RESTRICTED

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Serial No.2254
/D.c.8/

ICNAF Res.Doc.69/88

ANNUAL MEETING - JUNE 1969

# A Fishing Effort Data Aquisition System

by

James M. Crossen

## Abstract

An instrumented headrope float, the Fishnet Bathykymograph (FBK) has been developed to provide an accurate measure of fishing effort. The FBK is a part of a data aquisition system for providing information on fish population dynamics for use by the U. S. Bureau of Commercial Fisheries and possibly the International Commission for the Northwest Atlantic Fisheries. The system employs a shock isolated, 14-day time-depth recorder, and Dockside Support Equipment (DSE) for calibration and retrieval of data. The recording format is coded pulse on magnetic tape and is computer compatible.

The FBK is attached to the net aboard commercial trawlers and automatically records the number, duration, and depth of each tow.

## Introduction

An instrument which senses, records, and stores depth-time information is required for use on the nets of ground fishermen to improve the measure of fishing effort. The effective participation of the United States of America in the International Commission for the Northwest Atlantic Fisheries and to a large extent the effectiveness of ICNAF itself depends on our ability to measure changes in fisheries populations as they relate to fishing effort.

Data on fishing effort in the USA New England ports are now collected in ports by interviewers who contact vessel personnel as catches are unloaded. This method, while the best that can be employed at the present time, needs to be improved for the following reasons:

(1) Adequate numbers of interviewers are not available to interview vessel captains when the catch is landed.

(2) Most captains do not remember or make any serious attempt to record all the data required; and

(3) The lack of adequate standardization of such data, collected by different people, in different ports, and in different countries makes interpretation of data difficult.

The FBK system will:

(1) Permit the gathering of more data per man-day;

(2) Insure acquisition of accurate, complete and standard data on fishing effort regardless of vessel or country; and

(3) Enhance the facility of analysis and interpretation of results.

The function of the FBK as a part of the data collection system is the primary consideration in defining requirements. First, it must produce the desired data, i.e., the length of time and depth at which the net has been used; second, the data format must be suitable for input into the Dock Support Equipment (DSE) handling system; third, the record must be within certain limits of accuracy; fourth, it must be suitable for use by the personnel involved; fifth, it must withstand the use conditions to which it is exposed, and sixth, in satisfying these requirements the objective is to minimize the cost of the complete operation from data collection to the printing of the final report.

Telemetered and in-situ recorders, both acoustical and wired, have been used successfully to obtain data on trawl fishing operations. However, the economic limitations must be considered when a large quantity of recorders is necessary to obtain data for statistical studies in evaluating commercial fishing effort. In order to give a reliable measure of the effort of the New England fishing fleet, a sizeable fraction of the vessels will have to be equipped with FBK's. Present thinking on this is for about 100 instruments at sea at any one time, 100 shore ready to be sent out, and about 50 in the depot for maintenance and calibration.

Oceanographic instruments used at sea are usually accompanied by technicians who monitor the instrument operation, i.e., change batteries, adjust controls, replace faulty components, etc., and also guard against damage from shock and sea water. Effective use of the FBK requires that it operate reliably without servicing for the duration of a trip.

The use conditions of the FBK on a commercial trawler are extremely severe. The instrument is exposed to temperatures ranging from -25° to +60°C, it is intermittently slammed against the side of the trawler and dropped on the deck. In winter it will be covered with ice and in summer exposed to direct sunlight while the net is on deck between tows and en route to and from the fishing grounds. And of course, it would be subjected to the ocean pressure, salt water, and salt atmosphere common to oceanographic instruments. Inspection, calibration, and servicing is only possible between trips.

Scientists at the Bureau's Woods Hole Biological Laboratory conceived the idea that an instrument might be developed incorporating a standard headrope float as the housing. Foreign fishing fleets use similar headrope floats. The commercially produced floats are ideally suited as underwater housings for instruments such as pressure recorders, temperature recorders, etc. Being spherical in shape they are capable of withstanding pressures to 1400 p.s.i. (over 400 fathoms). The aluminum alloy type has good machinability as well as a high resistance to corrosion.

The spherical float was split at its equator and flanges welded to either hemisphere. One of the flanges was machined to accept an "O" ring for watertight integrity. Extensive seaching and testing was performed on pressure sensors, recording methods, and time drive mechanisms. Since cost was a prime consideration it was decided to use pressure sensitive strip chart in the recorder. The recorder was driven by battery powered solenoid wound clocks and direct current motors. The pressure sensors used were bourdon tubes and piston-spring devices. Several prototypes were designed, fabricated, and tested in the laboratory and on board the research vessel Albatross IV. Some success resulted from these early tests; however, the severe shocks resulted in excessive failures.

### Mechanical Shock Design

Early in the program preliminary shock tests were conducted using a standard eight inch headrope float fitted with a hard mounted instrument platform and accelerometers. The resultant peak G level of 1200 to 1500 at a pulse length of approximately eight milliseconds confirmed the fact that shock indeed was the major design problem.

A mechanical shock is characterized by changes of stress, position, acceleration, velocity or displacement in relatively short periods of time. That is, when it is of the same order of, or less than, that of the longest natural residual period of the structure under consideration. A shock, therefore, excites the structure so that it will vibrate at its natural frequency.

The FBK shock environment is basically a velocity shock. This basic type of motion is characterized by a sudden velocity change. The requirement that the instrument be capable of sustaining a five foot free-fall resulted in a velocity shock predicted by

$$V_s = \sqrt{2gh} = 17.8 \text{ feet/sec.}$$

where

$V_s$ = velocity shock, feet/sec.
$g$ = gravitational constant, 32 feet/sec.$^2$
$h$ = drop height, feet.

Establishing the anticipated G level on the instrument platform is a rather complex problem. However, if certain simplified assumptions are made a design G level can be determined for a single degree of freedom undamped spring suspended mass. The resultant G's due to an imposed velocity shock is given by

$$G = \frac{V_s}{g} W$$

where

$G$ = ratio of maximum acceleration to the gravitational constant
$g$ = gravitational constant, 32 feet/sec.$^2$
$W$ = natural circular frequency, rad. /sec.

A theoretical design target of 300 G's with a dynamic excursion of 0.760 inches was calculated as a result of the FBK housing dropping 60 inches to a 1/2-inch steel plate. The 300 G level should not be exceeded at the instrument platform level.

Several methods of shock isolation techniques were studied including the isolator ring support approach and the filling of the area between the instrument recorder platform and the housing with a resilient foam. The method adopted as most feasible was the annular rubber isolator ring.

A detailed analysis of shock characteristics was then made of various housing materials and sensor-recorder components. The results of these findings and selections are discussed later.

## System Design

### FBK Instrumentation-Housing

The FBK housing as shownin Figure 1 is cast aluminum alloy, with a molded out layer of P. V. C. The two hemispheres are held together with six recessed screws compressing an "0"-ring seal. The 9-1/2 inch housing, which is similar in appearance to a standard head-rope float is buoyant (1 pounds 6 ounces) in fresh water and weighs 16 pounds 10 ounces in air. The hydrostatic pressure capability is 600 meters. (See Table 3 attached.)

The material of construction was selected to allow long life in the ocean environment of salt water, severe shock, hydrostatic pressure, and weather conditions, while at the same time providing suitable protection for the internal recorder. Other housing materials were considered early in the program. This study was pursued with the basic trade offs between four candidate materials as listed in Table 1. The shock index factor represents a calculated stiffness characteristic for each material assuming a consistent geometry. Materials showing the greatest potential were aluminum (356-T6), stainless steel (3/6), titanium, and a polycarbonate resin--"Lexan." The latter material, while most ideal from the standpoint of weight, stress, and most important, shock, was found excessively expensive for the injection molding technique ($10,000 for tooling). (See Table 2 attached).

Table 1. --Material Comparison

| Material | Thk. | Wgt. | Rel. Cost | F. S. Elastic Stab. | F. S. * Maximum Stress | Shock Index |
|---|---|---|---|---|---|---|
| Aluminum 356-T6 | 0. 313 in. | 8. 22 # | 1. 0 | 4. 3 | 2. 7 | 1. 8 |
| Stainless Steel 316 | 0. 188 in. | 15. 5 # | 2. 5 | 3. 8 | 2. 6 | 1. 1 |
| Titanium | 0. 250 in. | 10. 8 # | 6. 1 | 3. 9 | 4. 5 | 1. 5 |
| Lexan | 0. 562 in. | 6. 5 # | 2. 8 | 5. 9 | 2. 1 | 1. 0 |

*Duration of Lexan Housing at Max. Press < 6 Hrs.

### Tape Recorder and Cartridge

The basic data recording medium is a magnetic tape cartridge containing an endless reel of approximately 400 feet, 1/4 inch magnetic tape (3M type 153). The cartridge assembly, a "Fidelipak," was chosen as the most rugged overall design as well as for its flexibility of handling.

The tape recorder (see Figure 2) consists of the following components: recording head; tape guides; contactor (grounding switch); tape cartridge housing; pressure roller assembly; tape drive assembly.

The contactor switch provides a short circuit to ground when actuated by a metallic splice in the magnetic tape reel. This acts as a safety factor, shutting the tape recorder off once a complete reel of tape has been recorded. This would occur if, by chance, the instrument were allowed to operate beyond the 14-day limit. Automatic shut-off prevents recording over previous data.

Table 2--Comparison Fabrication Techniques

| Fabrication Technique | Tooling | Sphere* Pc. Price | Additional Fabrication | Machining |
|---|---|---|---|---|
| Spinning | $ 550.00 | $32.00 | Yes | Yes |
| Forging | 3500.00 | 34.60 | No | Yes |
| Casting | 200.00 | 12.25 | No | Yes |

*500 Units

Table 3--Relative size and weight of FBK

| Diameter | Volume $In.^3$ | Vol. of $H_2O$* at 62.4#$^2$/float | of equivalent Volume of salt water |
|---|---|---|---|
| 7.0 inches | 180 | 6.5 | 6.7 |
| 8.0 | 268 | 9.6 | 9.9 |
| 9.375 | 430 | 15.5 | 16.0 |
| 9.625 | 470 | 17.0 | 17.5 |

*Maximum weight of FBK and still remain at neutral buoyancy in fresh water.

The tape drive assembly consists of the DC micromotor, a precision potentiometer, a gear box and capstan. The DC micromotor, "Portescap (Model SR)," is an extremely rugged device having withstood shocks having a peak magnitude of 707 G at a time duration of 1.5 milliseconds. The micromotor has been potted in a metal housing.

Battery System

Several battery systems were analyzed for possible application in the FBK instrument: the Leclanché (carbon zinc), Alkaline-manganese-zinc, mercury and nickel-cadmium.

The power requirements include the following: provide average of 5.0 ma current for 336 hours (1.68 amp hours) with a safety factor of at least 2.0, continue to supply current with ambient temperatures from -25°C to +60°C (-4°F to +140°F), and to fit within an envelope measuring 4-1/2" by 4-1/2" by 1-1/2".

The Leclanché and mercury cells were disqualified on poor temperature performance. Mercury cells provided the highest capacity to volume ratio of all batteries considered and otherwise met the FBK requirement. Nickel-cadmium and Alkaline cells meet the requirements fully, and Alkaline "C" cells /Eveready E93/ were selected. The package design as shown in Figure 3 consists of four stainless steel battery holders which use a conical spring to provide axial thrust for electrical contact.

Pressure Transducer

A bonded semiconductor strain gauge, pressure sensor assembly with a relatively high signal level of 100 millivolts per volt at the FBK maximum depth is required to convert the pressure transducer output to a sampled pulse interval code. The shock level of 1000 G's at eight milliseconds was also considered a most severe requirement. Existing transducers were evaluated and two families of transducers were given general consideration: bourdon tubes/potentiometer units and bonded strain gauge units.

Bourdon tube units fell short due to inherent complexity and inaccuracies of existing hardware. Although the bourdon tube seemed questionable from the ruggedness and accuracy standpoint, its low cost resulted in a decisionto test a bourdon tube/potentiometer assembly. Several design refinements over conventional bourdon units were made such as the elimination of the various linkage hardware normally associated with coupling a bourdon tube tip to an output shaft. The unit was so designed that the potentiometer shaft became the output shaft with one direct connecting link between the potentiometer shaft arm and the tube tip.

Test results showed this assembly to be outside the accuracy limits in the range of 0 to 45 p.s.i. Measured values were as high as 2.5 percent vs. the specification requirement of 0.5 percent in this range. Performance at higher ranges was satisfactory. Under shock testing an equivalent tube suffered a linearity change effect from a 275 G pulse.

Testing of the strain gauge units included static pressure, pressure vs. temperature and pressure vs. shock. Under static pressure the transducers showed accuracies within half the specification requirement of ± 3 meters over the depth range from 5 to 30 meters and an overall accuracy of ± 10 percent of the actual depth over the range from 30 to 400 meters. Under temperature testing, scale factor change and zero error also remained well within specification. The strain gauge has been shock tested to 700 G's resulting in no change in calibration and zero error.

Electronics Module

The FBK solid state electronics module is packaged to achieve minimum volume and maximum ruggedness. Two printed circuit boards are assembled in a can and encapsulated by a semi-rigid silicone potting compound (Dow Corning Sylgard 182).

Operation of the system is described as follows:

a. Timer Circuit--a 60 second multivibrator provides the basic interval time reference. This circuit turns the tape recorder motor "on" to initiate a data sample at 60 second intervals. Frequency stability of the timer over the 14-day period is required to stay within ± six hours (i.e., in 336 hours).

b. Control Counter--a three state logic circuit that sequentially gates three separate signals from the encoder circuit through the single channel signal gate and conditioning circuit. This circuit also originates the drive motor "stop" pulse once the data sample is complete.

c. Motor Control and Suppression--Provides amplification of the motor drive signal and filters out DC motor commutator noise which would otherwise interfere with the logic circuits.

d. Bridge-Encoder--Provides a trimming and bridge interface with the two element strain gauge. Motor driven motion of the potentiometer wiper arm causes ground to be applied to two reference voltages ($e_2$ and $e_1$) separated by a third voltage, $e_p$. Voltage $e_p$ is created as the wiper turns through the point causing the bridge to null out. The elapsed time between occurrence of $e_1$ pulse and $e_p$ pulse is directly proportional to pressure applied to the strain gauge (i.e., depth of FBK). Since the tape is being driven simultaneously with the potentiometer wiper, the pulses are recorded onthe tape in appropriate sequence. The interval between pulses $e_1$ and $e_p$ is then an accurate record of depth. Pulse $e_2$ becomes a reference marker (end of data sample) for subsequent automatic data conversion functions.

e. Signal Gate and Conditioner--Includes three Field Effect Transistor (FET) gates feeding an operational amplifier. Application of the three grounded signals to the amplifier input causes it to change state and coincidently to send a pulse to the tape recorder amplifier.

f. Tape Recorder Amplifier--A two stage amplifier that raises the level of the incoming pulse train sufficiently to drive the record head.

Automatic Manual Switch

The actuation switch is a piston driven positive action microswitch and is integrated with the strain gauge pressure transducer assembly. The switch automatically turns the FBK "on" at a depth of approximately five meters. The FBK then stays "on" throughout its complete mission of up to 14 days.

Manual operation of the on-off switch enables the agent to start and stop the recorder at will as well as preparing it for the next trip.

Dock Support Equipment (DSE)

Two major elements comprise the DSE: (1) the analog playback system which provides an immediate analog record of the FBK tape cartridge data; and (2) a calibration system for time and pressure.

Analog Playback System(APS)

The APS (see figure 4) contains electronics necessary for converting the pulse interval coded signal in analog readout. It also contains a direct reading meter for immediate observation of the data. The tape cartridge playback module is designed to accept the tape cartridge of the FBK instrument. The playback module will operate automatically on command from a switch on the front panel.

Time-Pressure Calibrator (TPC)

The calibration system (see figure 4) consists of a hydraulic hand pump, a vernier pressure control, a test gauge and electric-timing clock. Calibration pressure points are established by two step procedures starting with a rough setting with a hand pump and a fine adjust with the pressure control. The pressure gauge is a bourdon type and is accurate to 0. 26 percent.

Operation in the Field

The port agent opens the FBK case, removes the tape cartridge containing trip data, and inserts a new cartridge. The batterypower pack is also removed and a fresh pack inserted prior to initiating the next mission. The tape cartridges can be magnetically erased and re-used many times. Although not a requirement of this development, the possibility of adding another data channel on the same tape and thus obtaining a record of temperature as well as depth appears as a natural add on.

The following sequence of FBK operation is listed below. A typical fishing trawler application and Bureau of Commercial Fisheries (BCF) agent interface is assumed.

a. Retrieve FBK instrument from trawler.

b. At BCF facility:

1. Connect pressure line and apply pressure and time calibration (see 7 and 8 below).

2. Open instrument.

3. Shut off system.

4. Remove cartridge and record data on cartridge label. Play back cartridge and inspect strip chart for instrument O. K. If O. K. , go to next step. If not O. K. , complete trouble report form.

5. Replace new tape cartridge.

6. Replace battery pack and dessicant.

7. Connect pressure line and apply six pressure points at five minutes each.

8. Check timer operation against calibration timer.

9. Close unit (check 0-ring seat prior to closing.

c. Deliver FBK to next fishing trip.

## Field Test

Tests were conducted on board the fishing trawler "Liberty Belle" out of Provincetown, Mass. during December 1968. FBK Model 690, was given a preliminary check by running overnight. Pressure calibration levels of 400 meters and 200 meters depth were applied using the time-pressure calibrator. The unit was attached to the headrope adjacent to the port door of the #36 trawl. Five tows were made in water depths of 25-30 fathoms off Cape Cod, Massachusetts.

A copy of the playback tape as recorded on the Analog Playback System is shown in Figure 7.

## Electronic Data Processing (EDP)

The ultimate requirement of the FBK data aquisition system, will be a tabulated printout of data as shown in Figure 8. The two intermediary processing steps, preceding the computer operation, are described below:

Tape-to-Tape Code Conversion--This module will be required to receive data from the FBK tape cartridge in pulse interval coded form and convert the data to a serial binary coded decimal form.

Serial Data to Computer Compatible Tape Converter--This module will be required to accept the serial digital data and convert to multi-channel computer compatible magnetic tape formats. This includes provision for manual insertion (addressing of BCD heading information and manual control of recorder as may be required.

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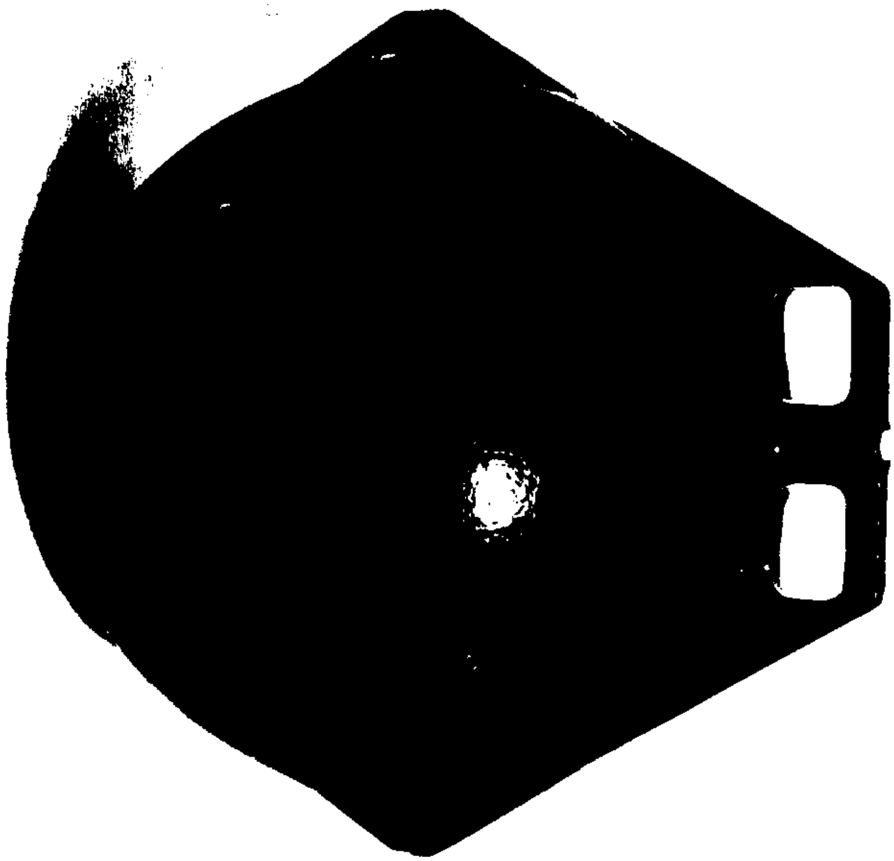


Figure 1. --FBK Instrument. FBK outer housing. Delrin plus (with pressure port) shown in place. Black PVC coating covers the cast aluminum housing.

Figure 2. --View of disassembled recorder. Micromotor and drive assembly is at upper center. Electronic module is in the center. Magnetic tape cartridge is at the bottom.

Figure 3. --View of instrument platform mounting plate group with top hemisphere removed. Battery package is visible with rubber "bumpers" at each corner. Tape cartridge partially visible upper left. Shock isolator assembly and housing 0-ring can, be seen in place.

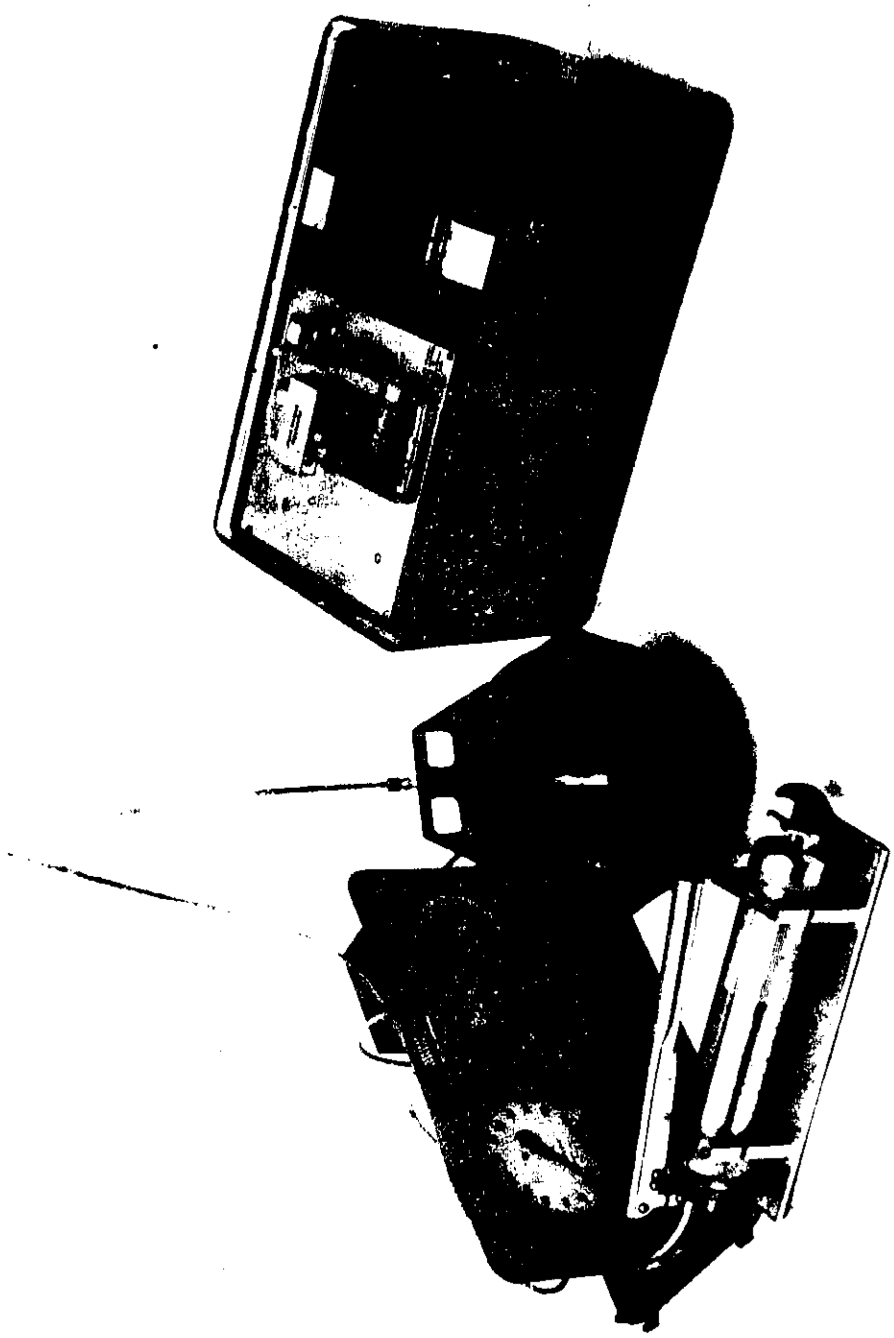
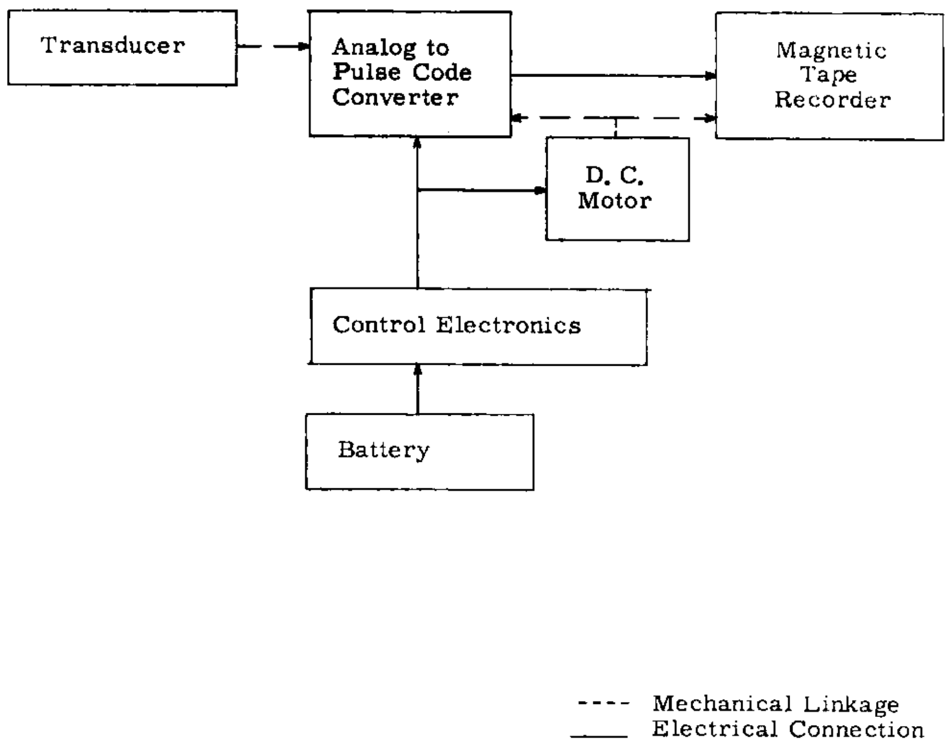
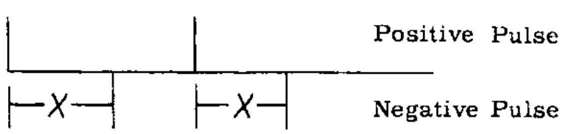


Figure 4. --FBK and Dock Support Equipment (DSE). FBK connected to Time-Pressure calibrator (TBC). Analog Playback System (APS) shown on the right.

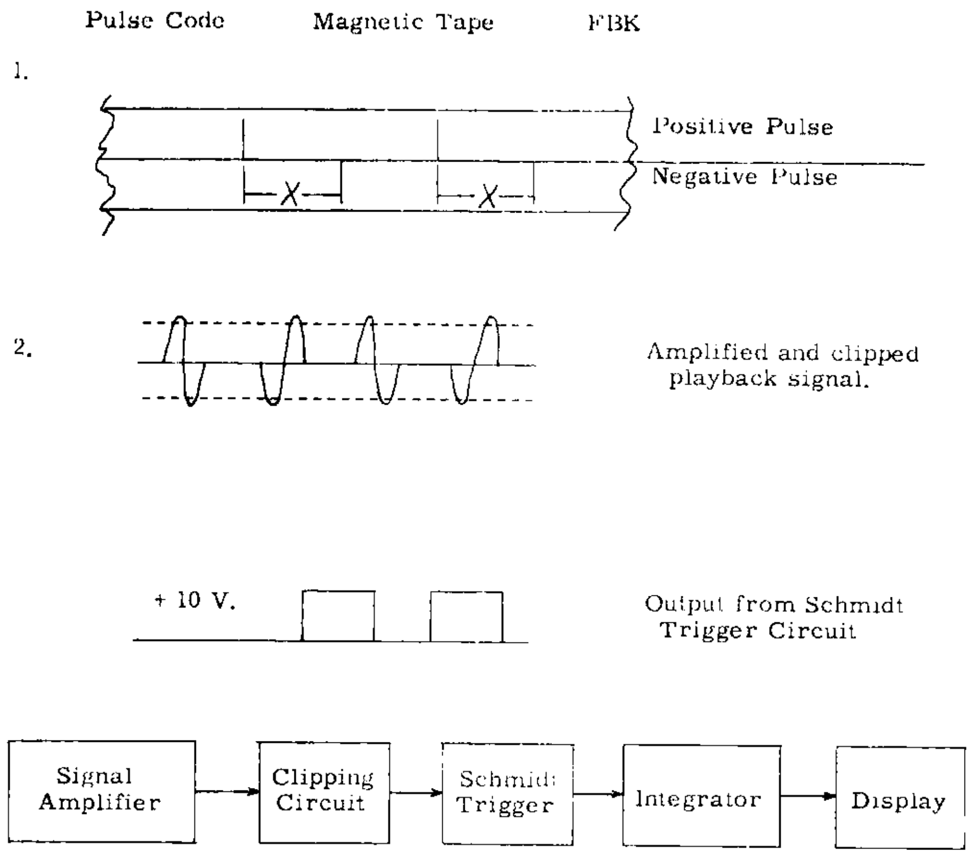



Magnetic Tape Code Pattern




X = K (depth)

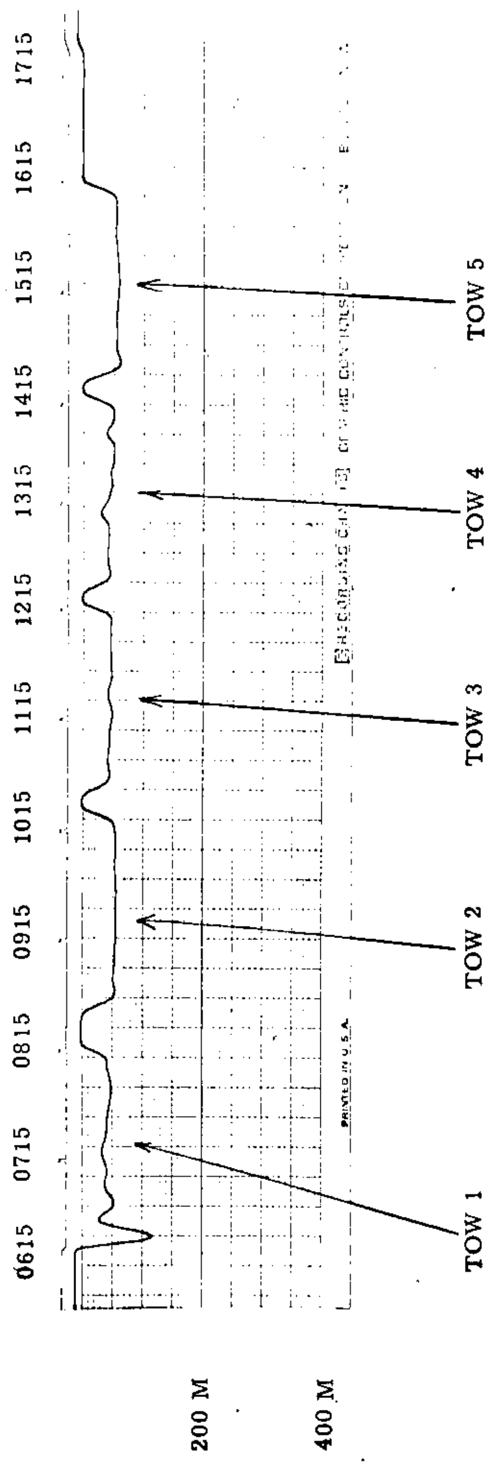
Figure 5. --Block Diagram of the Pulse Code Magnetic Tape Recording FBK.




Block Diagram of Playback Circuit

NOTE: Display consists of meter and strip chart recorder.

Figure 6. --Analog Playback System (APS).




Record of Fishing Trawls Liberty Belle
December 11, 1968

Figure 7.

Sample Output Data Sheet Format

| *Port Departed | *Date | *Port Returned | *Date | *Vessel Name | *Agent |
|---|---|---|---|---|---|
| Boston | 9/8/66 | Boston | 9/15/66 | Albatross IV | JMC |

| Tow No. | Duration (Hours) | Mean Depth (Meters) | Time Between Tows (Hours) | Elapsed Time (Hours) |
|---|---|---|---|---|
| 1 | 1.2 | 70 | --- | 1.2 |
| 2 | 1.1 | 64 | 2.4 | 4.7 |
| 3 | 1.3 | 82 | 4.5 | 10.5 |
| - | - | -- | --- | --- |
| - | - | -- | --- | --- |
| Σ 13 | 15 | 570 | 25 | 260 |
| Averages | 1.15 | 43 | (1.92) | |
| (± 3 value) | (.15) | (10) | (.25) | |

*FBK Serial No.

101

* Record Terminated

| Date | Time |
|---|---|
| 9/15/66 | 900 |

Calibration Data:

| Sample Rate (Seconds) | |
|---|---|
| Start of Trip | End of Trip |
| 60.2 | 60.8 |

Reference Pressure Readings (Meters)

| at 30 | at 100 | at 200 | at 300 | at 400 |
|---|---|---|---|---|
| 30.1 | 105 | 201 | 308 | 410 |

*Data entered by BCF agent on tape cartridge.

Figure 8.