliable erection of the float beacon transmitter antennae. Both of these faults can be cured by minor modifications.

The choice of underwater connectors was a disaster. This type of connector had been very successful in short term applications, but in long term use all the connectors gave trouble after periods ranging from three months to eleven months.

The timers and the tape decks, which were obtained commercially, were unsatisfactory, but they only caused an actual loss of data in the case of unit five.

The loss of useful output due to the cold joint was unfortunate but, given the complexity of the units, perhaps not surprising. The only way to avoid occasional failures of this type is to use construction and testing standards borrowed from the space projects. For earthbound projects, it is likely more economical to adopt the "cheap and many" approach and accept a finite failure rate.

The designers regard the RIP design as an outstanding success. Problems were encountered but these were few compared to the potentialities for disaster. This was a first attempt in a design area that can be classed as "state of the art".

THOUGHTS FOR A MK II DESIGN

The concept of a buoyant instrument package that floats to the surface in its entirety is still very attractive. At a depth of 2000 feet this is not practical with a steel case unless additional flotation is provided. Pressure cases of aluminum or fibreglass are now available and these would have to be evaluated for reliability. Tests made subsequent to the RIP design (Ref. 10) indicate that lead acid batteries, designed for low self discharge, are suitable for long term underwater applications. The batteries could be used as an anchor for the buoyant instrument case since they do not require a pressure case and are cheap enough to be regarded as expendable.

A shortcoming of the RIP experiment is the difficulty in correlating the ambient noise records with the weather records from weather stations up to 150 miles away. The problem was emphasized in April 1969 when quite different weather was experienced at two field camps only ten miles apart. It would be desirable to have a surface weather observatory placed on shore adjacent to each RIP. Even a simple temperature recorder would be very useful.

A difficulty in designing equipment for long term unattended use is the selection of components with sufficient reliability. An example of this is the RIP connectors. These connectors were satisfactory in a one month test of RIP in local waters, yet they were quite unsatisfactory for long term use. We do not know the answer to this problem since adequate test procedures give unacceptably long lead times.

The successful operation of a deep submergence vehicle (DSV) from an icebreaker (Ref. 9) opens up a number of possibilities not considered in the design of RIP. If the acoustic interrogation signal from the recovery icebreaker turned on an acoustic "pinger" a DSV could "home" on the unit for either recovery or servicing. This would allow the underwater unit to be relatively simple mechanically. The economics of such a system would depend on the number of units deployed, and other commitments for the DSV.

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13. ABSTRACT

A Recording Instrument Package or RIP was a completely self-contained bottom-mounted observatory designed to record digitally, on magnetic tape, the average spectrum of underwater ambient noise once an hour for one year. A recovery system was incorporated which was initiated by a coded acoustic signal sent from the recovery vessel. The RIPs were designed to characterize the seasonal changes in under-ice acoustic ambient noise in channels of the Canadian Arctic Archipelago.

This report discusses the electronic and mechanical design and describes the installation and recovery of the units in the Arctic.

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