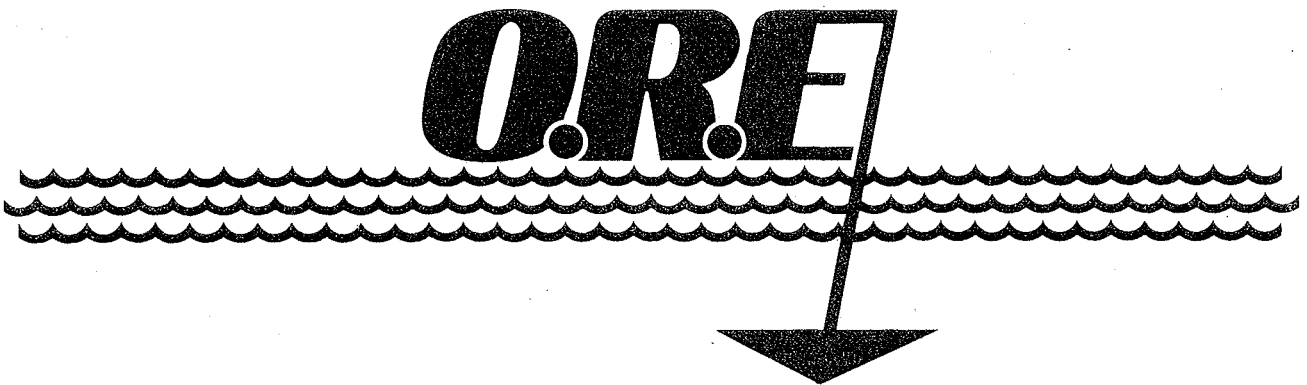OPERATING AND MAINTENANCE MANUAL

FOR THE

.O.R.E. MODEL 1036

HIGH POWER, MULTI-FREQUENCY

SUB-BOTTOM PROFILING SYSTEM

December, 1976

OPERATING AND MAINTENANCE MANUAL

FOR THE

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LIST OF FIGURES AND DRAWINGS

1. INTRODUCTION

The O.R.E. Model 1036 Sub-Bottom Profiling System is designed to obtain accurate, continuous acoustic profiles of layers beneath the surface of the sea bottom, as well as precision bathymetric data.

Records are obtained by transmitting high-power pulses of acoustic energy from a transducer array towed in a faired vehicle, or "fish", by the survey vessel. Because of the clean hydrodynamic characteristics of the fish, operation of the system can be maintained at normal cruising speeds and rough sea conditions without deleterious effects on the acoustic transmission path.

Acoustic pulses travel through the water, and a portion of their energy is reflected by the bottom. The remaining energy penetrates into the bottom. If layers of different materials are present, energy is reflected from the boundary between them. The degree of penetration and reflection is dependent on the properties of the bottom and sub-bottom material, the power, and carrier frequency.

The reflected pulses are detected by the same acoustic transducer used for transmission, and the resulting electrical signal is recorded on a precision recorder. The system is entirely similar in operation to a conventional echo sounding apparatus; it differs from an echo sounder by virtue of transmitting much higher power pulses, providing for adjustment of

operating frequency, pulse width, power, and receiver characteristics over a wide range. Specially designed transducers and receiver circuitry further enhance the ability to resolve echoes from sub-bottom layers.

2. GENERAL DESCRIPTION

2.1 Major Sub-Systems

The Model 1036 Sub-Bottom Profiler System consists of three major sub-systems, connected as shown in Figures 2.1 and 2.2.

(1) O.R.E. Model 140, 10 kw Transceiver

(2) Precision Recorder

(3) O.R.E. Model 136 Towed Transducer Vehicle and Cable Assembly

2.2 Transceiver

The Model 140 Transceiver contains a transmitter, whose electrical power output is continuously variable from 0 to 10 kilowatts. Transmitter frequency is continuously variable from 1 to 12 kHz. The transmitter is keyed by pulses originating from the Depth Recorder at a precisely determined repetition rate. Thus, the transmitter produces short bursts of electrical power at the selected frequency. The repetition rate and duration of these pulses is controlled by front panel switch settings on the recorder.

The transmitter is connected to the towed transducer array through the tow cable. The electroacoustic transducers convert the electrical energy into acoustic energy, which is propagated through the water.

2.2.1 Receiver

Returning echoes striking the transducers are converted back into electrical energy, and a switching network (T-R

switch) routes these signals to the receiver, which is the other major component of the transceiver.

The receiver is a tuned amplifier with variable center frequency, bandpass, and a time varying gain (TVG) control. Front panel adjustments permit the center frequency of the receiver to be adjusted to match the transmit frequency. The width of the bandpass filter can also be adjusted to accommodate the spectrum of the transmitted pulse (and echo). The TVG automatically holds the gain of the receiver to a low value until the point in time where the bottom echo is received. After this instant, the gain increases linearly with time to compensate for the attenuation of sound through the sub-bottom layers. This technique produces good records of both near and deep sub-bottom layers simultaneously, and maintains a nearly constant signal strength for presentation on the recorder. Signals from the receiver pass to the Precision Recorder, where they are displayed as a continuous record on permanent recording paper.

2.3 Precision Recorder

The Precision Recorder moves a 19-inch strip of specially treated paper over a stylus traveling at right angles to the direction of paper travel. Stylus speed is accurately controlled by a crystal clock, and may be varied in steps.

In the simplest mode of operation, a key pulse, causing the transducer to emit a burst of sound, is initiated each time the stylus is at the left-hand edge of the paper. Elec-

trical signals from the receiver, representing echoes, cause
a current to pass from the stylus through the paper to a
knife edge extending the width of the paper. The paper is
darkened at this point in proportion to the intensity of the
signal. Since the stylus travels across the paper at a con-
stant, accurately known rate, the elapsed time between outgoing
pulse and echo arrival may now be determined. Using an assumed
speed of sound in water of 4,800 feet per second, the recorder
is calibrated in units of time or distance, either fathoms or
meters. Selectable stylus sweep speeds representing full
scale from 20 to 2,000 fathoms are selected by a panel con-
trol.

The paper is fed at a rate of one step per sweep, and
the step length is selectable. Thus, for a given paper feed
rate, the successive echoes are displayed as a dark band
whose distance from the left edge of the paper represents
depth. If the survey vessel pursues its course at constant
speed, distance along the length of the paper approximates
distance along the ship's track.

The outgoing pulse ("ping") is visible at the left edge
of the paper, and depth and time calibration marks are auto-
matically printed on the paper, so that calibration of the
recorder is independent of dimensional changes in the paper.

2.4 Towed Transducer Vehicle Sub-System

2.4.1 General

This sub-system consists of the towed transducer vehicle, or "fish", which houses the acoustic transducer array, a faired tow cable, a retention for connecting the cable to the fish, a deck mounted winch, and an interconnecting cable to tie the winch end of the tow cable to the transceiver.

2.4.2 Fish

The fish consists of a hydrodynamically faired housing to enclose the transducer array, means for mounting the array in the housing, and a stabilizing tail. The faired housing floods with water, and the bottom half is acoustically transparent in the frequency range of interest. The unit tows from its balance point and maintains its depth at a given towing speed solely because of the relationship between its weight and drag. Trim tabs or hydrodynamic surfaces generating negative lift are not used. The device tows well at speeds in excess of 12 knots.

2.4.3 Towing Position

The fish is normally towed at a depth which positions it below the level of the vessel's keel. It may be deployed from davit or boom over the side or stern. The transducers are thus in a position clear of the ship's hull, where bubbles, machinery noise, flow noise, etc., usually cause undesirable interference. Due to its hydrodynamically clean design, the fish contributes little noise to the system.

2.4.4 Transducers

The transducers accept power from the transmitter over the range 3.0 to 7.0 kHz. Sound is projected downwards in a roughly conical beam 55 degrees wide at 3.5 kHz, 40 degrees at 5.0 kHz, and 30 degrees at 7.0 kHz. Maximum permissible power into the transducers is 10 kw at a 1% duty cycle.

2.5 Tow Cable

The tow cable combines a core of electrical conductors for the transducer connections with two layers of stainless steel outer armor for tensile strength. A special retention fitting, combining a watertight electrical connection and a mechanical strength connection, is used to connect the cable to the tow point of the fish. Flexible plastic fairing is attached to the submerged part of the cable to reduce drag and eliminate flow-induced vibration which could cause fatigue and acoustic noise.

2.6 115 Winch

The Model 115 Winch is a manually operated, medium duty type for shipboard applications. It can be fitted with a large variety of electrical tow cables for use with a variety of towed vehicle applications. The winch provides a 4:1 ratio for high-speed cable take-up, and a 24:1 ratio for use with heavy loads. There is a manual brake and a spring loaded holding dog which locks the gear assembly.

PRECISION DEPTH RECORDER

RECEIVER OUTPUT

KEY PULSE

TRANSCEIVER

10 KW TRANSMIT PULSE

RECEIVED ECHO SIGNAL

WINCH

SHEAVE

TOW CABLE

DAVIT

5°-45°

FAIRING

AT LEAST 5' BELOW KEEL

TOWED TRANSDUCER VEHICLE

MODEL 1036
SUB BOTTOM
PROFILING SYSTEM

2-C

FIG. 2.1

REVISED OCT 1975
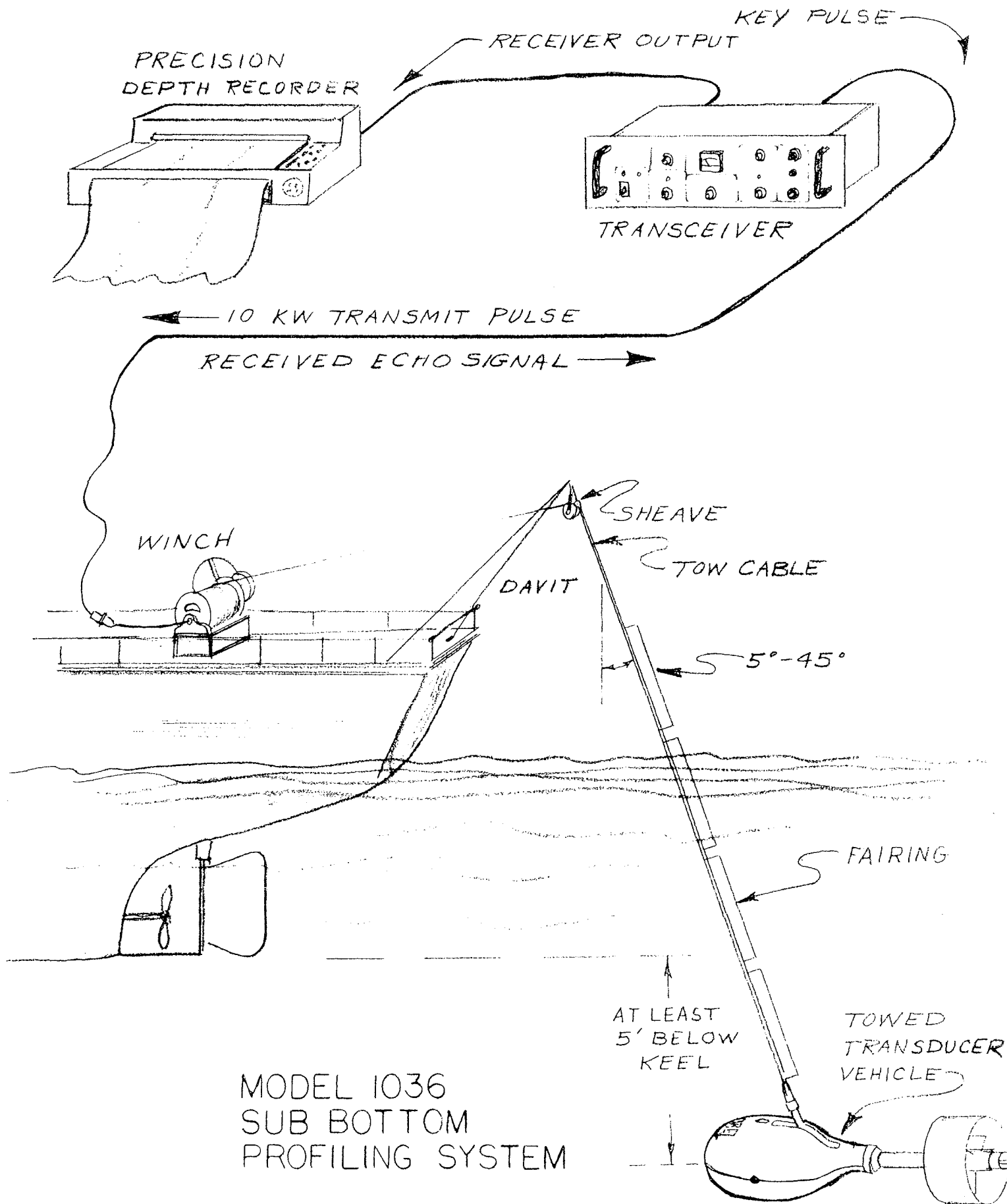
PRECISION DEPTH RECORDER

TRANCEIVER

PRECISION CLOCK

KEYER

XMITTER

T-R SWITCH

XDCR

SWEEP SPEED CONTROL

TIME VARYING GAIN

AMPL

SIGNAL to STYLUS

WRITE AMPLIFIER

VARIABLE BAND PASS FILTER
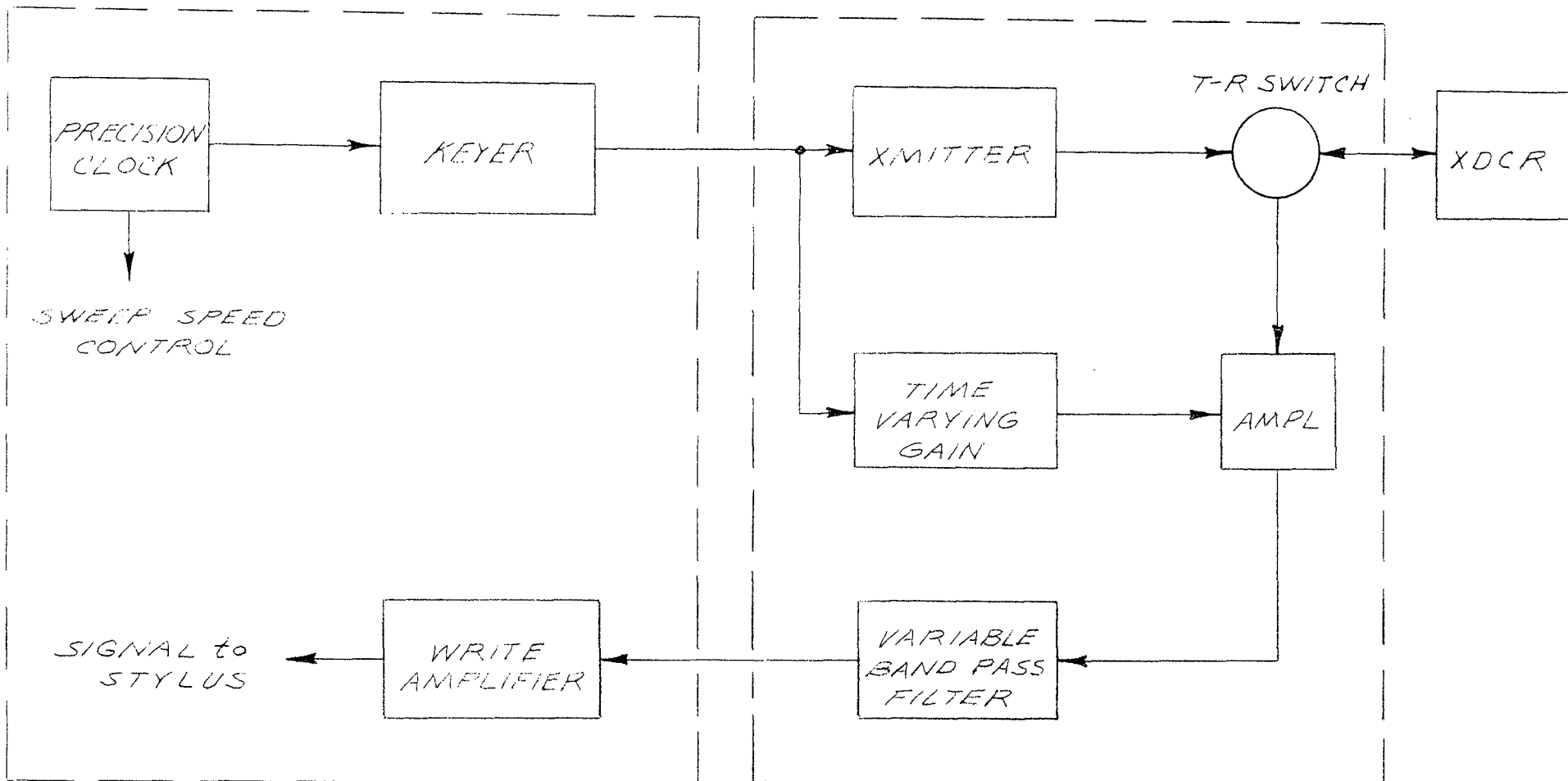
Fig. 2.2

REVISIONS		
	ORE OCEAN RESEARCH EQUIPMENT, INC. FALMOUTH, MASSACHUSETTS	
	TITLE MODEL 1036 SUB-BOTTOM PROFILER	
	SCALE	DR. BY Apollo	DRAWING NO.
	DATE 2/1/77	CK'D. BY	

3. SPECIFICATIONS

The following are general specifications or operational specifications for the components which make up the 1036 System

3.1 Model 140 Transceiver

3.1.1 Transmitter Section

Power output	10 kw RMS during key pulse.
Output impedance	5, 10, 20, 30, 40, 45, 50, 55, 60, 75, and 100 ohms.
Frequency	Continuously adjustable 1 - 12 kHz. other frequencies available.
Output power adjustment	Continuously adjustable from 0 to 10 kw at any of the above impedances.
Duty cycle	.75 per cent at 10 kw, proportionately higher at lower power settings.
Keying Signal	DTL/TTL compatible pulse, positive or negative going. (Compatible with most recorders.)
Protective circuits	Duty cycle automatically limited to less than 100 watts average transmitted power. Short circuit protected output stage. Overload protection. AC power interruption protection.

Internal switching is provided to separate transmitter output terminal from receiver input.

3.1.2 Receiver Section

Input impedance	10 K ohms
Frequency	Adjustable 1-12 kHz. Other frequencies available.
Bandpass filter	Center frequency continuously variable 1-12 kHz. Bandwidth adjustable from 0.5 kHz up to essentially flat.
Output impedance	Less than 100 ohms.
Maximum output voltage	4 V P-P minimum.
Sensitivity	30 microvolts RMS input (for 20 db signal-to-noise ratio) produce 1 V RMS output.

3.1.3 TVG Section

TVG dynamic range	26 db
TVG rate	Adjustable.
TVG delay	Adjustable from 1 ms to 1 sec.
TVG finder	Front panel push button used to locate beginning of TVG ramp by adding "blip" to receiver output which appears on recorder paper.
TVG bottom tracker	Using bottom tracker mode, TVG ramp automatically starts when first bottom return is received.

3.1.4 <u>Special Features</u>

(1) Transmitter and receiver frequencies independently adjustable.

(2) Receiver frequency is matched to transmitter frequency by depressing "Receiver Test" switch and tuning for maximum indication on "VU" meter. The "Receiver Test" switch produces a calibrated signal at receiver input, thus, also checking receiver sensitivity and bandwidth.

(3) "VU" meter is useful by itself for "listening" to remote sound sources (i.e. pingers, etc.). Transmitter can then be set to receive frequency by procedure similar to (2) above.

3.1.5 <u>Power Requirements</u>

Primary voltage	105-125 VAC 47-63 Hz.
	(230 V adapters available)
Power consumption	200 watts

3.1.6 <u>Construction</u>

Design guide	MIL-E-16400
Electronics	All modular silicone solid state construction with maximum utilization of digital and linear integrated circuits. Each circuit board contains up to eight test points accessible from top of card file.

Chassis	Bench/rack chassis fully enclosed and fan cooled.
Power supplies	Regulated, short-circuit proof supplies used throughout.
Size	17 inches wide by 17 inches deep by 7 inches high -- standard rack or bench mounting.
Weight	50 pounds.

3.2 Model 136A Specifications

3.2.1 Transducer Array

Transducers (four)	Model 137D
Frequency range	3.0-7.0 kHz
Maximum power input	10 kw at 1% duty cycle
Total beam width	55 degrees at 3.5 kHz
	40 degrees at 5.0 kHz
	30 degrees at 7.0 kHz
On axis source level at 10 kw	114 db re 1 ub at 1 yd.
Input impedance	50 ohms (200 ohms each)
Connection	4 units in parallel

3.2.2 Towed Transducer Vehicle-Model 136A

Weight	330 lbs. in air; 260 lbs. in water
Dimensions	Length 60 inches; width 18 inches; height 14 inches
Maximum towing speed	Over 12 knots

Transducer vehicle number
(less transducers)   D135-3732

Upper shell number   D135-3769

Lower shell number   D135-3770

3.3 Tow Cable-Model 143A

Standard length   100 feet

Length of faired section   30 feet

Diameter   3/8 inch

Armor   Two layers contrahelically wound

                                      stainless steel

Conductors   4, Number 19, stranded copper, poly-

                                      propylene insulated; 7.7 ohm/1,000 ft.

                                      per conductor; interconductor

                                      capacitance 40 pf per foot

                                      4, Number 24, stranded ground

                                      wires, uninsulated

Breaking strength   9,700 lbs.

Fairing   3 foot sections, Model 142A

Retention   Model 120 (rated for 3,000 lbs.)

3.4 Winch

Capacity   150 ft. tow cable with 50 ft. faired

Weight   300 lbs.

Dimensions   Length 30 in.; width 15 in.; height 26 in.

3.5 Interconnecting Cable (Winch to Transceiver)

Standard length   50 feet

4. INSTALLATION AND OPERATION

A separate manual for each of the three major components of the system -- Model 140 Transceiver, Precision Recorder, and Model 136 Towed Transducer Vehicle System -- explains in detail operation, maintenance, deployment, and installation. The following is a brief summary of system operation. Section 4.2 provides step-by-step operating procedures.

4.1 Operating Notes

4.1.1 Towing

The fish tows well at speeds in excess of 12 knots. Enough cable should be paid out so that the fish swims several feet below the level of the keel. A sufficient length of fairing should be used so that the entire submerged length of cable is faired. The standard cable length supplied is enough for most applications in medium and small size survey vessels. If water depth allows, the fish should be at least fifteen feet deep to prevent transducer cavitation.

<div align="center">

NOTE

Be sure that while the vehicle is being towed, the tow cable is outside of high turbulence areas such as directly behind screws, rudder, etc. This precaution will eliminate the possibility of armor wear due to fairing movement against the armored cable.

</div>

4.1.2 Transmitter Power

In most cases, maximum power (10 kw) will give best results. In very shallow water a short interval of "ringing" after termination of the transmit pulse may obscure the bottom. This is minimized by operation at 5 kHz. An internal switch in the transceiver (described in the Transceiver Manual) allows the choice of a mode of operation whereby two of the transducers in the array are used exclusively for transmitting and the other two for receiving only. This configuration is useful where a wider beam width is desirable, such as in pipe finding applications.

Cavitation when the transducer is less than fifteen feet deep may reduce power output somewhat; however, this does not harm the equipment.

4.1.3 Transmitter Frequency

In general, resolution increases with increase in frequency, while penetration depth will decrease. The receiver should always be tuned to the transmit frequency as described in the Transceiver Manual.

4.1.4 Pulse Duration

Pulse duration is controlled by the precision recorder, unless the transceiver has option A (see manual). Normally, a pulse duration should be chosen which is at least equal to the period of one cycle of the carrier frequency, although pulse lengths as short as one carrier cycle are useful where high resolution is required in shallow water.

4.1.5 Receiver Bandwidth

Bandwidth should be as wide as possible and still result in an acceptable signal-to-noise ratio. This adjustment will give maximum pulse rise time and resolution for a given pulse duration.

4.1.6 Adjustment for Optimum Results

As noted in the preceding section, transmit frequency, pulse duration, and receiver bandwidth are interrelated. Optimum adjustment depends on the results desired, and the geology of the area being surveyed. It is best determined by experiment.

4.1.7 Time Varying Gain

This feature is an extremely important factor in realizing the full potential of the system. The user should study the Transceiver Manual to acquire full understanding of its operation. Properly used, it enhances the signal-to-noise ratio by reducing the effect of reverberation near the bottom while increasing gain at a rate approximating the propagation loss in the bottom layers.

Normally, the automatic tracking mode will be used. The threshold should be adjusted so that the break point occurs at the instant the bottom echo is received, but should not be triggered by noise previous to the bottom echo. TVG Rate will best be found by experiment. Note that the TVG Finder will always confirm that the break point is occurring at the proper instant. (For more detailed information concerning the use of the TVG, see Section 4.2.3.S and the 140 Manual.)

4.1.8 Recorder Scale

For all information concerning the set-up and use of the recorder, refer to the specific Recorder Manual.

4.2 Operating Procedures

4.2.1 Equipment Required

It is advisable to have the following test equipment available to operating personnel for systems check-out and troubleshooting:

   a. Simpson 260 VOM or equivalent.

   b. Oscilloscope (minimum bandwidth 1 MHZ, minimum sensitivity .05 v/div. dual trace).

   c. 100 ohm, 100 watt dummy load for transceiver.

4.2.2 Set-Up Procedure

   a. Check for 105-125 VAC 50-60 Hz.

   b. After assembly of fish, measure for continuity/open circuit with VOM as follows on transceiver end of transducer cable.

For 136 Fish

A-B 25 ohms

A-D 25 ohms

B-D 50 ohms

C-open to A,B,D, short to winch drum and/or armor.

NOTE

Make sure transducer faces are clean.

If in doubt, wash off with Tide or

equivalent and warm water. Water

4-4

should "wet" transducer faces when
washing is complete. DO NOT GET
SILICONE OIL OR GREASE ON TRANS-
DUCER FACES.

4.2.3 Operation

    a. Visually inspect recorder stylus parts for any possible shipping damage.

    b. Set recorder controls as suggested in the recorder manual.

    c. Install roll of paper - plug in recorder.

    d. Turn recorder "ON."

    e. If necessary, place STOP/START to "START" to start scanning.

    f. Activate the mark function and adjust limit to full darkness trace (approximately mid-position).

    g. Leave recorder running.

    h. Set transceiver controls as follows:

       POWER OFF

       TVG RATE AND DELAY - Full CW

       TVG DELAY - 100 ms

       TVG THRESH - Full CCW (switch off)

       RCVR GAIN X20, Mid Pos. Vernier

       XMT, KW - Full CCW

    i. Turn on transceiver. O-Load Light may come on briefly, but should go out at next RCDR sweep.

j. Set XMT FREQ at desired operating frequency, 3.5 or 5.0 kHz.

k. Set RCVR BW control two positions from CCW. This corresponds to a BW of approximately 2 kHz. Inhibit keying from the recorder.

l. Depress RCVR TEST button; adjust RCVR FREQ for maximum indication on meter. Readjustment of RCVR gain vernier may be necessary to keep reading on the meter scale.

m. Restore edge keying from the recorder.

n. Remove transceiver top cover. Check to see that LOAD MATCH is in the correct setting, and that the toggle switches are in the "combined" position.

o. Advance XMT, kw to 2.5 kw. Transducers should be clearly heard. Advance to full power. H.V. light should come on. A good check at this time is to observe TP2 of modules no. 16 and 18 for 145-150VP-P, square wave at the operating frequency. Poor wave shape and/or overload indication shows probable short circuit or H.V. breakdown somewhere in transducer cable. (See troubleshooting section in Transceiver Manual.)

p. Reduce XMT, kw control to zero; wait for H.V. Indicator to go out. Turn off XCVR, recorder scan and recorder power IN THAT ORDER.

q. STOP SHIP. Deploy fish. Check towing characteristics as ship comes up to speed.

<center>NOTE</center>

It is advantageous to disconnect fish cable connector at winch while deploying and recovering fish to avoid undue twisting of cable.

Be sure power to transceiver is off before disconnecting or reconnecting cable.

r. Turn system back on. Increase XMT kw to full power as before (wait 30 seconds before advancing power).

s. To set-up TVG, set TVG DELAY, MS to a range which is greater than or equal to the sweep time.

t. Depress TVG FINDER and rotate TVG DELAY potentiometer counter-clockwise until the "blip" is observed above the bottom trace. Adjust blip to occur just above (1/8 inch) the bottom return.

u. Rotate TVG RATE control counter-clockwise until sub-bottom and/or second bottom are observed. In general, TVG RATE should be increased until some light writing occurs continuously following the bottom return.

v. As depth changes, depress TVG FINDER and turn both TVG RATE and TVG DELAY simultaneously so that "blip" always remains near the bottom return. In this way, both TVG RATE and DELAY are adjusted as depth changes.

w. To use automatic TVG, set-up as in S-T above. Then
    depress TVG FINDER and set "blip" at approximately
    one-half the depth, but be sure it is occurring in a
    white (non-noisy) section of the water column above
    the bottom.

    Rotate TVG THRESH full clockwise and gradually rotate
    counter-clockwise until TVG action resumes. Experi-
    ment with the setting of the TVG THRESH control. If
    it is set too low (counter-clockwise), the TVG cir-
    cuit is not activated and sub-bottom records are not
    enhanced. If it is set too high (clockwise), the TVG
    will fire too soon (on noise) and will cause satura-
    tion of the writing circuits caused by excess gain.

    The Automatic TVG will track the bottom over depth
    changes of ±30 to ±50 per cent. If the depth changes
    more than this, depress the TVG FINDER to relocate
    the "blip" (as in U above), and readjust the RCVR
    GAIN and TVG RATE controls. It should not be necessary
    to readjust the TVG THRESH adjustment.

<u>NOTE</u>

It is often convenient to observe
the TVG related waveforms on the
scope. Trigger on M27 TP6. Trace
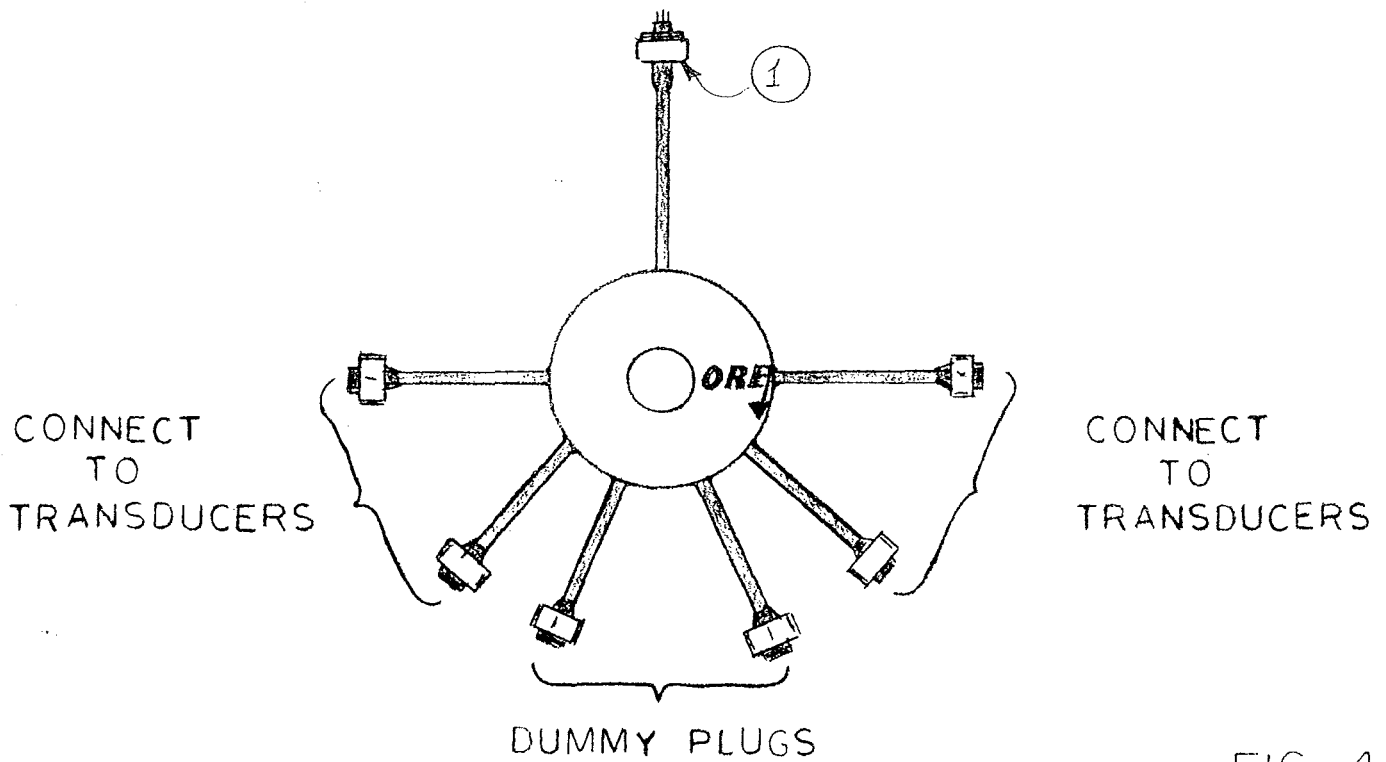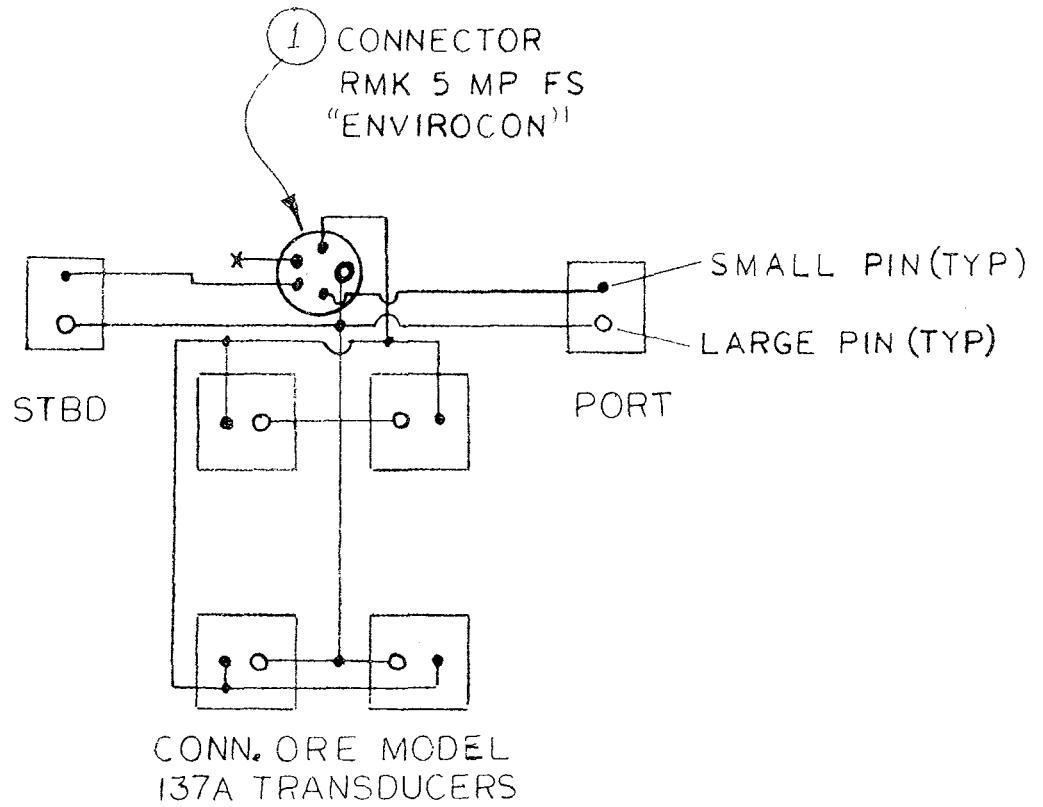A on M8 TP3 (TVG RAMP). Trace B
on M5 TP3 (RCVR OUTPUT).

① CONNECTOR
RMK 5 MP FS
"ENVIROCON"[1]

SMALL PIN (TYP)

LARGE PIN (TYP)

STBD

PORT

CONN. ORE MODEL
137A TRANSDUCERS

①

CONNECT
TO
TRANSDUCERS

ORE

CONNECT
TO
TRANSDUCERS

DUMMY PLUGS

FIG. 4.1

ORE MODEL T610 JUNCTION BOX

A1200 0001

4.2.4 <u>Recommended Order of Shutdown</u>

<u>Transceiver</u>

  (1) Reduce XMIT, KW to OFF.

  (2) Wait until H.V. indicator goes out.

  (3) Turn POWER OFF.

<u>Recorder</u>

  (1) Turn off Scan switch, if applicable.

  (2) Turn off Power switch.

  (3) Remove remainder of paper from recorder.

<u>Transducer Vehicle</u>

  (1) Stop ship.

  (2) Recover vehicle.

  (3) Secure vehicle.

4.3 <u>Operation of the 1036 System for Pipeline Location</u>

  An ideal use for the 1036 System is in the location of pipelines as small as 10 or 12 inches. Certain operational procedures (outlined below) vary from the standard sub-bottom profiling set-up.

  a. Set the Combined/Separate switch inside the 140 to SEPARATE. <u>Do Not Change</u> LOAD MATCH setting. (Nominally 50 ohms.)

  b. Connect the transducers as outlined in Figure 4-1.

  c. Adjust the XMIT and RCV FREQ. to desired scale settings.

  Using the SEPARATE mode of operation, causes two transducers to be used for transmitting and two for receiving. If the transducers have been properly connected, as in Figure 4-1, the beam pattern is effectively changed from the conical

shape used for sub-bottom profiling to a more forward and
after looking fan shape pattern, ideal for object location.

4.3.1 Fine Adjustments

As in sub-bottom profiling actual adjustments of the
transceiver controls will depend a great deal upon the specific
conditions experienced.

The most critical adjustment will probably be the trans-
mitter frequencies. In general transmit frequencies employed
in pipeline work are higher than those used for sub-bottom pro-
filing. It is advisable to start at 5 kHz and work up.
Higher frequencies will make smaller pipes visible and improve
resolution. Higher frequencies, however, also decrease penetra-
tion. Optimum results will be achieved with practice.

4.3.2 Pipeline Records

On a record a buried pipeline will appear as a parabola.
See Figure 4-2. The best pipeline records will occur when
the course of the survey vessel intersects the line of pipe
at a ninety degree angle.

By studying the scale factors of the record, the actual
depth of the pipe below the sea floor can be determined.

180°

8721
9638

16.35
40.31

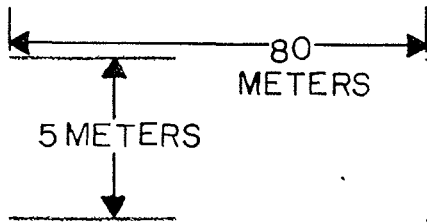FREQ:5 KHZ SUB BOTTOM
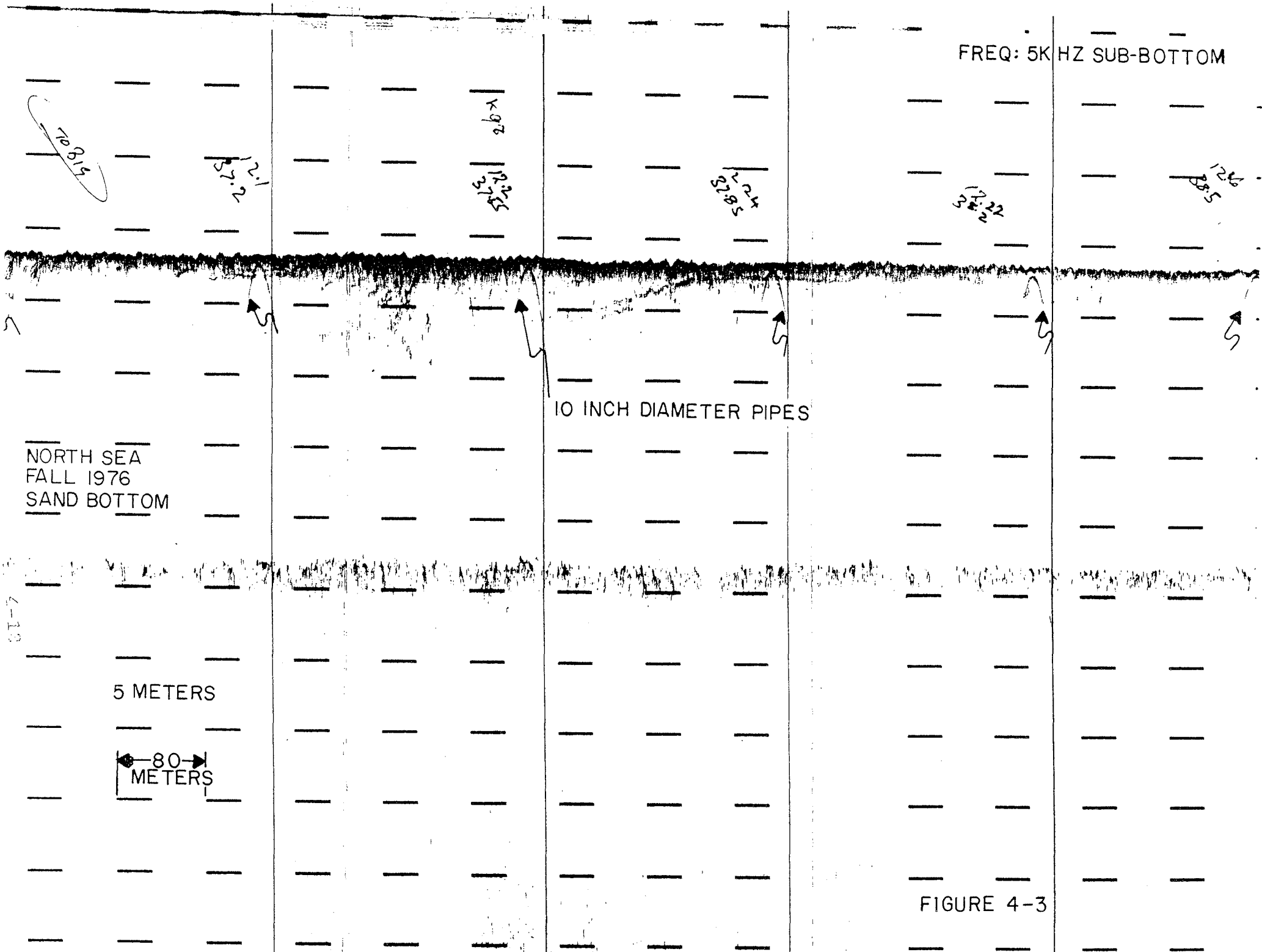
36 INCH DIAMETER PIPE
AT BOTTOM OF TRENCH

NORTH SEA
FALL 1976
FINE SAND BOTTOM

80
METERS

5 METERS

FREQ: 97 KHZ SIDE SCAN
USED AS DEPTH SOUNDER
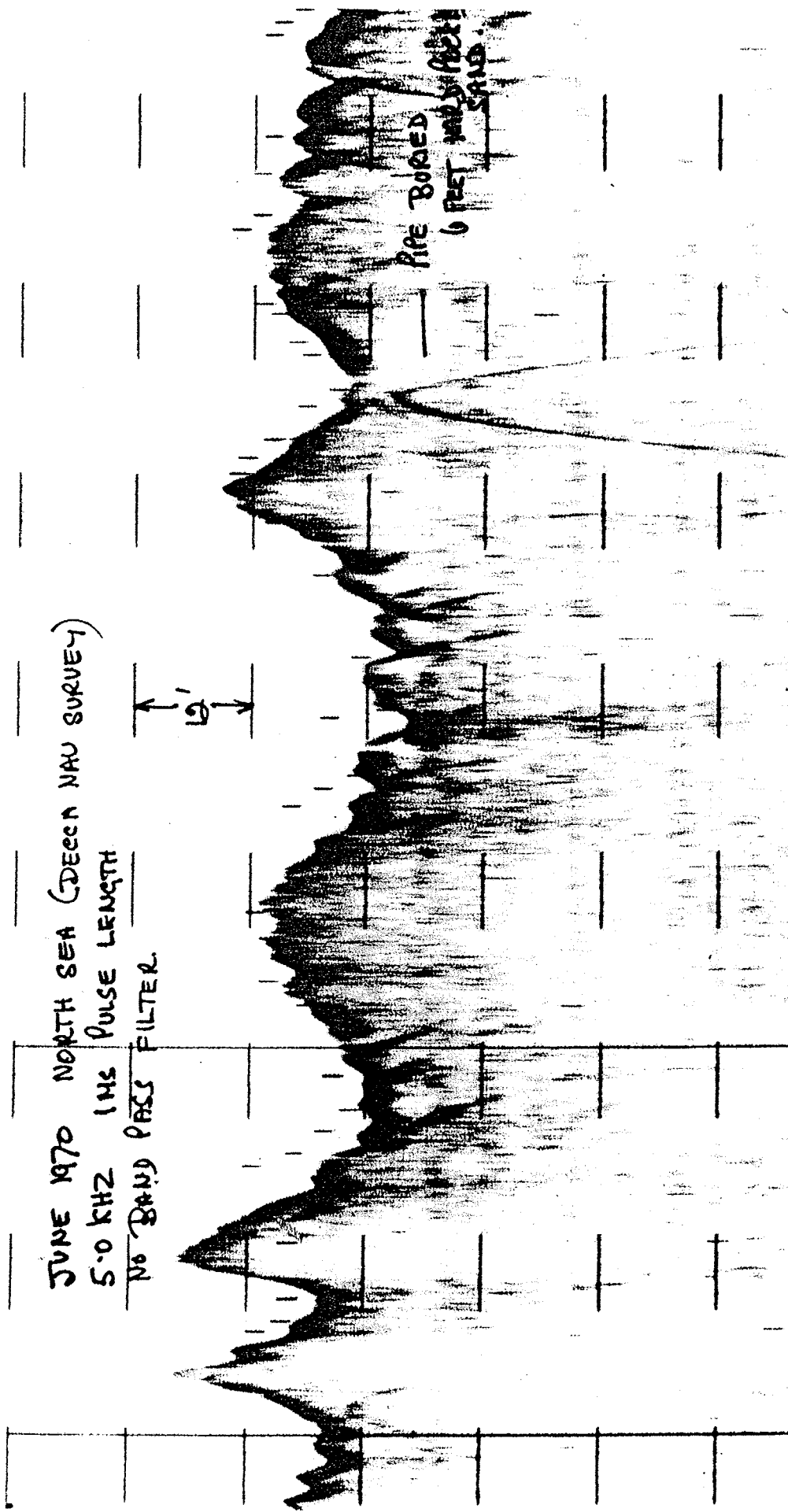FOR IMPROVED TRENCH
RESOLUTION.

FIGURE 4-2

FREQ: 5K HZ SUB-BOTTOM

IO INCH DIAMETER PIPES

NORTH SEA
FALL 1976
SAND BOTTOM

5 METERS

|←—80—→|
METERS

FIGURE 4-3

JUNE 1970 NORTH SEA (DECCA NAV SURVEY)
5·0 kHz 1ms PULSE LENGTH
NO BAND PASS FILTER

PIPE BURIED
6 FEET IN SAND

FIGURE 4-4

FIGURE 4-5
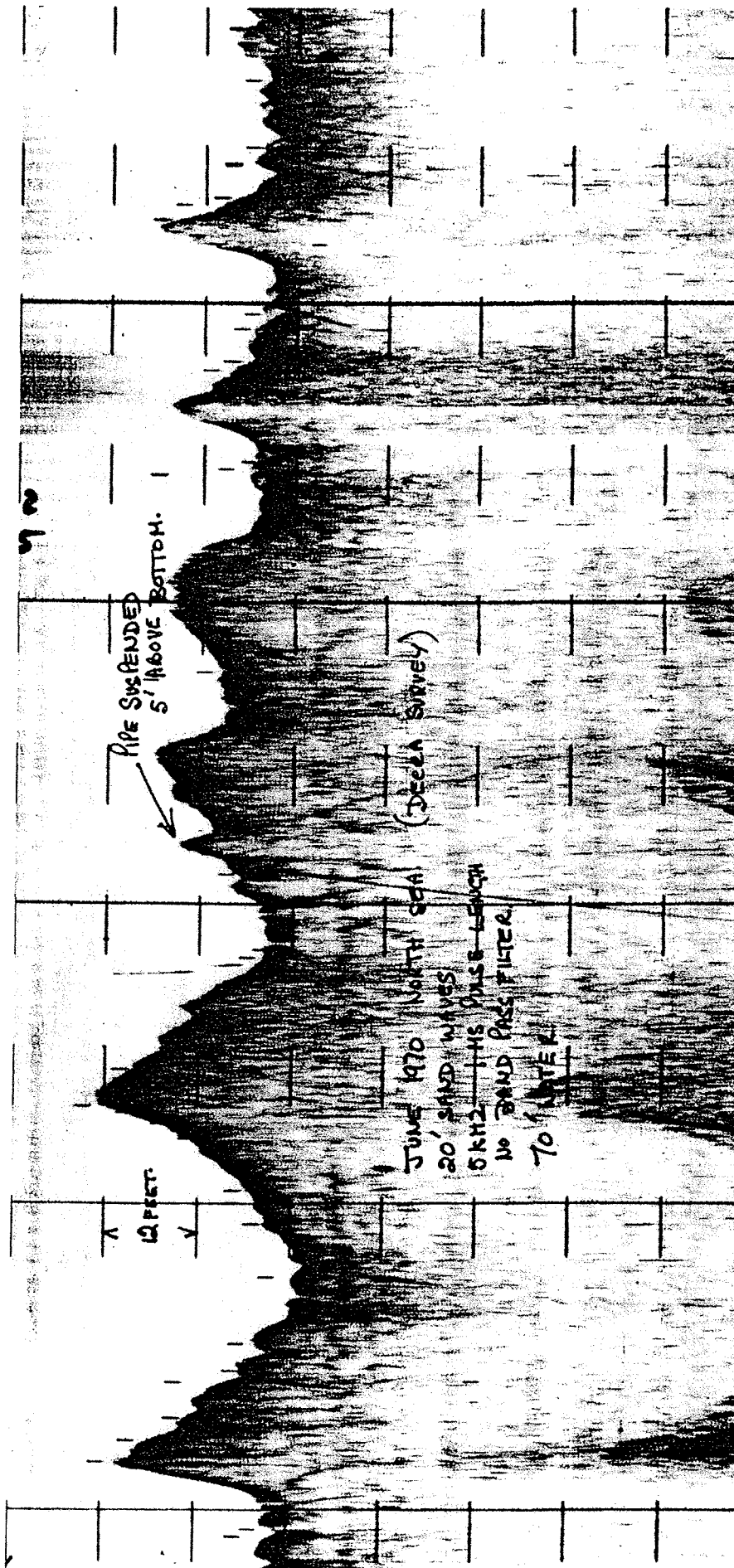
DECCA SURVEY.
BUC 1636 SIDEBOTTOM PREFER

JUNE 1970   NORTH SEA
1 MS PULSE LENGTH
6.0 KHZ.   NO BANDPASS FILTER.
40 FTM. SCALE   70 FEET WATER.

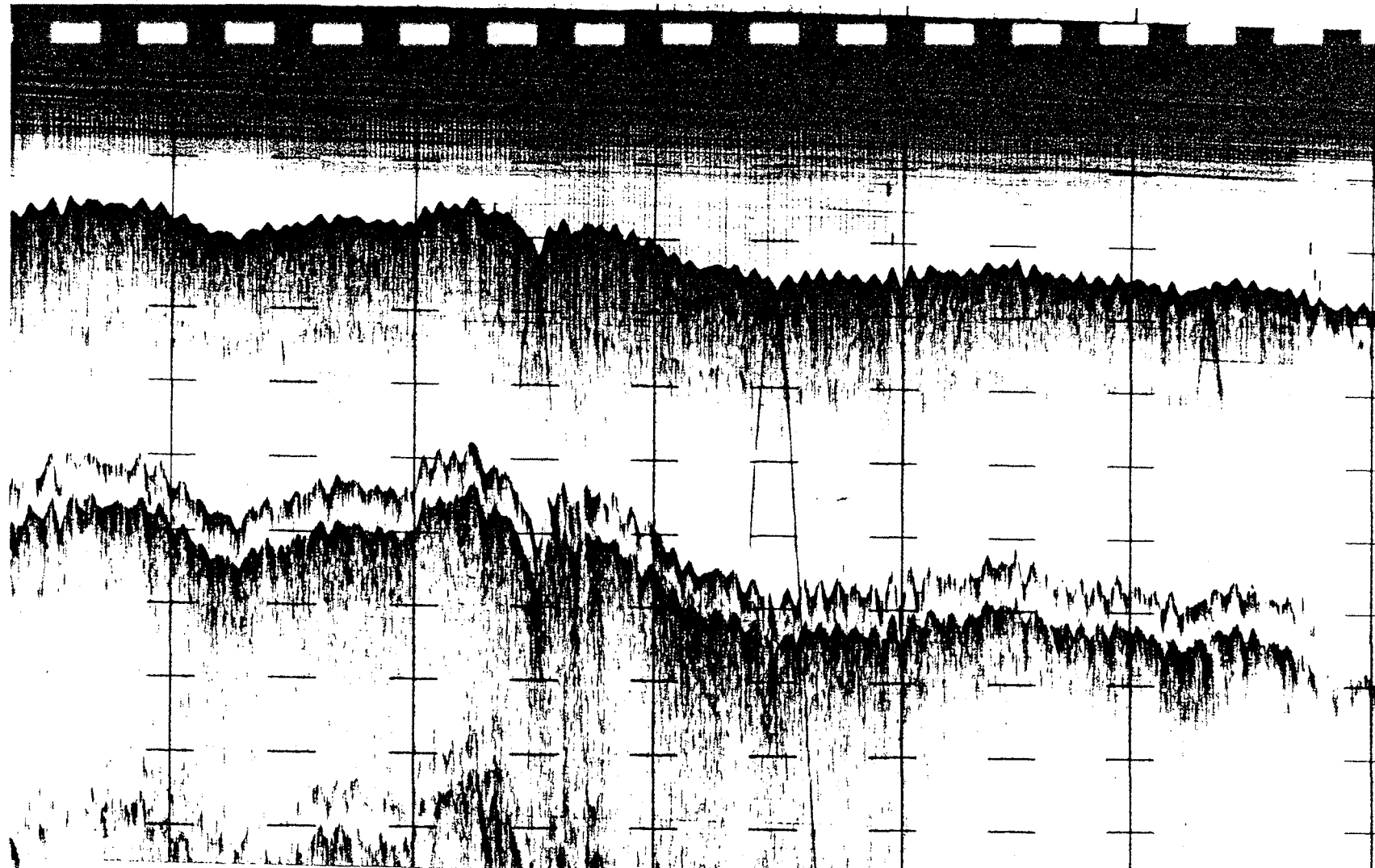10 FEET.

JUNE 1970

4-16

FIGURE 4-6

FIGURE 4-7
pipe line location

o.r.e. model 1036 system
3.5 khz key .5ms
north sea: north of great
yarmouth,england
bottom material: sand
pipe size: 48"cement covered

4-17

5. THEORY OF SOUND

Propagation of sound in sea water and the materials beneath
the sea bed is governed by a complex set of phenomena. For
a comprehensive treatment of the theory of underwater sound,
the reader is referred to the extensive literature on the sub-
ject. The purpose of this section is to present to the user
unfamiliar with acoustic techniques a brief qualitative summary
of the factors influencing echo sounding and the detection of
sub-bottom strata.

5.1 Speed of Sound

The speed of sound in a liquid or solid medium is a func-
tion of the properties of the medium. In water the speed is
approximately 4,800 feet per second, and varies with tempera-
ture, pressure, and salinity over a few per cent for the range
of these variables encountered in the sea.

The speed of sound in sediments and rock is usually faster
than in water, although for loosely compacted muds and sands
the speed may be slightly less than water.

The Precision Recorder used with the Sub-Bottom Profiling
System is calibrated for an assumed speed of 4,800 feet per
second for English system versions and 1,500 meters per second
for metric versions. Where extreme precision in bottom depth
measurements is required, accurate knowledge of the average
sound speed through the water column is necessary from inde-
pendent measurements.

Likewise, the actual depth of sub-bottom layers observed with the system, while often expressed in fathoms or feet as indicated on the recorder scale, will, in general, be deeper than indicated. The depth can only be determined from sound speed measurements made from an actual core taken at the site.

5.2 Propagation Loss

The intensity of sound in any medium decreases with distance from the source. The total decrease at a given distance is called the propagation loss. This loss is, in general, composed of two elements: spreading loss and absorption.

5.2.1 Spreading Loss

The first, in the case where channeling effects are not present, is spherical spreading loss, analogous to the free space case of optics. Spreading loss causes the intensity to decrease as the square of the distance from the source, and is entirely a function of geometry. In sonar practice, the reference distance is taken as one yard, and therefore, the total distance is also expressed in yards or kiloyards.

5.2.2 Absorption

The second component of propagation loss is due to absorption. Absorption loss is a function of the properties of the medium, distance from the source, and the wavelength or frequency of the sound. In all media, absorption loss at a given distance increases with frequency. For this reason, the operating frequency of a sonar system is inversely related to the maximum range required in water or the maximum penetration achievable in sediments.

At the frequencies (3.5-7.0 kHz) used with the Sub-Bottom
Profiler, the absorption loss in the water path is small and
in fact is negligible for the shallow depths where the equip-
ment is normally used.

5.3 Reflection and Refraction

The laws governing reflection and refraction of sound in
liquid and solid media are analogous to those governing light.
The methods of optics, in particular, ray tracing, are exten-
sively used in analysis.

5.3.1 Refraction

In echo sounding and sub-bottom profiling work, the angle
of incidence between the rays of interest and the generally
horizontal boundaries encountered is in the neighborhood of
90 degrees. Hence, refraction is seldom encountered and will
not be considered here.

5.3.2 Reflection

Reflection will occur wherever a well-defined boundary
exists, exhibiting an abrupt change in the specific acoustic
impedance. One other factor necessary for reflection is that
the surface of the boundary be smooth; i.e. the dimensions
of its "roughness" should be large compared with the wavelength
of the impinging sound.

The specific acoustic impedance of an acoustic medium is
ρc, where ρ is the density and c is the speed of sound in the

medium. A reflecting surface is characterized by a parameter known as the _reflection loss_, which is the ratio of the intensity of the reflected wave to the intensity of the incident wave at the surface.

5.4 Scattering and Reverberation

A fraction of the energy from a sound source may also be returned by the process of _scattering_. Scattering results from particles or small-scale inhomogeneities in the medium, whose dimensions are of the order of less than a wavelength. Sound impinging on these scatterers is re-radiated in all directions. The portion of energy radiated back toward the transmitter is called _backscatter_.

Backscatter gives rise to two types of reverberation: volume and surface.

5.4.1 Volume Reverberation

Volume reverberation results from scatterers distributed through all or part of the medium. The requirement for a scatterer need only be that its "ρc" be different from the surrounding medium. Scatterers in sea water have been identified as local inhomeogeneities in temperature and salinity, inorganic and organic particulate matter suspended in the fluid, air bubbles, and marine organisms including schools of fish.

5.4.2 Surface Reverberation

Surface reverberation is caused by backscattering from an acoustically rough surface where the scale of roughness is

now smaller than the order of a wavelength and the surface cannot be considered as a reflector.

The intensity of a backscattered return is, in general, dependent on the properties of the scatterer and the sound frequency, as well as the range.

5.5 Noise

Noise is defined as any unwanted signal which tends to obscure the desired echoes being recorded. Several types and sources of noise will be encountered in sub-bottom profiling; most important are background and reverberation noise.

5.5.1 Background Noise (See Figure 5-4 of the sample records)

Background noise comes from sources external to the equipment, and is uncorrelated with the transmitted pulse or sweep rate. Acoustic noise originating in the sea itself is caused by wave action (sea state noise), and certain marine organisms (biological noise).

Sea state noise is detectable over the entire spectrum of frequencies used in sonar work, and for this reason, although its intensity in a given frequency band is inversely related to frequency, it is considered to be "broad band noise."

Biological noise may exist over a broad band (for example, snapping shrimp) or be restricted to narrow bands as in the case of cetaceans. Man-made noise may contribute to the background noise level. This noise will principally originate from

the towing ship, and results from propeller cavitation, machinery noise transmitted through the hull, and flow noise. Noise originating from other ships may also contribute. Flow and cavitation noise tends to be broad band with general inverse relationship to frequency. Machinery noise will tend to show distinct peaks at frequencies harmonically related to the speed of rotation.

Electrical noise may contribute to the background, although it should not be apparent unless the equipment is improperly grounded. Ignition noise from a gasoline engine or 60 Hz "hum" from the power line can be encountered, and will usually be eliminated by proper grounding.

All forms of background noise will appear as more or less evenly distributed "snow" or streaks on the record. In the case of broad band noise, the snow will be uniform in character. Noise of one predominant frequency, such as 60 Hz hum, ignition noise, or machinery noise can usually be identified by the pronounced pattern of bands it will make on the record.

Even if all noise sources external to the equipment were to be eliminated, some residual noise always remains as a result of the electrical "self-noise" of the hydrophone and the input circuits of the receiver. Thus, if the receiver gain is increased to a high enough degree, the record will be darkened by noise. The background noise level is, therefore, the ultimate limiting factor in determining the sensitivity of the receiving system.

The signal-to-noise ratio is optimized by including a band-pass filter in the receiver. This filter passes only the band of frequencies included in the transmitted pulse. Its center frequency is the same as the carrier frequency, and its bandwidth should be inversely proportional to the duration of the pulse. Thus, the noise energy outside the band necessary to accommodate the pulse is excluded and the signal-to-noise ratio improved.

5.5.2 Reverberation Noise

Reverberation noise, unlike background noise, is correlated with the transmitted pulse and sweep rate, since it is the result of backscattered energy originating at the acoustic projector. At the high power levels used in sub-bottom profiling, volume reverberation from the water in the first hundred or more feet of depth produces a strong signal. Thus, when operating in shallow water, the reverberation noise may saturate the receiver circuits and obscure the bottom echo.

This condition is virtually eliminated in the present system by the use of Time Varying Gain (TVG). The TVG circuit controls the gain of the receiver as a function of the sweep time. Gain is held at a constant low value for the period equivalent to the distance to the bottom, thus reducing or eliminating reverberation noise from the record. The bottom echo, being stronger than the reverberation, will show on the record. At

this point, the gain starts to increase as a linear function of time for the remainder of the sweep. The threshold value of gain and the rate of increase are adjustable. The "break point" where the gain begins to increase may be manually adjusted, or in the automatic mode, will track the bottom. The TVG rate is ideally set to compensate for spreading and absorption losses in the bottom.

With the foregoing comments established, it is now possible to make some specific statements regarding the actual sub-bottom profiling process.

5.6 Penetration and Depth Resolution

In many cases the user of sub-bottom profiling equipment is concerned with obtaining maximum depth of penetration into the sub-bottom sediments with a high degree of resolution. Since these two goals are mutually exclusive, some knowledge of their interrelation is useful in order to arrive at a workable compromise.

5.6.1 Frequency Dependence

For a fixed amount of power, the depth of penetration in a given material increases as the carrier frequency decreases. However, depth resolution depends on the ability to resolve small increments of time. The time increment is ultimately inversely proportional to the carrier frequency, since the outgoing pulse must contain at least one or two cycles of the carrier. In other words, higher frequencies offer better resolution.

The present system is specifically designed for high resolution in the upper one or two hundred feet of sub-bottom. The power level is the maximum achievable at moderate cost and weight with electro-acoustic transducers. Deeper penetration is only accomplished with systems using lower frequencies. In this case, resolution is sacrificed for deeper penetration.

Adjustment of frequency over the range 3.5 to 7.0 kHz and pulse width over a wide range allows the user to select the best compromise between resolution and penetration for the conditions within the capabilities of the equipment.

5.6.2 Pulse Energy

Further affecting the resolution and penetration of the sound is the total energy of the pulse. The energy is the product of pulse duration and power. Thus, at a given power level, the energy increases in direct proportion to the pulse length. Full advantage of this fact is only realized if the bandwidth of the receiver is adjusted to conform to the pulse duration. The frequency spectrum of repetitive pulses is a band of discrete frequencies centered at the carrier frequency. The width of the band including the significant components is inversely proportional to the pulse duration. Since the background noise energy passing through a filter is directly proportional to the bandwidth of the filter, it follows that the signal-to-noise ratio (therefore, sensitivity) will be maximum when the filter is just sufficiently wide to pass the major components of the pulse frequency spectrum.

5.6.3 Pulse Duration and Rise Time

A correlary to the relationship between pulse duration and filter bandwidth is that the rise time of the filtered pulse is inversely proportional to the bandwidth of the filter. Note that the rise time determines the resolution with which the instant of arrival of the pulse may be determined, while the pulse duration determines how close an interval between two pulses, or echoes, may be resolved. Thus, as the pulse energy is increased, provided the receiver bandwidth is properly adjusted, the signal-to-noise ratio will increase, and more penetration may be expected.

5.6.4 Penetration Versus Resolution

The relationship between resolution and penetration may be summarized in the following table:

	Increase Penetration	Increase Resolution
Frequency	Decrease	Increase
Bandwidth	Decrease	Increase
Pulse Duration	Increase	Decrease
Power	Increase	

5.6.5 Transducer Directivity

The resolution of a sub-bottom profiling record is further affected by the beamwidth, or directivity, of the trandsucer. The transducer array and fish used with the system are designed so that virtually all of the sonic energy is directed downward.

By the same token, the unit is insensitive in the receive mode to background noise from directions widely separated from the vertical.

The pattern of radiation from the transducer array may be regarded as a cone whose total angle is inversely proportional to frequency. The angle varies from 55 degrees at 3.5 kHz to 30 degrees at 7.0 kHz. The beam angle is defined, according to standard practice, as the angle between the points at a fixed distance from the transducer where the power is one-half the level measured on the axis. At wider angles, the power falls off sharply, but some energy is radiated beyond the limits of the defined beamwidth.

The area of the bottom "illuminated" by the beam is, therefore, directly proportional to its angular width, limiting size of features which may be resolved. A further consequence of the beamwidth is that rough bottoms will tend to scatter energy back from the whole area illuminated by the beam, causing the bottom trace seen on the recorder to be wider (longer in time) than the original pulse width.

5.6.6 Sub-Bottom Composition

The final factor determining the degree of penetration is, of course, the composition of the bottom and underlying layers. Most bottoms act both as reflectors and scatterers. The reflection loss determines the amount of energy transmitted into sediments, and the absorption in the sediments
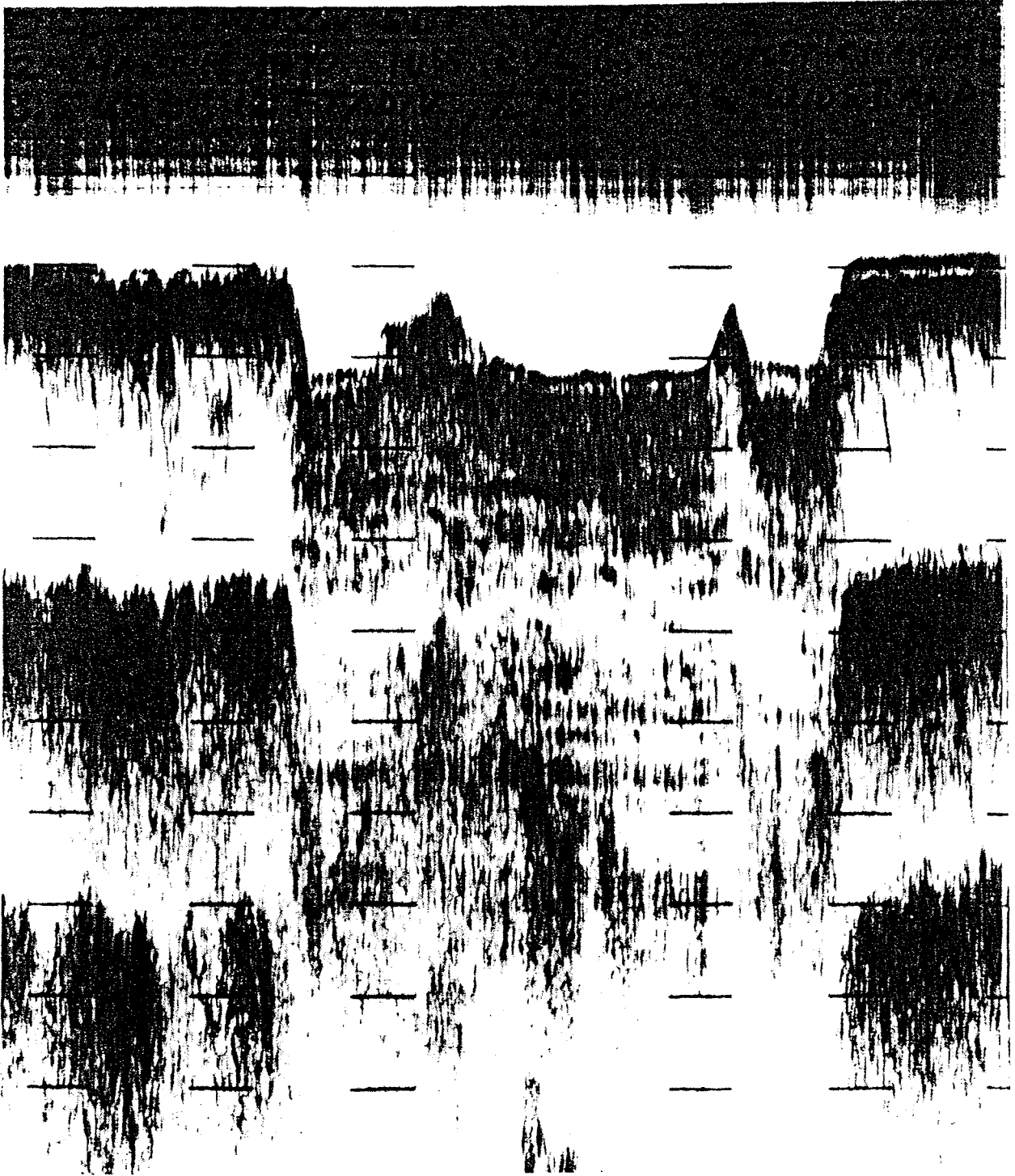
Figure 5.1

plus the reflection loss encountered at sub-bottom horizons, or interfaces, will also be factors determining the ultimate depth of penetration. Scattering may also occur in strata that are not perfectly homogeneous.

5.6.7 Illustrative Records

Figure 5.1 is a portion of a record showing the effect of a bottom where the reflectivity is so high that no useful energy penetrates. The record is of a traverse of a dredged channel. The undredged portion at the edges of the figure show multiple echoes of the bottom and no visible structure beneath. The multiple echoes are caused by "second bottom"; that is, the echo from the bottom is reflected from the water surface, back to the bottom and up again to the transducer. Thus, the "second bottom" can be identified by the fact that its distance from the top of the record is twice the indicated bottom depth plus the depth of the transducer. A third bottom is clearly evident in this record. Multiple bottoms are most likely to be observed in shallow depths, where bottom reflectivity is high.

In the center of the record showing the depression caused by dredging, definite layers are evident beneath the bottom and the second bottom is much weaker. It may, therefore, be deduced that the bottom reflectivity in the channel was much lower than in the shoal water, and sound energy penetrated into the sediments. The cause of this behavior was found to be a

CRE MODEL 1036
SUB BOTTOM PROFILER

16 TRANSDUCER ARRAY
HULL MOUNTED (WITH
ONLY 4 TRANSDUCERS
CONNECTED.
3.5 KH8, 0.5MS PULSE
10 KW. POWER.

10 FATHOMS

Figure 5.2
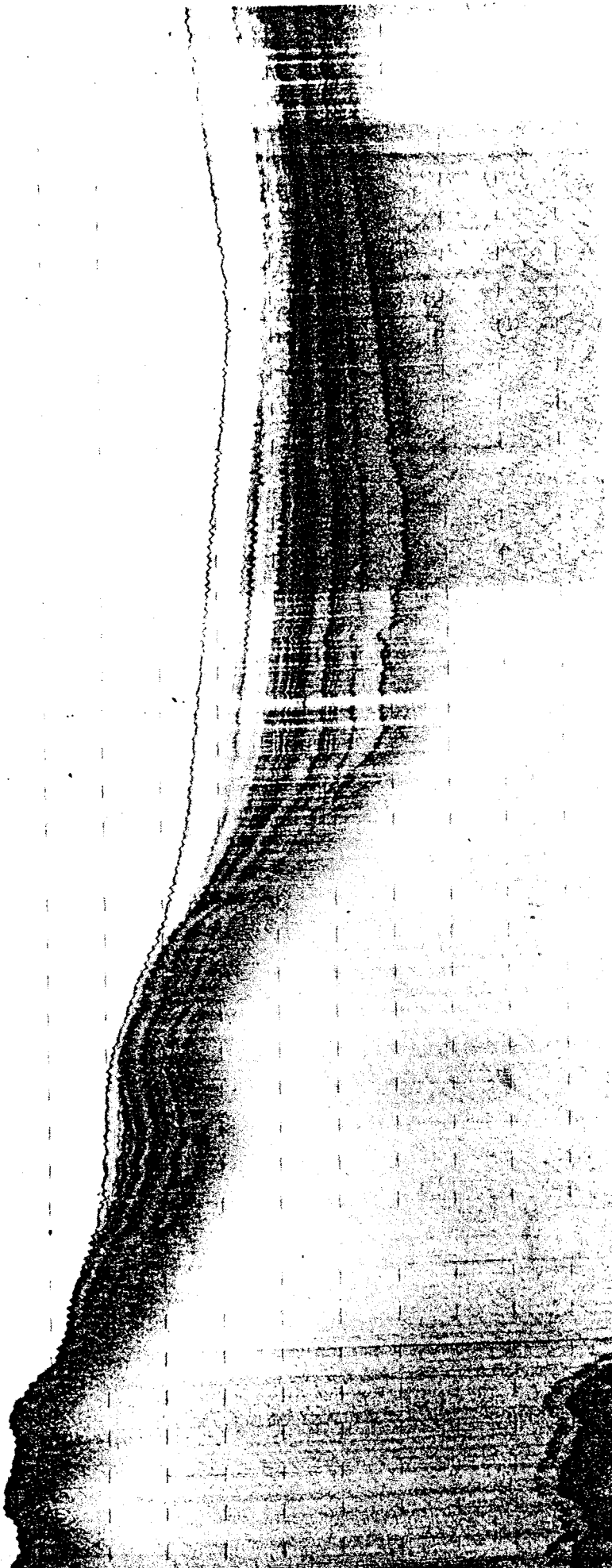
thin layer of decaying organic matter containing gas bubbles which formed a barrier to the sound. Recent dredging, shown by the deep part, removed this layer, allowing sound to penetrate.

The depth of penetration in coarse or hard-packed sand or gravel will be less than in softer materials such as mud or silt. In Figure 5.2 at the left-hand edge of the record, no sub-bottom layers are clearly visible. The bottom at that point is sand extending to a depth beyond the capability of penetration. The noise-like return extending below the bottom is probably due to scattering from gravel or rocks mixed with the sand. A second bottom return is visible in the lower left corner.

To the right of this feature is a depression where layers of muds and/or silts overlie the harder material. Note that there is little scattering return in the top layer of silt, indicating a fairly homogeneous medium. Below the silt, many layers and other fainter returns are clearly visible.

Figure 5.3 shows a high resolution record made with 10kw using time varying gain in shallow water. Reverberation noise is reduced to a low level and many layers are evident, The record also shows a second and third bottom. The small marks labeled "TVG Finder" are produced by a front panel control on the transceiver which marks the record at the break point of the time varying gain characteristic. In this case, the band pass filter was completely eliminated for highest resolution (widest bandwidth). This technique is possible in conditions of low noise and high signal strength frequently encountered
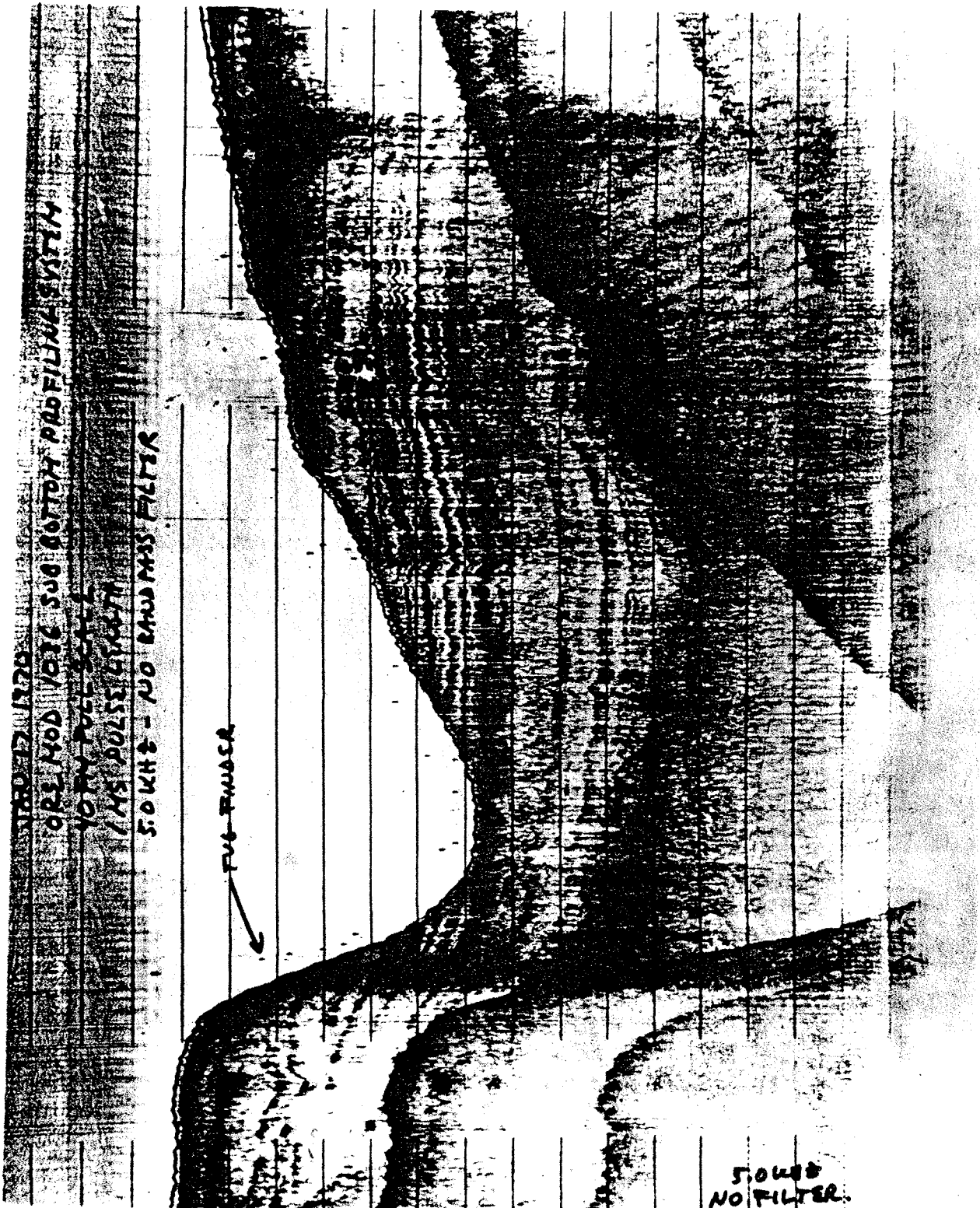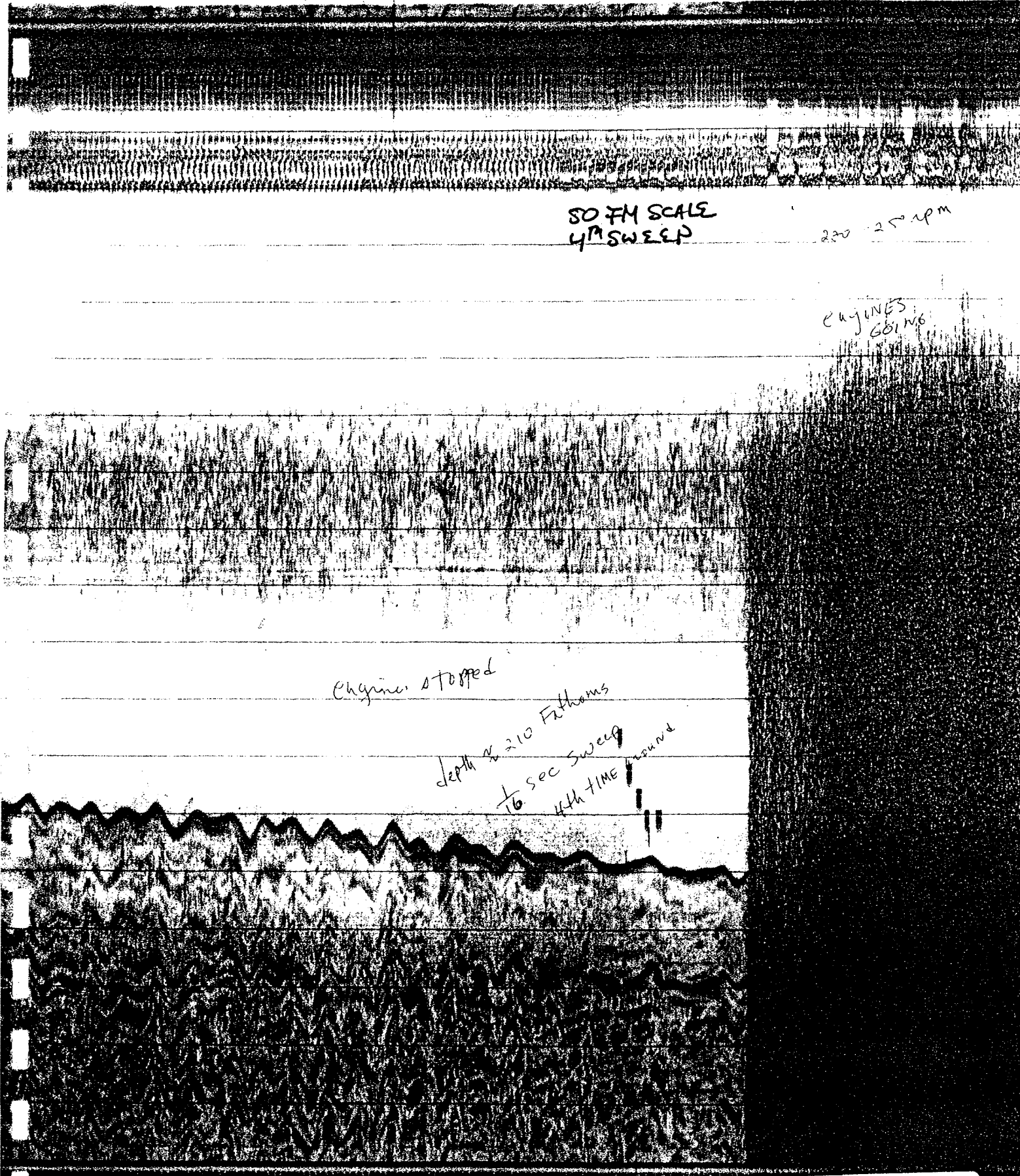
Figure 5.3

50 FM SCALE
4ᴹ SWEEP

270 - 250 RPM

ENGINES GOING

engines stopped

depth ≈ 210 Fathoms

1/6 sec sweep

4th TIME around

Figure 5.4

ORE MODEL 1036
SUB BOTTOM PROFILER
16 TRANSDUCER HULL
MOUNTED ARRAY
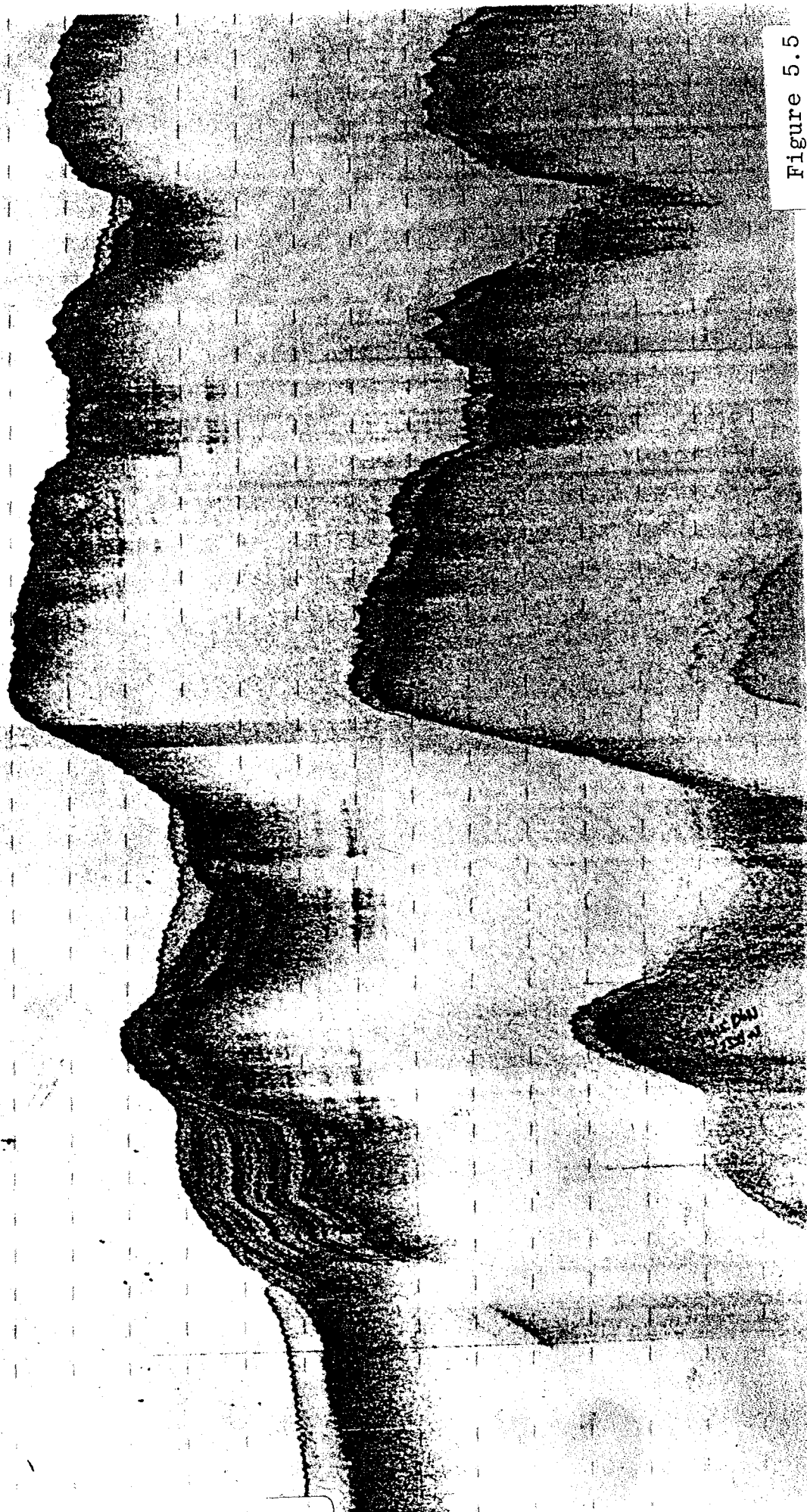3.5KHE, O.5MS PULSE
10 KW POWER

10 FATHOMS

Figure 5.5

in shallow water.

Figure 5.4 is an example of extreme noise conditions.
Under such conditions, it may appear as a system malfunction.
In this record on the right side, the noise from the ship
completely obliterates the record and no bottom return can be
seen. When the ship was stopped, the left side of the record,
the noise level decreased enough to obtain satisfactory records.
By changing the position of the towed vehicle, the survey was
able to continue with good results.

Using a hull mounted array with 16 transducers (4 x 4) will
also produce good records through the hull of a ship as can be
seen from Figure 5.5. The hull should be horizontal and flat
under the array and steel hull thickness up to one half inch can be
tolerated. Figure 5.5 shows a hull mounted array used at 3.5 kHz
with 10 kwatts of pulsed power out. At the left, a layer of
mud is visible over what appears to be a mixture of coarse and
fine sand possibly mixed with gravel. As the bottom rises on
the right side of the record, there are layers of mud and silts.
There is a pocet of silt mixed with coarse sand between the two
rises at the center of the record. Below the sub-bottom layer
is the second return with its typical 2 to 1 distortion of peaks
and valleys.

6. TROUBLESHOOTING

Failures which occur in the system are first isolated to a particular sub-system. Then the troubleshooting section of the appropriate sub-system manual can be used to isolate the failure to a particular component or subassembly.

6.1 Quick Subsystem Checks Versus Symptom

a. Recorder will not scan.

Problem is in recorder - most likely paper interlock switch or bad stylus.

b. Recorder will not write.

Depress mark button - if no mark with LIMIT at mid-scale, check for paper or stylus problem or failure in recorder writing circuits.

c. No bottom trace/no signal on recorder except scale lines with XMT kw above 2.5 kw.

(1) Check recorder wirting circuits as in b above.

(2) Check H.V. Indicator on transceiver is on with XMT, kw control beyond 2.5 kw. If not, continue checking transceiver and fish below.
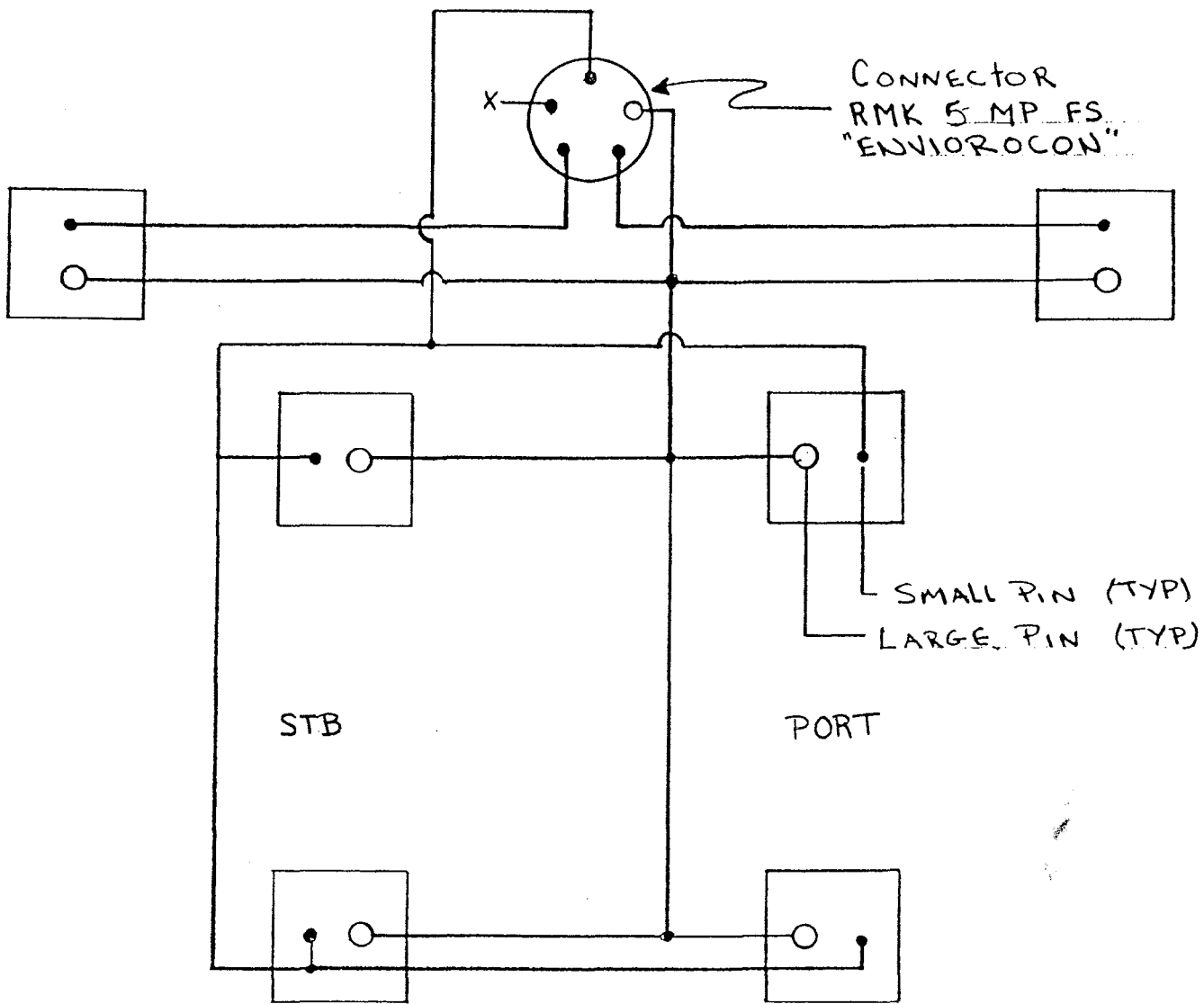
(3) Depress TVG finder - look for mark on recorder. If mark is present recorder is O.K., problem is in transceiver or fish.

d. No output from transceiver.

(1) Make sure XMT, kw is not turned up for 30 seconds after transceiver turn-on (SCR high voltage crowbar must drop out).
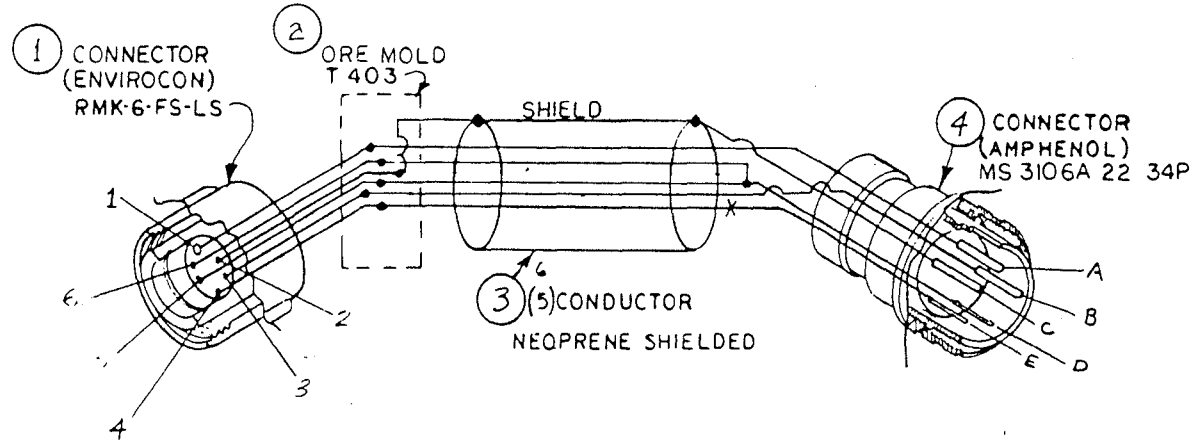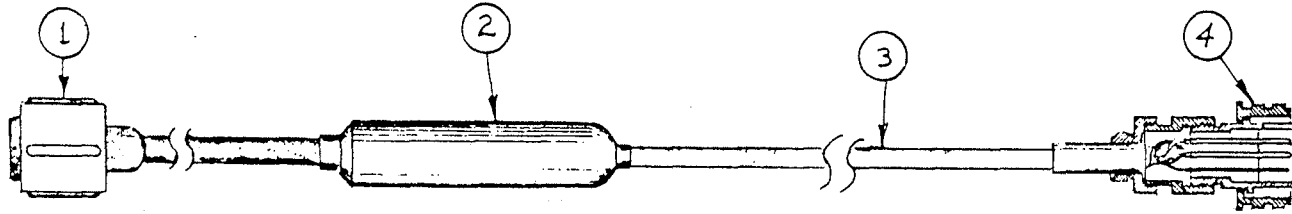
(2) Check transceiver with dummy load. See Trans-
ceiver Manual.

(3) Check fish for short/open circuit. See Fish
Manual.

e. Audible output from fish but no received signals on
recorder.

(1) Check fish for open circuit. See Fish Manual.

(2) Trouble-shoot transceiver receiver section. See
Transceiver Manual.

(3) Check recorder as in b, also check interface
writing signal to recorder from transceiver at
interface connector.

CONNECTOR
RMK 5 MP FS
"ENVIOROCON"

X

SMALL PIN (TYP)
LARGE PIN (TYP)

STB

PORT
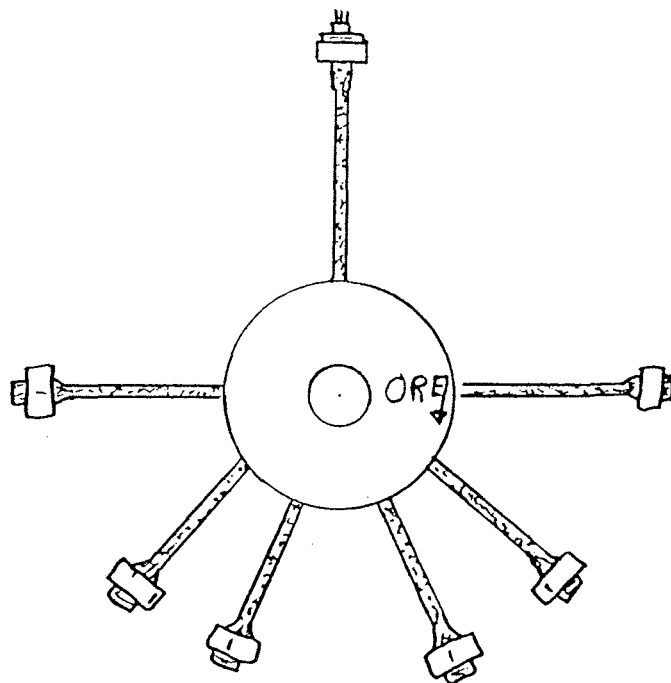
O.R.E. Model T-610 M
Junction Box

ORE

5	4	3	2	1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVE

① CONNECTOR (ENVIROCON) RMK-6-FS-LS

② ORE MOLD T 403

SHIELD
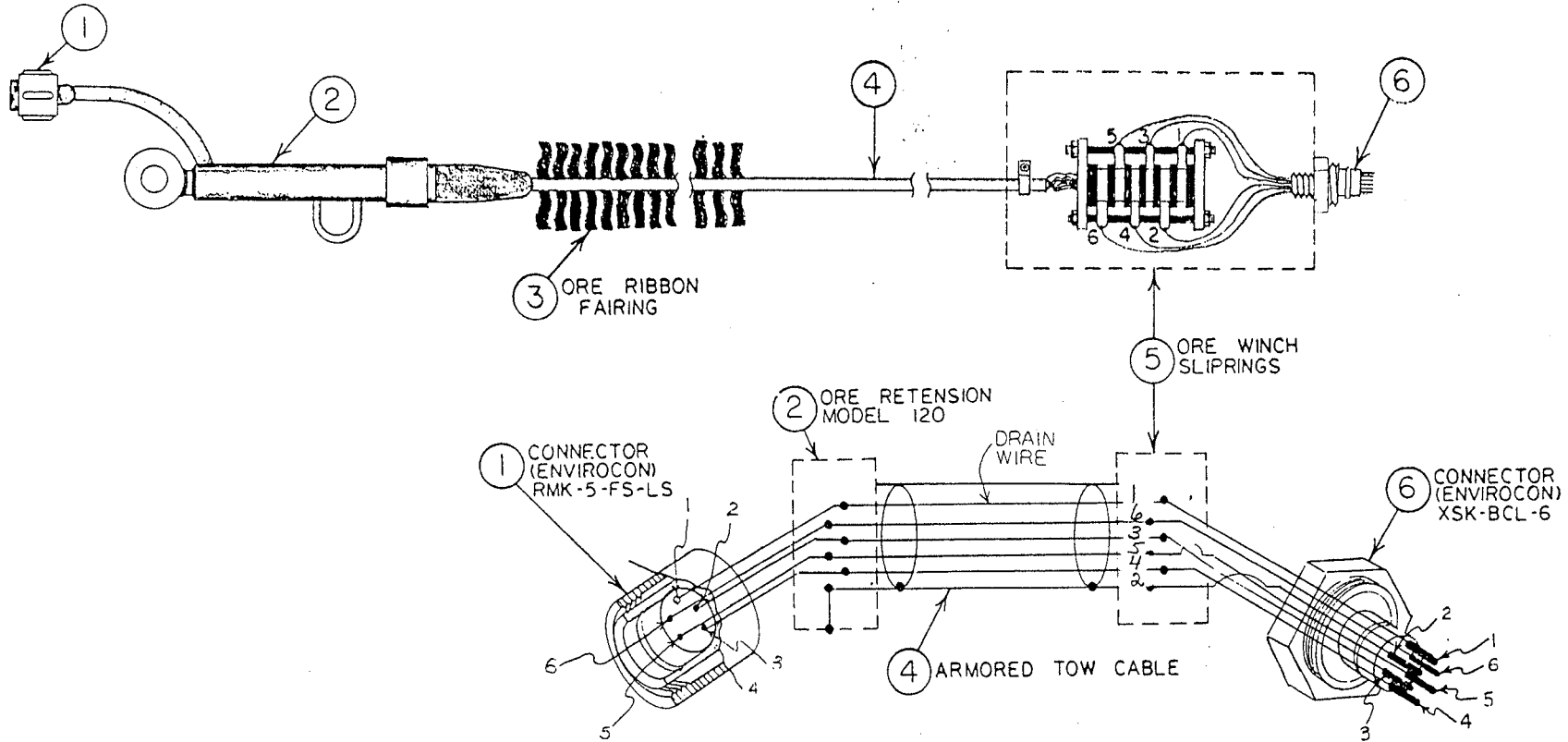
④ CONNECTOR (AMPHENOL) MS 3106A 22 34P

③ (5) CONDUCTOR NEOPRENE SHIELDED

WHITE 1 — A
RED 2 — C SHIELD
GREEN 3 — B
BROWN 4 — NC
BLUE 5 — D
BLACK 6 — D

		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CONTRACT NO		**ORE** OCEAN RESEARCH EQUIPMENT, INC. FALMOUTH, MASSACHUSETTS
		TOLERANCES ON	DRAWN J. PERRYMAN	5/10/74	NAME
		DECIMALS .XX .XXX ±— ±—	CHECKED R. PENTON	11/3/76	DECK CABLE MODEL 36 DC
		ANGLES ±—	ENGINEER R. PENTON	11/3/76	
		SURFACE ROUGHNESS ✓	APPROVED (JLD)	11/3/76	SIZE / CODE IDENT. NO / DWG NO / RE
NEXT ASSY	USED ON	MAT AS NOTED			B / 25993 / B1200-0005
APPLICATION					SCALE NONE / WT. LBS. / SHEET OF

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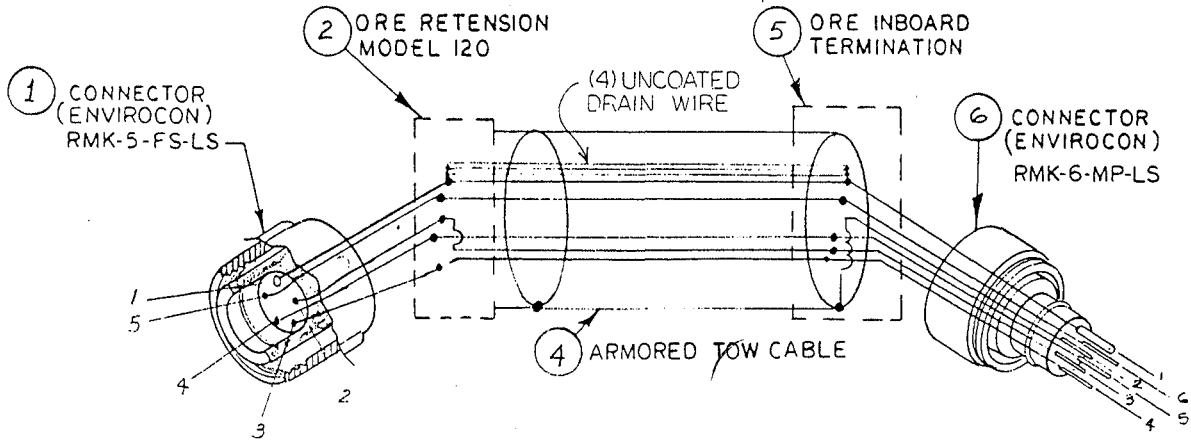## REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	CHANGED WIRING ARRANGEMENT	5-25-76	

ORE RIBBON FAIRING

ORE WINCH SLIPRINGS

ORE RETENSION MODEL 120

DRAIN WIRE

CONNECTOR (ENVIROCON) RMK-5-FS-LS

CONNECTOR (ENVIROCON) XSK-BCL-6

ARMORED TOW CABLE

WIRE LEGEND

1 — 1
2 — 2
3 — 3
4 — 4
5 — 5
6 — SHEILD

		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CONTRACT NO		**ORE** OCEAN RESEARCH EQUIPMENT. INC. FALMOUTH, MASSACHUSETTS
		TOLERANCES ON	DRAWN H.A. JEMISON	6/20/74	NAME TOW CABLE MODEL 144-1W
		DECIMALS: .XX .XXX ± ±	CHECKED	5/25/74	
		ANGLES ±	ENGINEER	5/21/76	
		SURFACE ROUGHNESS √	APPROVED	5/25/76	
NEXT ASSY	USED ON				SIZE **B** / CODE IDENT. NO 25993 / DWG. NO B1200-0010 / REV. A
APPLICATION					SCALE / WT. LBS. / SHEET / OF /

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	CHANGED DRAIN WIRES LOCATION	5-18-76	

A

B

3 ORE RIBBON FAIRING

5

6

4
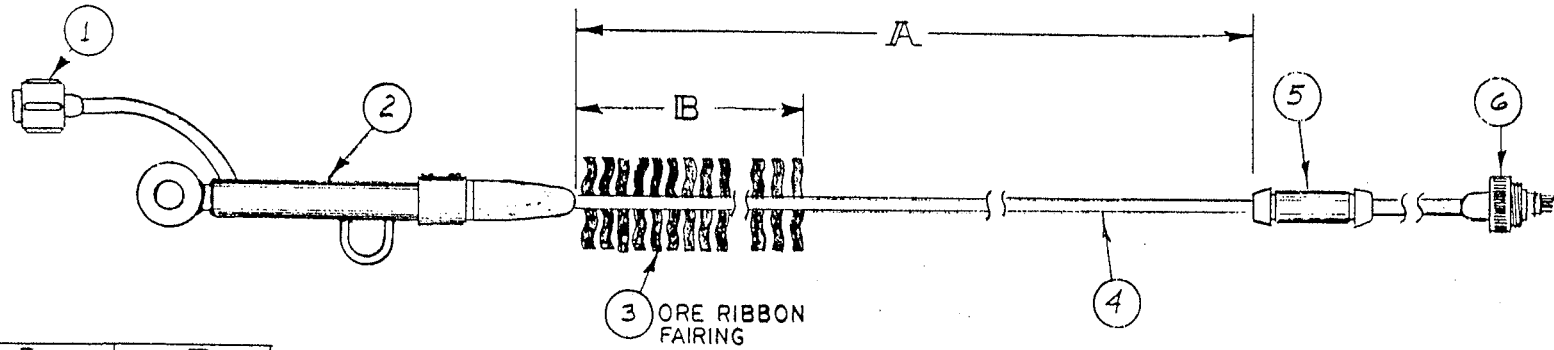
DASH	DIM A	DIM B
1	1000 FT.	450 FT.
2	2000 FT.	450 FT.

2 ORE RETENSION MODEL 120

5 ORE INBOARD TERMINATION

(4) UNCOATED DRAIN WIRE

1 CONNECTOR (ENVIROCON) RMK-5-FS-LS

6 CONNECTOR (ENVIROCON) RMK-6-MP-LS

4 ARMORED TOW CABLE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON

DECIMALS: .XX .XXX
±   ±
ANGLES ±
SURFACE ROUGHNESS √

CONTRACT NO

DRAWN J PERRYMAN
CHECKED   5-21-76
ENGINEER   -21-76
APPROVED WLD   5/21/76

MAT AS NOTED

NEXT ASSY | USED ON
APPLICATION

ORE OCEAN RESEARCH EQUIPMENT, INC.
FALMOUTH, MASSACHUSETTS

NAME
TOW CABLE MODEL 144
NO SLIP RINGS

SIZE	CODE IDENT. NO	DWG. NO	REV.
B	25993	B1200-0004	A

SCALE NONE | WT. LBS. | SHEET OF

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

SMA - - FS
(FACE VIEW)
WITH K-FLS-D
LOCKING SLEEVE

SHIELD — C
WHT — A
RED — B
BLUE — N.C.
BLK — D
BRN — D
GRN — N.C.
N.C. X

AMPHENOL # MS 3106A-22-341
O.R.E. SUPPLIED AND INSTALLED

BELDEN # 8426
CABLE 100 FEET LONG
± 2 FEET

NOTES:
1.) ALL CABLES SHALL BE CONTINUITY CHECKED END TO END.

2.) ALL CABLES SHALL BE MEGGA TESTED at 500 VOLTS

3.) INSULATION to be 10 MEG OHM or GREATER CONDUCTOR to CONDUCTOR

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES

TOLERANCES ON

DECIMALS: .XX .XXX
± ±
ANGLES ±
SURFACE ROUGHNESS √

CONTRACT NO	
DRAWN	A.H.	11/7/77
CHECKED	
ENGINEER	
APPROVED	

ORE OCEAN RESEARCH EQUIPMENT, INC.
FALMOUTH, MASSACHUSETTS

NAME
O.R.E. 36 DC DECK CABLE

SIZE	CODE IDENT. NO	DWG. NO	REV.
B	25993	B 1200-0036	

| SCALE | WT. LBS. | SHEET OF |

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVE
	A	1. WAS B1200-001B		

1096

SUB-BOTTOM AND SIDE SCAN
TRANSDUCERS CONNECTION
WITH MODEL T610 JUNCTION BOX

NOTE: NO SEPARATE / COMBINED
FUNCTION

1036/1032

SUB BOTTOM TRANSDUCERS
ONLY, FOR SEPARATE/COMBINED
FUNCTION CONNECT AS SHOWN

1096 / WITH PREAMP & JUMPER

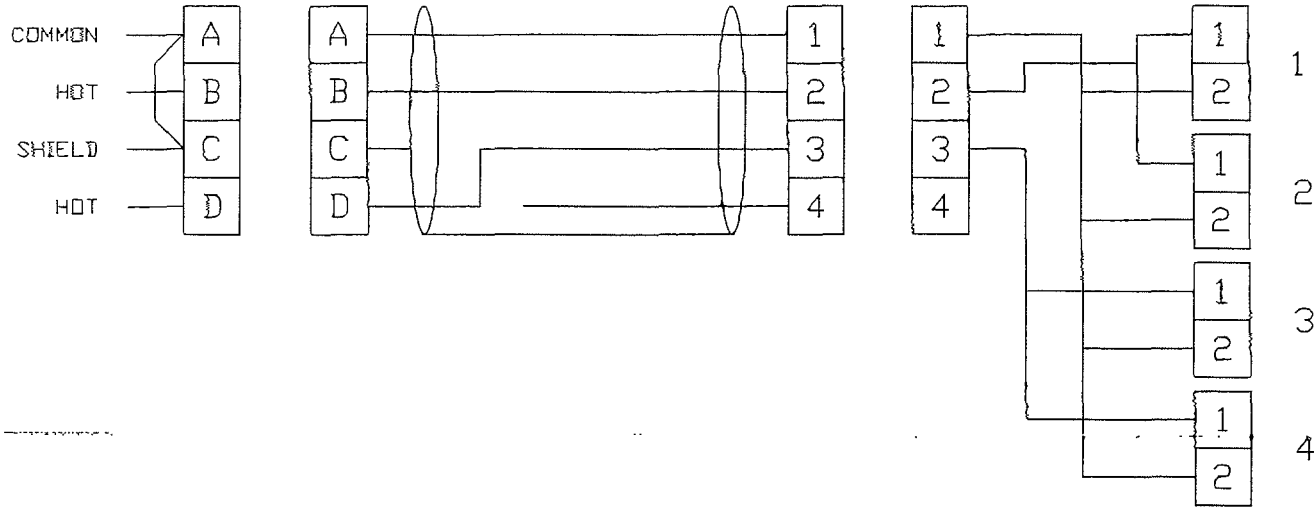|			UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	CONTRACT NO	**ORE** OCEAN RESEARCH EQUIPMENT, INC.
			TOLERANCES ON	DRAWN J PERRKMAN 5/10/15	FALMOUTH, MASSACHUSETTS
			DECIMALS .XX .XXX ±	CHECKED GRB 5/8/15	NAME 1036/1032 & 1096 SYSTEM
			ANGLES ±	ENGINEER RRB 5/8/15	TRANSDUCER CONNECTION
			SURFACE ROUGHNESS √	APPROVED	
NEXT ASSY	USED ON				SIZE B / CODE IDENT. NO 25993 / DWG. NO B1200 0021 / REV A
APPLICATION					SCALE ∿ / WT. LBS. / SHEET OF

Amphenol Bulkhead
97-3102A-22-16S

Amphenol connector
97-3106A-22-16P

Subconn
DM4F

Subconn
IL4M

Massa
C1 M2

COMMON — A

HOT — B

SHIELD — C

HOT — D

A

B

C

D

1

2

3

4

1

2

3

4

1
2   1

1
2   2

1
2   3

1
2   4

COMPANY		
Seabed Technology B.V.		

TITLE	Cable nr. 93421-5001 Modified ORE140		
SIZE A4	REV. NO. 0	DWG NO. 93421-6001	ENGINEER J.S
SCALE 1mm = 1mm	DATE 07-07-2000	SHEET 1 of 1	