NASA CR-137903

(NASA-CR-137903) TECHNIQUES AND INSTRUMENTATION EFFORT FOR WHALE MIGRATION TRACKING Final Report (Franklin Inst. Research Labs., Philadelphia) 178 p HC $7.50 CSCL 14B G3/35

N76-28531

Unclas 47241

Technical

Report

Final Report
F-C3799

TECHNIQUES AND INSTRUMENTATION EFFORT FOR WHALE MIGRATION TRACKING

May 1975

by

R. M. Goodman, FIRL
K. S. Norris, UCSC

and

L. Hobbs, UCSC
R. J. Gibson, FIRL
E. Dougherty, FIRL
J. Palladino, AII

Prepared for

The National Aeronautics and Space Administration
Ames Research Center, California

NASA Contract No. NAS2-8013

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
BENJAMIN FRANKLIN PARKWAY • PHILADELPHIA PENNSYLVANIA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER
MOFFETT FIELD, CALIFORNIA 94035

REPLY TO ATTN OF: NAS 2-8013
At:241-12

July 20, 1976

NASA Representative
Scientific & Technical Information Facility
P.O. Box 8757
Baltimore/Washington International Airport,
Maryland 21240

Subject: Transmittal of Contractor Report: "Techniques and Instrumentation Effort for Whale Migration Tracking," final report dated May 1975 by R.M. Goodman, K.S. Norris, et al, The Franklin Institute Research Laboratories, The Benjamin Franklin Parkway, Philadelphia, PA.

Reference; Program Code 178-56-12-02-00

The subject report prepared under Contract NAS 2-8013 has been reviewed at Ames and is recommended for release in STAR as CR-137903.

for William D. Balandis
Paul Bennett
Chief, Technical Information Division

Enclosure:
1 cy subject report

cc:
NASA Hqrs., Code KSI (w/o encs.)

NASA CR-137903

Technical

Report

Final Report
F-C3799

TECHNIQUES AND INSTRUMENTATION EFFORT FOR WHALE MIGRATION TRACKING

May 1975

by

R. M. Goodman, FIRL
K. S. Norris, UCSC

and

L. Hobbs, UCSC
R. J. Gibson, FIRL
E. Dougherty, FIRL
J. Palladino, AII

Prepared for

The National Aeronautics and Space Administration
Ames Research Center, California

NASA Contract No. NAS2-8013

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
THE BENJAMIN FRANKLIN PARKWAY · PHILADELPHIA PENNSYLVANIA 19103

ABSTRACT

Effort prior to and during the January - February 1974 Expedition is presented. Resulting data obtained from an instrumented Gray Whale is analyzed and commented. Recommendations for follow-on effort are made.

CREDITS

The work and results described in this report are the products of an interdisciplinary effort involving many people and several organizations. In addition to the authors already listed we recognize the contributions and participation of the following people:

NASA -	Paul Sebesta
	David Winter
NOAA -	David Wallace
NMFS -	George Rees
CONACYT, MEXICO -	Bernado Villa Ramirez
	Louis Fleischer
MEXICO -	Sr. Serrano, Lopez Mateos
	Sr. Armas, Port Captain, San Carlos
MEXICAN FISHERIES SCHOOL SYSTEM -	Jose Costello
SCRIPPS -	J. Kooyman
UCSC -	Sigmund Rich
	Roger Gentry
	Tom Dohl
FIRL -	John Price
	Earl Sonnie
TRAWLER LOUSAN -	Tim Houshar (skipper) and crew
AII SYSTEMS -	O. J. Hanas
	E. Haines

INTRODUCTION

The period of this contract ran from 1 December, 1973 through 30 November, 1974. At the outset of the period, extremely energetic efforts were carried out by the biology team under Dr. Norris at the University of California at Santa Cruz and the technology team under R. M. Goodman at The Franklin Institute Research Laboratories. These efforts were directed to completion of equipment and preparation of facilities, plans, various gear and logistics for the field expedition to take place at Baja California Sur, Mexico in mid-January of 1974.

Everything was completed in time by virtue of the unstinting efforts of all staff members involved. On 24 January, 1974 the UCSC and FIRL teams were joined at San Francisco and later that day arrived at La Paz, Mexico. On 25 January, after a 255 km overland trip, they were on site at Lopez Mateos. The trawler LOUSAN arrived that afternoon. Field activity initiated the next day.

In the course of our work in Mexico we met with both successes and disappointments. We acquired unique data on capture techniques, learned much about the responses of equipment to hostile environments, evolved detailed expedition safety codes as regards personnel safety and animal safety and made rewarding friendships with some of the people of Lopez Mateos and with Dr. Bernardo Villa-Ramirez. Senior Scientist and Professor (University of Mexico). We are happy to report that we obtained over four days of continuous diving activity data from a gray whale in its natural environment - a major achievement.

Part of our effort was to be related to the "bread-boarding" of an expendable transmitter, a device which is key to our ultimate system. As part of such a system, these transmitters will permit the acquisition of fiduciary fixes along the migration path. The transmitter design approach was related to the requirements of the Nimbus-F satellite system; being a representative RAMS system. This course was taken because enough problem similarities presently exist in transmitter design for use with any RAMS satellite. The funds necessary to support the transmitter design effort, as well as for support of parts of the biology team work, were placed in the contract through the good offices of The National Marine Fisheries Service of NOAA. Unfortunately, the transfer of these funds was delayed by administrative circumstances and our subcontractor, AII Systems, was forced to pursue the development under a most severe time constraint. Nevertheless, useful bread-boarding was completed and the insights the study was to evolve have been recognized and assimilated.

Because of the multi-faceted efforts involved in this long-term program, which involves a step-wise development of a system to make possible the tracking of the great whale species over their full migration routes, the Principal Investigators have decided to include the first two quarterly reports of this present effort within the Final Report. We feel the inclusion will provide the reader with a deeper insight as to the status of the overall effort and to details of importance.

CONTENTS

CONTENTS (cont)

FIGURES

TABLES

Technical

Report

Quarterly Report
Q-C3799-01

CONTINUATION OF TECHNIQUES DEVELOPMENT FOR WHALE MIGRATION TRACKING

Period: 1 December 1973—28 February 1974

R. M. Goodman
K. S. Norris

Prepared for

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, CA 94035

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
THE BENJAMIN FRANKLIN PARKWAY • PHILADELPHIA PENNSYLVANIA 19103

ABSTRACT

Completion of harnesses, flotation gear and instrument pods is discussed.

Preparations for the January-February 1974 field expedition are described; a preliminary reporting on the expedition is disclosed.

CREDITS

The authors are grateful for the support and cooperation of the entire scientific party and ship's complement in the work described; José Castello of Mexico, who came to observe and photograph, became a dedicated team member and helped in innumerable ways.

We want particularly to mention the remarkable courage and selfless efforts contributed by P. Sebesta of ARC and the understanding kindness and help of Dr. Bernardo Villa of Mexico who arranged for hot water in our showers, commandeered an aircraft so he could "count heads" to be certain that all hands were OK when the ship grounded, helped the men whose visas were lost with the ship as well as the crew whom he led through the intricacies of legal and language barriers in a country to which they were visitors and whose language they could not speak—all of this while suffering a broken sternum acquired just after ship grounding.

The authors were aided directly in the preparation of this report by R. Gibson of FIRL and R. Gentry and L. Hobbs of UCSC.

INTRODUCTION

For approximately twelve weeks prior to 1 December, 1973, the cooperative research team, made up of one group under R. M. Goodman (P.I.) at FIRL and a second under K. S. Norris (P.I.) at UCSC worked at full speed to develop and fabricate the protocols, devices and gear essential to the January-February 1974 field expedition.

On 1 December, 1973, the work continued under Contract NAS2-8013 and this present report is a record of effort activity and preliminary findings for the period of 1 December 1973—28 February 1974.

The goals desired under this present contract are as follows:

1. To complete fabrication of first model expansible (Mark II), instrument-pack-bearing harnesses (two each) for the juvenile whale, January 11, 1974 - Design to be furnished to FIRL by Ames Research Center.
2. To modify and fabricate a minimum of two (2) and up to five (5) if time permits of the 1973 model (limited expansible) gray whale harnesses.
3. To complete the design, construction and tests of two (2) P/T (water) instrument pack for application to the juvenile gray whale in the January/February 1974 expedition. Tests will be done by FIRL in pressure chambers simulating 72 foot depths which is 12 fathoms (36 PSI) or 200% of expected in-lagoon field conditions.
4. To carry out in-lagoon, behavioral field studies with a minimum of two instrumented whales for periods of one week. Studies are time dependent on erosion rates of harness release bolts. Therefore, the week study may be plus or minus up to 3 days. Studies are dependent on availability of animals. Therefore, the numbers of animals cannot be assured; however, a minimum of 2 are desired. If there is a release of equipment causing a short week study and another animal can be captured, a third study will be done.
5. To carry out pure following-track studies with a minimum of two (2) and up to three (3) instrumented whales at sea for periods of up to two weeks. Instrumentation is only the tracking

transmitter and Xenon flasher. The third study is only in event of an early harness release by one of the previous two tests. All studies are possible only if animals are available through the natural course of events.

6. To acquire behavioral data on individual activity and interpersonal activity on the whale mother and juvenile for inclusion in concept and design planning for the 3-6 month migration study in our next major field expedition.

7. To breadboard and perform laboratory evaluation on the performance of the expendable tracking transmitter.

8. To process and analyze the pressure/temperature data from the January/February 1974 expedition.

CONTENTS

CONTENTS (cont)

FIGURES

1. WHALE HARNESS AND GEAR

Testing and final production of harnesses and associated gear continued as scheduled prior to the field portion of the program.

1.1 THE INSTRUMENT HARNESS

A prototype of the modified girdle-type harness, used successfully in the 1973 captures, was tested on our whale model and found satisfactory with minor modifications and alterations indicated.

A backplate was designed and fabricated, in the UCSC shop, to incorporate appropriate harness attachments and receptacles for securing a radio tracking transmitter and the FIRL MK I instrument pod. Polyurethane flotation needs were calculated and units with hard, exterior fiberglass shells were molded. These are essential to protect and float the entire harness assembly upon its release from the whale.

Five such harnesses were fabricated for use in the field.

1.2 EXPANSIBLE HARNESS

In consultation with R. Mancini (NASA/ARC), a design for an expansible-contractible harness was completed. It incorporated springs and a "sandwich" backplate which could accommodate a tracking transmitter, a Xenon flasher and a depth-of-dive recorder.

The specially fabricated linear-expansion springs introduced a constant tension of approximately 20 pounds (9 kg) to be maintained during the expansion and compression experienced by the young whales during diving and resurfacing behavior.

Polyurethane flotation with a hard, fiberglass shell was also fabricated to the necessary volume and configuration for these harnesses.

1.3 RELEASE MECHANISM

Extensive laboratory testing of magnesium corrosible release bolts produced uncertain results and ocean tests were deemed necessary. These latter tests showed performance which appears reliable for periods up to one week and less reliable, but useful for up to two weeks.

We were thus able to design bolts with appropriate diameters for use in the field studies. A variety of bolts were fabricated to provide a range of release times. Specific bolts used in the field were to be selected from this supply.

1.4 TRACKING TRANSMITTER

An extensive survey of commercially available radio tracking units was carried out. It was finally decided to use the Model PT-219 radio tracking transmitter manufactured by the Ocean Applied Research, Inc. of San Diego.

The PT-219 transmitter is characterized by the following improvements: it has a greater transmission range than previously available, it mounts a specially flexible transmitting antenna considered to be highly desirable for our purposes and utilizes the newly available lithium fluoride batteries to provide necessary transmitter power and long life.

The unit works well and is compatible with the ADF 210 gear also made by OAR, Inc. This latter equipment will be used in the field work to track all animal packages and expansible harnesses.

1.5 XENON FLASHER

The addition of Xenon flashers to the harnesses was considered a usefully redundant location method—particularly because of possible damage to the tracking transmitter through the whale's activity.

General Oceans, Inc. of Florida, undertook the production of a flasher for our purposes. The resultant device was however, too large and heavy and, in our judgement, could have caused the floating harness (after release from the animal) to become hydrodynamically unstable. In addition, we were concerned that their concentrated mass might introduce a behavioral abberation in the whale's general activity.

With certain redesign and modification these units may be useful in the future.

2. INSTRUMENTATION

2.1 COMPLETION OF UNITS FOR USE IN THE FIELD

2.1.1 The Subminiature Recorder

Two recorders were completed and tested exhaustively for tape drive capability and recording and playback.

Recorder (Serial No. 2) was stepped through more than 300,000 increments and numerous records were made of the 40,960 word test pattern. These were played back and evaluated by visualization via the laboratory oscilloscope.

Recorder (Serial No. 3) was stepped through more than 2,900,000 increments and was similarly evaluated for record and playback capability. These recorders now appear as in Figure 2-1.

Then both units were loaded with approximately 210 feet (64 m) of 1/4 mil, polarized tape for use in the field. Prior to loading, all heads were cleaned and tape snubbers reset. As a final check, at least one test pattern (40,960 words) was recorded on each recorder and played back for visual analysis.

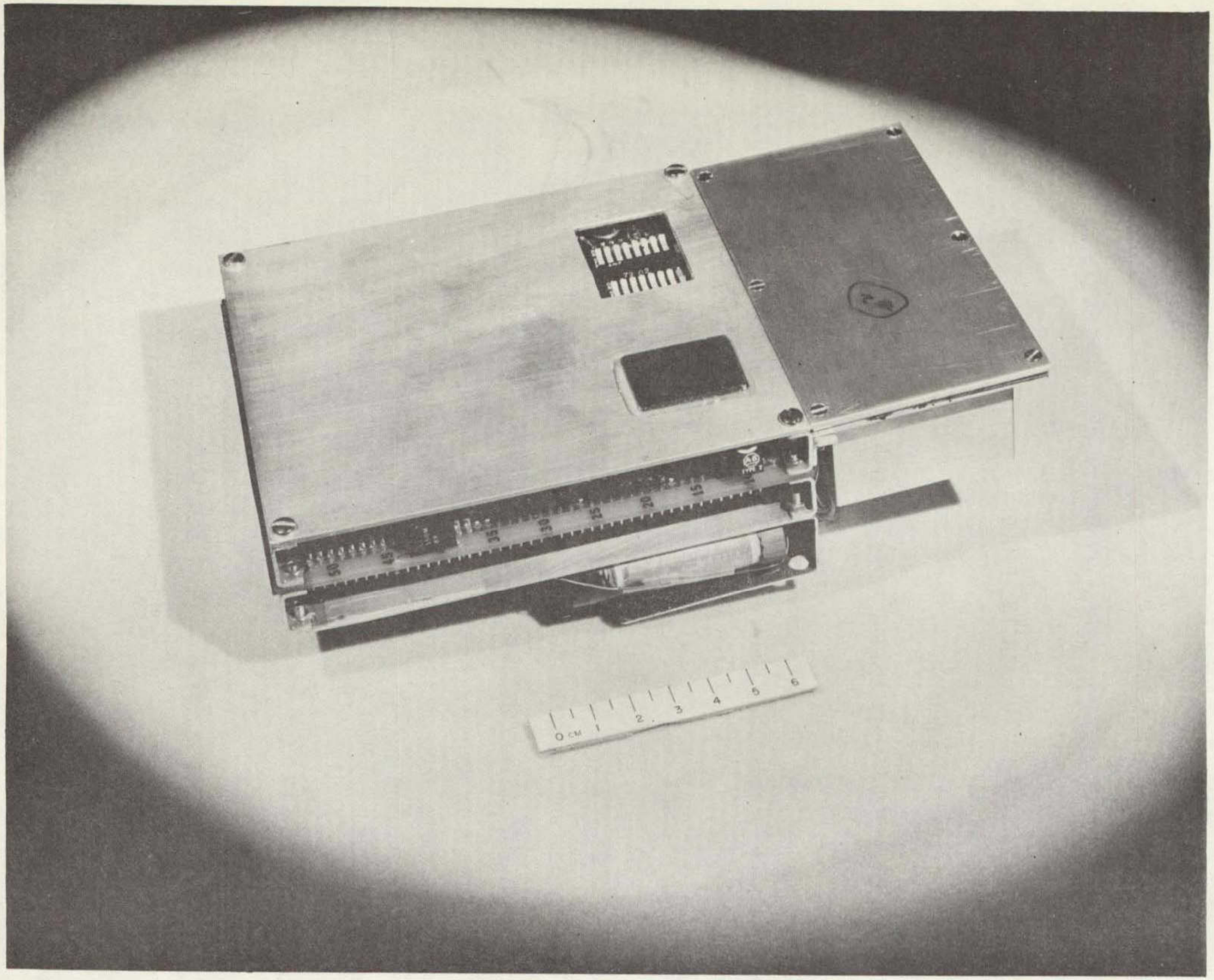
2.1.2 Sensors

2.1.2.1 Temperature Sensor

These units were electrically connected to the circuitry and zero balance rechecked prior to closing the units.

2.1.2.2 Pressure Sensor

Same as 1.1.2.1



Q-C3799-01

Figure 2-1. Microminiature Recorder—Top View

2.3 ELECTRONICS

All testing of the electronics circuit boards was completed and the supporting metal structure to hold the boards was also completed. The complete instrument package was then assembled including the recorder, electronics and battery supply. See Figures 2-2 and 2-3.

It will be noted from the Figures that the package becomes a single, integral unit with the exception of the transducers which are necessarily mounted on the pod casing.

Figure 2-2 shows clearly the aperture through which both the power and test switches are accessible as well as the red filter behind which the Test LED is located.

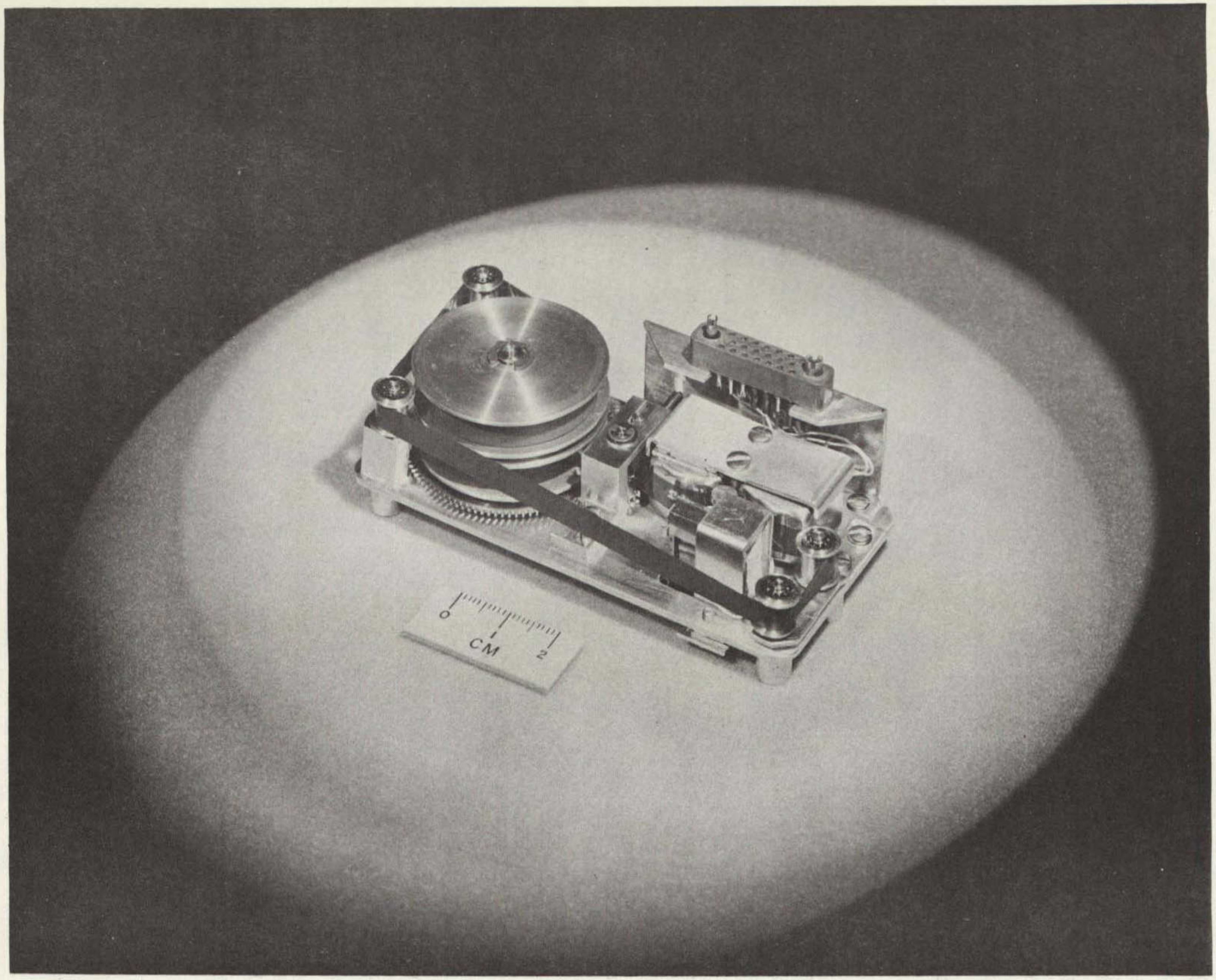
The total instrument package fits precisely into a polyurethane foam receptacle shown in Figure 2-4. This Figure is a photograph of the underside of the pod. Figure 2-5 shows the instrument package inserted into the foam-filled pod. In this latter Figure, a thin metallic cover has been emplaced over the test and power switch aperture to prevent intrusion of the thin foam (pre-cut) blanket, which normally is inserted between the instrument package and baseplate.

Both pod enclosures were sprayed with Emerson and Cuming shielding material Type ES; notes offering a reward for return of the pods (English and Spanish) were attached to the surface and the entire surface then was covered with a polymer gel coat. The only exception was at the lip of the cover where electrical connection was to be made to the baseplate. Figures 2-6 and 2-7 show the pod mounted on the baseplate. In Figure 2-7 the bonding lead from pod to baseplate can be seen clearly.

2.3.1 Testing

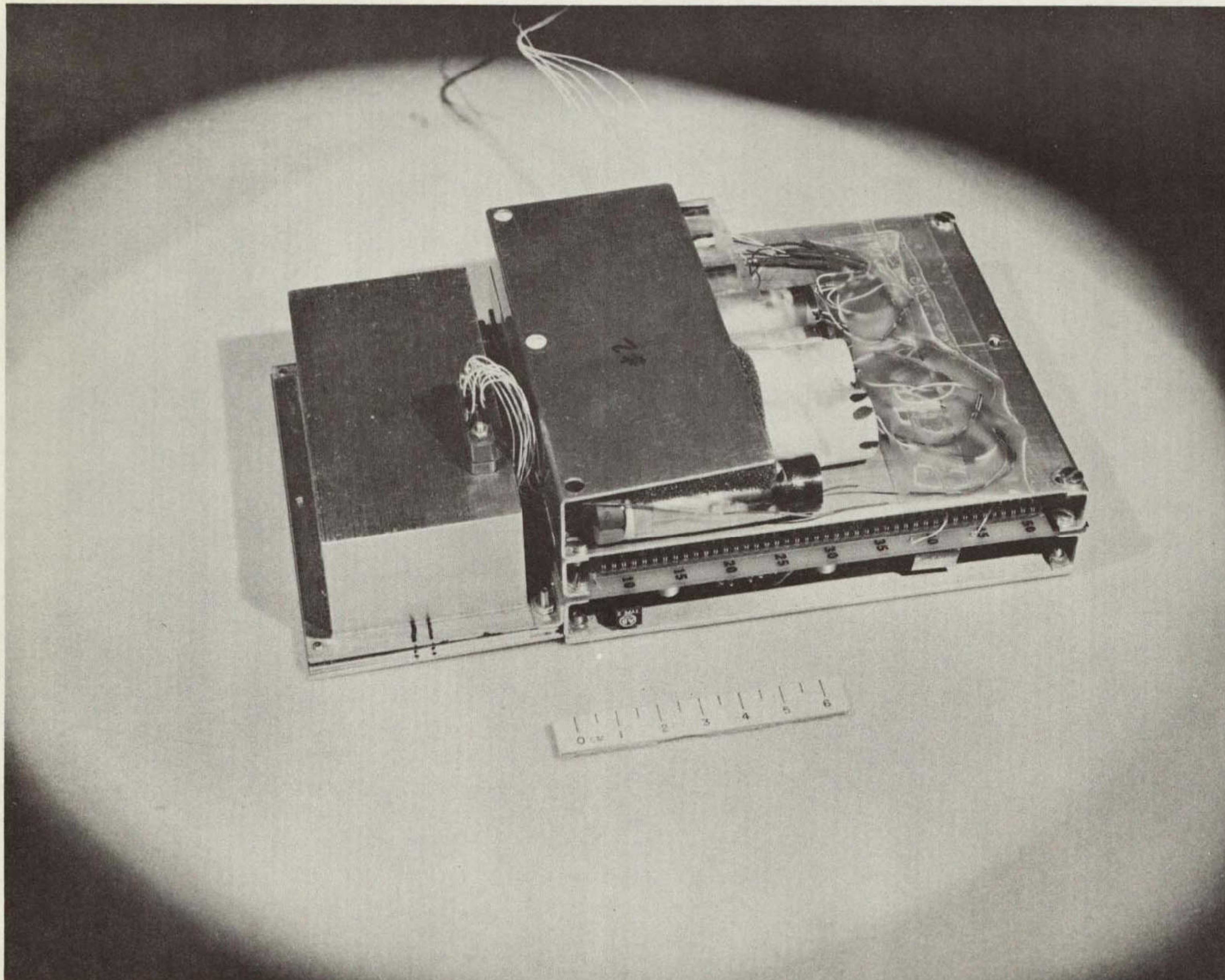
Both field units were powered up and key circuits and functions tested via the LED procedure which was detailed in our Report No. F-C3748.

Both units performed satisfactorily. Power was shut down and the instrumented pods were fastened to their respective baseplates with stainless nuts and bolts (thumb tight only).



Q-C3799-01

Figure 2-2. Pod Instrument Assembly—Top View



Q-C3799-01

Figure 2-3. Pod Instrument Assembly--Bottom View

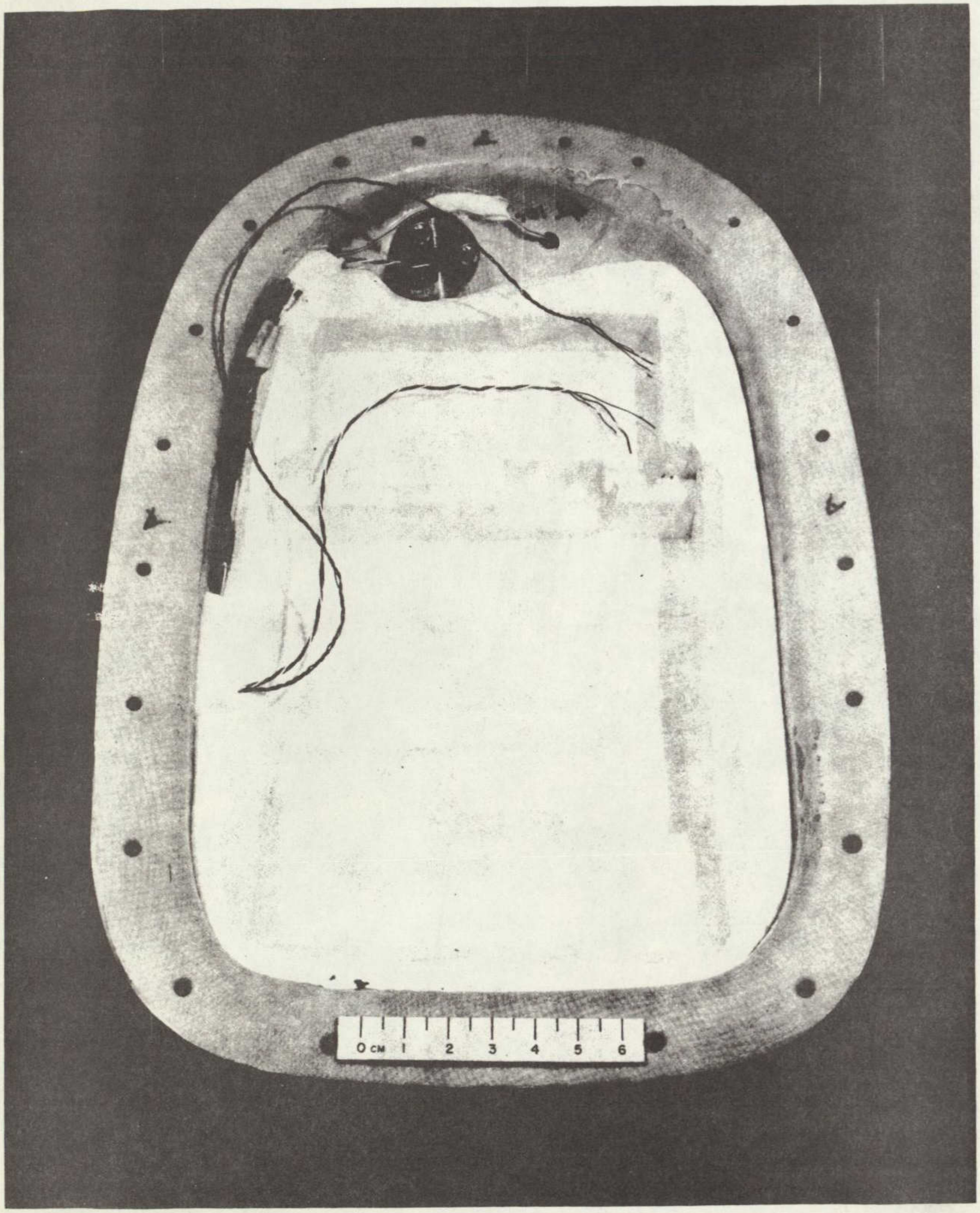
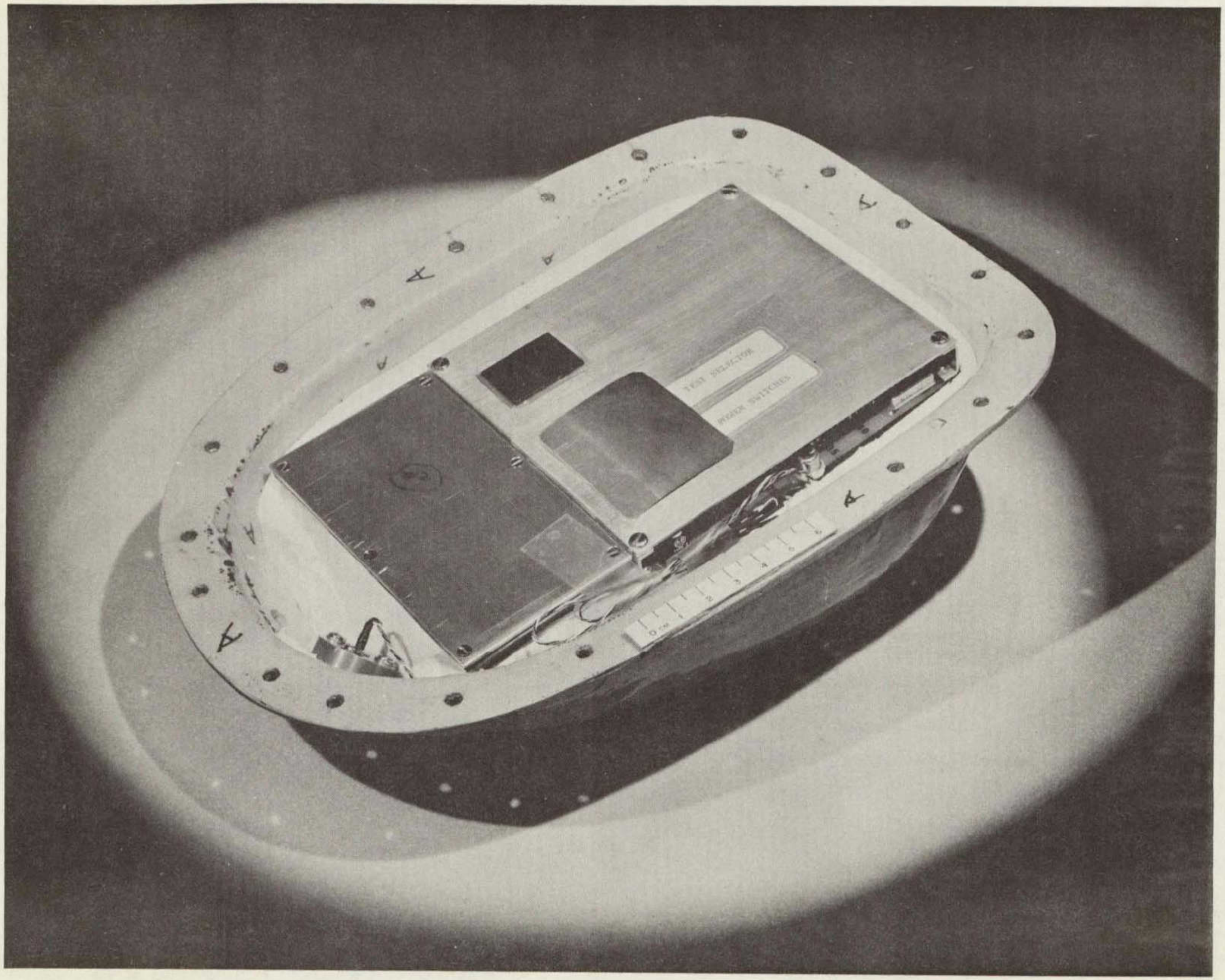


Figure 2-4. Pod—Internal Foam Padding



Q-C3799-01

Figure 2-5. Pod—With Instrument Assembly In Place

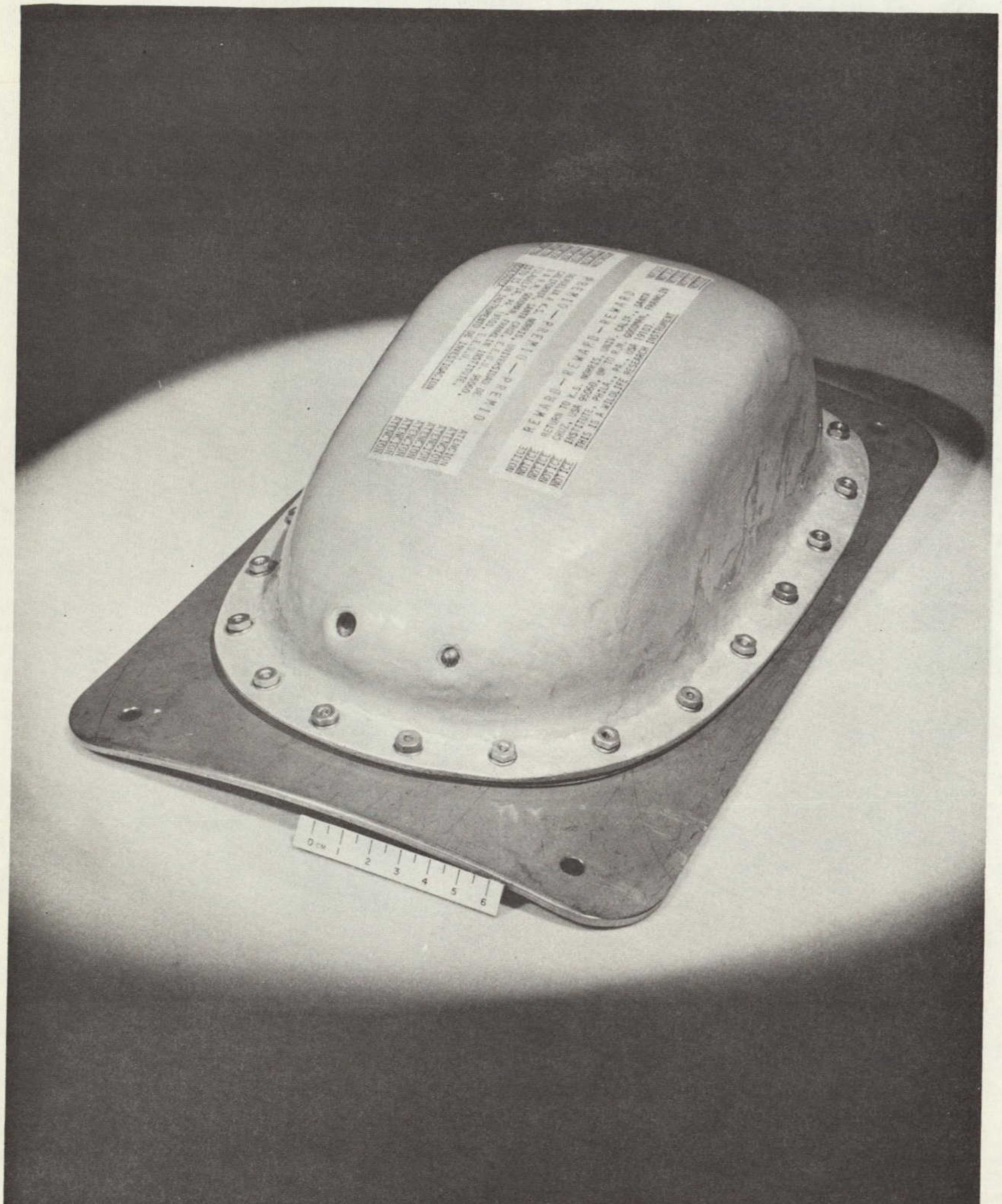


Figure 2-6. Pod Assembled to Baseplate--Rear View

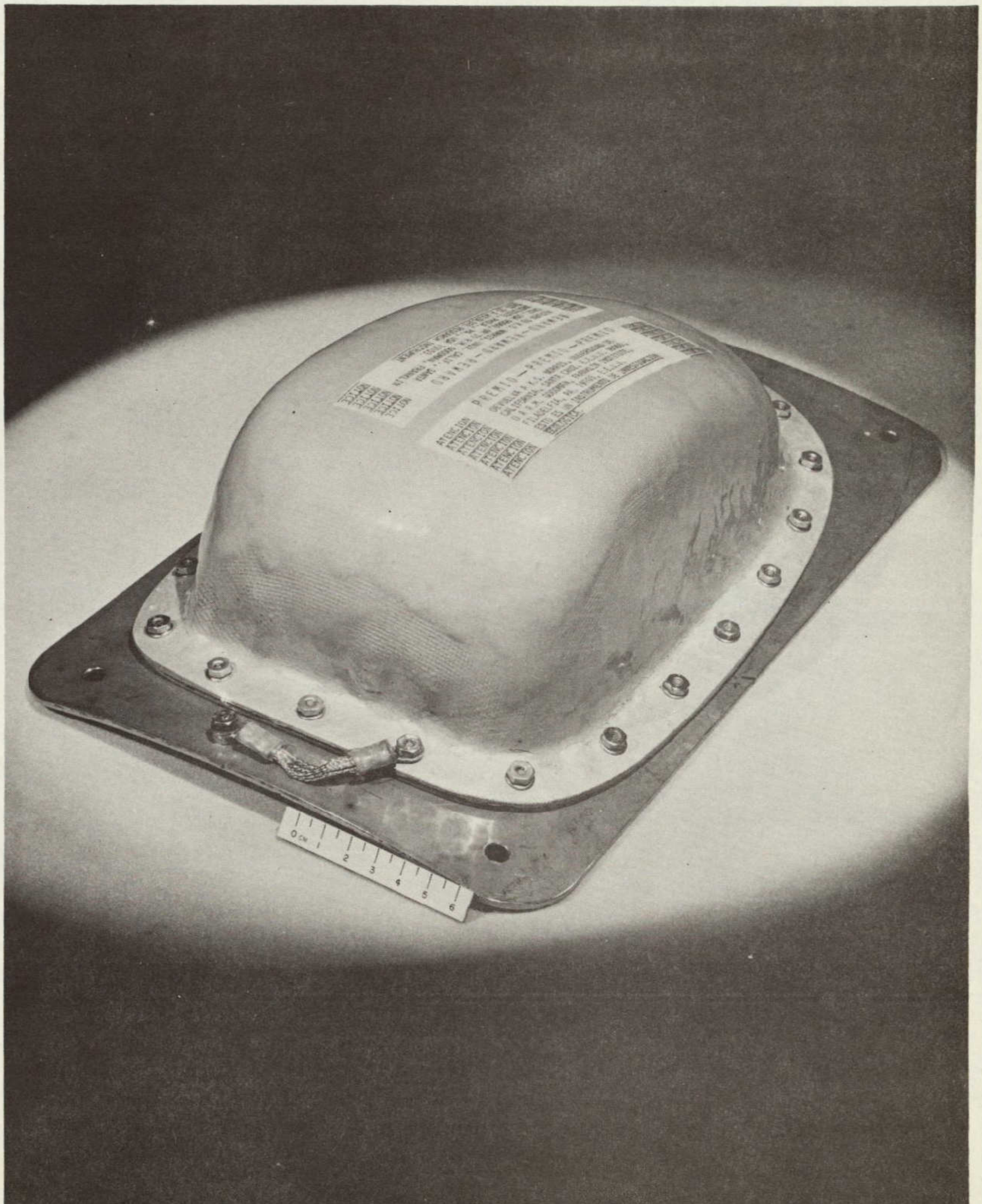


Figure 2-7. Pod Assembled to Baseplate—Leading Edge

2.3.2 Instrument Transport Packs

Two special boxes were designed and fabricated in which to transport the whale pods, miscellaneous tools, spare parts and the like. Each pod was multiply-wrapped in bubble plastic so that mechanical shock would not be transmitted to it. Packages were then screwed shut.

3. FIELD PREPARATIONS

Field preparations proceeded rapidly at both UCSC and FIRL after 1 December 1973. Considerable communication on this effort took place between the two parts of the team, and coordination of all matters which we could control directly was excellent.

3.1 PERMITS

Applications for permission to capture juvenile Gray Whales had been filed well in advance with both the United States' and Mexican Governments. However, for reasons beyond our contol, immediate action was substantially delayed.

The permit from the Government of Mexico was approved the week prior to the departure for the field (approval received during the week of Jan. 14, 1974). The necessary approval from the U.S. Government was received by telephone notification after our party had already reached our operations base in Mexico.

3.2 CAPTURE BOAT CHARTER

A final contract was negotiated with Swordfish Inc. to charter their 45 foot fishing vessel *Louson*, Timothy Houshar, Captain.

The charter cost for whale capture and tracking included the vessel, captain (who has previous experience in marine mammal capture) and a crew of three. Also included in the charter arrangements was an added rider to the extant vessel insurance coverage to bring the overall policy up to standard charter requirements of the University of California—which includes protection from vessel grounding or loss.

3.3 FIELD EQUIPMENT

3.3.1 Food, Supplies, Boat Gear

All field equipment, capture gear, assembled harnesses, water barrels and stocked food containers were consolidated at Santa Cruz and shipped to San Diego which was the departure point for the vessel *Louson*. Food supplies for the expedition were procured in San Diego and stowed with the field gear aboard the *Louson*.

While in San Diego, the ADF equipment to be used in the field was reconditioned and adjusted at the factory.

3.3.2 Instrument Pod Gear

Special carrying containers were fabricated for the two instrument pods. The design was such that the units fit under commercial aircraft seats which meant that they could be carried aboard by member of the party.

Arrangements were made to by-pass normal airport X-ray and magnetometer checks because of potential damage to our gear.

4. TRAVEL ARRANGEMENTS

Travel arrangements were coordinated through the UCSC group. The main scientific party met at San Francisco (from Santa Cruz and Philadelphia) and then proceeded to La Paz, Mexico. The following day, they continued on to Lopez Mateos by bus.

José Castello was kind enough to provide the party with a fisheries' school bus from Villa Constitucion to Lopez Mateos. This gracious gesture made our last lap remarkably easier and more comfortable.

The remainder of the total party arrived by car and boat for a rendezvous at Lopez Mateos on 25 January.

No difficulty was experienced in by-passing the X-ray checks at the airlines by the group from FIRL. This was essential because of the fear that the pulsed X-rays might damage the CMOS integrated circuits in the instrument pods. Excellent arrangements were made for us with United Airlines and Hughes Air West by Mr. David Moore, FIRL Security and Mr. Paul Sebesta of Ames (ARC), NASA.

The only untoward event which occurred in this regard was when a helpful Air West personnel carried Instrument Pod A through a magnetometer before we could stop him. Our concern was over the fact that our data-tape recorder uses pre-polarized tape which could conceivably be erased.

5. PRELIMINARY FIELD REPORT

The objectives of this year's Gray Whale instrumentation and tracking effort were sixfold:

a. To gain additional experience in the capture and handling of young whales and in fitting them with harnesses and instrument packages.

b. To test new instruments and housings in the marine environment when mounted on a whale.

c. To learn more of the factors which lead to harness abrasion and to check the animal for possible chafing from the harness.

d. To measure the total volumes and respiration profiles in young Gray Whales.

e. To carry out a short sea track from which to gain experience with the logistics necessary to such an effort.

f. To study the distribution, numbers and behavior of whales in the channels of Boca de Soledad and northern Magdelena Bay, Mexico.

Most of the objectives were attained although under difficult circumstances. The abrasion and chafing studies were incomplete and no sea track was carried out due to the loss of our collecting vessel *Louson*.

5.1 CAPTURE AND HANDLING OF YOUNG WHALES

During the first capture a young whale was lost. This was due to a malfunction of the capture gear which resulted in a line being attached only to the tail instead of both head and tail. An autopsy was performed and the entire procedure immediately reviewed. Procedural changes in technique were incorporated to minimize the possibility for recurrence of such an accident. In addition, all capture operations were halted until proper authorities were notified of the circumstances and occurrence. No further capture activity was carried out until permission was received to proceed five days later (See Appendix for log of Field Activities for 27 Jan. 1974).

Three additional captures were made subsequent to receipt of permission to proceed. Two resulted in the placement of harnesses and instrument pods with subsequent tracks and one was released when the mother animal was not seen for a time during the capture. With regard to this latter animal, it was felt that the additional time required to take the animal ashore, attach a harness and release it might increase the difficulty of reunion between mother and young. Hence the juvenile was released and seen to rejoin its mother.

Before these captures were carried out an unmarked juvenile was noted alone in the shallows along the sand dune coast near the fishing village of Lopez Mateos. It was examined, acoustical recordings attempted of heartbeat, physical measurements taken—including the crucial one of chest expansion during breathing, a measurement needed for harness design. A series of measurements of breathing profiles were made using a specially constructed instrument designed to be held in place over the blowhole. The very high rate of expiration of 200 ℓ/s was obtained. The animal was then directed into deeper water and is presumed to have reunited with its mother since it was not seen again in the restricted confines of the channel system around Lopez Mateos.

The young animal that was released (see above) associated itself, for a time, with the collecting vessel *Louson* and it was only with some difficulty that the vessel was able to move away from it. This and other events will be described more fully below.

5.2 INSTRUMENTS AND HOUSING TESTS

Both instrument pods were powered up, taken through the built-in-LED-indicated checkout procedure and then sealed with double vellumoid gaskets coated with Permatex No. 2 sealant. The pods were attached to stainless steel baseplates as part of the sealing procedure.

On completion of sealing, the pod baseplates were then attached to the harness baseplates with four 1/4/20 bolts. The complete harness package consisted then of an instrument pod, a tracking transmitter and a protective flotation casting. The two completed units were named KNUTE and PATTI respectively. Both the instrument pods and the flotation castings were marked in both English and Spanish with identification information so that retrieval of the units from persons other than our own party would be enhanced. In this latter regard, we learned that even when markings were covered with a fiberglass gel coat, it was not sufficient to prevent the abrasive action of water-carried sand from grinding through. Future packages will be marked by deep engraving on the stainless steel baseplate to ensure its longevity.

The first instrumented harness (KNUTE) was fitted with a 4-day corrosible release bolt. It floated off the animal on 5 February and was recovered by a beach party searching for it on 6 February (the day after the loss of the *Louson*). On return of this unit the sealed pod was removed from the harness baseplate and the recorder-stepper-drive "click" could be heard through the fiberglass enclosure so that we knew it was still operational. It was not until the night of 7 February in La Paz that we opened the unit, shut off the power and determined that it had retained its seal. Visual inspection seems to indicate normal function. The unit was returned to FIRL on 9 February.

With regard to the second pod (PATTI), it is presumed that it came free of its host sometime around 9—10 February. However, since the animal was in the Pacific and we no longer had either a ship or ADF gear it was beyond our capability to retrieve the package. We can only hope that the notices of "reward, etc." stay legible on the package and that some fisherman will find it and return it to us.

5.3 HARNESS ABRASION AND CHAFING

These tests were not completed. It was originally planned to recapture one of the harnessed whales (No. 2) prior to automatic harness release and to examine the animal for chafing. The loss of the collection vessel precluded this effort.

The information retrieved in this area was obtained from inspection of a jettisoned harness and instrument pack (KNUTE) recovered at the mouth of Boca de Soledad. The modified harness design, planned to correct for abrasions noted on harnesses used in the first year's tests, appeared to function well since *no abrasion* was noted. No visual evidence of chafing or other related problems were noted from our shipboard observations of the harnessed anaimals moving freely in the inland channels. The harnesses did not appear to vibrate or flap in the water as the whale swam and they seemed firmly in place over the pectoral fins at all times. No lateral slippage was noted.

5.4 RESPIRATION MEASUREMENTS

Two sets of quantitative measurements of the sequence, rate and volume of inhalation and exhalation were made. These represent the best such data from whales to date.

One long series of measurements, as mentioned above, were taken from the young whale found partially stranded on the lagoon beach. Another shorter set of measurements was made from the second animal to be harnessed.

Photographic observations of respiration were made which show that most exhalations start while the blowhole is still under water and that a considerable part of the "spout" is undoubtedly sea water.

5.5 SEA TRACK

The loss of the chartered collection vessel *Louson* at the entrance to the lagoon made it impossible to carry out our plans for a two week sea track. We plan to attempt to test tracking systems during the year—using porpoises since whales will be absent.

5.6 DISTRIBUTION, NUMBERS AND BEHAVIOR OF WHALES AT LOPEZ MATEOS

A census was made of whales, porpoises and sea lions within the inland waters near Lopez Mateos. We also made a cursory survey of their occurrence near San Carlos in upper Magdalena Bay.

Two hundred and five whales, thirty-one bottlenose porpoises and two California sea lions were counted in the Lopez Mateos area. Whale pairs were found to be abundant in upper Magdalena Bay though no count was attempted. Whales proved to be scattered rather uniformly in the channel at Lopez Mateos, mostly in mother-young pairs; a few smaller lone animals, assumed to be males, were seen and some three-whale groups were noted.

Mating was observed in the lagoon entrance (Boca Soledad) and two chases were noted inside the lagoon in which pairs of adults raced in the channel, or thrashed in remarkably shallow water. In one instance such a chasing pair was accompanied by a newborn young (assumed to be the calf of one of the adults) which seemed able to keep up with the adults even though the chase was rapid.

It is suspected however, that abandoned young so commonly seen in these lagoons—especially Scammon's to the north—may result from such events in areas of complex tidal channels. The Lopez Mateos region is a single, simple channel which occasionally broadens into somewhat larger bays, but no complexity such as exists at Scammon's is to be found. At Lopez Mateos we believe that abandoned young have an excellent chance of recontacting their mothers when such chases are over.

Defensive reactions of mother-young pairs were observed and studied. They seem stereotyped and composed of simple behavioral components: (a) lifting of the young animal by the mother or by pairs of adults; (b) tail thrashing; (c) incidental (perhaps) pressure of adult against young; and (d) evasive swimming and diving maneuvers. Even though capture places the vessel close to mother-young pairs with a man suspended about ten feet over the pair (he is on the bow pulpit), no attempt was made by the adult to direct an attack at either the man or the boat.

Thigmotaxis, the tendency of an organism to contact with a surface, appears to be a dominant feature in the behavior of the young animals. They constantly rub, or press against attending adults, sliding this way and that over the swimming animal (possibly with the aid of the adult) and when separated from an adult, seem to seek another surface to satisfy this behavioral need. In one instance, a juvenile assumed a position alongside the collecting vessel, pressing against it and making what appeared to be attempts to nurse at various points along its length (at overboard discharges, rudder, etc.). We are even led to consider that the persistent behavior of abandoned young to beach themselves is a related phenomenon. In the case observed, the juvenile sought contact with a beach and persistently returned to it even though repeatedly pushed into deeper water.

5.7 BRIEF FIELD CHRONOLOGY

Jan. 24 Scientific party arrived at La Paz after receiving preliminary permit from the Marine Mammal Commission; R. Gentry and G. Kooyman arrived at Lopez Mateos by car.

Jan. 25 Took bus to Villa Constitucion and received final permission from the Marine Mammal Commission by phone there; arrived in Lopez Mateos in the late afternoon and located ourselves near the fish cannery's laboratory; prepared radio gear in the evening.

Jan. 26 Set up and tested radio tracking gear on *Louson*; extensive discussion in the evening about duties, procedures, and responsibilities during capture and harnessing scheduled for the following day.

Jan. 27 Set to capture and harness two whales, but first animal died during capture; shock, autopsy, and official report.

Jan. 28 K. Norris and R. Goodman made official accident reports by phone from V. Constitucion to all appropriate authorities; those remaining in Lopez Mateos worked at photography and hydrophone recordings in the lagoon; evening meeting and preliminary recording analysis.

Jan. 29 One group of the party walked the beach from Boca de Soledad to Lopez Mateos in search of skeletal parts—found *Mesoplodon* skull; the rest of the party did a census of the whales in the lagoon; awaited word from the Marine Mammal Commission concerning continuance.

Jan. 30 Excellent early morning photography; found stranded calf and took measurements and measured respiration with G. Kooyman's flow meter.

Jan. 31 Received permission to proceed with captures; captured large calf and successfully placed instrumented pack "Knute" and harness on animal No. 1; no respiration tests were taken on this animal; 24 hour ADF tracks maintained.

Feb. 1 8 chases, but no whales captured; broke line on whale with two adults; last whale noosed fouled the propeller with the capture line.

Feb. 2 K. Norris left for the States; successfully captured, harnessed with instrumented harness, and released animal No. 2; respiration data was collected by G. Kooyman; relocated animal No. 1 near devil's bend (ADF & visual).

Feb. 3 Animal No. 2 went out through the Boca during the early morning; took *Louson* to Colina Coyote and put a party ashore to locate the animal on the ocean side with a hand-held RDF; photographed animal No. 1 with the pack in place and then tracked him north to the Boca; it went south inside the lagoon during the night watch.

Feb. 4 Propeller fouled as we left anchorage; found animal No. 1 south of the cannery and followed him north to the Boca where we observed the remainder of the day.

Feb. 5 Hobbs and Fleischer observing behavior from sandhill south of Colina Coyote; "Knute" harness released in the morning and *Louson* was abandoned at 1830 and went down with the tide; K. Norris was notified by 'phone of the accident.

Feb. 6 Found radio pack "Knute" on the beach 4 miles north of the Boca in excellent condition; Captain Housher and crew went to San Carlos to report the boat sinking and then on to La Paz.

Feb. 7 Remainder of party departed for meetings with K. Norris and D. Winter in La Paz.

Feb. 8 K. Norris, D. Winter and R. Gentry returned to Lopez Mateos for an on-site inspection; others left for their home laboratories.

Feb. 9 D. Winter and K. Norris reviewed capture techniques and sites and then returned to La Paz in the evening.

6. POST EXPEDITION ACTIVITY

6.1 BEHAVIORAL STUDY DATA

Behavioral information was obtained by direct observation, by ciné photography and by still photography. In the latter instance, a motor-drive attachment was used so that sequential records were obtained of features such as respiration, swimming patterns, harness and instrument pack placement and effects, capture, strandings, thigmotaxis and association patterns and distribution of whales in the lagoon.

6.1.1 Observational Data

The vessel *Louson* was an excellent platform from which to carry out observations. Use of the crow's nest—some 30 feet above water level—permitted observers to look or photograph downward on nearby animals. By careful handling of the ship, animals engaged in activities of interest could be brought very close aboard. In this way, complete sequences of swimming and respiratory behavior were obtained. This same vantage point was useful for observing the effects of the harness and instrument pack upon the mother-young pairs.

Counts of respirations versus time of mother-young pairs were made prior to, during and after capture from the *Louson*. In this manner, a baseline was obtained against which any aberrations caused by harnessing could be noted. None were observed. Respiration, like that of all whales is irregular, consisting of breaths taken rapidly at the surface as the animal arcs upward and descends below the surface again. Breath-holding is predominant and of variable interval. Normally, in undisturbed animals engaged in swimming, dives varied from 10 seconds to about 2 minutes in length—and tended to be bunched. That is, a series of breaths separated by short dives was typically followed by one or two (deeper) longer dives which were then followed by another series of shorter breaths. Once pursuit and capture were begun, dives became shorter and the tendency for bunching lessened. When the tail line and head net were in place, the animal spent most of the time at the surface with blows still occurring irregularly, but rapidly—varying from a few to about 45 seconds in interval. When the captured juvenile was returned to its mother and thereafter undistrubed, the respiration patterns returned to a format indistinguishable from those observed on undisturbed animals.

Most of the activity of young whales in the company of mothers (when undisturbed) seems to be in maintaining contact of body or snout against the mother, in nursing and in short sorties away from the parent. During the census taking effort, six young whales were observed for which no accompanying adult could be seen. Often adults stayed below the nearby opaque water for longer periods than the young so we presume they may have been nearby. Nonetheless, the young do move some distance from the adults as a matter of course. As previously mentioned, truly abandoned young have also been noted and likely result from male-female chases in which the young animal is simply not able to keep up.

An attempt was made to plan for more detailed observations of undisturbed whales in subsequent years. A site was located at a large sandhill, called Colina Coyote, on which an observer can occupy the top of a 75 foot high sand bluff that falls off directly into the channel occupied by numbers of whale pairs. The channel is deep enough close to shore so that an observer can look almost directly down into the water and whale pairs—and their behavior—should be clearly visible. A camp is planned at this site next season so that two weeks can be spent (prior to capture) observing whale behavior in the lagoon. We hope these continuous observations will provide a more realistic baseline for natural behavior and its meaning than we now have.

The two successful harnessings resulted in radio tracking data containing some new information. The first animal was harnessed on 31 January 1974. It was netted, using a headline only; and beached at the north end of "Big Bay" somewhat to the north of Colina Coyote. It proved to be a male, 560 cm in total length. It was harnessed about 35 minutes after being beached and released to the waiting mother. The pair proceeded north up the channel and then circled around and moved back down toward Colina Coyote where they stayed for three days. On the afternoon of 3 February, *Louson* tracked the pair from Colina Coyote north to Boca de Soledad. During the night of 3 February, the animals passed *Louson* (anchored at Lopez Mateos) heading south. The pair turned again, going to the Boca the following day and this time staying in the vicinity of Boca de Soledad. On the morning of 5 February, the *Louson* moved in pursuit of the pair. The harness was jettisoned from the young whale at about 0900 on that day. It was recovered from the beach, four miles north of the lagoon entrance, on 6 February.

The movements of this animal pair were reminiscent of the intention movements of birds, which point and move in the direction they will follow during migration, but prior to movement. It will be interesting to see if future animals exhibit such movements.

The second animal to be harnessed was cought on 2 February at 1450. It proved to be a very large, young female, 578 cm in total length. That same night, it moved past the anchored *Louson* out of the lagoon entrance and southward along the outer side of the sand bar barrier between the lagoon and the sea. It was tracked across the dunes as far as Colina Coyote. A shore party, with a hand-held RDF went ashore on the dunes and crossed to the Pacific side. From a position about 6 meters above sea level, the tracking signal came in over an angle of about 270°±20 true. Using 8 power binoculars an attempt was made to correlate whale blows with signal occurrence. This was carried out in a slow sweep over a 40 minute period. No correlation could be made and we assumed that PATTI was at least beyond binocular resolution range. The horizon, with an observer 20 feet above sea level, is at about 5 miles. The party returned to the *Louson* and signals were subsequently lost. We presume that the harness and pod are lost since the release bolt was set to go at eight days. The entrance channel of Boca de Soledad out of which these animals passed, turns southward so this direction of initial movement was to be expected. Whales leaving and entering the lagoon were seen to stay close to the edges of the tidal channel that transects the entrance sand bar. Thus, their normal course becomes southward prior to reaching the open sea. However, the continuance of this pair southward, at least to Colina Coyote (15 miles to the south from the Bôca) was unexpected. Because of these varying observations, behavior of whales about to make the long swim north holds much interest.

6.1.2 Ciné Photography

Complete records of capture, beaching, harnessing and releases were made. Records of the behavior of whale pairs subsequent to harnessing were also made. Two full sets of films were made; one by Thomas Dohl of UCSC and the other by José Castello of the Direccion General de Educacion en Ciencias y Tecnologia de Mar. These are presently being edited to produce a comprehensive film of the research effort and of natural behavior of whales in the lagoon at Lopez Mateos.

6.1.3 Still Photography

All aspects of the expedition were photographed including capture, harnessing, natural behavior, respiratory experiments, personnel, the local scene, the autopsy, equipment and its preparation and certain other subjects such as the skull of a rare beaked whale (*Mesoplodon*) found by a beach party. This photo will allow identification of the rare find; the skull was lost with the *Louson*.

6.2 REVIEW OF CAPTURE TECHNIQUE

The first year's flawless capture performance was not duplicated in this year's effort—largely due to some small and seemingly innocuous changes in gear. Difficulty was experienced—in certain parts of the operation, but was ultimately corrected in the field to allow two successful captures to be made.

Capture is achieved by following a whale pair with the capture vessel, with a man stationed in the pulpit about 35 feet out from the bow. This man wields a capture noose and net. First, as the vessel brings him up upon a pair of animals and the attending speedboat distracts them, he waits for them to surface beneath the pulpit. He then places a noose of line over the young animal's head. This line is designed to slip back to the tail stock and cinch tight there. The line in contact with the animal is a soft braided line to minimize abrasion to the animal. Then the young animal is allowed to run free a short distance from the vessel while another hoop with a head net attached is brought to the man on the pulpit. The ship is then positioned closer and closer to the animal and finally the pulpit is again over it. Then the head net is placed, both head and tail lines taken ashore and the animal beached in shallow water.

We found two flaws in the procedure when it was compared to what occurred on the first expedition. First, the tail noose was mounted (this time) in a strong stainless steel hoop instead of an aluminum one. The noose is held to the hoop by ties of fine, weak twine designed to break loose under the stress of capture. The effect of the change in materials was that the stainless hoop resisted bending as it circled the animal and the tail line was scraped free at about the point of the pectoral fins. Because of the pliable skin of the young whale, the line sometimes cinched tight there and would not slip to the tail. This meant that the animal was held only at mid-body and subsequent placement of the head net was impeded because the "tail line," now under the placed head net, had the effect of loosening and causing it to be thrown off. The problem was solved by spreading the stainless hoop until it was considerably larger than the girth of the young whale; subsequent placements were uneventful in this regard. The second problem was in the use of a head net that proved some inches too shallow. When placed over the animal's head it failed to pass the pectoral fins and hence, sometimes failed to lock in place and slip off forward. This was solved by construction, on shipboard, of a deeper net. The head net is not designed to "hold" the animal by itself, but merely to place a noose at the proper level of the animal's body. A result of these problems was that on the first capture the head net fell free as the animal was being brought onto the beach. The animal had taken out considerable line and was far off the beach when this happened and hence difficult for the shore party to see in detail. This meant that the animal was being towed ashore by the tail. Old porpoise capture techniques, using a "tail grabber" have been used in various places, especially in Florida, but have been notorious for causing occasional "drownings" of animals. The animal struggles against a force pulling its tail upward and hence its head is caused to dip, making breathing difficult. Unless this is being watched for, death can result.

Another problem in the beaching operation was inadequate communication from ship to shore. Even though the problem with the first capture was noted instants after the head net fell free, the crew ashore did not understand what had happened until a man could be sent from the ship to inform them. By that time it was too late and the animal could not be revived in spite of heroic efforts to do so. Correction of this problem was accomplished by establishing radio communication between two assigned individuals—one on the boat and one ashore.

Problems also occurred because most members were assigned two or more tasks to perform and when difficulty occurred, some tasks were abandoned in favor of others.

We also faced the problem of adoption of the ship by young whales. Concern was felt for these animals as the ship attempted to maneuver away because of danger to the animal from the screw. While no such injuries occurred, steps must be taken to preclude them. Also, any vessel moving in the nursery area is a similar potential hazard.

A final problem was presented by the characteristics of the mouth of the lagoon. The entrance is treacherous. Because it is narrow, currents are swift and the channel is unmarked. Tidal changes make this an even more difficult situation.

Consideration of these problems has suggested the following changes for future field plans:

1. The use of a tail line appears to be unnecessary as has been shown by the many captures of whales at sea using only a head net and by the capture of animal No. 2 on this expedition. Since the tail line has been demonstrated to introduce a hazard we

recommend the use of a head net only. The head net, placed as it is, just posterior to the pectoral fins, pulls the animal sideways and upward; it is always possible for the animal to breathe.

To compensate for the loss of one line, additional men will be placed on the remaining line and a gasoline-operated net gurdy provided as a source of additional power.

2. Communication between ship and shore was markedly improved by using citizens' band radio. However, all communication aspects of future expeditions will be further reviewed and steps taken to assure coverage of both situations and personnel.

3. Ogranizational changes will be made in expedition operation. It is planned to assign specific tasks to the scientific crew; timing of respiration to two members, measurements of body and changes in diameter with breathing to another pair, a harnessing team of three people will be designated, the veterinarian will monitor the well-being of the animal and a photographer will operate without disturbance. In addition, a shore coordinator will see to it that various functions are carried out.

4. The site of operations will be moved to the region of San Carlos, Upper Magdalena Bay. This is also the site of the Baja California Fisheries School. José Castello, a member of the central administration for this group (located in Mexico City) has suggested that we may be able to involve students from the school in our operations. We feel they could provide manpower for beaching the whale thus leaving the scientific crew free to carry out its duties.

5. To avoid injuring whales in proximity to the collecting vessel, we plan to equip it with a basket over the screw and to similarly outfit skiffs we may use. We feel this source of danger so serious to the whales that a requirement for safety baskets on ship and boat screws should be made on *all* vessels entering the nursery area.

6. The problem of passage out of Boca de Soledad will be avoided by shifting operation to Upper Magdalena Bay in the vicinity of San Carlos. Many whales were seen on our reconnaisance of the area and mangrove flats are available for beachings. The channel to the sea is deep and miles wide. These factors combined with access to the fisheries school make this an attractive alternative.

6.3 REVIEW OF SAFETY PROTOCOLS

While most safety protocols in past work seem adequate there are certain changes that will be made in future work. In the past, the number of people placed aboard the collecting vessel has been large and they have had to remain in areas where they would not interfere with the activities of the crew. More freedom of action is deemed both necessary and desirable for those performing functions vital to the collecting operation. The remaining members of the team may be deployed by skiff some distance from the collecting vessel awaiting the netting of an animal. Only key personnel will be permitted on board: the party chief, the photographer, the instrument personnel, logistics personnel and those concerned with obtaining and recording respiration and behavior data.

Though none have been needed to date certain basic equipment will be placed in all small powered boats in future work. These items include: oars, first aid supplies, flashlight, flares and a walkie-talkie.

Communication call-in arrangements will be established for all groups which may leave the main group in the course of their work and related channels will be monitored.

A check-off list of safety precautions for both the vessel and shore operations will be prepared.

6.4 MAGNETIC TAPE DATA

Work is under way to link the subminiature recorder to the PACER-100 computer. A disk file and magnetic tape input-output system for the PACER is expected by 15 April, 1974 and it will be tied in to the computer on delivery.

While awaiting the computer peripheral gear we are attempting to debug the linking amplifiers to the computer. This work is progressing slowly.

Although a final decision has not yet been made, it is likely that we will print a duplicate of the data on the pod tape. To date, that tape has not been run and will not be until the decision to copy it has been made.

Appendix

LOG OF FIELD ACTIVITIES OF 27 JANUARY 1974

Log of Capture

Q-C3799-01

At 10:15 on the morning of January 27, 1974 a mother_ young pair of
California Gray whales was sighted off "Shm Shell Mound", south of Lopes Mateos, Baja California Sur, Mexico. The young animal was judged to be about 14 feet long and suitable for expansible harness test which would be carried out wholly within the lagoon. The pair was followed at a distance of approximately 150 yards in order to check respiration cycles. Timings were made of dives and a count taken of blows. These usually consisted of two or three blows in rapid succession (3-10 seconds apart) followed by a dive which often exceeded 3 minutes in duration. xftxr

After about 30 minutes of observation it was decided to attempt capture. Accordingly capture gea was rigged and pursuit begun. The speed boat was lowered to assist in herding the whales toward the pulpit afxthx on the bow plank ofthe collecting vessel Louson . In rather short order, the first loop was placed on the animal's tail at 11:14 AM. The pair swam off together, now staying more consistently at the surface. The young was allowed to swim on a nearly slack line for approximately 22 minutes in order to bring it close to shore and to tire it gradually. It was then brought again under the pulpit and the head net was quickly put in place. The animal then went off, tethered head and tail, as has proven a successful method in previous captures.

The line men went ashore and began to tow the young animal onto the beach, with the adult in attendance, sometimes crossing back and forth over the lines. Shortly the captain noted that the head net was no longer in place but had slipped free. The head net serves the function of allowing the men ashore to pull on both head and tail simultaneously, thus breaking the normal swimming pattern of the animal and allowing it to be brought in quickly without disruption of normal respiration.

As soon as the slippage was noted a boat was sent ashore to notify the shore team. About the time this boat arrived the line crew noted a lessening of resistance from the captive. The animal was towed in and as soon as it could be seen clearly it was decided that it was in trouble. Several members rushed out in waist deep water to the animal and found it lying quietly, sputtering, but regular respiration was absent.

It was taken quickly to shallow water and attended by Dr. Sigmund Rich, DVM, who found eye and skin reflexes absent and was unable to detect a heartbeat. Under his direction resuscitation efforts were initiated, first by mouth to mouth methods and shortly thereafter by use of a hand operated air pump. Periodic pressure was applied to the thoracic region by two members of the scientific crew to expell air. These efforts were continued for approximately 20 minutes when air was noted issuing from the angle of the mouth, indicating the air was no longer reaching the trachea because of displacement of the arytenoid extension of the larynx which normally crosses the esophagus and allows breathing in whales and porpoises. An attempt was made to reseat the trachea during resuscitation by reaching down the throat, but this failed due to the small diameter of the esophagus and the long distance to the trachea. The animal was determined to be dead shortly thereafter, by the veterinarian Dr. Rich.

This is the first serious capture problem which has been encountered in efforts of this sort on young whales by us or by other investigators who have taken these animals during similar studies.

The principal investigators determined immediately the following course of action.

(1) No further capture would be undertaken until consultation with both Mexican and American authorities.

(2) A thorough autopsy would be performed to determine the cause of death, with samples and procedures to be performed by both Dr Rich and a representative of the Mexican scientific community, if possible.

(3) Appropriate authorities in the Mexican and US governments would be informed as soon as possible.

Today being Sunday no contacts can be made until tomorrow morning.

Since it is impossible to preserve the animal intact Dr Rich was requested to sample important organs for later pathologic examination. These are to be preserved in the ship's refrigerator.

On analysis of the occurrence described above it is clear that the recurrence can be avoided by use of a heavier head net of larger mesh (8") that will slip over the pectoral fins and prevent slippage. Such a net has been constructed by the Captain of the Lowson. It will permit safe completion of our scientific experiments.

We firmly believe that continuance of the gray and other species depends upon learing their migration routes, and hence numbers, upon which rational management must be based. The methods we are developing represent the only present effort to develop non-lethal means by which such data can be gathered. It is our fervent hope that the unfortunate accident which occurred today will not prejudice the continuance of these essential efforts, which will, we hope extend to threatened species around the world.

The principal investigators speak for the entire scientific party and the crew of the Lowson in expressing their deep personal regret for this incident but hope that it will be weighed in its true perspective.

killing

Recently an international permit for the capture of 100 gray w... was issued for scientific studies to the National Marine Fisheries Service and this quota was not entirely taken. It is hoped that this animal may be considered as included in that quota, to which both the Mexican and American governments were signatories.

~~Qxxx~~ It is essential to our effort to be allowed to continue within a week or less for the following reasons:

(1) The work can only be done in the Mexican lagoons, and the animals will leave in a short time.

(2) Data packs have been activated and sealed and must be used within one week or they will be expended. These instruments represent a design time effort by the Franklin Institute of approximately two years duration.

(3) The vessel Lowson is on charter which cannot be extended and will have to leave if work cannot be completed within the time stated above.

We sincerely hope that our request to continue this important work can be ~~guaranteed~~ given quickly.

Technical

Report

Quarterly Report
Q-C3799-02

CONTINUATION OF TECHNIQUES DEVELOPMENT FOR WHALE MIGRATION TRACKING

Period: 1 March 1974—31 May 1974

R. M. Goodman
K. S. Norris

Prepared for

National Aeronautics and Space Administration
Ames Research Center
and
National Oceanographic and Atmospheric Agency
Washington, D.C.

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
THE BENJAMIN FRANKLIN PARKWAY · PHILADELPHIA, PENNSYLVANIA 19103

ABSTRACT

Status of effort at UCSC in the period is discussed. Work at FIRL is covered including data reduction, the subminiature recorder and initial efforts related to expendable transmitter circuitry design.

CREDITS

The authors were aided directly in the preparation of this report by L. Hobbs of UCSC and R. J. Gibson and E. Dougherty of FIRL.

INTRODUCTION

The period which this quarterly report covers has been spent primarily in working on data reduction and assessing problem areas uncovered by our experience in the field.

CONTENTS

PRECEDING PAGE BLANK NOT FILMED

1. WORK AT UNIVERSITY OF CALIFORNIA AT SANTA CRUZ

1.1 BEHAVIORAL PHOTOGRAPHIC DATA, CINÉ

A motion picture was put together from the film shot during the January-February field work. The film runs for about 20 minutes and records various aspects of behavioral data and capture techniques. It will be studied and reported on in the annual report.

1.2 BEHAVIORAL PHOTOGRAPHIC DATA, STILL

Analyses of these films will be made in correlation with field notes and reported in the annual report.

1.3 EQUIPMENT EVALUATION

Preliminary evaluation of the harness and associated gear recovered from the first instrumented animal shows remarkably little wear. Further comment on these will be reported later and will detail some design changes to avoid capture of sand which can reduce chances of gear recovery.

2. WORK AT FIRL

2.1 THE PACER 100 COMPUTER

The computer was fitted with peripheral input-output magnetic disc memory and drive plus magnetic tape capability. A number of initial debugging efforts was involved and has finally been completed.

It should now be possible to read the *entire* recovered recorder data (from whale pod) onto a disc for analysis.

In the interim while awaiting completion of the debugging effort, we have been sampling data from the tape and working out processing programs to preclude apparent errors caused by playback irregularities. As a matter of fact, these irregularities have led to certain redesign considerations appropriate for the subminiature recorder.

Original data on the tape were sampled at high frequency such that a number of computer bits was generated for each original bit. We then devised a program to condense the samples to obtain an approximately bit-to-bit correspondence. Teletype printout provided a binary-coded replica of the original data. Where drop-outs appeared, the time sequence could be used to fill in the gaps. A readout of 23 hours of continuous data (2 February 1974, 0245 to 3 February 1974, 0140) was completed. These data were fully corrected and comprised about 500 pages of data containing about 33,000 seven-bit words. The points were entirely translated, corrected and plotted. Dive data for this period are included in the Appendix to this brief report.

Over 250 dives were plotted and their occurrence times, within the total trip from onset: 1500, Jan. 31, 1974, were indicated within 1—2 minutes. Actual relative time and duration of each dive is known to within 5 seconds. Absolute time of day is known to within about 2 minutes.

Some statistical analyses of dive data are now under way and will be reported and commented on by both the biologists and physical scientists involved.

Most dive data seen so far are in the range of 8—12 feet (2.4—3.7 meters), the deepest being 29.3 feet (8.9 meters). We note parenthetically that the charts indicate the deepest channel depths to be on the order of 35 feet (10.7 meters). There were periods up to 40 minutes during which no dives were made. Recorded dives should be accurate to within a foot (.305 meters).

Apparently water mixing within the lagoon was relatively complete. Our temperature recordings show differences on the order of 0.5°F. (.22°C) with dives and mean temperatures of about 63°F. (17.2°C) Tidal currents in the lagoon reach velocities on the order of 5 knots and thus one can expect fairly complete mixing in the relatively constricted volume involved. The least count of our temperature/recorder system was 0.156°F. (.087°C)

2.1.1 Effort in the Next Period

We expect to transpose the entire pod-tape to a single disc memory unit, clean up irregularities in data and produce:

1. a compressed activity record vs. time for the full 4 day, 19 hour trip
2. a detailed temperature/pressure record showing dive profiles for the full trip
3. activity frequency distribution analyses
4. biological insights to the data.

2.2 THE SUBMINIATURE RECORDER

Detailed data analysis brought to light several areas for improvement in the recorder. These problems are primarily mechanical in nature and are correctable. The first deals with the fact that incremental stepping was non-uniform. This was known prior to the field trip and was not considered a detriment for our first operation. However, in long runs, it will be essential for accurate .001 inch (.025 mm) steps. The second problem was more serious and showed up as tape skewing in the playback mode. It was not possible to check this prior to the expedition because of the compressed work-time scale and the fact that computer interface gear was not yet built.

Several approaches to correcting the difficulty were worked out and we decided to prototype them insofar as present budgeting would allow.

> The tape drive was redesigned in such a manner that the tape is driven on the return stroke of the magnetic motor, rather than on the powered stroke. The advantages are several: the power stroke which produces a spring tensioning produces maximum force at the end of the stroke at the maximum spring tension; this maximum tension is then available at the beginning of the tape drive stroke where it is needed. Further, tape drive on the return stroke can be controlled very precisely and movements of .025 mm will be attained. In this configuration the tape motor is mounted horizontally rather than vertically to permit improved fixing by clamps. In this position, simple removal, if desired, is also achieved. Design effort on this part of the system is about 80% complete.
>
> The recording heads are now rigidly mounted in dovetailed slides on a separate baseplate. This permits total removal and accurate replacement where necessary. It also permits simple micrometer, head adjustment for channel interlacing—a chore which in the past was painstaking at best. This effort is about 60% complete. Another attribute of this separate mounting arrangement allows for straightforward tape threading.
>
> The capstan gear drive was redesigned to permit partial disassembly without requiring *total* disassembly. This arrangement simplifies adjustment. In addition, the capstan is now captured between two bridges instead of being hung from a single bridge. This effort has been completed.
>
> The tape guidance system has been redesigned, but not yet built. Tape will now be guided across the heads by three static posts and the capstan will no longer double as a tape guide. These changes are expected to minimize skew.

2.3 PACKAGING MARKING

Because of the high sand content caused by fast tidal currents in the lagoon, wear on the outer pod surfaces is substantial. About five days of such exposure was almost sufficient to scour off the "reward" notes on the outside of the package. These notes were mounted on the pod surface and covered with a gel coat.

In the future, critical markings and notations will be engraved on stainless steel plaque or the baseplate for permanence.

3. WORK AT AII SYSTEMS

3.1 THE EXPENDABLE TRANSMITTER CIRCUITRY

Work performed thus far has concentrated in the area of a high efficiency 401 MHz amplifier. Problems encountered have been with transistors capable of a 2-watt output with an 8-volt supply. The present design is a three-stage amplifier with the last stage operated in a Class C mode. The transistor presently being tested is a CTC B2-8Z type. Preliminary test results are encouraging.

Studies have been performed on crystal oscillator designs which would exhibit the required stability of one part in 10^8 per fifteen-minute periods without the use of an oven. The most promising approach appears to be to use a high quality TCXO mounted to the outside wall of the transmitter. The wall of the transmitter will act as a constant temperature heat sink by dissipating the heat into the ocean.

3.1.1 Planned Tasks

Within the next six weeks a breadboard design and implementation of the transmitter will be completed. The breadboard model will be tested and evaluated. The transmitter will be designed to operate for 48 hours with a 2-watt output using lithium batteries for power. The duty cycle will be one second of transmission and 59 seconds off. During the one second of transmission, the format will be .36 second of CW, two 8-bit synchronization words, one 14-bit identification word and four 8-bit data words.

Appendix

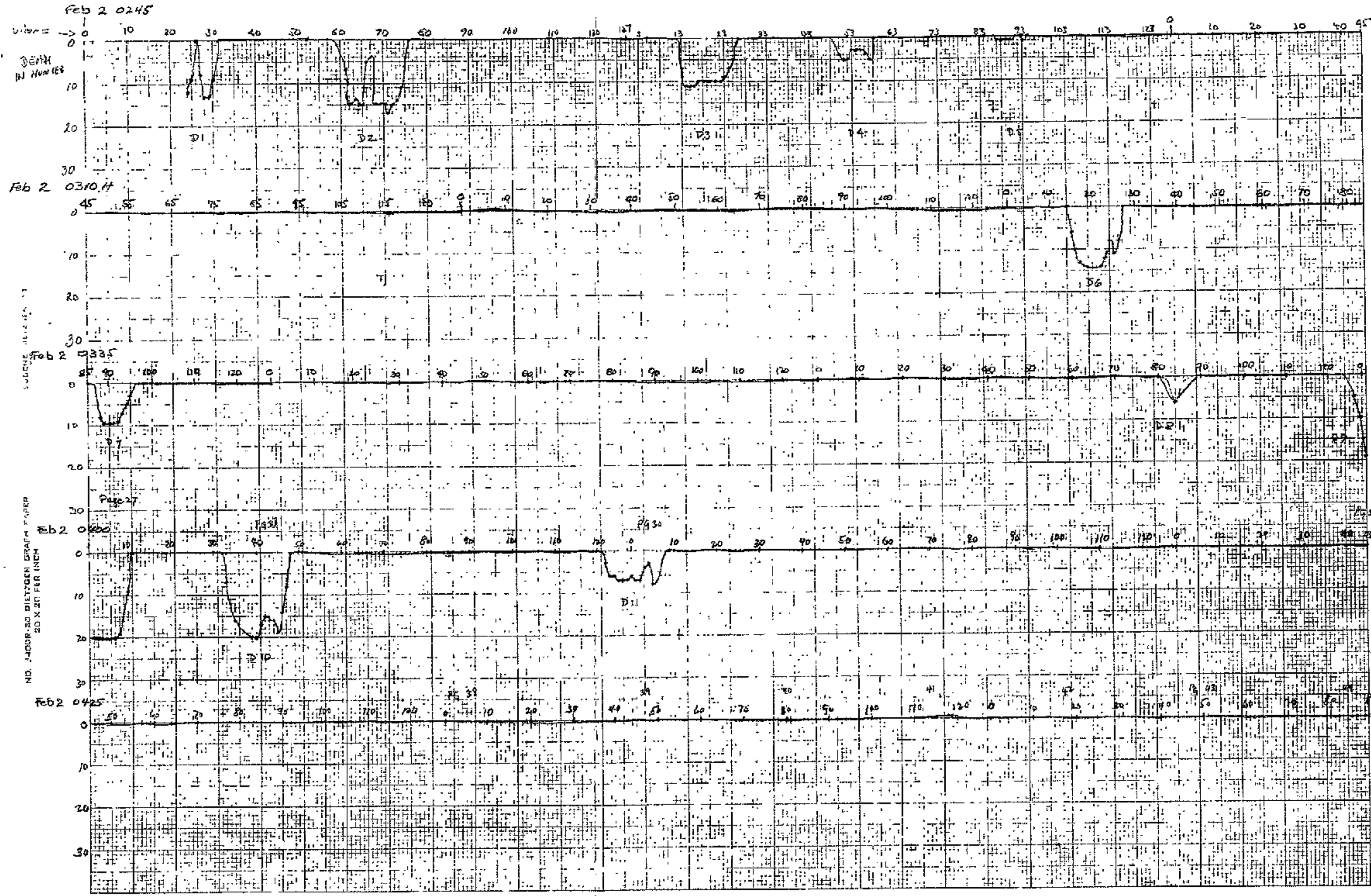
DIVE DATA COVERING THE PERIOD FROM
2 FEB. 1974, 0245 HRS.
TO
3 FEB. 1974, 0140 HRS.

ORDINATE: 0.891 x depth number = feet

ABSCISSIA: 100 seconds/inch
(25 minutes across full sheet)

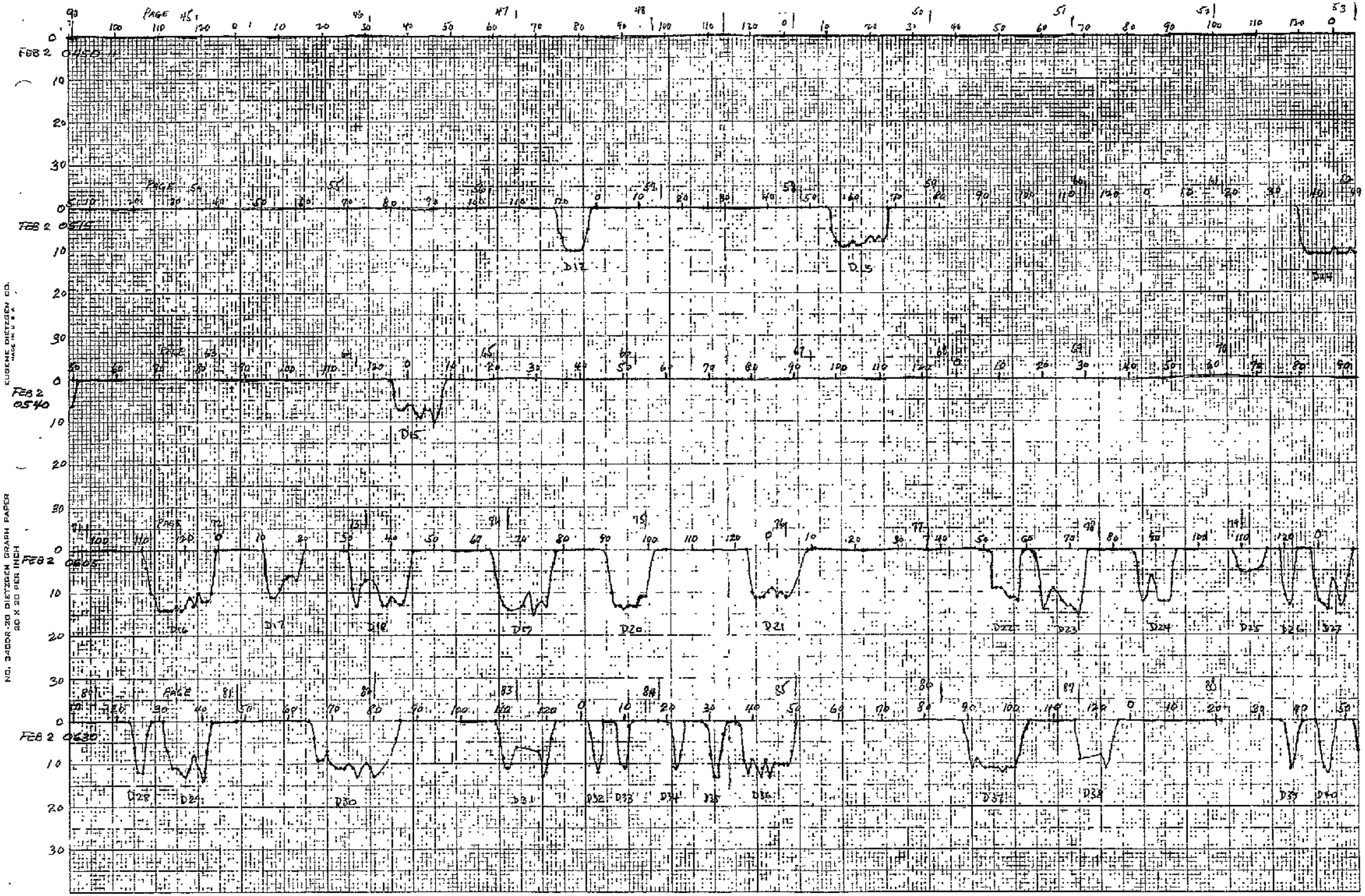
FOLDOUT FRAME

FOLDOUT FRAME 2



NOTE: SCALES ARE CALIBRATED AS FOLLOWS
ORDINATE = 0.891 X depth number = FEET; ABCISSA = 100 SEC/INCH

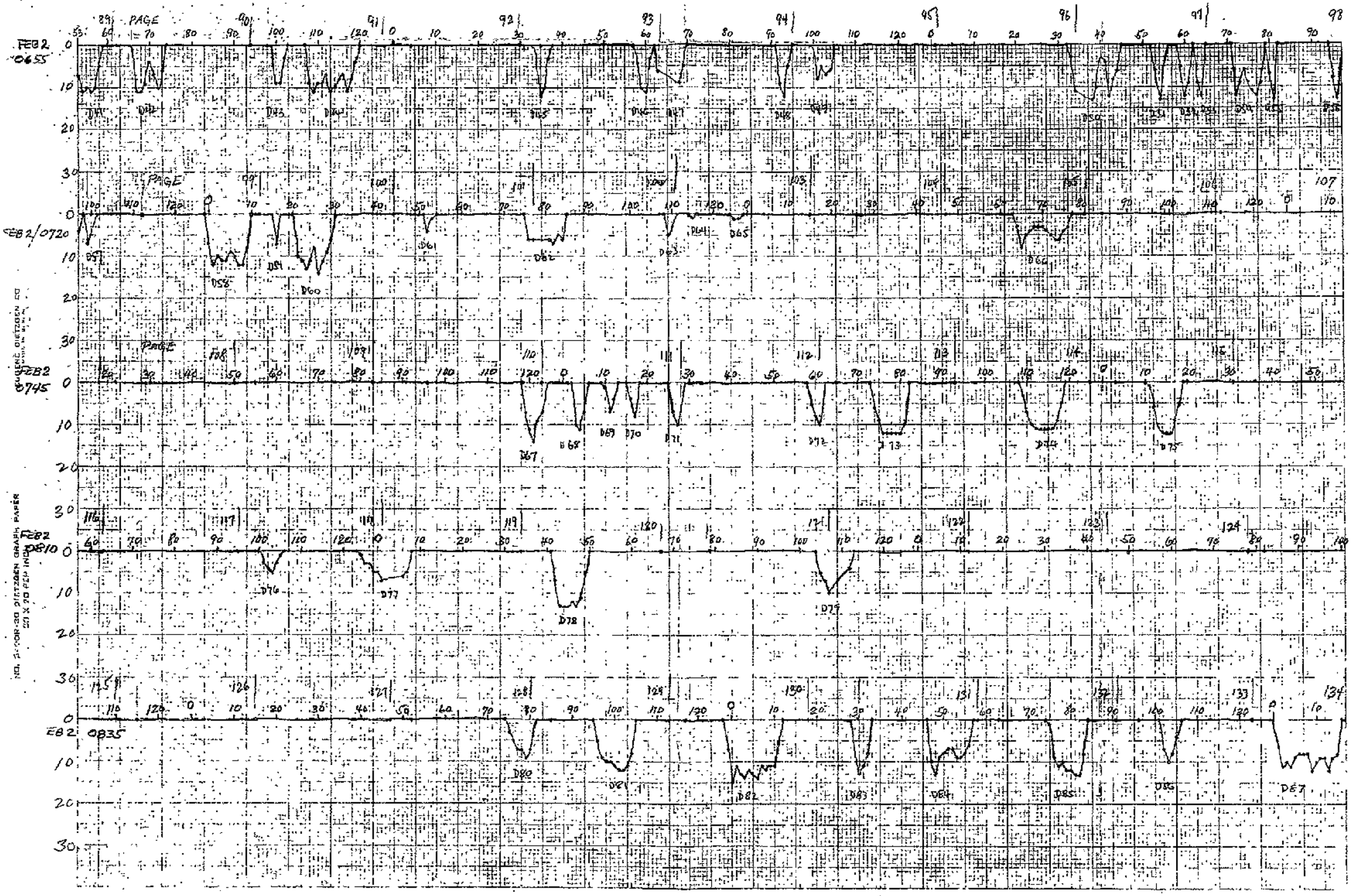
GRAPH #1 PAGE 1 TO 44 (25 minutes across paper) 10 small divisions = 50 SEC. 12 " " = 1 MIN.



GRAPH #2 PAGE 45 To 89

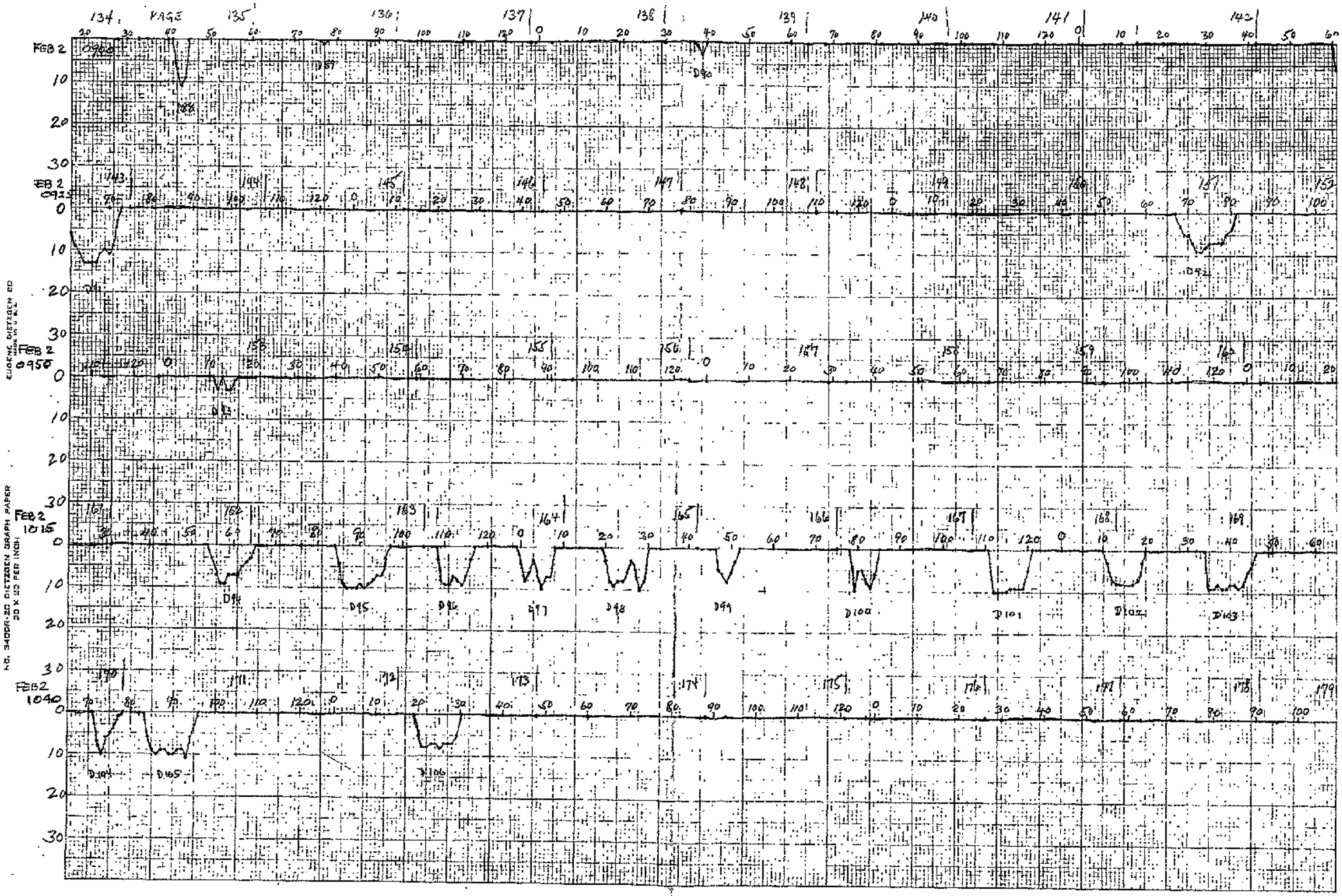
FOLDOUT FRAME

FOLDOUT FRAME 2



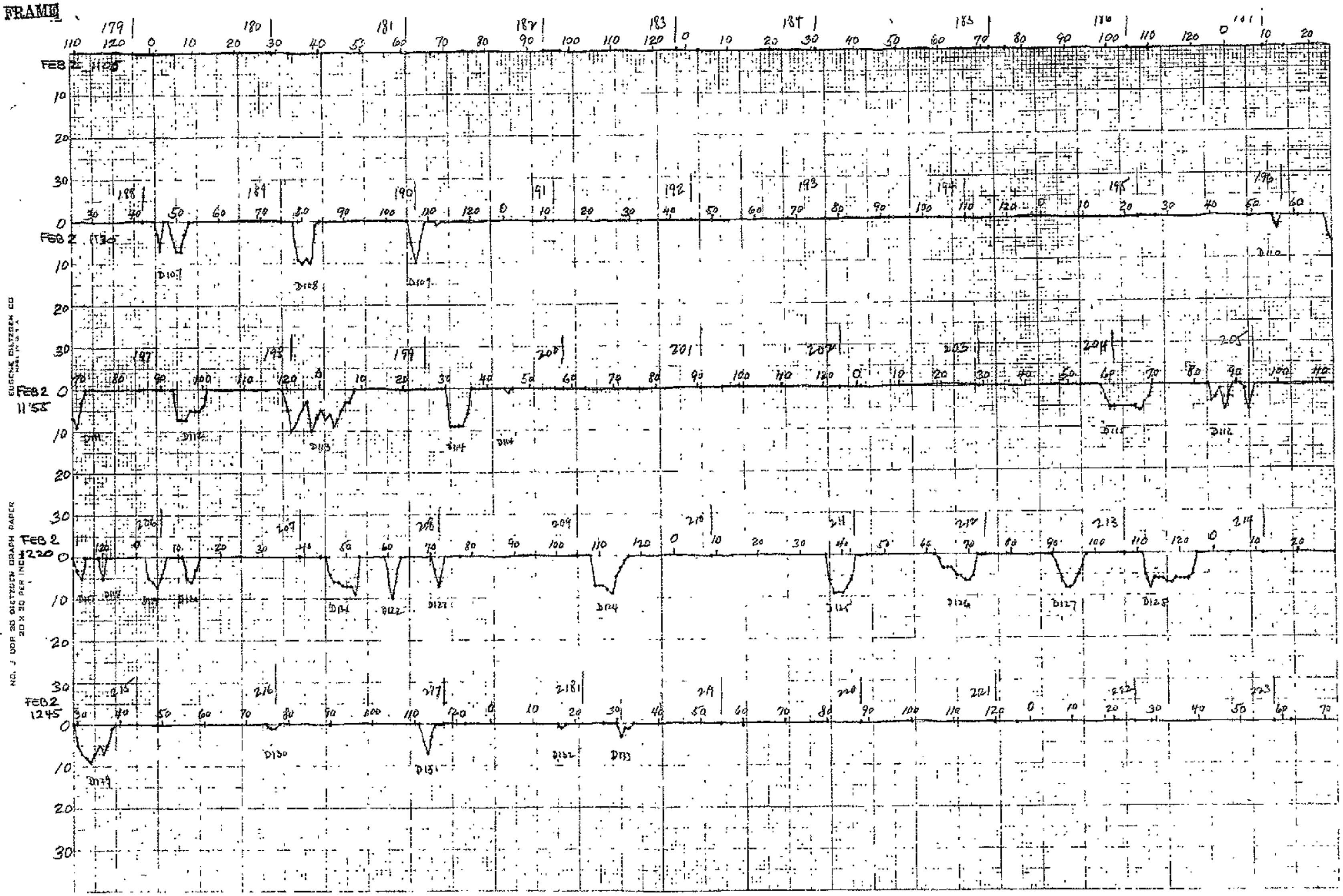
GRAPH 3 PAGE 89 TO 134

③



GRAPH 4 PAGE 134 TO 179

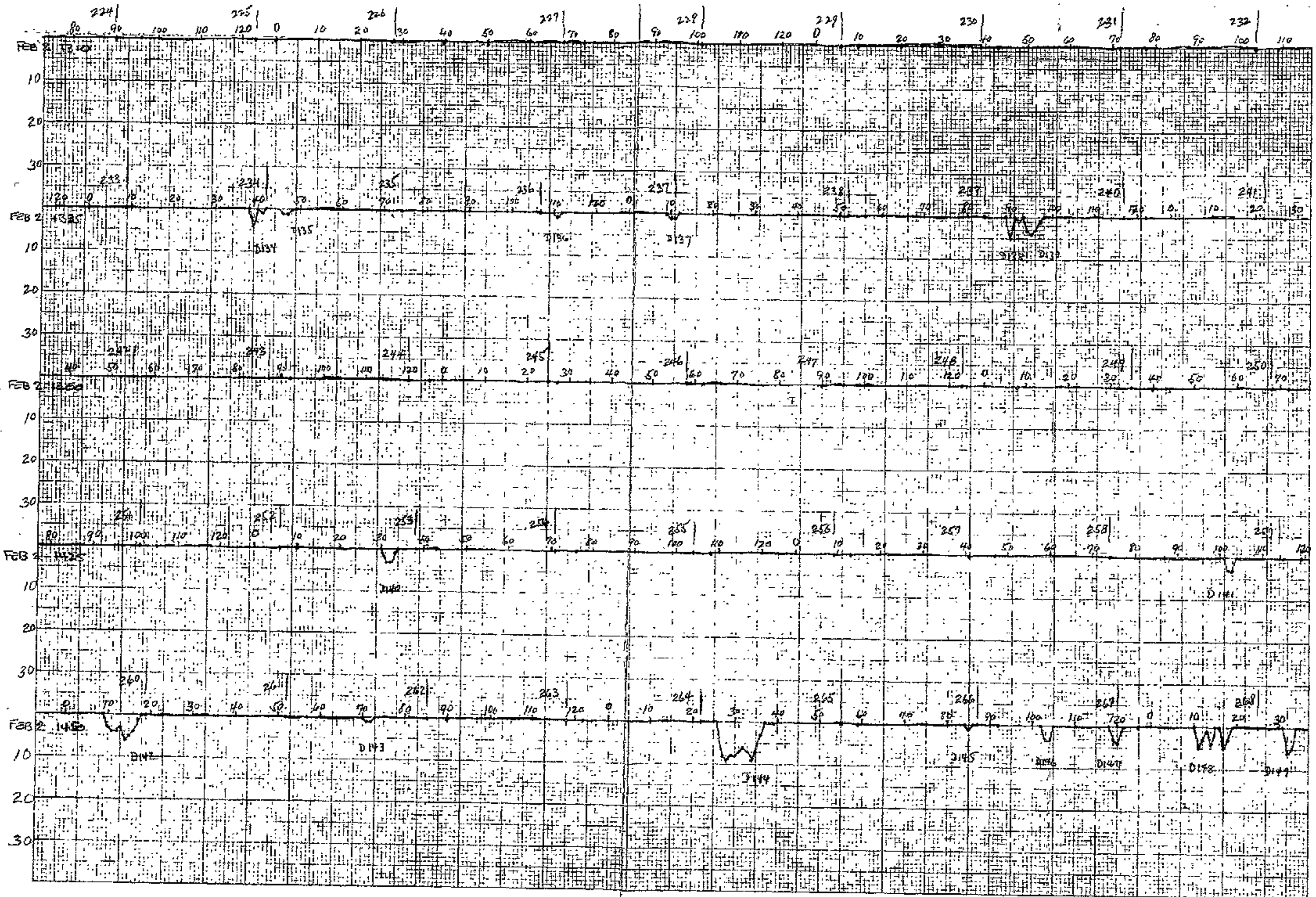
FOLDOUT FRAME



GRAPH 5 PAGE 179 TO 223

FOLDOUT FRAME

FOLDOUT FRAME 2

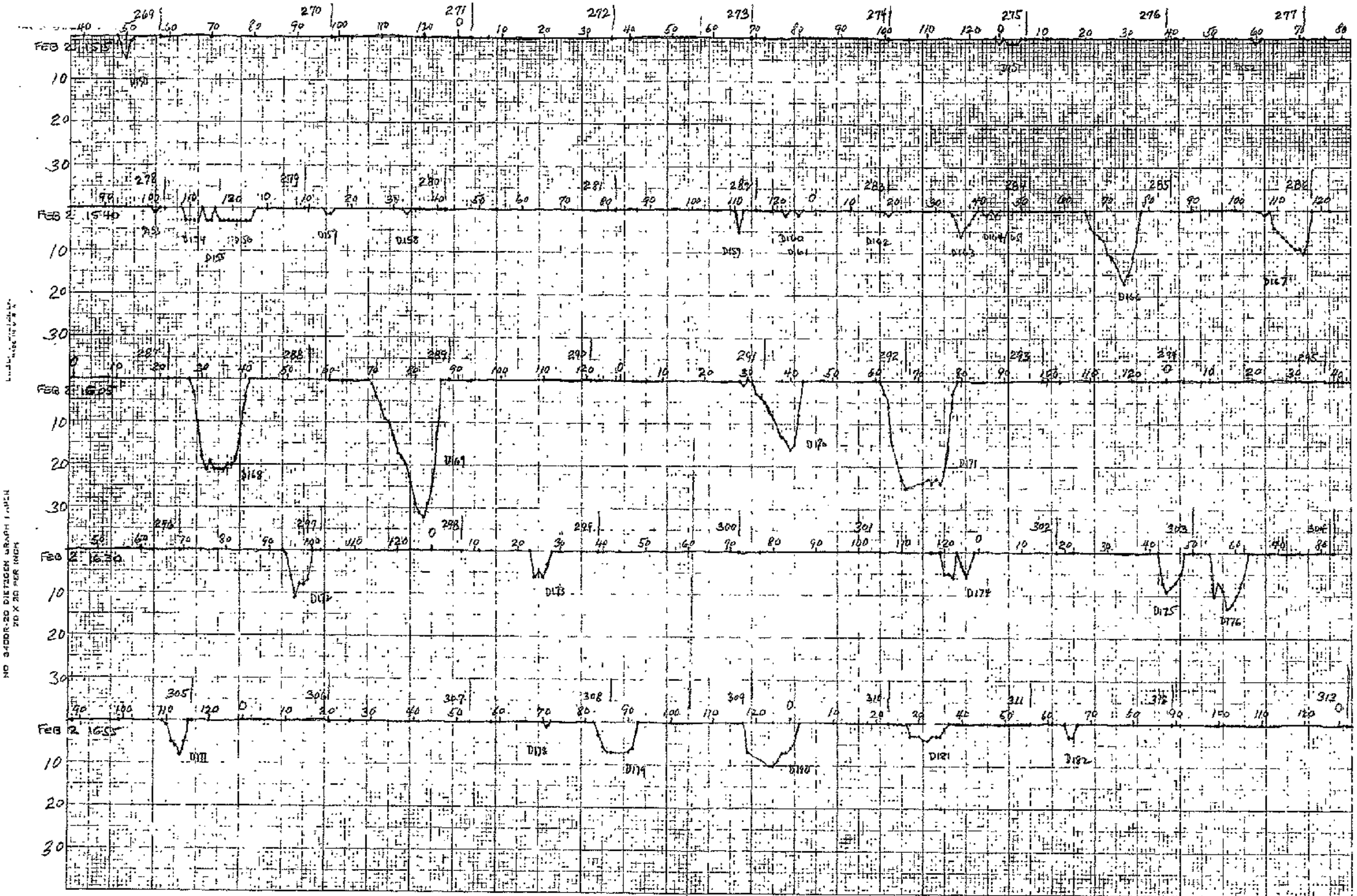


GRAPH 6 PAGE 224 TO 168

6

FOLDOUT FRAME

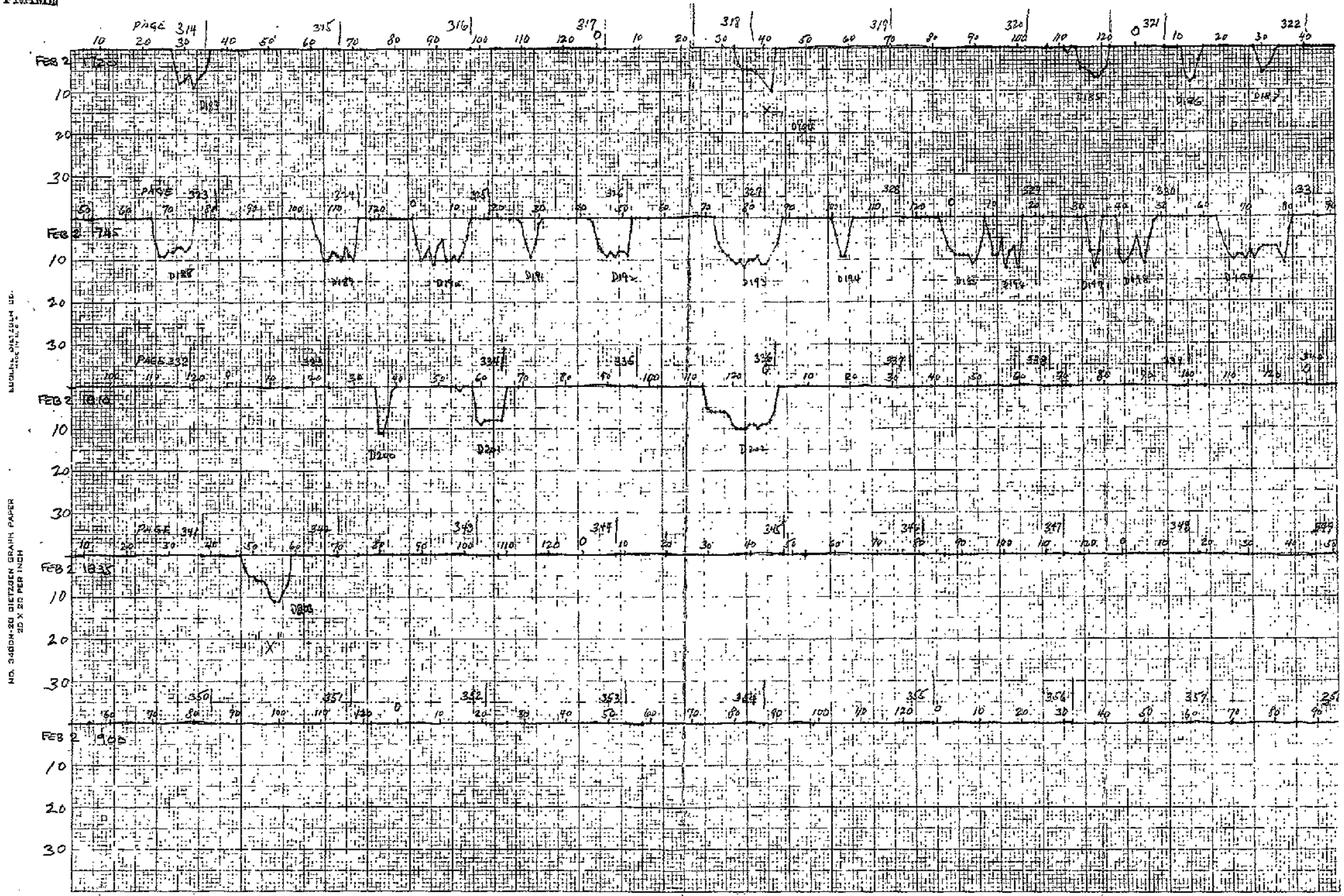
FOLDOUT FRAME 2



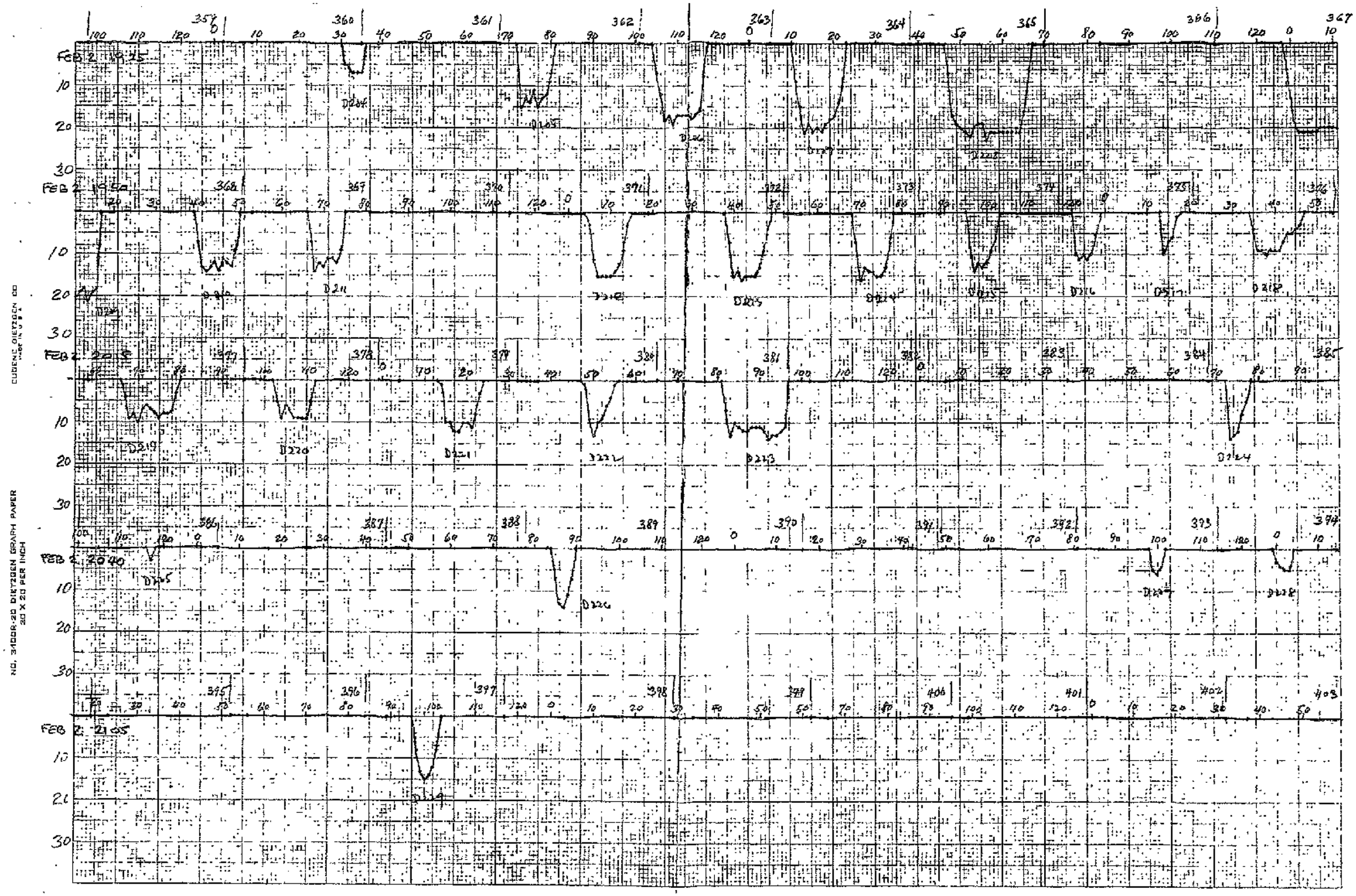
GRAPH 7 PAGE 169 TO 313

FOLDOUT FRAME

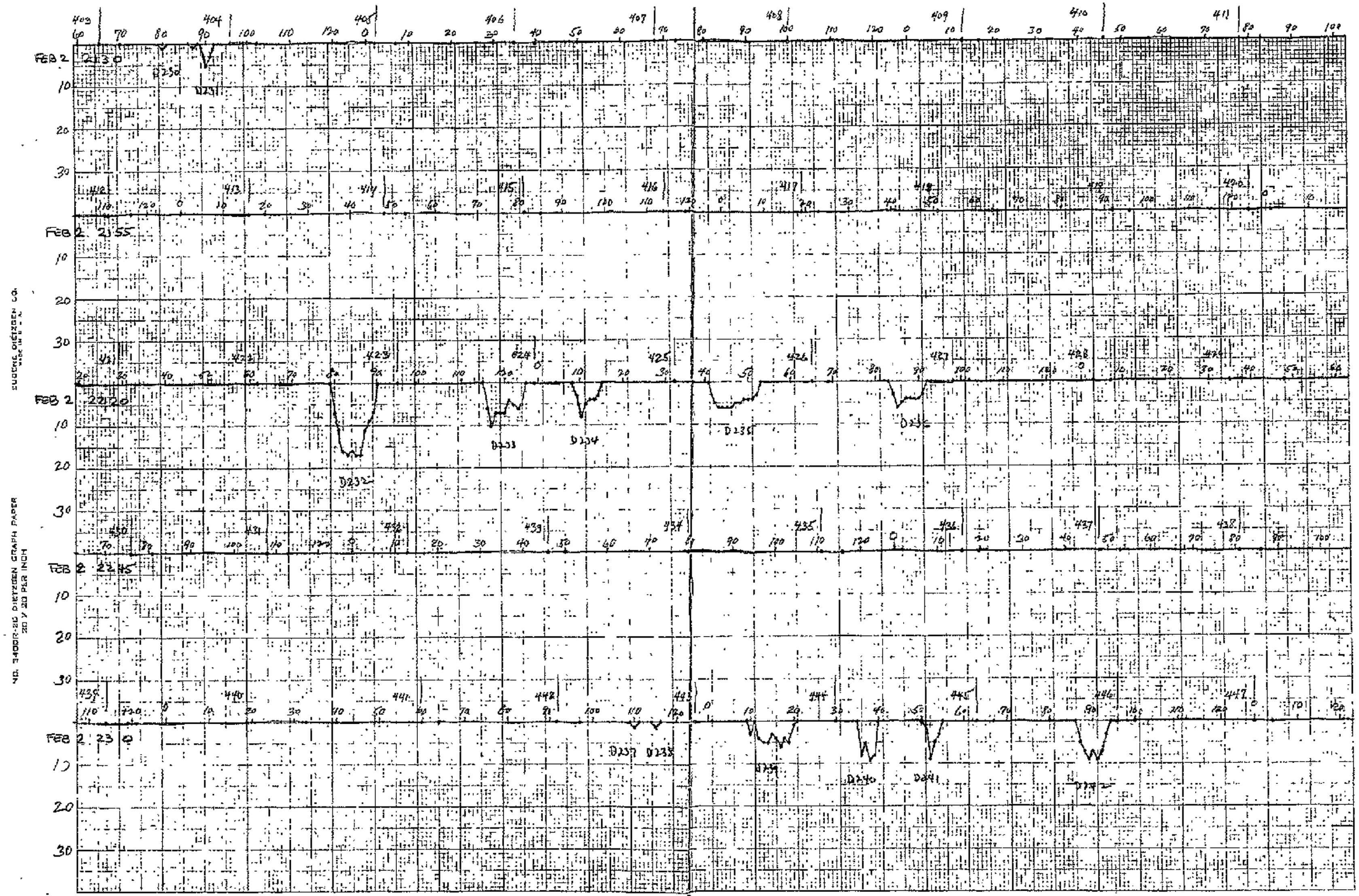
FOLDOUT FRAME 2



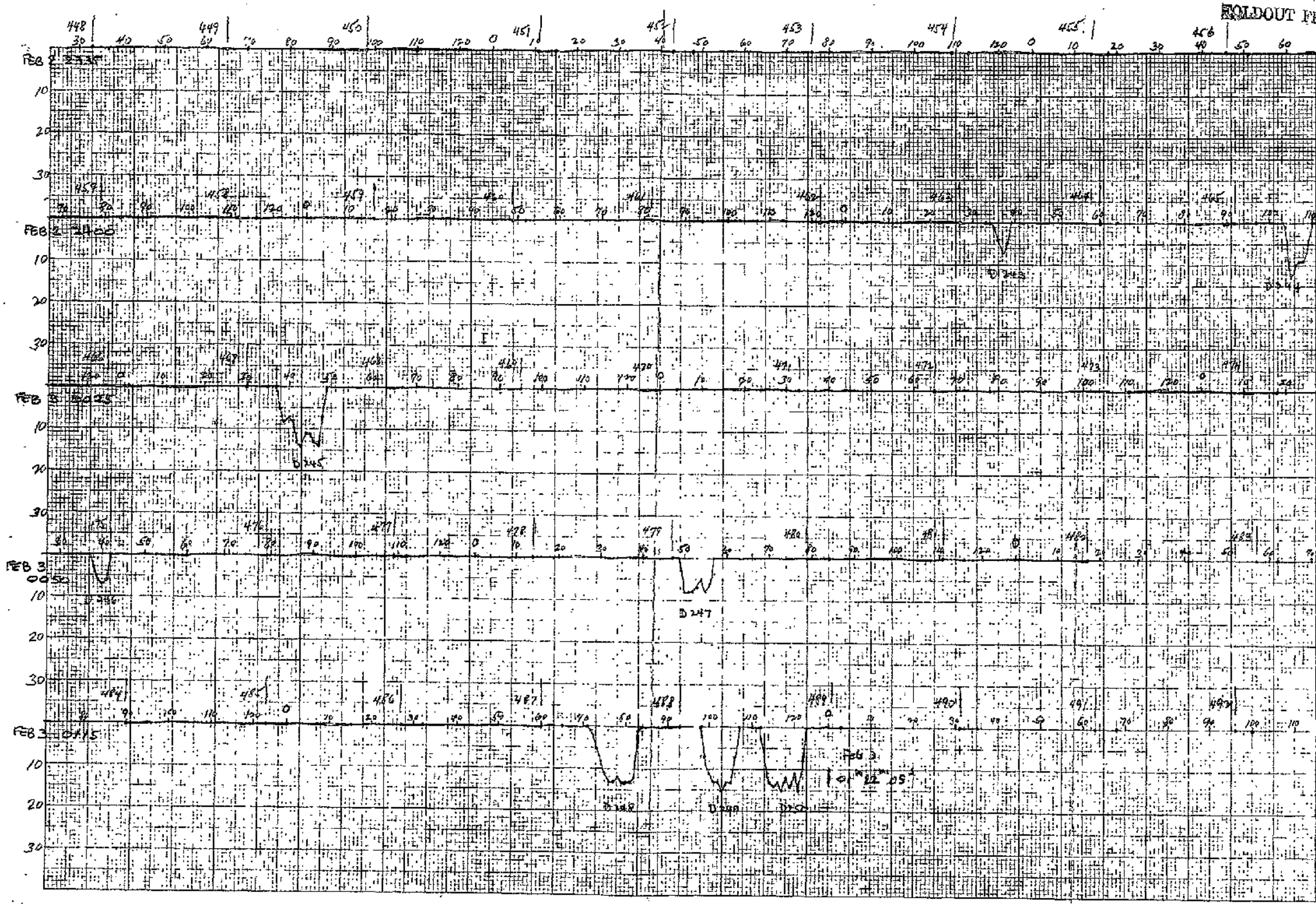
GRAPH 8 PAGE 314 TO 358



GRAPH 9 PAGE 358 TO



GRAPH 10 PAGE 403 TO 448



GRAPH 11 PAGE 448 TO 492

Technical

Report

Final Report
F-C3799

TECHNIQUES AND INSTRUMENTATION EFFORT FOR WHALE MIGRATION TRACKING

May 1975

Prepared for

The National Aeronautics and Space Administration
Ames Research Center, California

NASA Contract No. NAS2-8013

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
THE BENJAMIN FRANKLIN PARKWAY • PHILADELPHIA PENNSYLVANIA 19103

1. DATA ANALYSIS

The instrument pod recovered from the juvenile gray whale sensed water pressure and water temperature each five seconds. The designed tempterature sensing range was 55°F (12.8°C) to 75°F (23.9°C) with a least count of 0.16°F (.09°C). Temperature data is recorded in binary form with "zero" being 12.8°C and "127" being 23.9°C. In a similar manner, pressure is sensed over the range of 0 - 50 psi, referenced to atmospheric pressure. The system was usable to 60 psi. The least count was 0.39 psi or .89 feet (.305m).

Data taken each five seconds were accumulated on the magnetic tape of the subminiature recorder. In each five second period, from the initiation of the experiment, a data-group count (0 - 127), a water temperature and a water pressure were recorded. Thus, in an estimated recording period of 4^{d} 19^{h}, about 248,000 data were accumulated. Of these, there are about 83,000 each of temperature and pressure (depth).

The following sections describe the software developed to obtain the data from the tape, cleanup problems which originated because of tape skew in the recorder and the like. Further, the simple form of data presentation from the computer is described and a preliminary biological analysis of the data presented.

We note here that most of the problems which complicated the software effort, to date, are not expected to be encountered in the future. These occurred primarily because of certain mechanical design aspects of the recorder which became apparent as a result of this study -- a situation created by the telescoped time-scale within which the effort was undertaken. Corrective measures are known and future recorders will be far easier to work with in this regard.

1.1 MANUAL DATA REDUCTION

In the early stages of the development of the software to permit data readout from the miniature recorder magnetic tape we obtained a numerical readout of approximately one day's data. (See Sample X-1, Figure 1-1). From this numerical readout exact timing information could be obtained. Since a pressure, temperature and data group count was recorded each five seconds exactly, and this was printed out in this type listing, the dives could be plotted with exact duration and relative timing. This was done and is shown in Sample X-2, Figure 1-2. In Sample X-1, Figure 1-1, the count can be seen progressing from 115 to 127, next count 0 and there through 15. Since a great deal of information was present in this printout, ambiguities if any, and missed bits, if any, could be corrected, interpreted or inserted without error.

Dives each had their characteristic shape and on later analog traces of the full experiment could be identified. The timing from Sample X-2, Figure 1-2 was used to calibrate the analog write-out (see Sample X-3, Figure 1-3) for time. Approximately 500 computer data pages of 3 columns of 29 lines each was manually interpreted and plotted. Sample X-1, Figure 1-1 shows part of page 79, all of page 80 and part of page 81. On page 80, counts 126 through 8 show a dive which lasted, from surface to surface, a time equal to 10 intervals of 5 seconds, or a duration of 50 seconds. The pressure count went to a maximum of 14. The conversion factor relating count to pressure and pressure to depth is 0.891 counts/foot. Hence, the maximum depth of dive was 0.891 x 14 equal to 12.47 feet. The constant 0.891 was determined by

$$K = a\frac{P}{dc} \quad \text{feet/count}$$

p = full scale pressure gage = 50 psi
c = full scale count = 127 counts
d = density sea water = 63.63 lbs/ft^3
a = constant = 144 in^2/ft^2

The dive on page 80 (Sample X-1, Figure 1-1) is the numbered dive D27 shown in graph #2, line 3 in Appendix of Quarterly Report Q-C3799-02. This is shown again in a small sample as Sample X-2, Figure 1-2.

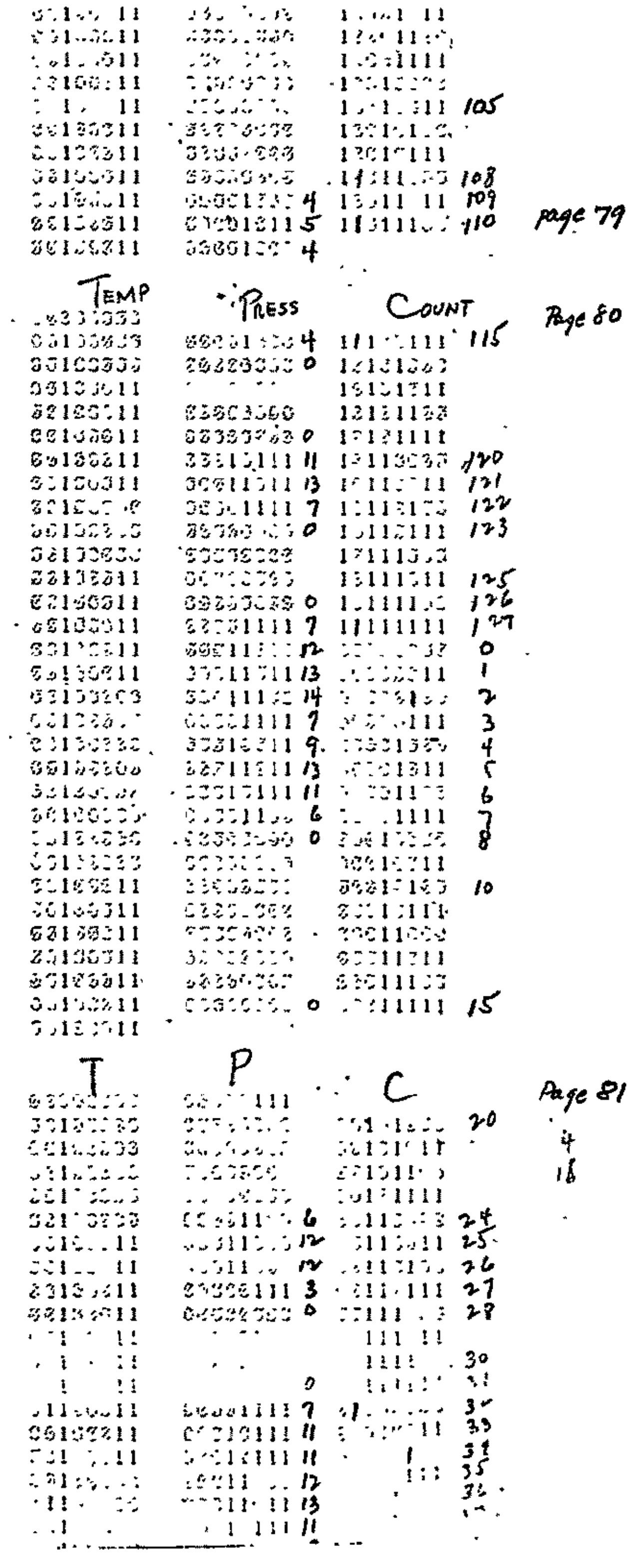
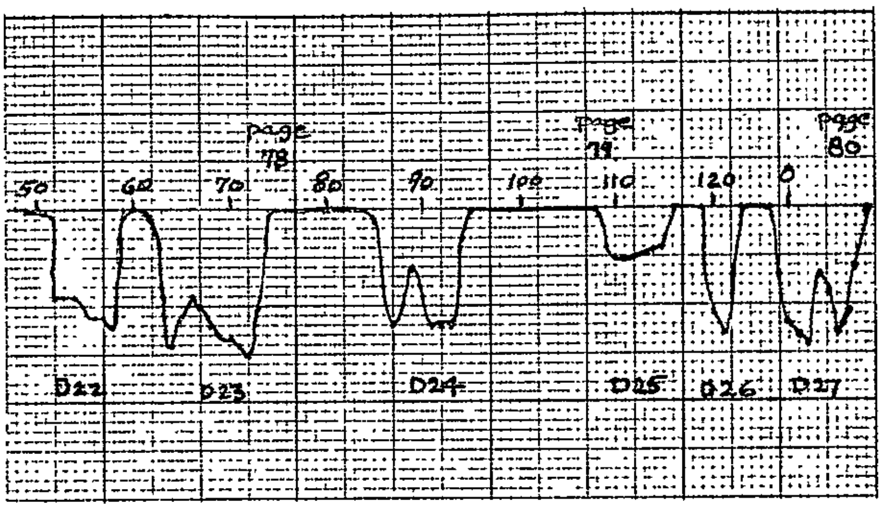


Figure 1-1. Sample X-1



Data Sample X-2

Scale Horz. 1 div = 5 sec
      Vert. 1 div = 0.891 Feet (1 count)

Figure 1-2.

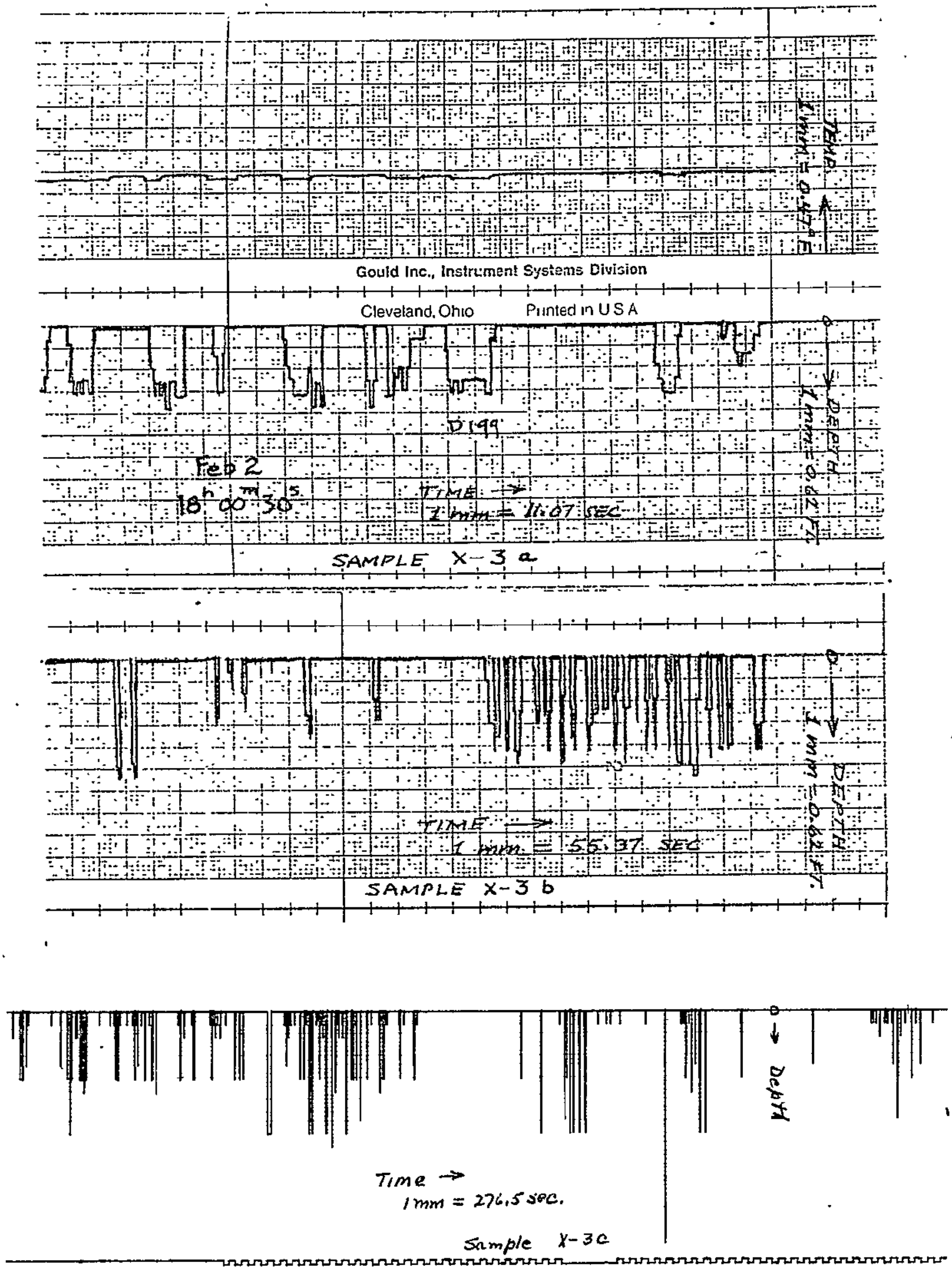


Figure 1-3. Sample X-3C

The temperature varied very little and there was some difficulty in interpreting the temperature as the 2nd bit from the left (= 32) did not always appear when it should have. The 7th and 8th bits from the left are always the same and are the least significant bit (= 1). The temperature shown on page 80 is then read as 62.69°F (17.05°C) for 00100011 where the missing bit is inserted to give 01100011. This binary number then is read as 1 + 16 + 32 = 49 decimal. The temperature is determined from:

$$T°(F) = 55 + 0.157\ C$$

Then

$$T = 55 + 0.157\ (49) = 50 + 7.69$$
$$\doteq 62.69°F\ (17.05°C)$$

This changed to 1 count less during the dive giving 62.54°F. (16.97°C). The other bits were considered reliable and since the 2^4 bit did not disappear, this is believed to be the true state of affairs. That is that the temperature was remarkably uniform at all depths. Tidal currents on the order of 5 knots contributed to this mixing as well as the animals' motion. In addition the ship's water thermometer observed over a period of several days varied less than 2 degrees F. (1.1°C)

1.2 COMPUTER DATA REDUCTION

1.2.1 Methods

Programs were written and debugged (see Section 1.3) to provide a signal suitable for digital-to-analog conversion. These data were then processed through a D/A converter and plotted at various speeds on a strip chart recorder.

Three time bases for the analog records were chosen: a slow speed (approximately 11 seconds real time/mm) to reveal fine detail in each dive and detail of dive intervals, a faster speed 5 times the slow speed (≃55 sec. real time/mm) and very fast speed approximately 25 times the slow speed. The two "faster" records were made to allow a visual comparison of the dive density and to be able to see the complete track in a few feet of record. Calibration and discussion of these three analog records is discussed in the next section.

1.2.2 Results

Three analog records were produced where the time base is at three different speeds. These three speeds give the following real time bases of the track and may be used to compute the dive duration, dive intervals, etc.

1 mm = 11.074 sec.

1 mm = 55.37 sec.

1 mm = 276.5 sec. (4^m 36.5^s)

For all time bases:

- The temperature calibration starts at 55°F (12.8°C) and increases upwards by 0.47° (.26°C) each mm.
- The pressure calibration starts at zero feet and increases downwards by 0.62 feet per mm.
- Because of the computer capacity limitation the total run was broken into four sections labeled W1 through W4. The start and end of each section is labeled and time at end of W1 is the time at beginning of W2, etc.
- W4 data is <u>not</u> useful.
- Portions of data at each of the three time bases are shown in Sample X-3a, b, c. Time in day, hours, minutes and seconds is given for the beginning of each "W" section and for a number of intervals throughout each section.
- The absolute local time of any point on the readout can be determined by adding to one of the marked times the product of the number of mm after that time, times the time-base for that particular chart. Any time on the chart is probably accurate to within two minutes from start time and is usually much better. small time differences up to a few hours are probably accurate to a few seconds.
- Complete analog records have been made for both FIRL and UCSC for further analysis.
- Certain parts of the record contain erroneous output due to the computer readout. These are crossed out in red and should be disregarded; time continues through these sections, however.

- The analog readout by the computer had its problems. Occasionally the computer would mistake a temperature, or a record number (not shown) for a dive depth or vice versa. Also because of skewing of the data on the tape, many of the dive profiles are not exact on the analog readout. The marked dives D1, D2, etc. were plotted by hand from a digital readout and corrections made for this skewing. The depths and contours and times on the manually reduced data are exact, probably 99% of the time. The analog data, however, is precise in its timing and separation of dives with the possible omission of a dive with about the same error.

- For both temperature and pressure (depth) the values are digitized and should be smoothed. Pressure transducer response was instantaneous and so only sharp corners should be smoothed. Temperature response was on the order of 5 secs. and lags true temperature change by approximately this time.

- The time of entrance into water and the time when whale started swimming are both estimated, but are believed to be accurate to within a few minutes. Time when whale was released set at Jan 31 $15^h\ 00^m\ 00^s$.

- Data on section W4 (starting Feb $4^d\ 16^h\ 50^m\ 18^s$ and thereafter) was not recoverable due to problems with tape and computer readout. This amounts to about the last 7 or 8 hours of data which was not recoverable depending on exactly when the harness released from the whale.

- The dives from Feb $2^d\ 02^h\ 45^m\ 00^s$ on the hand-reduced (large scale) data are numbered. These same dives are numbered on the analog record (11.074 sec/min).

- These records can be used for analyses involving total activity, periodicity of activity and the like. One the other hand, we believe, the set of manually reduced data, which are included in the Appendix to the joint Quarterly Report No. Q-C3700-02, are more representative of detailed dive activity including the dive profile itself.

1.3 COMPUTER SOFTWARE

Several computer programs were written on FIRL's PACER 100 computer to test and read data from the miniature data recorder. This section deals with the development and use of these programs.

1.3.1 Recorder Tests

The testing procedure included prerecording patterns on the tape via a specially designed pattern generator. The test patterns were such that they represented the worst-case conditions for the miniature recorder. For example, one pattern was alternating 1's and 0's. Two methods of evaluating the miniature recorder were used. One method involved oscilloscope viewing and the other the PACER 100 computer.

The first method simply used an oscilloscope to monitor the output channels of the miniature recorder. This provided information on the shape of the data pulses, duration, height, noise and the relative position of one channel to another. Based on the observations of this display, adjustments to the mechanics or electronics could be made.

The computer method read the 8 channels of prerecorded data into the computer. The computer, programmed to know what was prerecorded on the tape, was then able to count the number of errors and store up to 500 error words. At the end of the run the computer would print out the number of errors and, at the discretion of the user, would print out up to 500 of the erroneous data words.

The tests were expected to reveal that each channel would be played back with very little skewing and that each channel would be coincident with the other (as shown in Fig. 1-4).

It was expected that the time between pulses (T_2) and the pulse widths (T_1) would be constant. While T_1 and T_2 did prove to be acceptably consistent, skewing was much greater than anticipated. In fact, the skew was so great at times as to have bits of one data word overlap into the next data word (see Figure 1-5). Fortunately, the skew was fairly consistent so that once the skew pattern was established, it varied very slightly during the run and could therefore be corrected.

Because the expedition had to adhere to a tight time schedule, the mechanical cause of the skew was not corrected and thus the computer was programed to compensate for the skew.

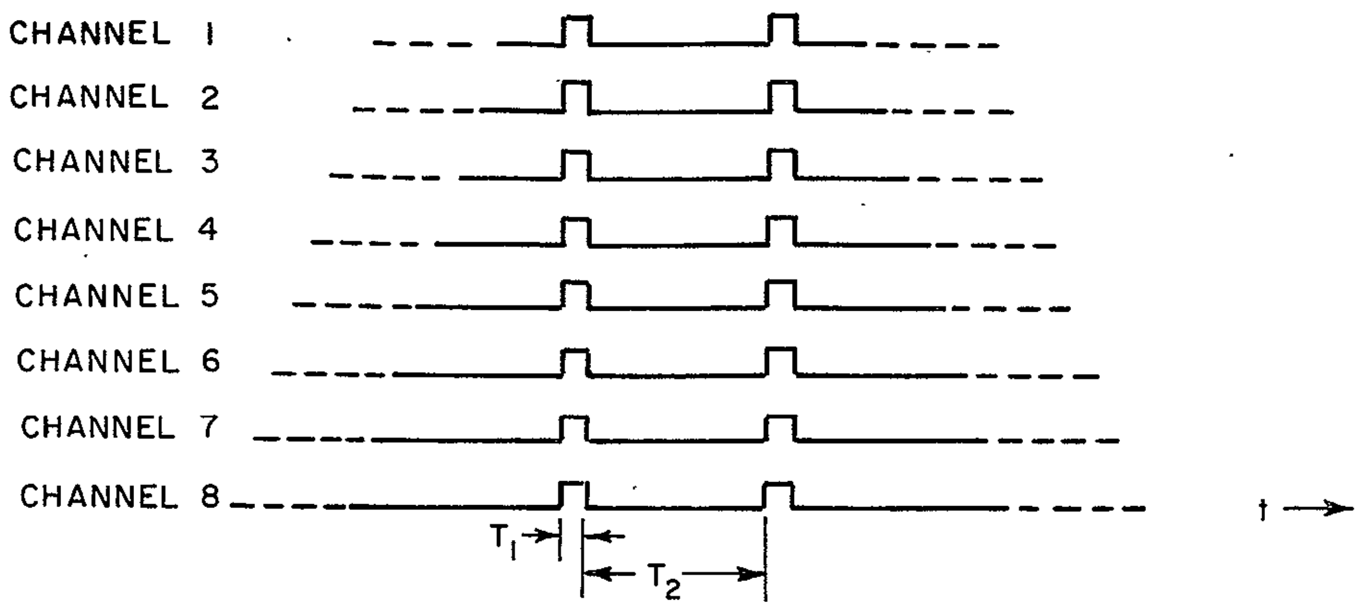


Figure 1-4. Expected Relative Position of Channels

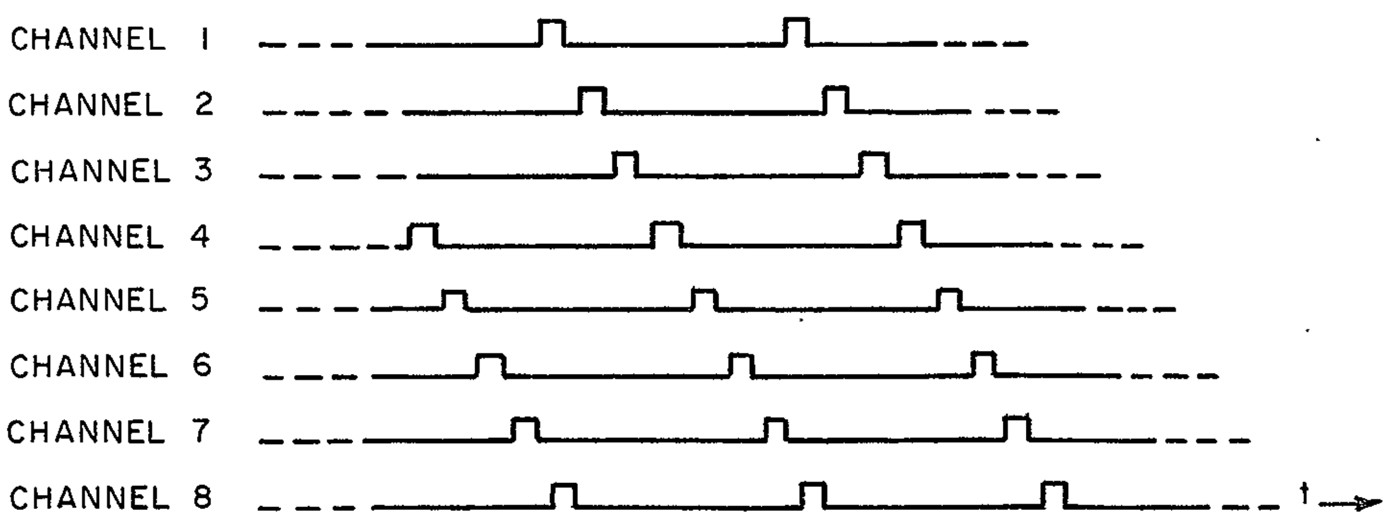


Figure 1-5. Example of Extreme Skewing

1.3.2 Data Recovery Programs

The objectives of the programs to read the field data were to correct for skewing, separate the three types of data (time, temperature and pressure), store the data on disk and magnetic tape, plot the data vs. time on the strip chart recorder and perform statistical analysis on data (e.g. mean-time between dives). Except for the statistical analysis, all of the above were performed with reasonable success.

The statistical analysis was not undertaken because of lack of funds.

Three types of programs were written. The first type read the 8 channels of data from the recorder and transfered the data on the PACER's disk memory. The second type of program was used to display the data from the disk on a teletypewriter. The third type plotted the data in analog form on the strip chart recorder.

The programs to read the data from the miniature recorder were real-time, assembly language programs. Because the recorder plays back at high speed and is essentially free running, the programs could do very little processing other than read in the data. Therefore, no skewing corrections were attempted with these programs. Because of the skewing, the program sampled the tape outputs as shown in Figure 1-6. The sampling rate was such that at least two samples were taken during each data pulse. The program condensed the sampled data by performing a logical OR on groups of the samples and by writing the condensed samples into a buffer in the computer's memory (see Figure 1-7). Once the buffer was filled, the contents of the buffer were written on the disk. Because of finite time is required to write onto the disk and because the miniature recorder is free running, some samples were missed every time the buffer was filled. The time lost each time the buffer was filled was a small percentage of the total sampling time and did not significantly deteriorate the information content of the data. The lost samples were minimized by creating two buffers in the computer. Because the PACER has direct memory access, one buffer could read from the miniature recorder while the other was writing onto the disk. Another method of minimizing

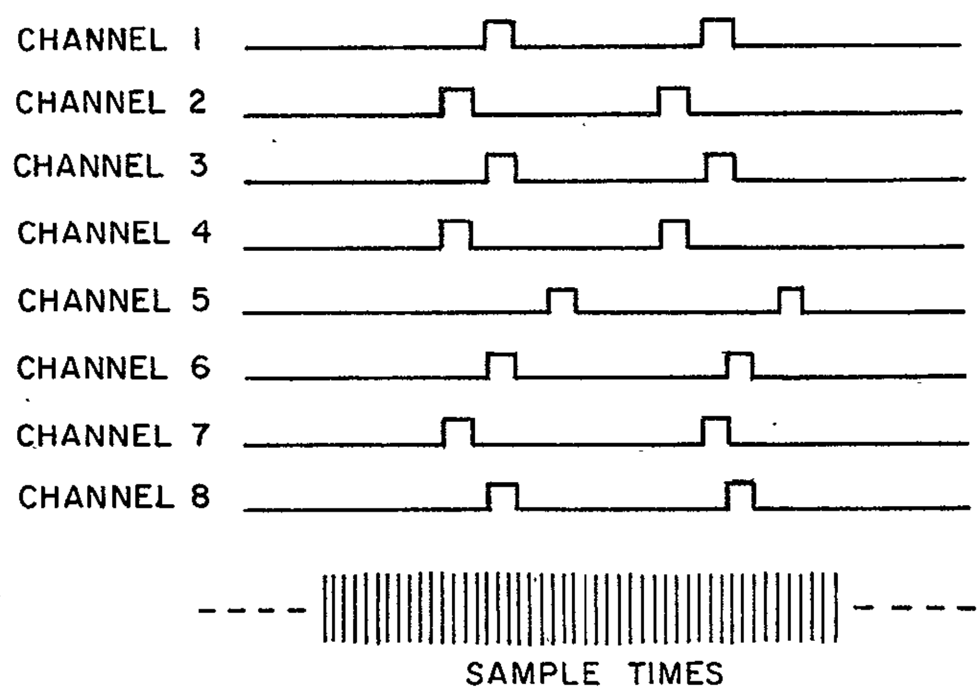
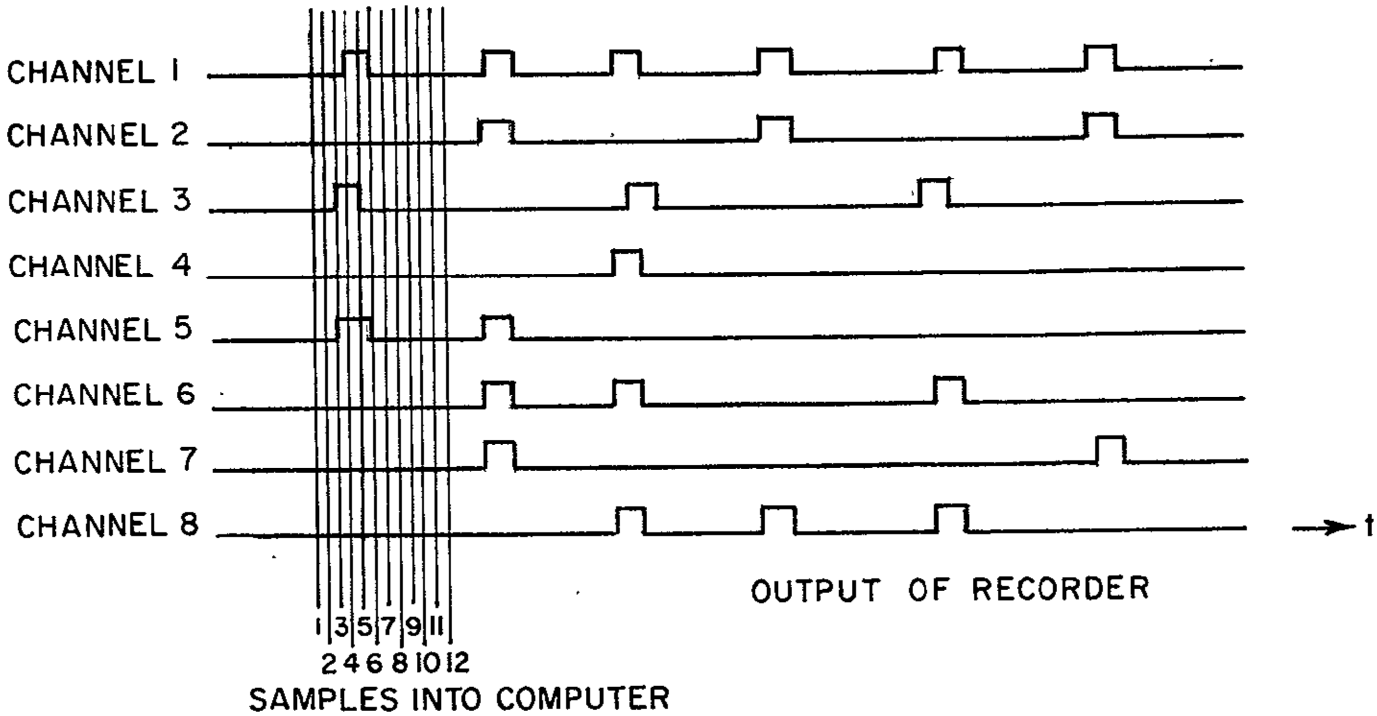


Figure 1-6. Data vs. Sampling Rate

F-C3799



SAMPLE	CHANNEL 1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0
4	0	0	1	0	1	0	0	0
5	1	0	1	0	1	0	0	0
6	1	0	0	0	1	0	0	0
7	1	0	0	0	1	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
	1	0	1	0	1	0	0	0

Samples 1–12: SAMPLES AS READ BY THE COMPUTER

Last row: CONDENSED VERSION OF SAMPLES AFTER APPLYING LOGICAL OR FUNCTION.

Figure 1-7. Condensing of Sampled Data

the importance of the lost data is to make the buffers as large as possible; this will reduce the number of data gaps. Through futher programming refinements, the data gap can be completely eliminated.

The second type of program, printed out on the teletype the whale data as stored on the disk. Through observation of these data, methods were developed to correct for skew, to condense the data and to separate the three types of data. These methods were programmed, applied to the data on the disk and the results printed on the teletype.

After many iterations of this sort, final programs were written to plot the data on a strip chart recorder. These programs applied the algorithms developed earlier in the project. The programs read the raw data from the disk, corrected the skewing, condensed the samples and, through the computers digital to analog converters, supplied the analog signals to the strip chart recorder. One channel of the strip chart recorder displayed the temperature; the other channel displayed the pressure. The program displayed the pressure as a negative value to give the visual effect of a dive.

1.3.3 Summary

The computer software described in this section represents some 15 assembly language programs to test and retrieve data from the miniature tape recorder.

The development of the software was a larger effort than anticipated. The major reason for this was the necessity to correct for recorder skewing.

The software and experience gained under this project are expected to prove valuable in future efforts. Details of the various programs developed will be found in the Appendix to this report.

1.4 PRELIMINARY ANALYSIS OF DIVING DATA

Our original plan was to obtain data on diving rhythms and behavior from two sources: (1) from the five-second records of pressure acquired by the instrument pod harnessed to the animal and (2) from data observed on shipboard of the tracking transmitter signal originating on the animal.

Only the instrument pod record from the first animal, was recovered and available for analysis. The second animal, left the lagoon before it jettisoned its harness and the instrument pod is assumed lost. The tracking transmitter, mounted on the ventral part of the harness, transmits only when the antenna (a vertical whip) breaks the water and hence the received signal is available only when the animal is essentially surfaced. From such information, crude correlations between recorded pressure data and occurrence of transmitter signal should be possible. Unfortunately, the transmitter data were lost with the collecting vessel LOUSAN.

Animal No. 1 carried the instrument pod for over four days. The patterns of diving indicated from its taped records are of three kinds. First, very frequent shallow dives of 1 - 2 feet; second, extended periods when the young animal remained within a foot (approximately the least count of the sensing system) of the surface; and third, clusters of deep dives, many nearly as deep, or as deep as the bottom of the channels in the lagoon.

1.4.1 Shallow Dives

It is surmised that these frequent and strikingly uniform depth dives by the young animal represent swimming around its mother and may also relate to nursing activity. They seem to occur at all times of the day and their average frequency is 3.91 dives/hour. They are all short in duration, ranging from 5 to 55 seconds and with an average duration of 16 seconds. Nevertheless, there is a fluctuation in occurrence frequency noted with the periods of greatest frequency centered at early morning and mid-afternoon. Figure 1-8 illustrates this frequency distribution versus the 24-hour day.

From visual observations of mother - young pairs in the calving lagoons it was not common to identify behavior that is clearly nursing. Often, the young animal can be seen diving near its mother and sometimes is seen diving under her body. We can only guess that nursing may be occurring at these times. However, because of the rapid growth rate evidenced by the young whales, it is clear that considerable effective

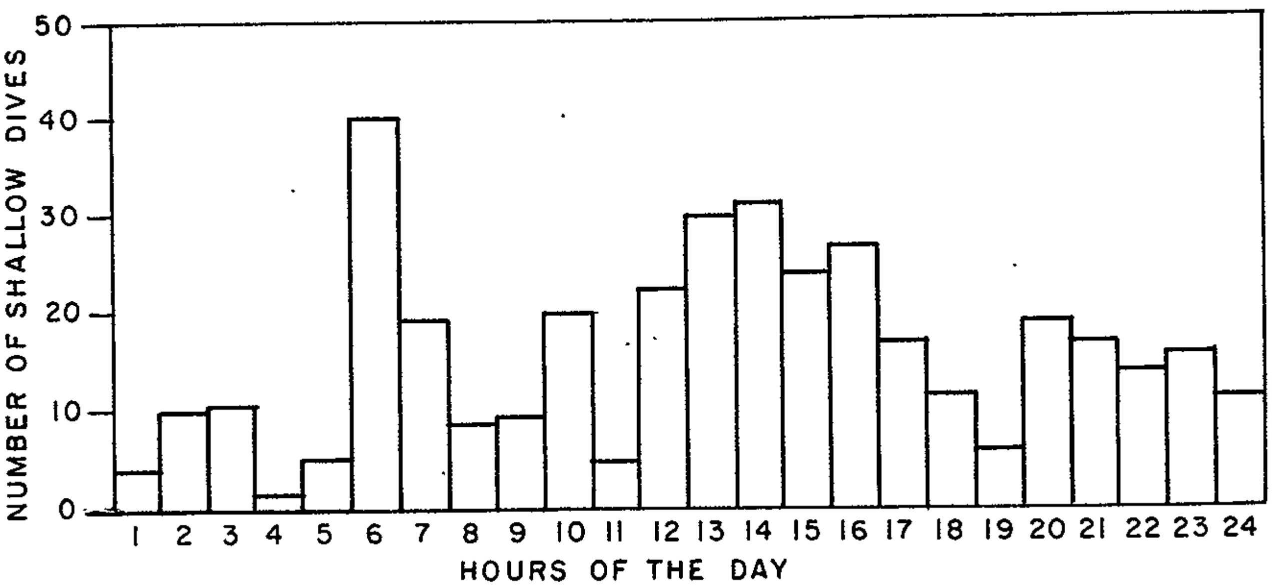


Figure 1-8. Shallow Dives

nursing is occurring - and very likely during these dives around the mother. These observations provide some confidence that some of the recorded short dives, in the range indicated, represent nursing.

1.4.2 "Surface" Periods

The record recovered from the data pack carried by animal No. 1 contains many extended periods during which the dorsal surface of the young animal was within a foot of the water surface - showing up as data "zero" or "no dive". These periods are scattered throughout both day and night where the indications are that the animal stayed at or very close to the water surface. Simultaneously we note that the temperature record indicates no sharp changes such as those which might be anticipated were the data pack and its temperature transducer free of the water and subject to evaporative cooling. Since equipment analysis indicates no obvious malfunction, we can only assume that the animal swam in the surface layer during these periods.

While our visual observations of whale pairs indicate the young animals to be at the surface around the mother frequently, it is our impression that such behavior (where the dorsal area has actually broken the water surface) is generally of fairly short durations. Also, even though radio transmission records were lost, it is our impression that transmissions were always intermittent and never constant for more than a minute or two. One may deduce then, that the young animal typically submerges its dorsal surface with this frequency. It follows then, that only if the excursions between actual surfacings are spent in very shallow submergences can our two sets of observations be reconciled.

Figure 1-9 illustrates the occurrence and duration of these "surface" periods.

1.4.3 Deep Dives

Deep dives apparently occurred in bouts during each of which several dives generally would be taken. These often reached bottom, or near bottom. The deepest of these correspond closely to the depths shown on

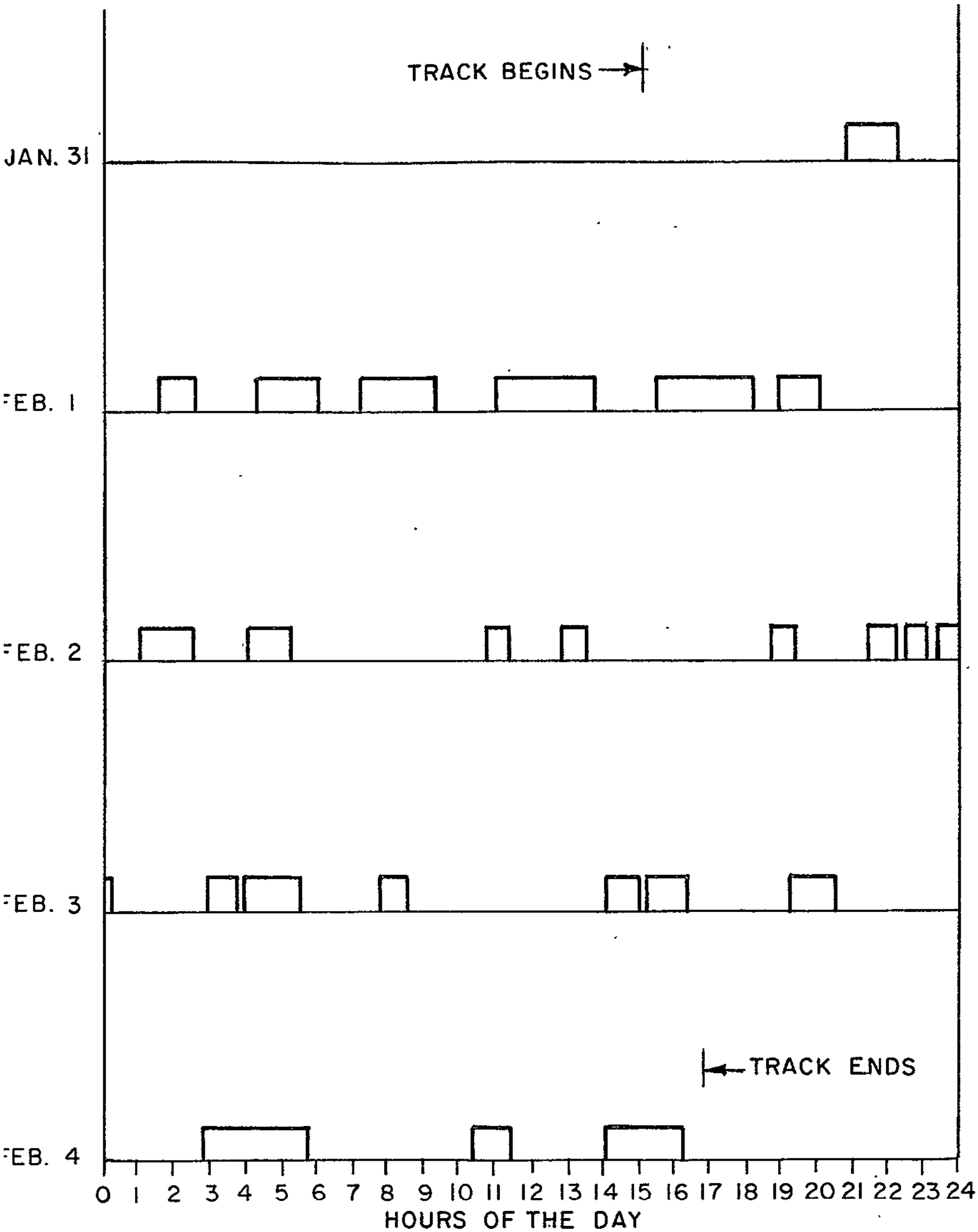


Figure 1-9. Surface Periods Over 45 Minutes

our navigational charts for the area. Further, since the recorded dives do not exceed these chart depths, we have additional confidence in the validity of the recorded data. A histogram of dive depths is presented in Figure 1-10.

Dives ranged in duration from 15 seconds to $2^m\ 35^s$ and bouts of several dives range from 15^m to $6^h\ 5^m$. The dives appear only slightly related to time of day, being somewhat more frequent in the early morning, late afternoon and near midnight than at other times. The lowest frequency of occurrence is at 0400 hours. Figure 1-11 illustrates dive frequency versus time of day.

Diving bouts also show little correlation to time of day. However, there is more activity in the morning and around midnight than at other times, correlating somewhat with dive frequency. The diving bouts are given in Figure 1-12.

Other information available to us suggests that during migratory swimming, Gray Whales often dive near the bottom, even at sea. Some observers suggest that this behavior may be related to the acquisition of navigational cues in terms of depth and bottom features.

1.5 THIGMOTACTIC BEHAVIOR

A striking characteristic of mother-young behavior was the amount of bodily contact between the two. The young animal was usually in physical contact with the mother, both when the pair was swimming slowly, or when resting. Often when the mother surfaced to breathe, the baby would be observed draped across her rising body. This contact occurred along the full length of the mother's body from tail to head and the young animal appeared to be relatively limp as it was being supported. During the pursuit phase of capture, this thigmotactic behavior increased in intensity.

Two additional examples of this apprent predilection for physical contact by the young animal were observed. In one instance a stranded young animal made contact with the collecting vessel. For perhaps a half

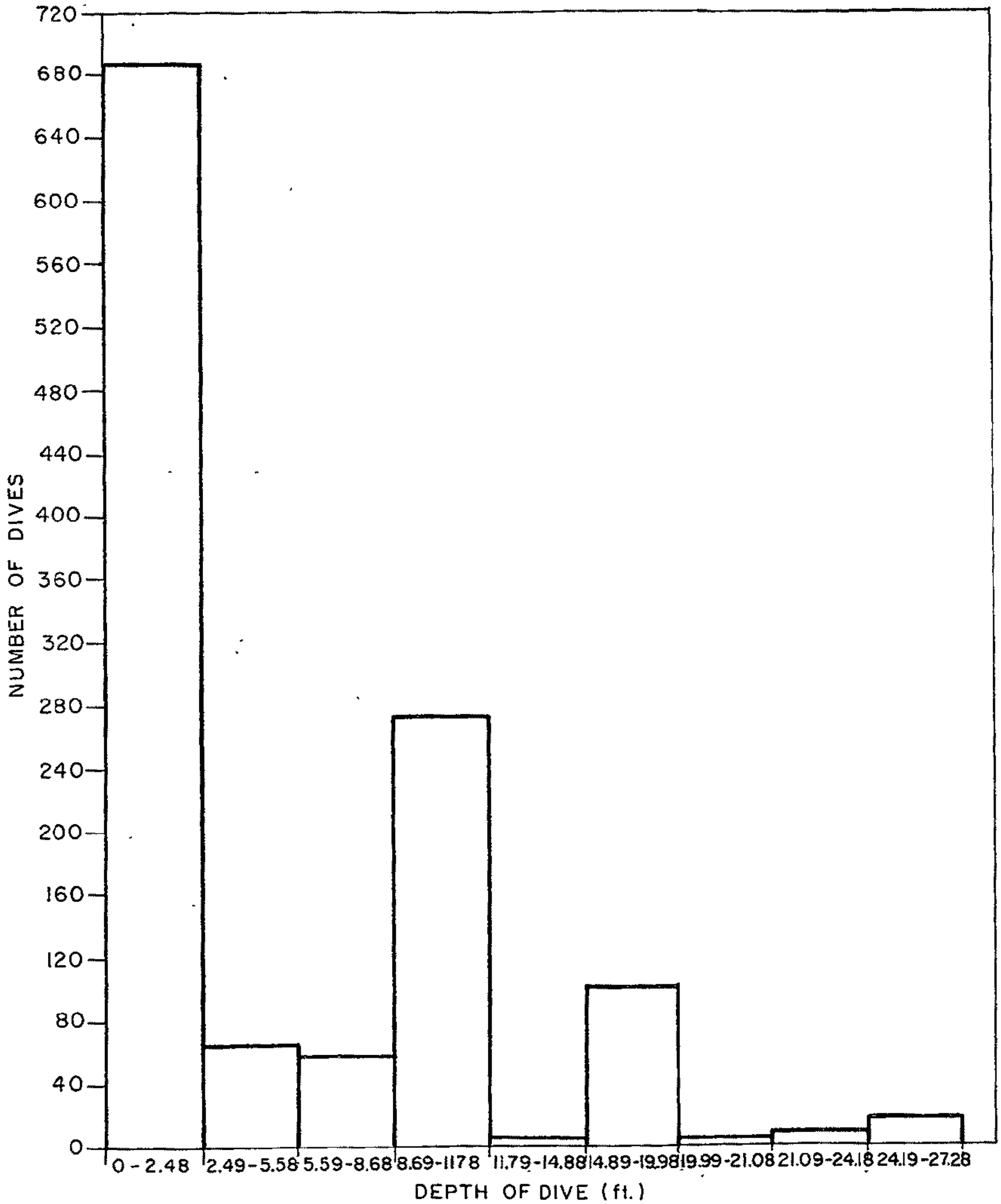


Figure 1-10. Number of Dives vs. Depth

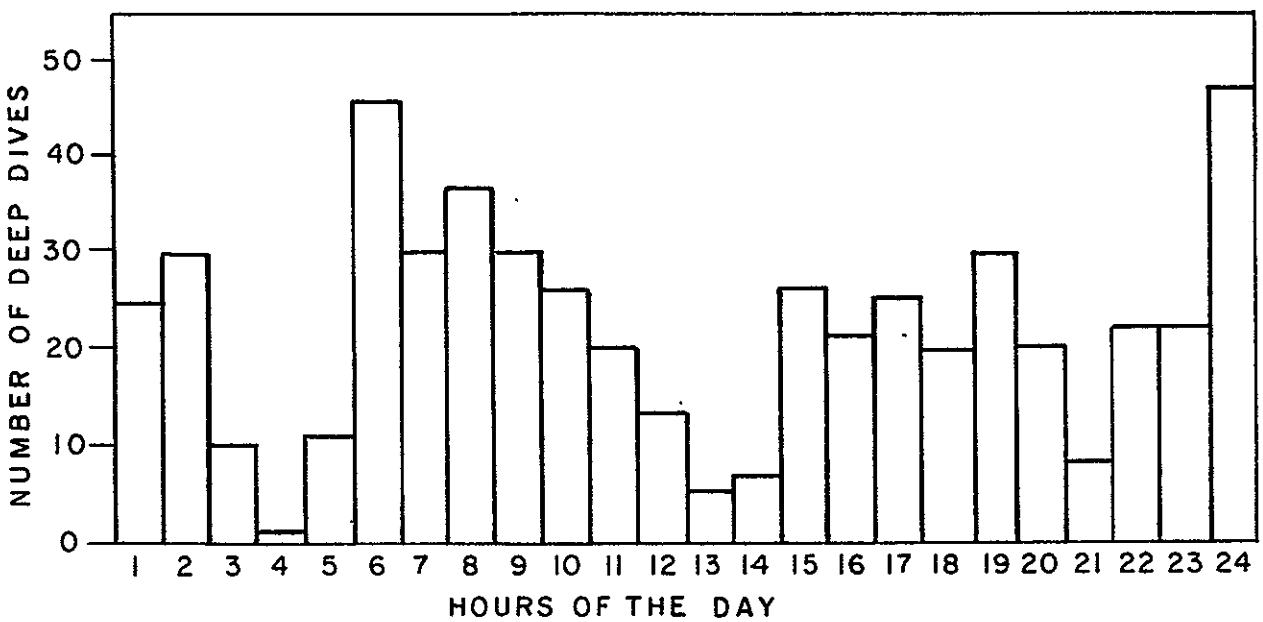
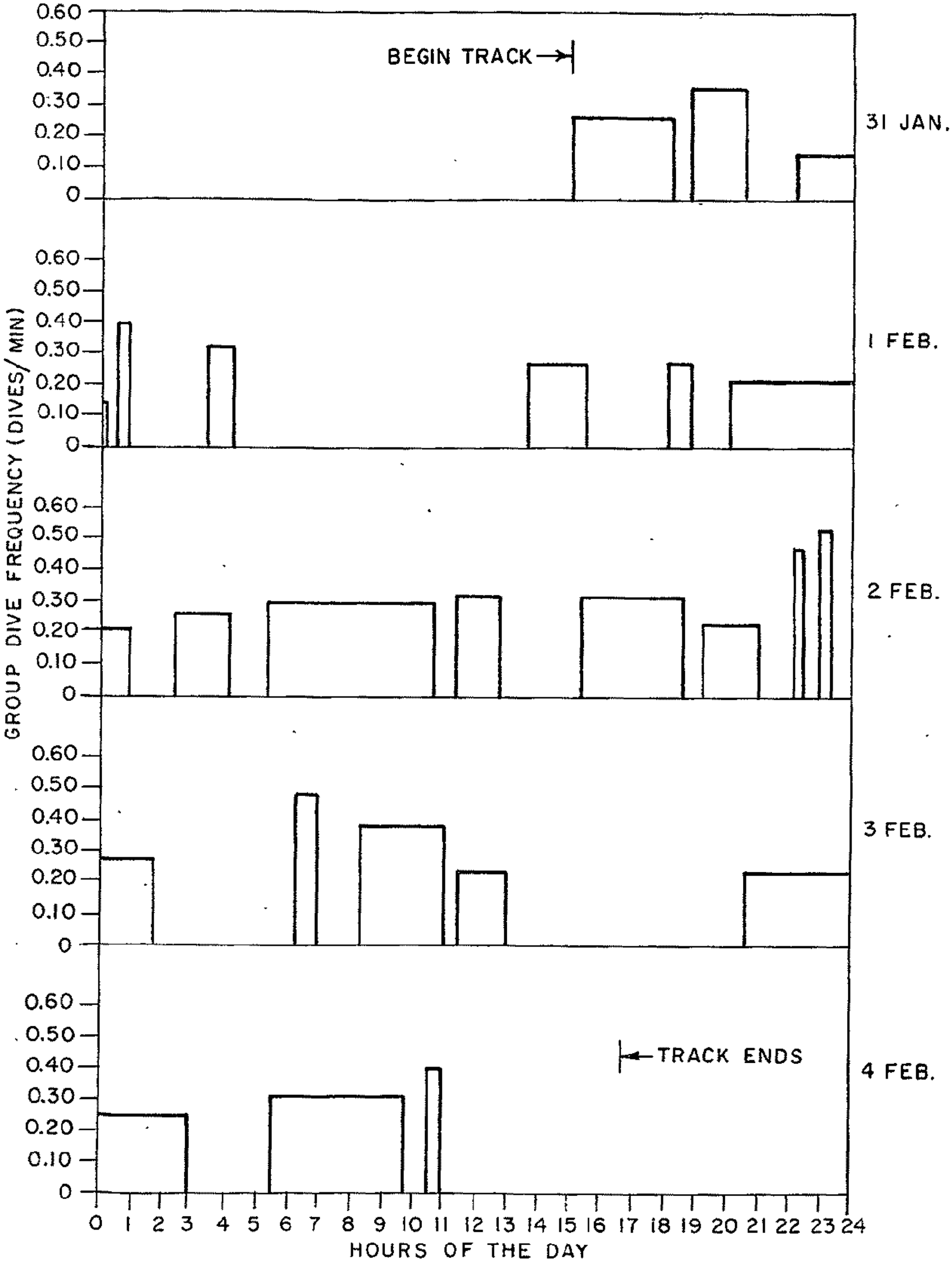


Figure 1-11. Deep Dives


BEGIN TRACK
31 JAN.
1 FEB.
2 FEB.
3 FEB.
4 FEB.
TRACK ENDS
GROUP DIVE FREQUENCY (DIVES/MIN)
0
0.10
0.20
0.30
0.40
0.50
0.60
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
HOURS OF THE DAY

hour it rubbed against the vessel, especially at the stern and amidships adjacent to the overboard discharge of engine cooling water. Attempts were made to move the animal away from the ship by pushing it gently and by making loud noises in the nearby water. Only after the most skillful maneuverings of the vessel by the skipper were we able to free ourselves of the young animal. One of our concerns about this animal being close to the ship involved the danger of it being wounded or killed by the screws. In cases of pursuit of mother-young pairs, the mother often lifted the young animal from the water with her back or tail. In one case, a 14-15 foot young animal was actually thrown completely free of the water by the adult; such lifting behavior was noted particularly during collection.

Young animals lost or for some unknown reason stranded from the mothers, and apparently healthy, were observed at the beach in contact with the bottom. All attempts by us to steer the young into deeper water, where it could swim easily, proved futile. We suspect that again we were observing a thigmotactic need as the young animal pressed its body against the bottom in the shallow water.

1.6 WATER TEMPERATURE DATA

The temperature data, as recorded in the instrument pod recovered from animal No. 1 showed little in the way of variation. Temperatures appeared to range between 17.0°F and 17.7°C with the lower figure correlating with dives.

These data correspond well with water temperatures in the lagoon because the water is well mixed by the very strong tidal currents. The temperature distribution is almost uniform from the surface to the bottom.

We noted earlier that the temperature records do not show evaporative cooling occurring - which one might have expected when the animal broke the water surface. On analysis, we realize that the thermal sensor is shielded from above by the thick layer of the syntactic-foam float; it would be almost impossible for the sunlight to reach it and evaporative cooling would, in any case, have considerable lag. In the underwater situation however, the sensor was in constant contact with the water streaming by.

2. THE EXPENDABLE TRANSMITTER STUDY

2.1 SYSTEM DESCRIPTION

For the purposes of this initial effort, the system is directed toward the use of the Nimbus-F satellite which is equipped with a random access measurement system.

The problem of tracking (in the case at hand, of obtaining ficuciary fixes) an animal which is submerged most of the time has been solved by virtue of a sequence of releasable buoy packages, each being a RAMS-compatible transmitter. Periodically, at times predetermined by a clock internal to the instrument package, one of the buoys is to be released. It is electronically activated after it reaches the water surface. The transmitter for this package has been bread-boarded by AII Systems

To bring the requirements for the transmitter package into focus, we must first examine the nature of the Nimbus-F satellite and its inherent measurement and communications capability. The satellite is in near polar orbit at an inclination of 100° and its orbit is approximately circular at an altitute of 965 km. Visibility to any ground transmitter, from the satellite, is restricted to a range of roughly 2100 miles (3379 km). The time duration of an orbit is 108^m. The satellite receives signals from transmitters within its visibility region as it orbits the Earth. Signals transmitted to it are acquired by an internal Doppler measurement system and the frequency characteristics of the transmitting unit are derived and recorded together with received data also transmitted from the ground. Figure 2-1 illustrates the configuration of the Nimbus-F system. The satellite eventually passes over a ground station to which Doppler and other data, previously recorded, is transmitted.

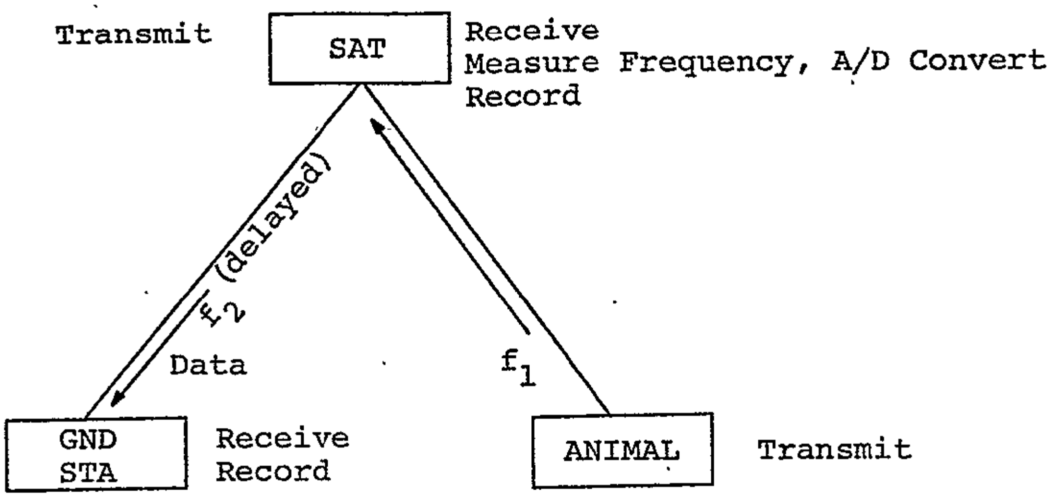


Figure 2-1. NIMBUS F Satellite System

2.2 RAMS CHARACTERISTICS

The RAMS system is a Doppler measurement system which operates at a carrier frequency of 401.2 MHz. The design of the animal platform for operation with that system consists of a data buffer, oscillator, modulator, transmitter and antenna as well as the battery pack to power the package. Compatibility with the RAMS system requires that the animal platform transmit for one second of each minute during a satellite overpass.

A comparison of the bread-board developed, with the Random Access Measurement System as presented in Table 2-1.

2.3 OVERALL BLOCK DIAGRAM

The bread-board unit block diagram is shown in Figure 2-2. The signal path consists of a crystal oscillator which is amplified and multiplied to a frequency of 416* MHz. The signal is then applied to a modulator which feeds the final power amplifier, delivering two watts. Control logic, which operates from a 1 KHz clock, controls both B+ switching to conserve power and provides data modulation to the modulator in the signal path. The B+ switching conserves power when the expendable unit is not operating.

*Authorized by FIRL for this study only

Table 2-1. RAMS and Breadboard Specifications

	RAMS	BREADBOARD
Carrier Frequency	401.2 MHz	416.0 MHz*
Power Output	2W	2W
Antenna Gain	0 dB	N/A
Polarization	Linear	N/A
Osc. Stability	$1x10^{-8}$ in 15 min. $.5x10^{-6}$ in a year	$1.9x10^{-8}$ in 15 min. $.5x10^{-6}$ in a year
Modulation	PSK, 60° phase shift	PSK, 60° phase shift
On Time	1 sec	1 sec
Duty Cycle Interval	60 secs	60 secs
Preliminary Demodulated Interval	.36 secs	.36 secs
Bit α Frame Sync Words	Two 8 bits each	Two 8 bits each
Mode ID	2 bits	2 bits
Platform ID	14 bits	14 bits
Information Words	Four 8 bits each	One 8 bits*
Total Bits	64	40
Bit Rate	100 bps	100 bps
Volume	N/A	25.3 cu. in.
Weight	N/A	10 oz. (circuitry)
Power Consumption	N/A	168 mw. avg.

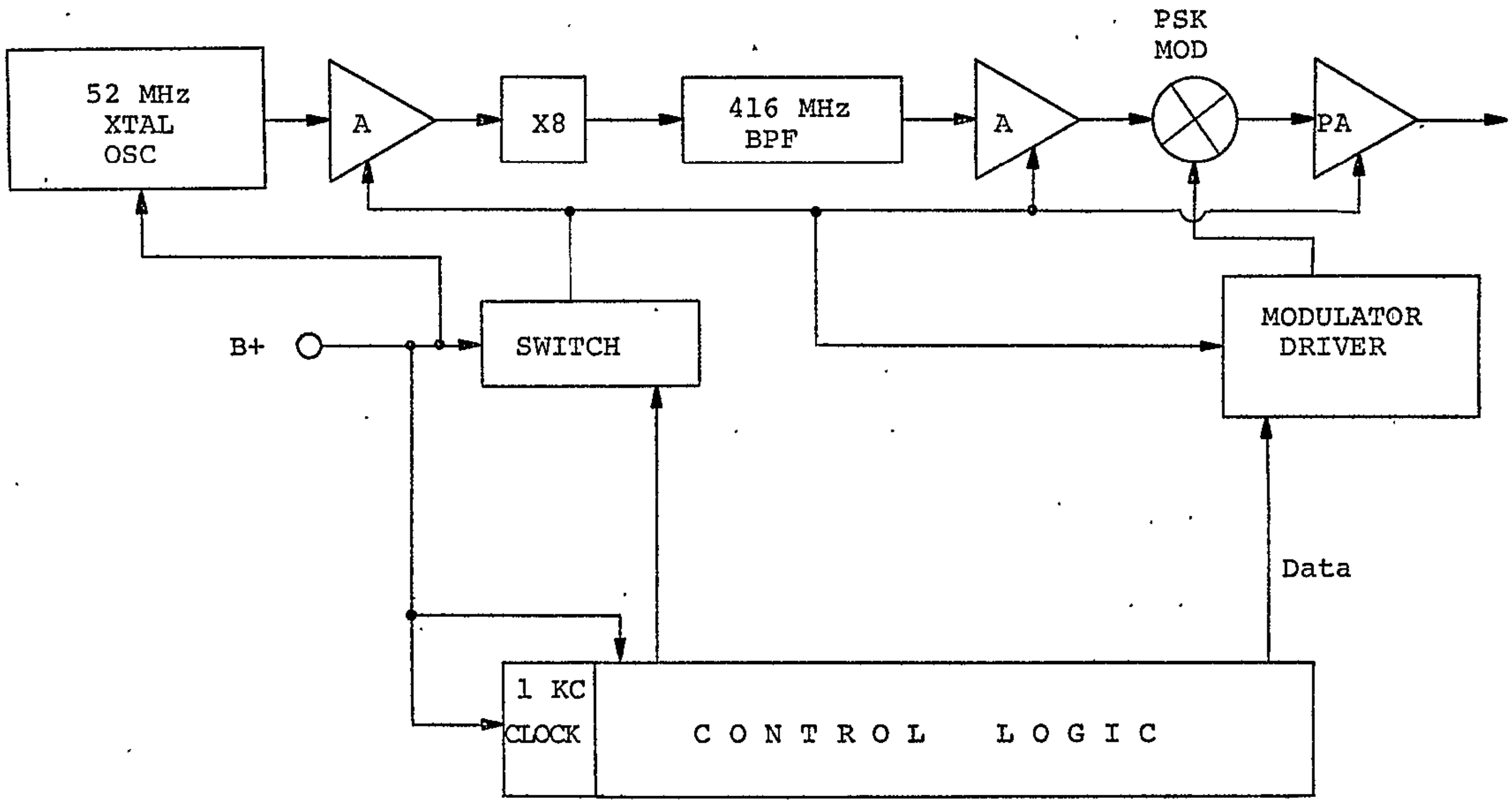


Figure 2-2. Whale Tracker Overall Block Diagram

F-C3799

Individual units in the block diagram are discussed in subsequent sections regarding their electrical, mechanical and physical specifications.

2.4 THE CRYSTAL OSCILLATOR

This is a 52 MHz unit utilizing a 2N2857 transistor in the common-base configuration. The base, however, is not directly grounded nor normally bypassed. The crystal, a series-resonant type, is placed in the base to provide grounding at the crystal frequency; at other frequencies, the base is essentially open-circuited. External feedback is provided around the 2N2857 to ensure start-up conditions and stable oscillation. The schematic of the crystal oscillator appears in Figure 2-3. This unit provides about +3 Dbm of output power at 52 MHz.

The 52 MHz crystal was used in our breadboard only because it was readily available and delivery on an optimum (for our purposes) 200.6 MHz unit was prohibitive.

2.4.1 Oscillator Performance Evaluation

Frequency versus temperature characteristics of the crystal oscillator were measured and appear in Figure 2-4. These temperature runs the oscillator was turned on at an assumed sea water temperature of 1.7°C. The unit was allowed to stabilize at that temperature and the ambient was then raised to 12.8°C. Stabilization was again permitted and the ambient was returned to 1.7°C. As the figure illustrates, the maximum denation was 36 parts in 10^8 for a 11.1°C change in ambient. This results in 1.8 parts per degree Fahrenheit, or a 7 1/2 Hz change per degree F. The data shown in Figure 2-5 is a reproduction of the recording chart showing frequency versus time for the varying temperature ambient. It also shows the oscillator drift for constant temperature. In this latter case, the drift was less than 10 Hz or 2 1/2 parts in 10^8 over a 20 minute time span.

A more effective approach, from both the electrical performance and physical size viewpoints, is shown in Figure 2-6.

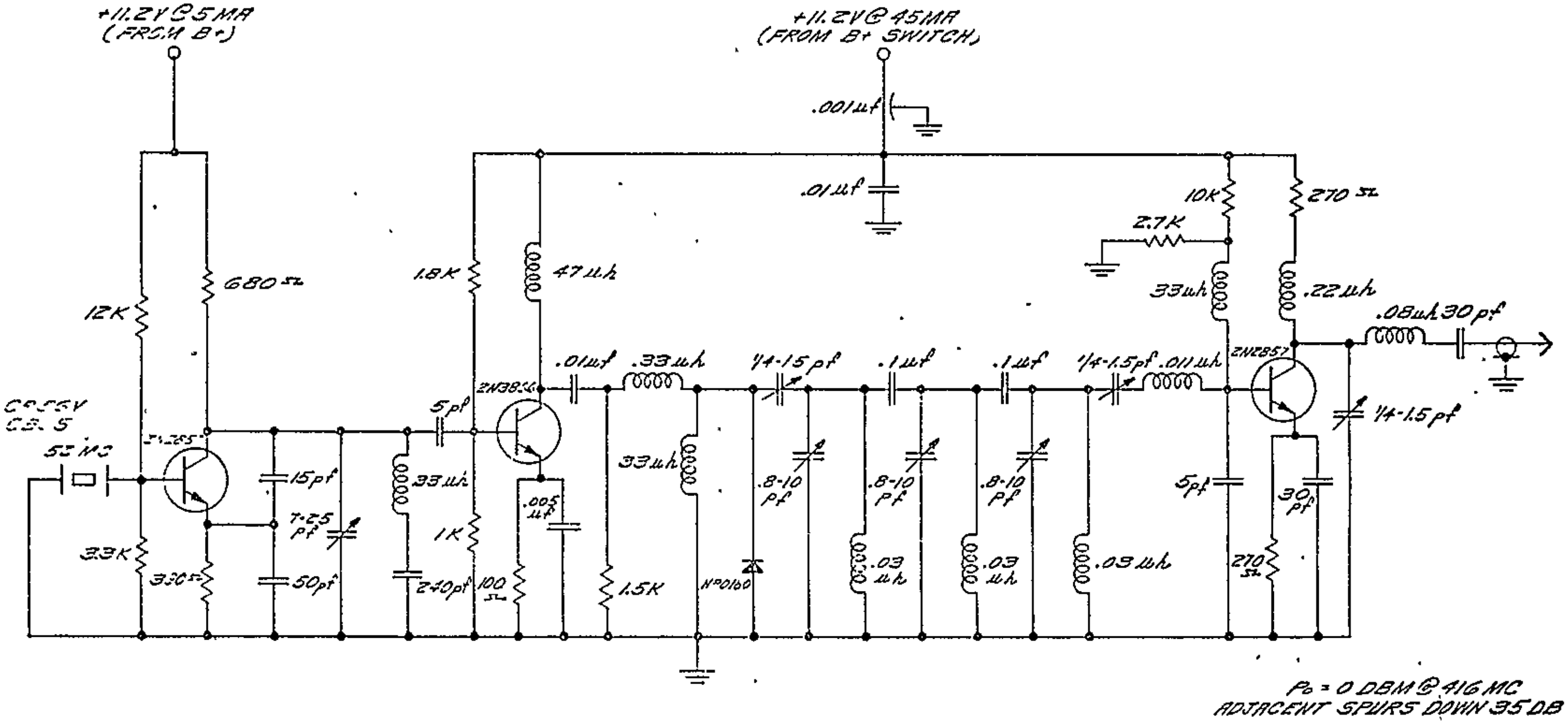


Figure 2-3. 416 MHz Crystal Controlled Source

F-C3799

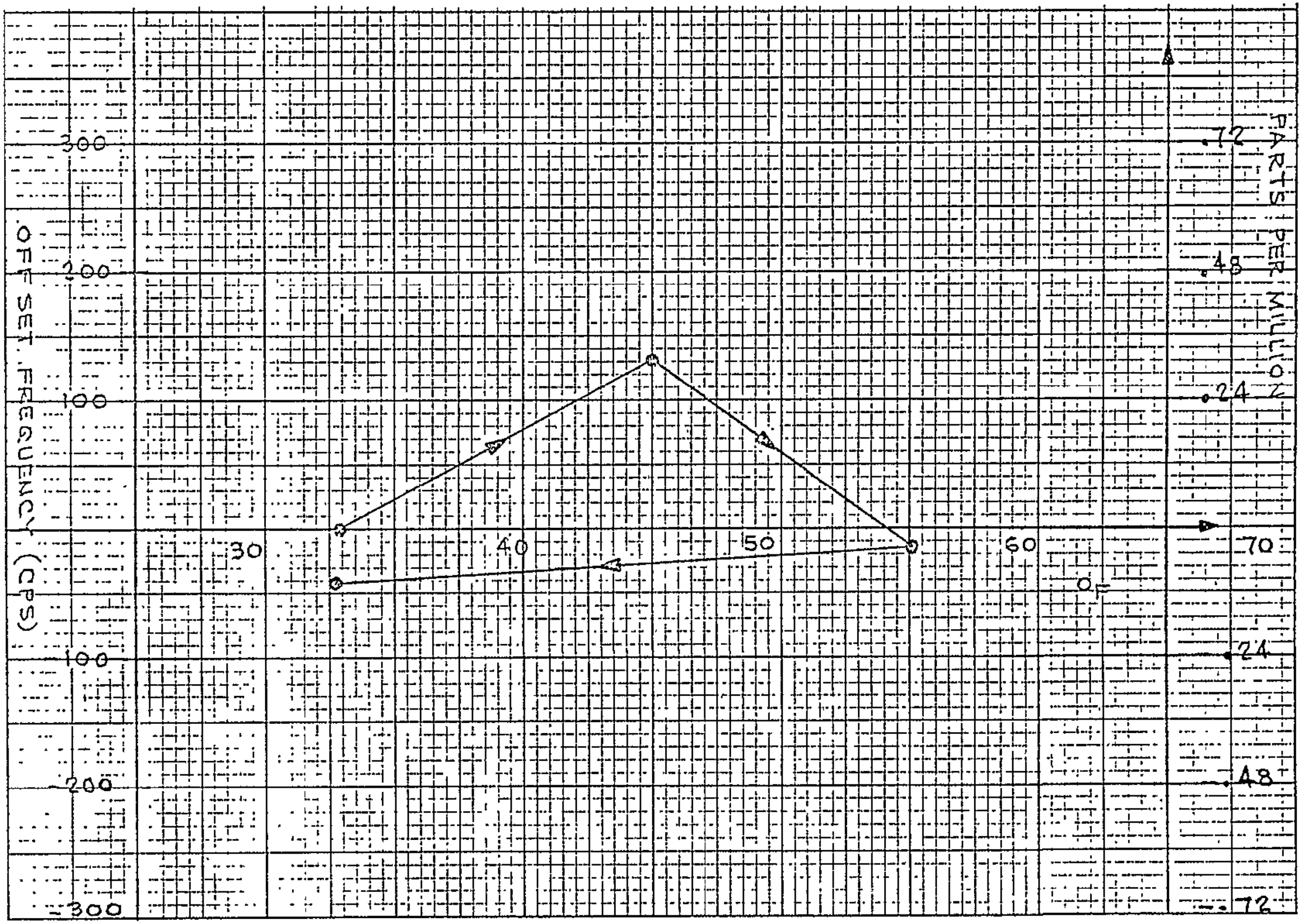


Figure 2-4. Transmitter Frequency Drift vs. Temperature

F-C3799

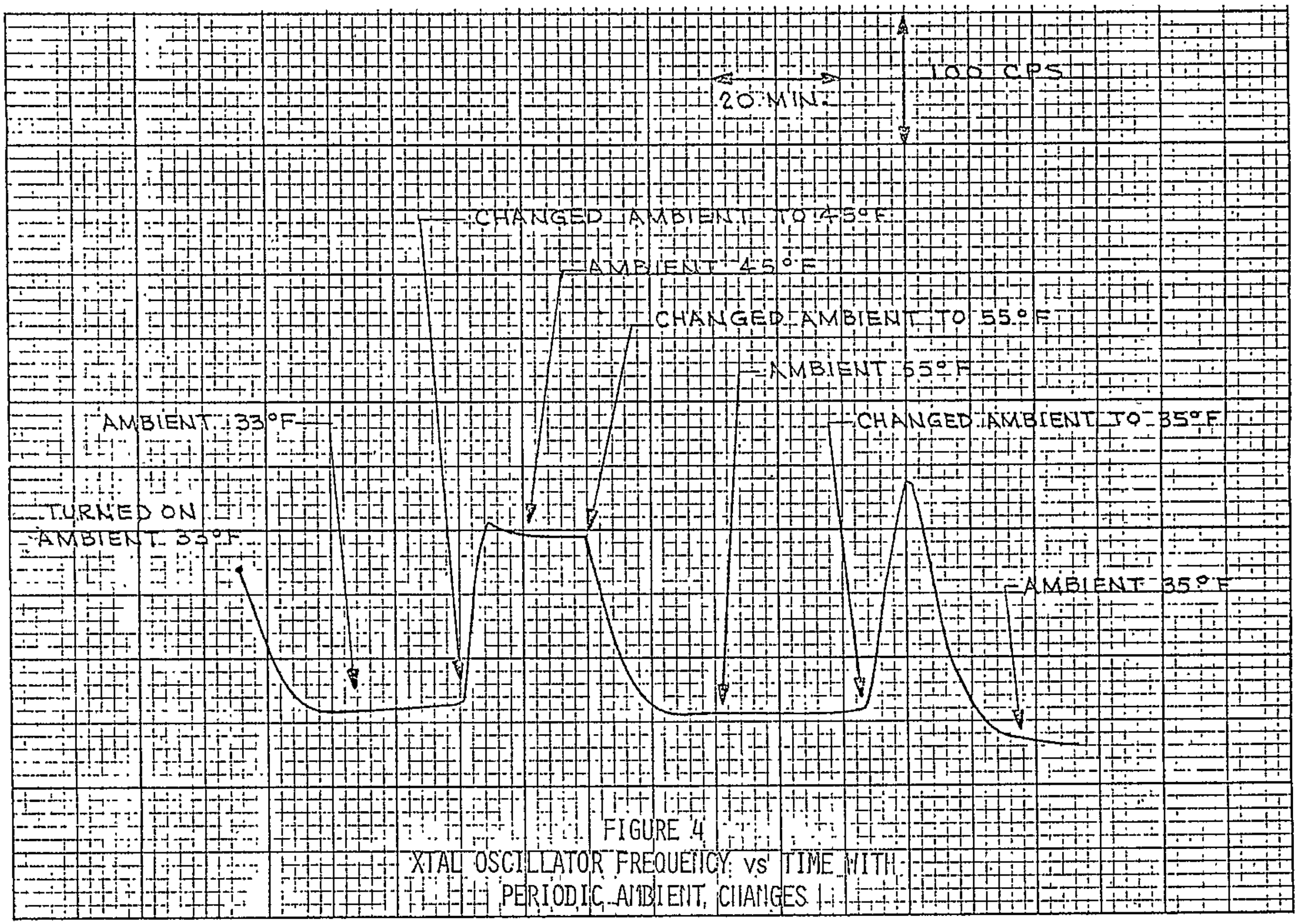


Figure 2-5. Transmitter Oscillator Frequency vs. Time with Periodic Ambient Changes

F-C3799

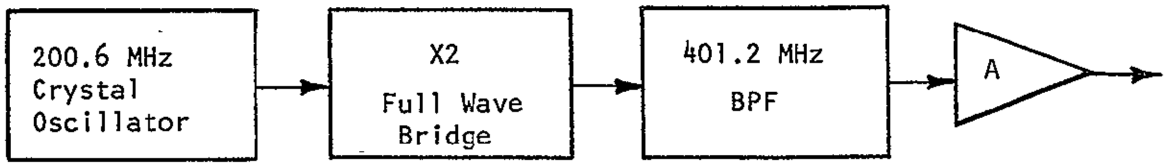


Figure 2-6.

In this scheme, the 200.6 MHz crystal oscillator necessitates a 9th or 11th overtone crystal. These crystals are inherently more stable than lower overtone units by roughly the ratio of the square of the overtone $(m_1/m_2)^2 > 3$.

The doubler is a full-wave bridge-type which gives rise to even harmonics and inherently rejects the odd harmonics. This minimizes the filtering requirement. Thus with the proper crystal used as stated, the circuitry is simpler and the stability performance substantially improved.

2.5 MULTIPLIER AND FILTER

The multiplier and filter are shown schematically in Figure 2-3. The buffer amplifier receives its input from the 52 MHz crystal oscillator. It provides about +15 dBm of power at 52 MHz. The X8 multiplier is a step-recovery diode type (utilizing a Hewlett Packard type 0180 diode). It is followed by a three-section bandpass filter and a 416 MHz amplifier. The step-recovery diode multiplies the input frequency to 416 MHz with a conversion loss of approximately 19 dB. The bandpass filter selects the eighth harmonic at 416 MHz. Its bandwidth is adjusted to be as narrow as possible while achieving appropriate power output of 0 dBm at the 416 MHz buffer amplifier. This results in adjacent spurs around the desired harmonic being rejected by 35 dB. Hence the carrier source is a 416 MHz source with spurious output down at least 35 dB, 52 MHz away from the desired carrier. The power required by the 416 MHz source line at 50 milliamperes is 500 mw.

The process of buffer amplifying, multiplying by a large order (that is, eight), bandpass filtering and further buffer amplifying consumes 0.5 W of power and requires considerable space. In the final hybrid model transmitter a 200.6 MHz crystal will be used in the oscillator. A high-efficiency, balanced type frequency doubler will be used with inherent rejection of the fundamental, third, fifth and other odd harmonics while delivering to the output, the even harmonics including the required 401.6 MHz signal. The filtering requirements will, of course, be greatly reduced resulting in considerably lower spur levels which are further removed from the carrier. As a result, the space requirement will be reduced by 50% and the power requirement by 33%.

2.6 MODULATOR

The data modulator is shown schematically in Figure 2-7. It is essentially a double-balanced mixer used to provide phase-shift keying of the CW signal. The unit employed here is an MCL-SRA-1. It introduces about a 5 dB insertion loss to the CW signal. In the final hybrid model, the insertion loss may be further reduced by applying a higher-performance mixer which may be more costly, but which will be physically smaller.

The driver directs 10 ma. of current in two different directions through the double-balanced mixer to provide phase-shift keying. The entire modulator consumes 200 mW of power (20ma. @ 10V.). The speed of the modulator is on the order of a few microseconds, considerably in excess of the data rate. Phase Shift accuracy is within 10° of $\pm 60°$.

2.7 POWER AMPLIFIER

This element is depicted schematically in Figure 2-8. Its input is received from the data modulator at a level between 0 and -2 dBm. The first stage is an HP type 26E transistor which brings the level to +12 dBm. The next two stages consist of type 2N3866 transistors bringing the level to +20 to +21 dBm. They are operated in Class-C mode. Their output at 100 mW, is fed to a CTC C2-8Z transistor which outputs between 0.5 and 1.0 watt. This then drives a 2N5646 producing the desired 2 watt final

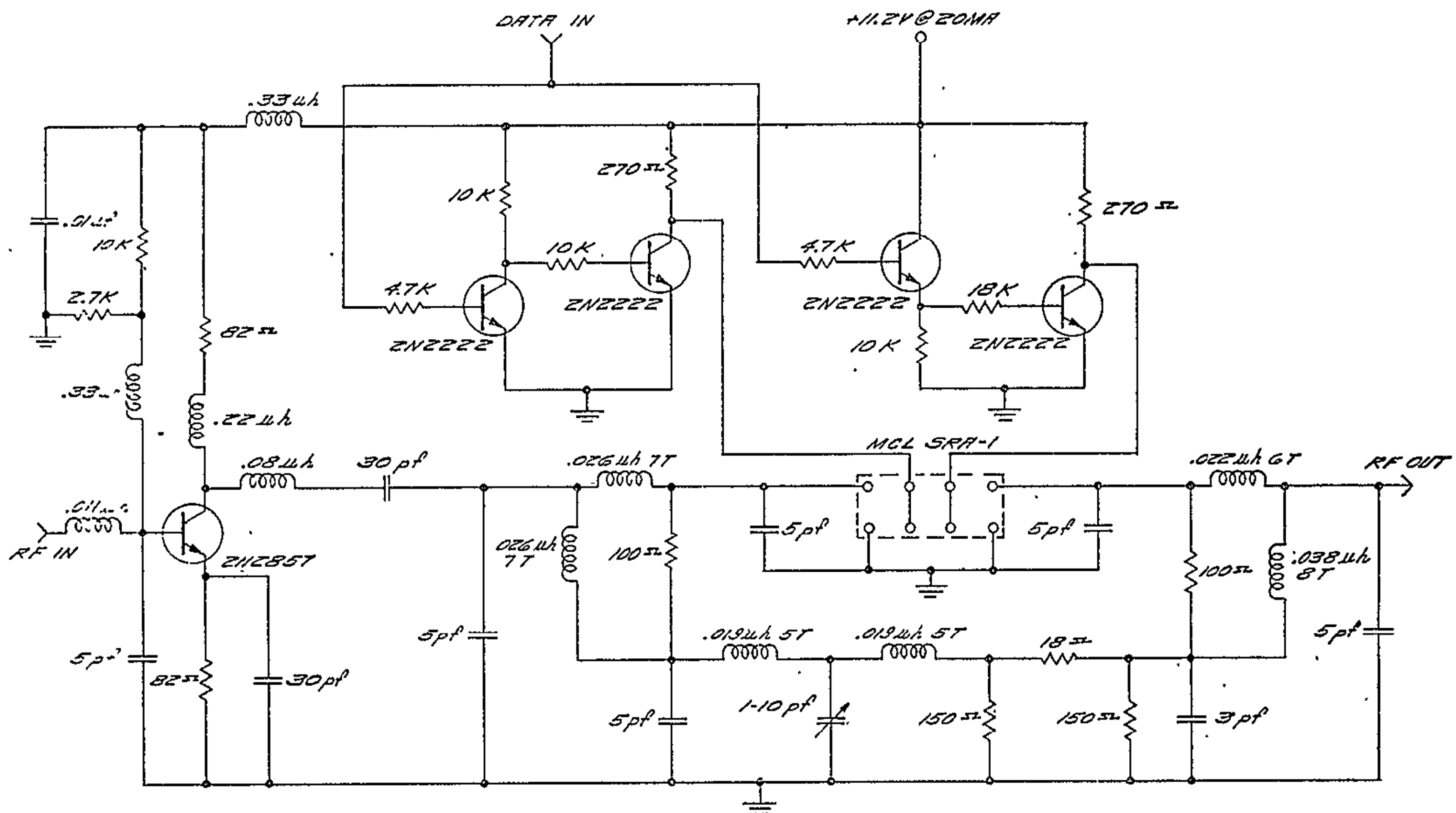


Figure 2-7. Data Modulator (± 60° PSK)

F-C3799

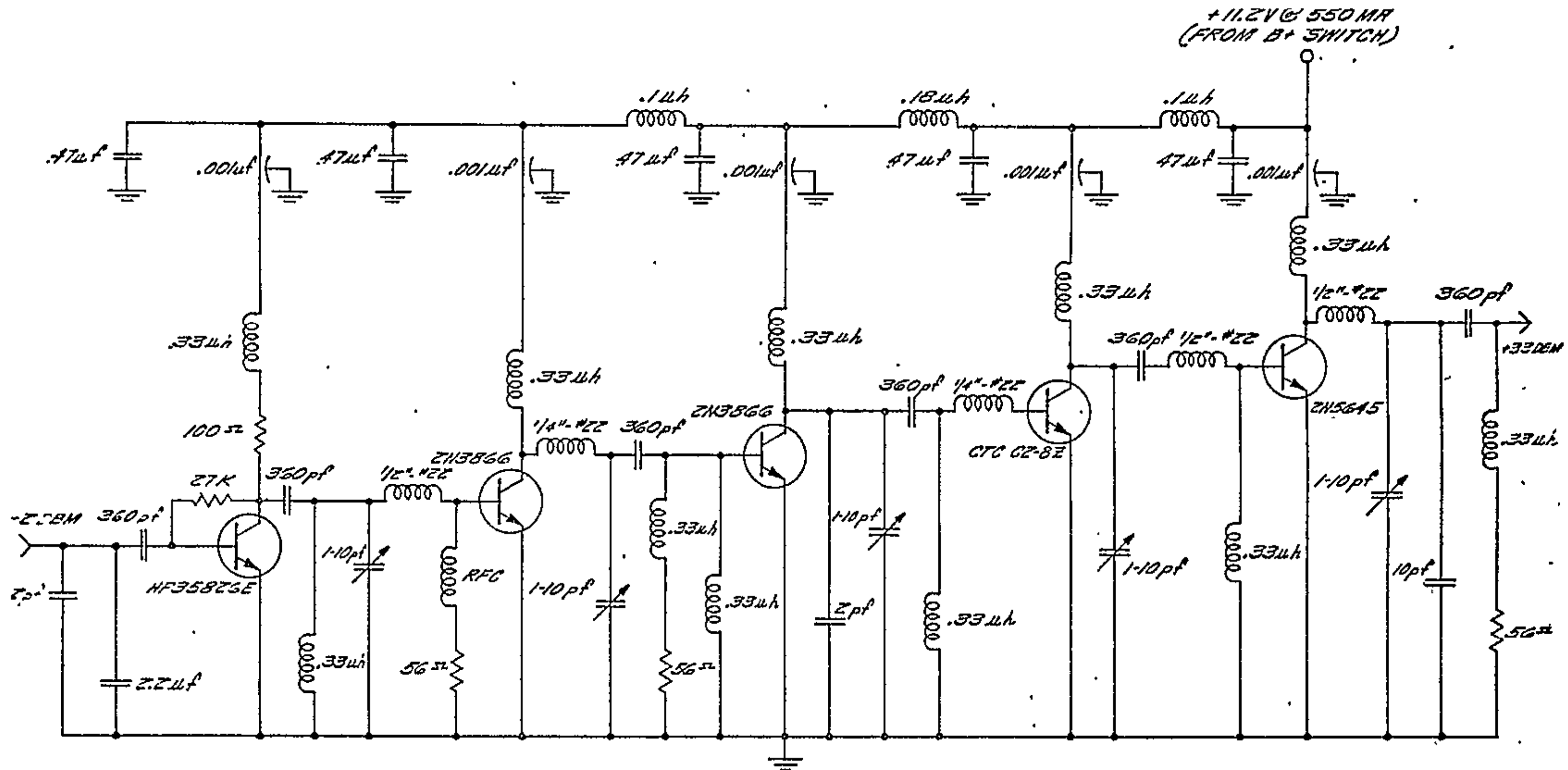


Figure 2-8. 416 MHz 2-Watt Power Amplifier

F-C3799

output. A total of 6160 mW is fed to the power amplifier. Its efficiency is 33%. The output stage itself runs at an efficiency of 60%.

It is anticipated that when the optimized crystal oscillator (200.6 MHz) is incorporated into the final, hybrid model transmitter that the drive to power amplifier will be increased and less amplification in that module will be required. This is expected to reduce the power amplifier power requirement by at least 15%.

2.8 CONTROL AND DATA LOGIC

The data transmission circuit consists of an oscillator, a 40-bit shift register, control logic and PSK code generation. The circuit was designed exclusively with C-MOS devices to minimize power consumption and to provide high reliability.

The circuit transmits data for one second of each 60 seconds. During the transmission period a "window" signal is provided to turn on the r.f. transmitter. At the completion of the one-second transmission the transmitter is turned off. The transmitter circuit is self-starting.

The data transmitted consists of the bit sync., the frame sync., the unit identity; data words are programmable externally by placing proper voltage on the inputs. These data are all converted to PSK code prior to modulation. This type of transmission code was selected because it produces minimum bit errors. The circuit was implemented with 14 C-MOS IC's. Analysis indicates that when we move on to hybrid circuits, we will reduce the number of IC's to two.

The schematic of the control and data logic is shown in Figure 2-9. The schematic for the B+ switch is shown in Figure 2-10. This switch drives everything in the regional path except the 52 MHz oscillator. This is done to eliminate warm-up frequency shifts in the oscillator while conserving as much battery power as possible.

2.9 SIZE, WEIGHT, POWER AND FREQUENCY CONSIDERATIONS

As mentioned above, the use of a 52 MHz crystal introduced severe penalties in weight, power and volume requirements. Use of the proper

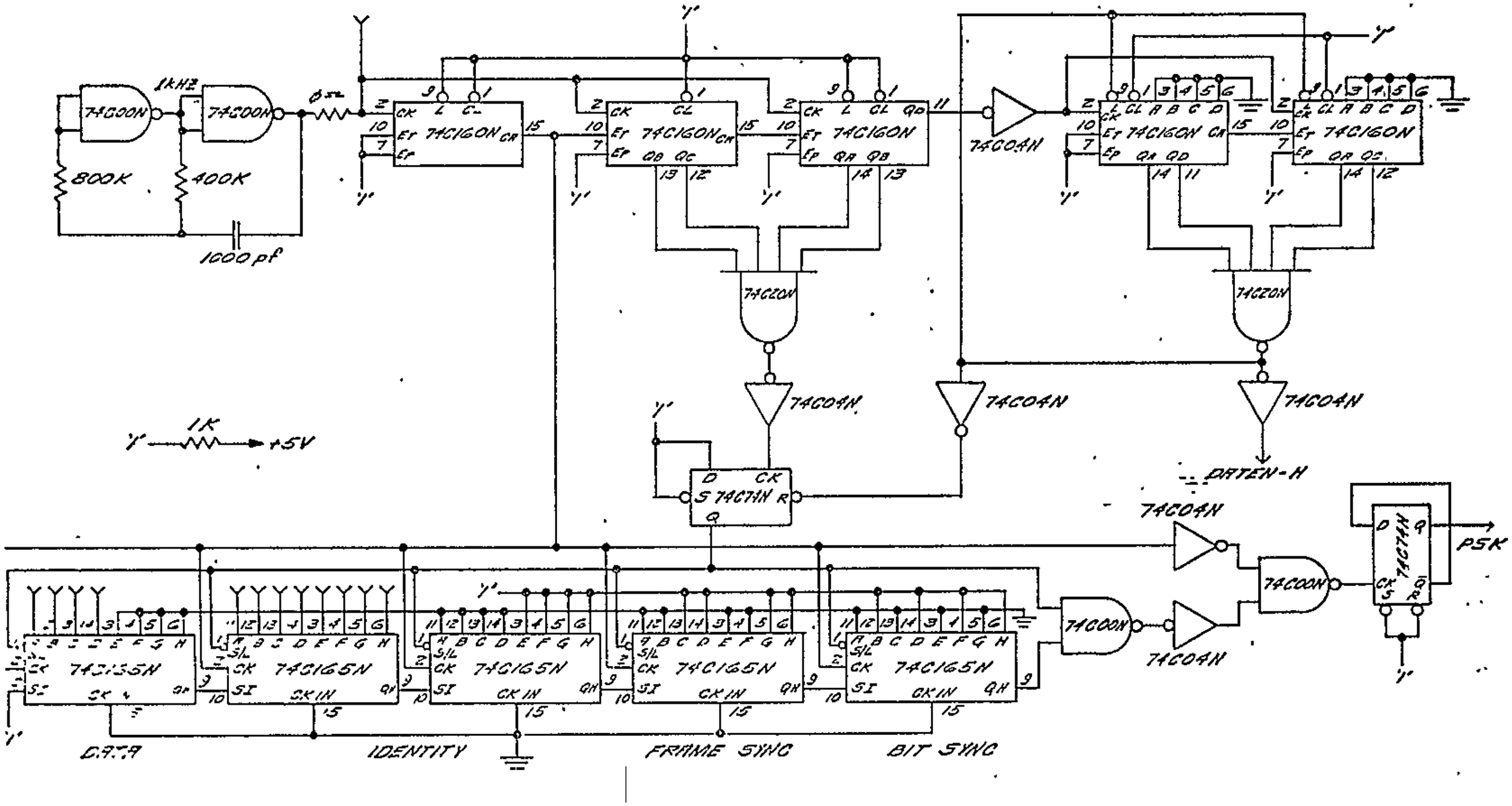
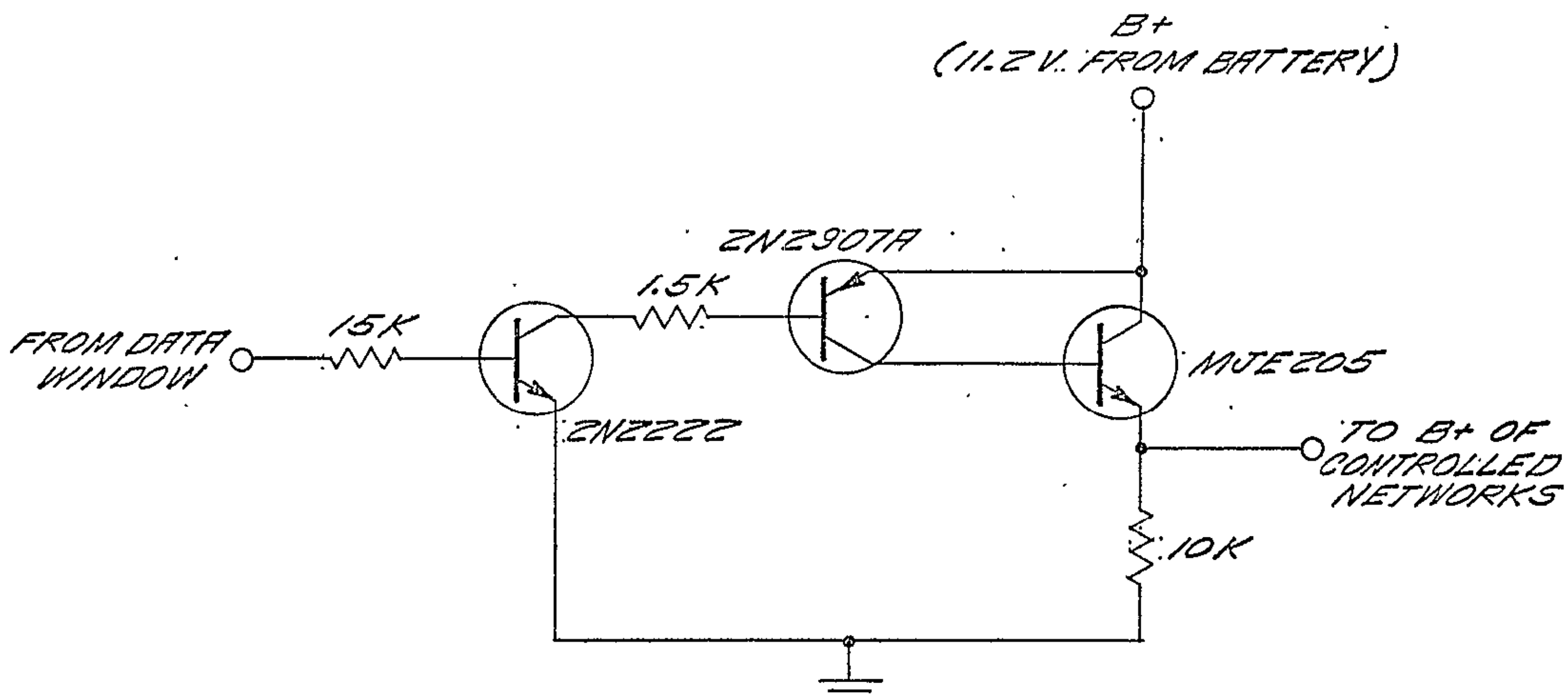


Figure 2-9. Control and Data Logic

F-C3799



F-C3799

Figure 2-10. B+ Switch

crystal will cut the current drain of the crystal-controlled source by 1/3 and its volume by 1/2. The frequency stability of the oscillator will be improved.

The present power amplifier weights 3 ounces (85 f) and requires 5.9 cubic inches (97 cc). This unit is difficult to miniaturize because of series conductors used as matching elements. Nonetheless, size and weight reduction appears achievable.

The data modulator can be reduced in size with chip transistors. This will cut the volume by about 90%. The mixer is susceptible to a 33% reduction in volume. No degradation of electrical performance is anticipated. The B+ switch can also be reduced in volume by using complementary transistors in a chip configuration.

The control and data logic circuitry, currently using C-MOS IC's is susceptible to a 90 - 95% reduction in volume by shifting to two or three hybrid IC's.

The total weight of the circuitry is presently 10 ounces (284 g). We estimate that this can be reduced to 4 ounces or less ($\leq$114 g). The breadboard occupies 25.3 cubic inches (415 cc); the hybrid model has an anticipated volume less than 5.8 cubic inches (95 cc).

2.10 POWER SUPPLY CONSIDERATIONS

The breadboard transmitter operated on 11.2 V derived from four 2.8 V cells in series at a current drain of 626 ma. This current is supplied to the transmitter for one second each minute. During the remaining 59 seconds only the oscillator is operating at 10 ma. The average constant current drain is 15 ma.

Power supplied by type "AA" (size 5cm x 1.4cm) lithium flouride cell (Power Conversion, Inc.) can support the breadboard transmitter for about 80 hours. This will be further improved in the hybrid model development.

3. RECOMMENDATIONS FOR FOLLOW-UP EFFORT

It is the intent of the overall effort to involve an operational and non-harmful system for application to the great whale species. This will permit the establishment of critical migration route paths. It is such path data which will then permit the evolution of systematic and successful censusing techniques resulting in "hard" population data.

The operational system involves the availability of a suitable satellite* (Nimbus -F, or any other polar orbiting satellite with Doppler location capability), an instrument package for sensing and recording data at the subject animal throughout the migration run, a pod of releasable, expendable location transmitters for operation from the animal through the migration run and an expansible - contractable - releasable means (harness) for mounting and holding these gear on the subject animal.

The overall operation of this system is described elsewhere and need not be considered in further detail here. However, it is important to recognize that specific problem areas should be attacked in a stepwise fashion if we are to optimize results with economy and within a reasonable time frame.

The harness design represents a problem which is a complex of behavioral, biologic growth, organic attack, subject tolerance and tear and abrasion parameters. This harness must grow with the animal, yet it must not loosen when the animal dives and its body contracts. The harness must carry both the instrument and releasable transmitter pods, and the entire arrangement must be tolerated by the animal and introduce no behavioral aberrations. Upon automatic release, the harness and its

* Other systems than RAMS are potentially applicable and are described in this context in FIRL report F-C3482, "Animal Tracing Satellite System Study."

gear must float off the animal and surface with a predetermined positional orientation. Initial approaches now completed, have proven the feasibility of a harness attachment with the Californial gray whale. It remains for the development of an expansible - contractable unit to be fully undertaken, completed and tested.

The instrument package must contain all sensors, conditioning circuits and power sources necessary to accumulate path and related behavioral data. The sensed data are to be accumulated in a recoverable recorder. In addition, this package must contain a fixed, location and homing transmitter to permit its recovery on release from the subject animal. Initial development has envolved the basic electronics for the package, pressure and temperature sensors and their conditioning circuits and a first engineering prototype miniature, micropower, high-data-density digital recorder. This preliminary system was built and tested on a juvenile gray whale in its natural habitat. It remains for the path sensors - suitable for our purposes - to be developed along with appropriate conditioning and pre-computing circuitry. Indicated improvements in recorder design must be incorporated and tested. All circuits are to be reduced to hybrid form.

An expendable transmitter has been breadboarded. Early data makes us optimistic with regard to desirable characteristics for a final package. This first design is appropriate electrically for use with the Nimbus -F satellite. It remains for the specific satellite system to be selected, transmitter electrical design optimized to that system, circuits to be reduced to hybrid form, mechanical, thermal and hydrostatic stability designs to be undertaken, release mechanism to be designed and tested and antenna release system to be built and proven.

The problems presented by the foregoing are, in our opinion, not only soluble, but will upon solution provide the "building blocks" for a variety of almost immediately applicable systems to the area of wildlife monitoring and assessment.

The sections which follow are categorized by Federal Fiscal Year on the assumption that the described effort will proceed in the systematic way beginning with FY'76. The specific efforts to be undertaken in each period are described tersely. The goal is an operational system. It is contemplated that when operational, system application and support will be the responsibility of the User Agency.

3.1 FISCAL 1976

Effort by biology team

- Carry on expansible harness development and fabricate two harness for field test
- Continue animal behavioral studies (cine and still photography) re aberrations introduced by gear
- Study harnesses for organism attack upon their recovery from field study
- Plan and lead the field expedition, Baja, Mexic.
- Take part in analysis of recovered data.

Effort by technology team

- Complete improvements to tape recorder
- Design and fabricate eletronic release mechanisms for use in field
- Design and fabricate Xenon Flasher for use in field
- Fabricate two instrument pods (P,T) for use in field study; must tolerate depths to at least 200 meters.
- Process recovered data and take part in analysis
- Participate in field study

This effort will permit work on the expansible harness to go forward, first designs of the electronic release mechanism for the harness, and allow evaluation of water pressure (depth)/temperature data at sea.

The expedition will make possible the acquisiton of field performance data on the new harness design, new depth-of-dive data at sea and the subsequent evaluation of the effects of marine organisms on the harness materials as well as wear-and-tear on the harness because of the subject's behavior in the field. The data analysis will provide new insights to time at the surface and other matters of later importance to census taking strategy evolution.

3.2 FISCAL 1977

- Continue expansible harness development and fabricate two latest design units for field study
- Continue studies (cine and still photography)
- Upon harness recovery from field, study marine organism effects
- Plan and lead the field expedition; one month track at sea
- Take part in analysis of recovered data

Effort by technology team

- Initiate development of the following sensors: pitch-angel, axial velocity, magnetic heading and light level
- Develop related interfacing circuitry for above
- Identify satellite system to be used operationally
- Initiate expendable transmitter development
- Start development of expendable transmitter pod and transmitter release mechanisms
- Improve harness release mechanism designs based on previous field experience
- Fabricate Xenon flashers for field study
- Fabricate two instrument pods for 30 day track at sea
- Process recovered data and take part in analysis
- Participate in field study

This effort is preliminary to the prototype expansible harness; first designs of: key tracking sensors, expendible transmitter packages, the expendible transmitter pod and the expendible transmitter controlled-release mechanism.

This field work will add to our knowledge of subject behavior, give us performance data on the release mechanism prior to prototyping, further insights to marine organism effects and wear-and-tear. Data analysis will provide replicative behavioral data and equipment performance data prior to prototyping.

3.3 FISCAL 1978

Effort by biology team

- Pre-prototype expansible harness
- Integrate harness for two instrument pods
- Continue behavioral studies (cine and still photography)
- Upon harness recovery from field, study marine organism organism effects
- Plan and lead the field expedition; two month track
- Take part in analysis of recovered data

Effort by techology team

- Prototype: pitch angle sensor
  velocity sensor
  magentic heading sensor
  light level sensor
  interfacing circurtry
- Prototype expendible transmitter and test in coastal waters
- Prototype expendible transmitter release mechanism
- Prototype expendible transmitter pod
- Prototype expendible harness-release mechanism
- Fabricate Xenon flashers for field study
- Fabricate three instrument pods (pressure, temperature, light level, time)
- Process recovered data and take part in analysis
- Participate in field study

Indicated subsystems are prototyped in this effort and partially tested at sea during the field study. The somewhat extended track at sea permits additional necessary evaluation of the expansible harness and accumulation of further dive and other behavioral data.

3.4 FISCAL 1979

Effort by the biology team

- Prototype the 2-pod, expansible harnesses and fabricate three for sea study

- Continue behavioral studies (cine and still photography)
- Upon harness recovery from field, assess marine organism effects
- Plan and lead the field expedition (instrument three animals for satellite, 6-months track at sea.
- Take part in the analysis of recovered data.

Effort of technology team

- Fabricate three complete prototype instrumented, sensing and recording pods for 6-month track
- Fabricate three complete prototype expendible transmitter pods
- Fabricate twenty prototype expendible transmitters
- Fabricate three prototype homing transmitters
- Fabricate three prototype harness release mechanisms
- Fabricate three Xenon flashers
- Fabricate three prototype expendible transmitter release systems
- Process data recovered from field study and take part in analysis
- Participate in field study

A successful sea test in this effort means the entire system can be considered operational. All aspects of the total system are tested in this effort including up-links to the satellite.

* * * * * * * * * * * * * * * * * *

3.5 FISCAL 1980-1981 1/2 (19 mos.)

Biology team effort

- Fabricate twelve expensible, 2-pod harnesses carry out behavioral studies local to animal capture area
- Plan and lead field expedition to capture and instrument up to ten animals
- Analyze status of harnesses on recovery
- Take part in data analysis

Technology team effort

- Fabricate ten complete 2-pod data and tracking systems
- Participate in field work
- Process recovered data and take part in analysis
- Analyze recovered instrumentation for reuse on/or modification

This first operational experiment will provide path and related behavioral data from up to ten animals over a full migration (one year).

APPENDIX A: COMPUTER PROGRAMS WRITTEN FOR WHALE MIGRATION STUDIES

1. INTRODUCTION

This Appendix documents 8 of the assembly language programs written under this Project. The programs are written for FIRL's PACER-100 computer.

The programs utilize the PACER's digital input lines, direct memory access channel, moving head disk, real time clock, and digital-to-analog converters. The purposes of the programs are to read data from the miniature recorder, to store the data on a magnetic disk, to correct the data for skewing, to seperate the pressure, temperature and time information, and to plot this information on a strip-chart recorder.

This Appendix includes brief descriptions of each program, provides instructions on the operation of the programs, and presents object listings of the programs.

2. DESCRIPTION AND OPERATION OF COMPUTER PROGRAMS

2.1 WLC2 - DESCRIPTION

This program samples the 8 channels of the miniature recorder at a high rate, condenses groups of these samples into data words and prints out the data words (in binary) on the teletype. The program can store up to approximately 10,000 samples and will print out all of the samples on the teletype. The teletype print-out displays the binary bit pattern as read by the computer. Channel one is left-most, channel eight right-most.

2.2 WLC2 - OPERATION

After data (or a pattern) have been written on the miniature tape, the tape must be rewound and placed in the playback interface to the computer.

1. Load WLC2 via monitor (#L, WLC2, 21)
2. Load Oedipus via monitor (#L, OED, 21)
3. Execute Odeipus (#G, 72ØØØ)
4. Set number of words to be read, in octal, in NMAX (1062:<u>2ØØØØ</u> 2ØØØØ)*
5. Turn on tape
6. Execute WLC2 via Oedipus (1ØØØG)

2.3 PTWL2 - DESCRIPTION

This program reads a data file from the disk and types the data on the teletype in binary. This is normally used in conjunction with WLD2 and presents the data as they were read by the computer.

---

* NOTE: Underlined portion typed by computer is not necessarily 2ØØØØ. User can type any number up to $\approx$ 7ØØØØ, but normally 2ØØØØ is sufficient.

2.4 PTWL2 - OPERATION

1. Load PTWL2 via monitor (#L, PTWL2, 21)
2. Position the data file to be read - xxxxx represents the name of the file (#P, xxxxx, 21)
3. Execute the program (#G, 1000)

2.5 SKEW 2 - DESCRIPTION

This program is similar to PTWL2 except that SKEW 2 allows a constant correction for skewing of the miniature tape.

2.6 SKEW 2 - OPERATION

Same as PTWL 2.

2.7 WLD2 - DESCRIPTION

This program samples the 8 channels of the miniature recorder at a high rate, condenses groups of these samples into data words and writes a file on the disk. This is essentially the same program as WLC2 except WLD2 writes the condensed data not on the teletype but onto the disk.

2.8 WLD2 - OPERATION

1. Load WLD2 via monitor (#L, WLD2, 21)
2. Load Oedipus via monitor (#L, OED, 21)
3. Execute Oedipus (#G, 72ØØØ)
4. Set number of words to be read, in Octal, in NMAX (1Ø43:<u>1Ø2Ø</u> 1Ø2Ø)*
5. Get back into monitor (177777G)
6. Name a file (#N, xxxxx, 21, 3, 1Ø2Ø)**

---

* Underlined portion is typed by the computer and is not necessarily 1Ø2Ø. User can type any number up to 7ØØØØ, but normally 1Ø2Ø is sufficient.

** The xxxxx can be any name not already on disk.

7. Position the file (#P, xxxxx, 21)
8. Assign the file (#A, xxxxx, 1020, 372)***
9. Execute Oedipus (#G, 72000)
10. Turn on tape
11. Execute WLD2 (1ØØØG)
12. When the computer pause light lights, turn the recorder off.

2.9 WLSKP2 - DESCRIPTION

This program reads in data from the disk in pages of 528 words; condenses further the sampled words into single 8 bit words as originally recorded on the miniature tape; and prints the binary data words in three columns on the teletype.

2.10 WLSKP2 - OPERATION

1. Load WLSKP2 via monitor (#L, WLSKP2)
2. Position data file to be read - xxxxx represents the name of the file (#P, xxxxx, 21)
3. Execute the program (#G, 1ØØØ)
4. The computer will pause 2 (pause lamp lights)
5. If a single page is to be printed go to 5a, otherwise go to 6.
   - 5a. push sense switch H up
   - 5b. push run down
   - 5c. push down SGL
   - 5d. push run up; go to 4.
6. If it is desired to skip to the next page go to 6a; otherwise go to 7.
   - 6a. make sure all sense switches are down
   - 6b. push run down
   - 6c. push down sgl
   - 6d. push run up
   - 5e. go to 4.
7. To print out all pages continuously, put sense switches C and H up.

***The xxxxx must be the same as in step 7.

8. Push run down, push down sgl, push run up.

2.11 CSKW2 - DESCRIPTION

This program reads in data from the disk in pages of 528 words; condenses further the sampled words into single 8 bit words as originally recorded on the miniature tape; corrects for skewing of the tape and prints the binary data words in three columns on the teletype.

2.12 SCKW2 - OPERATION

1a. Load SCKW2 via monitor

1b. If standard skew correction desired, go to 2; otherwise go to 6.

2. Position data file to be read - xxxxx represents the name of the file (#P, xxxxx, 21)
3. Put sense switches C & H up.
4. Execute the program (#G, 1Ø76)
5. Release run, depress single, push run up. Stop.
6. In order to program for non-standard skew Oedipus must be loaded and executed #L, OED, 21
   #G, 72ØØØ
7. Skew correctors are in cells 1425 through 1934. The choice of skew correction is made based on results of running WLD2. The position of 1's in the cells 1425 to 1434 will be OR'ed in parallel, the 0's will be ignored.
8. Return to 2.

2.13 WLTD2 - DESCRIPTION

This program samples the 8 channels of the miniature recorder at a high rate, condenses groups of these samples into data words and writes 4 files on the disk using almost the full disk. This is essentially an expanded WLD2 program.

2.14 WLTD2 - OPERATION

1. Load WLTD2 via monitor (#L, WLTD2, 21)
2. Load Oedipus (#L, OED, 21)

3. Let y = 1
4. Name a data file (#N, xxxxy, 2y, 3, 102Ø)*
5. Assign the file (#A, xxxxy, 1Ø2Ø, 372)**
6. Let y = y + 1, Do y = 5? if no go to step 4, if yes continue to 7.
7. Execute Oedipus (#G, 72ØØØ)
8. Assign number of pages to be read in. The number of negative, octal and assigning to PMAS. (21113:177406 176766)***
9. Turn on tape
10. Execute WLTD2 (2Ø22G)
11. When computer pause lamp lights, turn recorder off.

2.15 ARF2 - DESCRIPTION

ARF2 is a program to read a data file from the disk and plot the temperature and pressure on a strip chart recorder.

The computer reads in a page (528 samples) at a time, corrects for skew, condenses the data so it will appear in the form, originally recorded by the miniature recorder, seperates temperature, pressure and time data, converts the data to analog form and presents these analog signals on channels 4,5 and 6 of the PACER's digital to analog converts output panel. The computer presents the data at a frequency compatable with the strip chart recorder. The computer also sends out a page turning signal to the recorder on channel 3. This signal is usually connected to the recorder's event marker input.

2.16 ARF 2 - OPERATION

1. Load ARF2 via monitor (#L, ARF2,21)
2. If standard skew correction is desired, got to 6, otherwise go to 3.
3. In order to program for non-standard skew Oedipus must be loaded and executed #L, OED, 21
   #G, 72ØØØ
4. Skew correctors are in cells 1541 through 155Ø. The choice of skew correction is made based on the results of running WLD2.
5. Return to monitor (77777 G).

6. Position the data file to be read - xxxxx represents the name of the file (#P,xxxxx, 21)
7. Put sense switches C & G up
8. Turn on strip chart recorder
9. Execute the program (#G, 1111)
10. When pause lamp lights up, turn off strip chart recorder

NOTE: Temperature is displayed on digital-to-analog (D/A) channel 4. Pressure is displayed on D/A channel 5. Time is displayed on D/A channel 6.

The strip chart recorder used on this project was a Gould Brush 220. The speed of 25mm/sec proved adequate for most runs. The temperature channel was normally set at 200 MV/DIV, and the pressure channel was set at 50 mv/div.

3. LISTING OF COMPUTER PROGRAMS

WLC2

```
                               * E DOUGHERTY PRGMR       4/4/74
                               * WHALE JOB
                               * SAMPLE AT 9.8 MICRO S   AND
                               * CONDENSE  CNDS AT A TIME
                               * PRINT OUT DATA
00000        00000                    REL      0
00000  53062 00062                    LX       NMAX
00001 141057 00060            CL      LA       CNDS        COND. #
00002 161057 00061                    STA      CX
00003  26740                          CLR                  CLR MEM
00004 167066 00072                    STA,IX   ADER
00005  02007 00007            RD      DI       7           RD BIT PAC
00006 107064 00072                    OR,IX    ADER        OR GROUP
00007 167063 00072                    STA,IX   ADER        STORE"
00010  71051 00061                    AOM      CX          DONE COND?
00011  41774 00005                    J        RD          NO, RD
00012  22777 00071                    DCX      1
YES,NXT,DNE ALL?
00013  41766 00001                    J        CL          NO,CLR
00014  41001 00015                    J        DONE        YES, PRINT
00015  53045 00062            DONE    LX       NMAX
00016 141046 00064                    LA       TYPON       RDY TYPER
00017  25001 00001                    DF       1
00020  61032 00052            TYPWD   L        TSTAT
00021 147051 00072                    LA,IX    ADER
00022  26540                          EQ
00023  26302 00002                    LLD      2
00024 151041 00065                    A        ASCII
00025  03001 00001                    LO       1
00026 141040 00066                    LA       M5
00027 161040 00067                    STA      C5
00030  71037 00067            KOT     AOM      C5
00031  41002 00033                    J        TOK
00032  41007 00041                    J        TRO         DONE TYPG WD X
00033  61017 00052            TOK     L        TSTAT
00034  26743                          CLP
00035  26301 00001                    LLD      1
00036 151027 00065                    A        ASCII
00037  03001 00001                    DO       1
00040  41770 00030                    J        KOT
00041  61011 00052            TRO     L        TSTAT
00042 141026 00070                    LA       CR          CARR. RTN
00043  03001 00001                    DO       1
00044  61006 00052                    L        TSTAT       LINE FD
00045 141024 00071                    LA       LF
00046  03001 00001                    DO       1
00047  22777 00001                    DCX      1
00050  41753 00020                    J        TYPWD
00051  25001 00001                    P        1
00052  00000 00000            TSTAT   ADR      0
00053  04001 00001                    SI       1
00054  24100                          SAE
00055  41002 00057                    J        *+2
00056  41775 00053                    J        *-3
00057  45773 00052                    J,I      TSTAT
00060 177762                  CNDS    DEC      -14
00061        00001            CX      BSS      1
00062  20000                  NMAX    OCT      20000
```

```
00058: 00063  44374          TIM    OCT    44374    40 MICRO S
00059: 00064  00000          TYPON  OCT    0
00060: 00065  00260          ASCII  OCT    260
00061: 00066 177770          M5     OCT    -10
00062: 00067  00000 00000    C5     ADR    0
00063: 00070  00215          CR     OCT    215
00064: 00071  00212          LF     OCT    212
00065: 00072  XXXXX 00073    ADER   ADR    BNK
00066: 00073        20010    BNK    BSS    8200
00067:              00000           END    0
```

```
       ADER      ØØØ72   REL
       ASCII     ØØØ65   REL
       BNK       ØØØ73   REL
       CL        ØØØØ1   REL
       CNDS      ØØØ6Ø   REL
       CR        ØØØ7Ø   REL
       CX        ØØØ61   REL
       C5        ØØØ67   REL
       DONE      ØØØ15   REL
       KOT       ØØØ3Ø   REL
       LF        ØØØ71   REL
       N5        ØØØ66   REL
       NMAX      ØØ262   REL
       PD        ØØØØ5   REL
       TIM       ØØØ63   REL          NPF
       TON       ØØØ33   REL
       TPO       ØØØ41   REL
       TSTAT     ØØØ52   REL
       TYPON     ØØ264   REL
I.←    TYPUD     ØØØ22   REL
```

PTWL2

```
                        * E DOUGHERTY 5/22/74 11:30
                        * WHALE READ
                        * READ IN DATA FROM DSK21
                        * IN PACKS OF 528
                        * AT P=2, A SINGLE WILL:
                        * PRINT, IF SSW H UP
                        * SKP TO NEXT PAGE, IF SSW DWN
00000            00000            REL      0
00000 141060 00060                LA       STWD        SET STUS
00001  26700                      ES                   FOR TRAPS
00002  24540                      SMI                  SET NSTP INTRPT
00003 141056 00361                LA       PARAM       OUTPUT 21 DSK
00004 165350 00362                STA,I    SP
                        * READ 528 WDS FROM DSK 21
00005  27321 00021      INDEX     T        17          .MEIN
00006 XXXXXX 00073                ADR      BNK         STRT ADR
00007 XXXXXX 71112                ADR      BUF-1       END ADR
00010  41047 00357                J        LPROP
00011  25032 00002                P        2           DONE MEM LD
00012  23471                      SSW      H           UP PRNT
00013  41772 00005                J        INDEX       READ NXT
                        * PRINT OUT 528 BUFFER
00014  53047 00260                LDX      NMAX
00015 141047 00364                LA       TYPON       RDY TYPER
00016  45001 00001                LF       1
00017  61000 00051      TYPWD     L        TSTAT
00020 147052 00372                LA,IX    ADET        PRNT WD X
00021  26540                      EC
00022  26302 00002                LLL      2
00023 151042 00265                A        ASCII
00024  03001 00001                DO       1
00025 141041 00066                LA       C5
00026 161041 00067                STA      C5
00027  71047 00067      KOT       AOM      C5
00030  41062 00032                J        TOK
00031  41037 00042                J        TRO         DONE TYPG WD X
00032  61017 00051      TOK       L        TSTAT
00033  26740                      CLF
00034  26301 00001                LLD      1
00035 151000 00065                A        ASCII
00036  03001 00001                LO       1
00037  41770 00027                J        KOT
00040  61011 00051      TRO       L        TSTAT
00041 141027 00072                LA       CR          CARR. RTN
00042  03001 00071                DO       1
00043  61000 00051                L        TSTAT       LINE FEED
00044 141005 00071                LA       LF
00045  03001 00001                LO       1
00046  53777 00001                DCX      1
00047  41751 00017                J        TYPWD
00050  41735 00005                J        INDEX
                        * TYPER STATUS SUBROUTINE
00051  00000 00000      TSTAT     ADR      0
00052  04001 00001                SI       1
00053  24140                      SAE
00054  41002 00056                J        *+2
00055  41775 00052                J        *-3
00056  45770 00051                J,I      TSTAT
```

```
00059: 00057  25001 00001     ERROR  P         1
00060: 00060 100000           STWD   OCT       100000
00061: 00061  04021           PARAM  OCT       4021
00062: 00062  77666 77666     SP     ADR       '77666
00063: 00063  01020           NMAX   OCT       1020
00064: 00064  00000           TYPON  OCT       0
00065: 00065  00260           ASCII  OCT       260
00066: 00066 177770           M5     OCT       -10
00067: 00067  00000 00000     C5     ADR       0
00068: 00070  00215           CR     OCT       215
00069: 00071  00212           LF     OCT       212
00070: 00072  XXXXX 00073     ADER   ADR       ENK
00071: 00073        01020     ENK    BSS       528
00072: 01113  00000 00000     DUM    ADR       0
00073:              00000            END       A
```

ADER	00072	REL
ASCII	00065	REL
CNK	00073	REL
CR	00070	REL
C5	00067	REL
DUM	01113	REL
ERROR	00057	REL
INDEX	00005	REL
KOT	00027	REL
LF	00071	REL
M5	00066	REL
NMAX	00063	REL
PARAM	00061	REL
SP	00062	REL
STPD	00063	REL
TOK	00002	REL
TRO	00042	REL
TSTAT	00051	REL
TYPCN	00064	REL
TYPWD	00017	REL

SKEW 2

```
                              * SKEW0,1,2
                              * DOC 6/21/74  3:30
                              * READS 528 WRDS FROM DSK 21
                              * CORRECTS FOR SKEW
                              * PRINTS CORRECTED ON TTY
00000              00000             REL      0
00000 141060 00060                   LA       STWD       SET STUS
00001  26700                         ES                  FOR TRAPS
00002  24540                         SMI                 SET MSTR INTRPT
00003 141056 00061                   LA       PARAM      OUTPUT 21 DSK
00004 165056 00062                   STA,I    SP
                              * READ 528 WRDS FROM DSK 21
00005  27021 00021          INDEX    T        17         .MSIN
00006  XXXXX 00273                   ADR      BNK        STRT ADR
00007  XXXXX 01312                   ADR      DUM-1      END ADR
00010  41047 00057                   J        ERROR
00011  23401                         SSW      H          UP PRNT
00012  41773 00005                   J        INDEX      READ NXT
                              * PRINT OUT 528 BUFFER
00013  53050 00063                   LX       NMAX
00014 141050 00064                   LA       TYPON      RDY TYPER
00015  05001 00001                   DF       1
00016  61033 00051          TYPWD    L        TSTAT
00017  61152 00171                   L        NXTS
00020 141252 00272                   LA       TEMP3
00021  26540                         EQ
00022  26322 00302                   LLD      2
00023 151042 00065                   A        ASCII
00024  03001 00001                   DO       1
00025 141041 00066                   LA       M5
00026 161041 00067                   STA      C5
00027  71040 00067          KOT      AOM      C5
00030  41002 00032                   J        TOK
00031  41007 00040                   J        TRO        DONE TYPG WD X
00032  61017 00051          TOK      L        TSTAT
00033  26740                         CLR
00034  26301 00001                   LLD      1
00035 151030 00065                   A        ASCII
00036  03001 00001                   DO       1
00037  41770 00027                   J        KOT
00040  61011 00051          TRO      L        TSTAT
00041 141027 00070                   LA       CR         CARR. RTN
00042  03001 00001                   DO       1
00043  61006 00051                   L        TSTAT      LINE FEED
00044 141025 00071                   LA       LF
00045  03001 00001                   DO       1
00046  22777 00001                   DCX      1
00047  41747 00016                   J        TYPWD
00050  41735 00005                   J        INDEX
                              * TYPER STASTUS SUBROUTINE
00051  00000 00000          TSTAT    ADR      0
00052  04001 00001                   SI       1
00053  24100                         SAE
00054  41002 00056                   J        *+2
00055  41775 00052                   J        *-3
00056  45773 00051                   J,I      TSTAT
00057  25001 00001          ERROR    P        1
00060 100000                STWD     OCT      100000
```

```
00061  04021                PARAM   OCT      4021
00062  77666  77666         SP      ADR      '77666
00063  01020                NMAX    OCT      1020
00064  00000                TYPON   OCT      0
00065  00260                ASCII   OCT      260
00066 177770                M5      OCT      -10
00067  00000  00000         C5      ADR      Z
00070  00215                CR      OCT      215
00071  00212                LF      OCT      212
00072  XXXXX  00273         ADER    ADR      BNK
00073         00074         BUF1    BSS      60
00167  00000  00000         BUF1A   BSS      1,0
00170  XXXXX  00073         ABUF1   ADR      BUF1
00171  00000  00000         NXTS    ADR      0
00172  26740                        CLR
00173 161077  00272                 STA      TEMP3
00174 147676  00072                 LA,IX    ADER
00175 131065  00262                 AND      AND1
00176 161074  00272                 STA      TEMP3
00177  22777  00001                 DCX      1
00200  41002  00202                 J        *+2
00201  41604  00005                 J        INDEX
00202 147670  00072                 LA,IX    ADER
00203 131063  00263                 AND      AND2
00204 101066  00272                 OR       TEMP3
00205 161065  00272                 STA      TEMP3
00206  22777  00001                 DCX      1
00207  41002  00211                 J        *+2
00210  41575  00005                 J        INDEX
00211 147661  00072                 LA,IX    ADER
00212 131052  00264                 AND      AND3
00213 101057  00272                 OR       TEMP3
00214 161056  00272                 STA      TEMP3
00215  22777  00001                 DCX      1
00216  41002  00220                 J        *+2
00217  41566  00005                 J        INDEX
00220 147652  00072                 LA,IX    ADER
00221 131044  00265                 AND      AND4
00222 101050  00272                 OR       TEMP3
00223 161047  00272                 STA      TEMP3
00224  22777  00001                 DCX      1
00225  41002  00227                 J        *+2
00226  41557  00005                 J        INDEX
00227 147643  00072                 LA,IX    ADER
00230 131036  00266                 AND      AND5
00231 101041  00272                 OR       TEMP3
00232 161040  00272                 STA      TEMP3
00233  22777  00001                 DCX      1
00234  41002  00236                 J        *+2
00235  41550  00005                 J        INDEX
00236 147634  00072                 LA,IX    ADER
00237 131030  00267                 AND      AND6
00240 101032  00272                 OR       TEMP3
00241 161031  00272                 STA      TEMP3
00242  22777  00001                 DCX      1
00243  41002  00245                 J        *+2
00244  41541  00005                 J        INDEX
00245 147625  00072                 LA,IX    ADER
```

```
ØØ246 131Ø22 ØØ27Ø          AND      AND7
ØØ247 1Ø1Ø23 ØØ272          OR       TEMP3
ØØ25Ø 161Ø22 ØØ272          STA      TEMP3
ØØ251  22777 ØØØØ1          DCX      1
ØØ252  41ØØ2 ØØ254          J        *+2
ØØ253  41532 ØØØØ5          J        INDEX
ØØ254 147616 ØØØ72          LA,IX    ADER
ØØ255 131Ø14 ØØ271          AND      AND8
ØØ256 1Ø1Ø14 ØØ272          OR       TEMP3
ØØ257  222Ø7 ØØØØ7          ICX      7
ØØ26Ø 161Ø12 ØØ272          STA      TEMP3
ØØ261  45713 ØØ171          J,I      NXTS
ØØ262  ØØ4ØØ          AND1  OCT      4ØØ

ØØ263  ØØ4ØØ          AND2  OCT      4ØØ
ØØ264  Ø1ØØØ          AND3  OCT      1ØØØ
ØØ265  Ø3ØØØ          AND4  OCT      3ØØØ
ØØ266  122ØØ          AND5  OCT      122ØØ
ØØ267  54ØØØ          AND6  OCT      54ØØØ
ØØ27Ø  64ØØØ          AND7  OCT      64ØØØ
ØØ271  2ØØØØ          AND8  OCT      2ØØØØ
ØØ272  ØØØØØ ØØØ2Ø    TEMP3 BSS      1,Ø
ØØ273        Ø1Ø2Ø    BNK   BSS      528
Ø1313  ØØØØØ ØØØØØ    DUM   ADF      Ø
             ØØØØØ          END      Ø
```

ABUF1	00170	REL	NRF
ADER	00072	REL	
AND1	00262	REL	
AND2	00263	REL	
AND3	00264	REL	
AND4	00265	REL	
AND5	00266	REL	
AND6	00267	REL	
AND7	00270	REL	
AND8	00271	REL	
ASCII	00065	REL	
BNA	00273	REL	
BUF1A	00167	REL	NRF
BUF1	00073	REL	
CR	00076	REL	
C5	00067	REL	
DUM	01313	REL	
ERROR	00257	REL	
INDEX	00205	REL	
NOT	00027	REL	
LF	00371	REL	
N5	00066	REL	
NMAX	00063	REL	
NXTS	00171	REL	
PARAM	00061	REL	
SP	00232	REL	
STVE	00063	REL	
TEMP	00273	REL	
TON	00332	REL	
TTO	00240	REL	
TSTAT	02351	REL	
TYPON	00364	REL	
TYPWD	00016	REL	

WLD2

```
                              * E DOUGHERTY 5/21/74   1:30
                              * WALED
                              * SAMPLE AT 9.8 MICRO S   AND
                              * CONDENSE  CNDS AT A TIME
                              * WRITE ON DISK
00000              00000                 REL      0
00000  141036  00036                     LA       STWD
00001   26700                            ES
00002  141035  00037                     LA       PMAS
00003  161035  00040                     STA      SAMP
00004   53037  00043       A             LX       NMAX
00005  141034  00041       CL            LA       CNDS        COND. #
00006  161034  00042                     STA      CX
00007   26740                            CLR                  CLR MEN
00010  167034  00044                     STA,IX   ADER
00011   02007  00007       RD            DI       7           RD BIT PAC
00012  127032  00044                     OR,IX    ADER        OR GROUP
00013  167031  00044                     STA,IX   ADER        STORE"
00014   71026  00042                     AOM      CX          DONE COND?
00015   41774  00011                     J        RD          NO, RD
00016   22777  00001                     DCX      1
YES,NXT,DNE ALL?
00017   41766  00005                     J        CL          NO,CLR
00020   41001  00021                     J        DONE        YES, PRINT
00021   24540              DONE          SMI
00022  141013  00035                     LA       PARAN
00023  165011  00034                     STA,I    SP
00024   27020  00020                     T        16
00025   XXXXX  00045                     ADR      BNK
00026   XXXXX  01064                     ADR      DUM-1
00027   41004  00033                     J        ERROR
00030   71010  00040                     AOM      SAMP
00031   41753  00004                     J        A
00032   25007  00007                     P        7
00033   25001  00001       ERROR         P        1
00034   77666  77666       SP            ADR      '77666
00035   04021              PARAN         OCT      4021
00036  130000              STWD          OCT      130000
00037  177014              PMAS          DEC      -500
00040              00001   SAMP          BSS      1
00041  177762              CNDS          DEC      -14
00042              00001   CX            BSS      1
00043   01020              NMAX          OCT      1020
00044   XXXXX  00045       ADER          ADR      BNK
00045              01020   BNK           BSS      528
01065   00000  00000       DUM           ADR      0
                   00000                 END      0
```

ADER	ØØØ44	REL
A	ØØ2Ø4	REL
ENR	ØØØ45	REL
CL	ØØØØ5	REL
CNDS	ØØØ41	REL
CX	ØØØ42	REL
DONE	ØØØ21	REL
DUM	Ø1Ø65	REL
ERROR	ØØØ33	REL
NMAX	ØØØ43	REL
PARAM	ØØØ35	REL
PMAS	ØØØ37	REL
RD	ØØØ11	REL
SAMP	ØØØ4Ø	REL
SP	ØØ234	REL
STUD	ØØØ36	REL

WLSKP2

```
                              * E DOUGHERTY 6/4/74  1:00
                              * WHALE READ
                              * READ IN DATA FROM DSK21
                              * IN PACKS OF 528
                              * AT P=2, A SINGLE WILL:
                              * PRINT, IF SSW H UP
                              * SKP TO NEXT PAGE, IF SSW DWN
                              * TO SKIP SEVERAL PAGES
                              * PUT SSW A UP; USING OED
                              * LOAD NEG # IN X REG
                              * PUT SSW B UP
                              * AT P2 PUT A&B DOWN
                              * SSW C UP, ALONG WITH H WILL ALLOW
                              * CONTINUOUS PRINT OUT
00000              00000               REL     0
00000 141203 00203                     LA      MI
00001 161221 00222                     STA     NZP
00002 141207 00211                     LA      MTHRE
00003 161207 00212                     STA     WPL
00004 161207 00213                     STA     SCT
00005 141216 00223                     LA      STWD       SET STUS
00006  26700                           ES                 FOR TRAPS
00007  24540                           SMI                SET MSTR INTRPT
00010 141214 00224                     LA      PARAM      OUTPUT 21 DSK
00011 165214 00225                     STA,I   SP
                              * READ 528 WRDS FROM DSK 21
00012  27021 00021             INDEX   T       17         .MSIN
00013  XXXXX 00236                     ADR     BNK        STRT ADR
00014  XXXXX 01255                     ADR     DUM-1      END ADR
00015  41165 00202                     J       ERROR
00016  23600                           SSW     A          MULTI SKP,UP
00017  41005 00024                     J       PAUSE
00020  23500                           SSW     B
00021  45157 00210                     J,I     OED        PUT # IN X
00022  22021 00021                     ICX     1          & PUT B UP
00023  41767 00012                     J       INDEX      EG -8=177770
00024  23440                   PAUSE   SSW     C
00025  25002 00002                     P       2
00026  23401                           SSW     H          UP PRNT
00027  41763 00012                     J       INDEX      READ NXT
                              * PRINT OUT 528 BUFFER
00030  53176 00226                     LX      NMAY
00031 141176 00227                     LA      TYPON      RDY TYPER
00032  45201 00001                     DF      1
00033  26740                           CLF
00034 161165 00221                     STA     ZCNT
00035  61137 00174             TYPWD   L       TSTAT
00036  26740                           CLF
00037 161150 00227                     STA     TEMP       INTL DATA 0
00040 141144 00204             WRITE   LA      MONE
00041 161144 00205                     STA     SKP
00042 147173 00035                     LA,IX   ADER
00043 121150 00215                     C       ZERO
00044  27410                           SE
00045  41015 00062                     J       DATA       NO
00046 141153 00221                     LA      ZCNT       YES
00047  71152 00221                     AOM     ZCNT
00050 121145 00215                     C       ZERO       1ST 0?
```

```
00051   27410                   SE
00052   41003 00055             J       UPDT        NO
00053  141134 00207             LA      TEMP        YES,PRNT DATA
00054   41032 00106             J       PRNT
00055   22777 00001   UPDT      DCX     1
00056   41762 00040             J       WRITE
00057   23440                   SSW     C
00060   41732 00012             J       INDEX
00061   41106 00167             J       SKIP
00062  141137 00221   DATA      LA      ZCNT        DATA
00063  121133 00216             C       EIGHT       ZERO WRD?
00064   27412                   SGE
00065   41013 00100             J       DATOR       NO,DATA
00066  141132 00220             LA      MTWO        YES,SET UP IF
00067  161133 00222             STA     NZP         DOUBLE 0
00070  141131 00221             LA      ZCNT
00071  121126 00217             C       FOURT       DOUBLE
00072   27412                   SGE
00073   71127 00222             AOM     NZP         NO,SAT 0 INDX
00074   26740         DZ        CLR                 YES
00075  161124 00221             STA     ZCNT
00076   22701 00001             ICX     1
00077   41007 00106             J       PRNT
00100   26740         DATOR     CLR
00101  161120 00221             STA     ZCNT
00102  147133 00235             LA,IX   ADEP
00103  171134 00207             OR      TEMP
00104  161133 00207             STA     TEMP
00105   41750 00055             J       UPDT
00106   26540         PRNT      LQ
00107   26302 00002             LLD     2
00110  151120 00230             A       ASCII
00111   23001 00001             DO      1
00112  141117 00231             LA      M5
00113  161117 00232             STA     C5
00114   71116 00232   KOT       AOM     C5
00115   41006 00123             J       TOK
00116   71074 00212             AOM     UPL
00117   41030 00155             J       SPACE
00120  141071 00211             LA      MTAPE
00121  161071 00212             STA     UPL
00122   41007 00131             J       TRO         DONE TYPG UD X
00123   61051 00174   TOK       L       TSTAT
00124   26740                   CLR
00125   26301 00001             LLD     1
00126  151102 00230             A       ASCII
00127   23001 00001             DO      1
00130   41764 00114             J       KOT
00131   61040 00174   TRO       L       TSTAT
00132  141101 00233             LA      CR          CARR. RTN
00133   23001 00001             DO      1

00134   61040 00174             L       TSTAT       LINE FEED
00135  141077 00234             LA      LF
00136   23001 00001             DO      1
00137   71046 00205             AOM     SKP
00140   41771 00131             J       TRO
00141   71045 00206             AOM     PAS
00142   41002 00144             J       GO
```

```
00143  41647 00012           J     INDEX
00144  71056 00222  GO       AOM   NZP
00145  41020 00165           J     DBZ
00146 141035 00203           LA    M1
00147 161053 00222           STA   NZP
00150  22777 00001           DCX   1
00151  41664 00035           J     TYPWD
00152  23440                 SSW   C
00153  41637 00012           J     INDEX
00154  41013 00167           J     SKIP
00155  61017 00174  SPACE    L     TSTAT
00156 141036 00214           LA    SPCE
00157  03001 00001           DO    1
00160  71033 00213           AOM   SCT
00161  41774 00155           J     SPACE
00162 141027 00211           LA    MTHRE
00163 161030 00213           STA   SCT
00164  41760 00144           J     GO
00165  26740        DBZ      CLF
00166  41720 00106           J     PRNT
00167 141022 00211  SKIP     LA    MTHRE
00170 161015 00205           STA   SKP
00171 141013 00204           LA    MONE
00172 161014 00206           STA   PAS
00173  41736 00131           J     TPO
                    * TYPER STASTUS SUBROUTINE
00174  00000 00000  TSTAT    ADR   0
00175  34001 00001           SI    1
00176  24100                 SAL
00177  41002 00201           J     *+2
00200  41775 00175           J     *-3
00201  45773 00174           J,I   TSTAT
00202  25001 00001  ERROR    P     1
00203 177777        M1       OCT   -1
00204 177777        MONE     OCT   -1
00205  00000 00000  SKP      BSS   1,0
00206  00000 00000  PAS      BSS   1,0
00207  00000 00000  TEMP     BSS   1,0
00210  72030 72030  DEL      ADR   '72030
00211 177775        MTHRE    DEC   -3
00212        00001  TPL      BSS   1
00213        00001  SCT      BSS   1
00214  00240        SPCE     OCT   240
00215  00000        ZERO     DEC   0
00216  00010        EIGHT    DEC   8
00217  00016        FOURT    DEC   14
00220 177776        MTWO     DEC   -2
00221  00000 00000  ZCNT     BSS   1,0
00222  00000 00000  NZP      BSS   1,0
00223 100000        STWD     OCT   100000
00224  04021        PARAM    OCT   4021
00225  77666 77666  SP       ADR   '77666
00226  01020        NMAX     OCT   1020
00227  00000        TYPON    OCT   0
00230  00262        ASCII    OCT   262
00231 177770        M5       OCT   -10
00232  00000 00000  CS       ADR   0
00233  00215        CR       OCT   215
```

```
ØØ175: ØØ234  ØØ212         LF     OCT     212
ØØ176: ØØ235  XXXXX ØØ236   ADER   ADR     BNK
ØØ177: ØØ236        Ø1Ø2Ø   BNK    BSS     528
ØØ178: Ø1256  ØØØØØ ØØØØØ   DUM    ADR     Ø
ØØ179:              ØØØØØ          END     Ø
```

```
ADER     ØØ235   REL
ASCII    ØØ23Ø   REL
BNK      ØØ236   REL
CR       ØØ233   REL
C5       ØØ232   REL
DATA     ØØØ62   REL
DATOR    ØØ1ØØ   REL
DBZ      ØØ165   REL
DUM      Ø1256   REL
DZ       ØØ274   REL          NRF
EIGHT    ØØ216   REL
ERROR    ØØ2Ø2   REL
FOURT    ØØ217   REL
GO       ØØ144   REL
INDEX    ØØØ12   REL
KOT      ØØ114   REL
LF       ØØ234   REL
MONE     ØØØØ4   REL
MTHRE    ØØ211   REL
MTWO     ØØ22Ø   REL
M1       ØØ2Ø3   REL
M5       ØØ231   REL
MMAX     ØØ226   REL
NZP      ØØ222   REL
OED      ØØ21Ø   REL
PARAM    ØØ224   REL
PAUSE    ØØØ24   REL
PKS      ØØ2Ø6   REL
PRNT     ØØ136   REL
SCT      ØØ213   REL
SKIP     ØØ167   REL
SMP      ØØ2Ø5   REL
SPACE    ØØ155   REL
SPCE     ØØ214   REL
SP       ØØ225   REL
STUD     ØØ223   REL
TEMP     ØØ2Ø7   REL
TOM      ØØ123   REL
TPO      ØØ1Ø1   REL
TSTAT    ØØ174   REL
TYPON    ØØ227   REL
TYPUD    ØØØ35   REL
UPDT     ØØØ55   REL
UPL      ØØ212   REL
URITE    ØØØ4Ø   REL
ZCNT     ØØ221   REL
ZERO     ØØ215   REL
```

CSKW2

```
                          * E DOUGHERTY  6/25/74
                          * 8:30
                          *
                          * CSKW0,CSKW1,CSKW2
                          * CONDENSES WEALE DATA FROM DISK
                          * AND CORRECTS FOR SKEW
                          * PRINTS OUT IN 3 COLS
                          * SSWC UP TO RUN CONTINUOUS
                          * SSWH UP TO PRINT
00000               00040             REL    0
00000               00074     BUF1    BSS    60
00074        00002 00002      BUF1A   BSS    1,2
00075        XXXXX 00000      ABUF1   ADR    BUF1
00076       141214 00312              LA     M1
00077       161222 00321              STA    NZP
00100       141211 00321              LA     MTHREE
00101       161210 00311              STA    WPL
00102       161216 00312              STA    SCT
00103       141217 00322              LA     STWD        SET STUS
00104        26700                    ES                 FOR TRAPS
00105        24540                    SMI                SET MSTR INTRPT
00106       141215 00323              LA     PARAM       OUTPUT 21 DSK
00107       165215 00324              STA,I  SP
                          * READ 528 WDS FROM DSK 21
00110        27021 00021      INDEX   T      17          .MSIN
00111        XXXXX 02437              ADR    BNK         STRT ADR
00112        XXXXX 01456              ADR    DUM-1       END ADR
00113        41166 00301              J      ERROR
00114        23030                    SSW    A           MULTI SKP,UP
00115        41005 00122              J      PAUSE
00116        23500                    SSW    E
00117        45175 00327              J,I    ODD         PUT # IN X
00120        22001 00001              ICX    1           & PUT B UP
00121        41757 00110              J      INDEX       EG -8=177770
00122        23440            PAUSE   SSW    C
00123        25302 00002              P      2
00124        23421                    SSW    H           UP PRNT
00125        41763 00110              J      INDEX       READ NXT
                          * PRINT OUT 528 BUFFER
00126        53177 00325              LX     NMAX
00127       141177 00326              LA     TYPON       RDY TYPER
00130        05001 00001              DF     1
00131        26741                    CLR
00132       161166 00320              STA    ZCNT
00133        51142 00273      TYPWD   L      TSTAT
00134        26740                    CLR
00135       161151 00306              STA    TEMP        INTL DATA 0
00136       141145 00323      WRITE   LA     MONE
00137       161145 00334              STA    SKP
00140        61174 00334              L      NXTS
00141       141275 00436              LA     TEMP3
00142       121152 00314              C      ZERO
00143        27413                    SE
00144        41015 00161              J      DATA        NO
00145       141153 00320              LA     ZCNT        YES
00146        71152 00320              AOM    ZCNT
00147       121145 00314              C      ZERO        1ST 0?
00150        27410                    SE
```

```
00151  41303 00154           J      UPDT      NO
00152 141134 00306           LA     TEMP      YES,PRNT DATA
00153  41032 00205           J      PRNT
00154  22777 00001   UPDT    DCX    1
00155  41761 00136           J      WRITE
00156  23440                 SSW    C
00157  41731 00110           J      INDEX
00160  41106 00266           J      SKIP
00161 141137 00320   DATA    LA     ZCNT      DATA
00162 121133 00315           C      EIGHT     ZERO WRD?
00163  27412                 SGE
00164  41012 00177           J      DATOR     NO,DATA
00165 141132 00317           LA     MTWO      YES,SET UP IF
00166 161133 00321           STA    NZP       DOUBLE Ø
00167 141131 00320           LA     ZCNT
00170 121126 00316           C      FOURT     DOUBLE
00171  27412                 SGE
00172  71127 00321           AOM    NZP       NO,SAT Ø INDX
00173  26740         DZ      CLR              YES
00174 161124 00320           STA    ZCNT
00175  22001 00001           ICX    1
00176  41227 00205           J      PRNT
00177  26740         DATOR   CLR
00200 161124 00320           STA    ZCNT
00201 141225 00436           LA     TEMP3
00202 131104 00306           OR     TEMP
00203 161103 00306           STA    TEMP
00204  41750 00154           J      UPDT
00205  26540         PRNT    EQ
00206  26302 00002           LLD    2
00207 151120 00327           A      ASCII
00210  03001 00001           DO     1
00211 141117 00333           LA     M5
00212 161117 00331           STA    C5
00213  71116 00331   NOT     AOM    C5
00214  41006 00222           J      TOK
00215  71074 00311           AOM    WPL
00216  41036 00254           J      SPACE
00217 141071 00310           LA     MTHRE
00220 161071 00311           STA    WPL
00221  41007 00230           J      TRC       DONE TYPC WD X
00222  61051 00273   TOK     L      TSTAT
00223  26740                 CLR
00224  26301 00001           LLD    1
00225 151102 00327           A      ASCII
00226  03001 00001           DO     1
00227  41764 00213           J      NOT
00230  61043 00273   TRC     L      TSTAT
00231 141101 00332           LA     CR        CARR. RTN
00232  03001 00001           DO     1
00233  61043 00273           L      TSTAT     LINE FEED
00234 141077 00333           LA     LF
00235  03001 00001           DO     1
00236  71046 00334           AOM    SKP
00237  41771 00230           J      TRC
00240  71045 00305           AOM    PRS
00241  41002 00243           J      GO
00242  41646 00110           J      INDEX
```

```
00243  71056 00321     GO     AOM     NZP
00244  41020 00264            J       DBZ
00245 141035 00302            LA      M1
00246 161053 00321            STA     NZP
00247  22777 00001            DCX     1
00250  41663 00133            J       TYPWD
00251  23440                  SSW     C
00252  41636 00110            J       INDEX
00253  41013 00266            J       SKIP
00254  61017 00273     SPACE  L       TSTAT
00255 141036 00313            LA      SPCE
00256  03001 00001            DO      1
00257  71033 00312            AOM     SCT
00260  41774 00254            J       SPACE
00261 141027 00310            LA      MTHRE
00262 161030 00312            STA     SCT
00263  41760 00243            J       GO
00264  26740           DBZ    CLR
00265  41720 00205            J       PRNT
00266 141022 00310     SKIP   LA      MTHRE
00267 161015 00304            STA     SKP
00270 141013 00303            LA      MONE
00271 161014 00305            STA     PKS
00272  41736 00230            J       TRO
                     * TYPER STASTUS SUBROUTINE
00273  00000 00000     TSTAT  ADR     0
00274  34021 00001            SI      1
00275  24100                  SAE
00276  41002 00300            J       *+2
00277  41775 00274            J       *-3
00300  45773 00273            J,I     TSTAT
00301  25001 00001     ERROR  P       1
00302 177777           M1     OCT     -1
00303 177777           MONE   OCT     -1
00304  00000 00000     SKP    BSS     1,0
00305  00000 00000     PKS    BSS     1,0
00306  00000 00000     TEMP   BSS     1,0
00307  72000 72000     OEE    ADR     '72000
00310 177775           MTHRE  DEC     -3
00311        00001     WPL    BSS     1
00312        00001     SCT    BSS     1
00313  00240           SPCE   OCT     240
00314  00000           ZERO   DEC     0
00315  00010           EIGHT  DEC     8
00316  00016           FOURT  DEC     14
00317 177776           MTWO   DEC     -2
00320  00000 00000     ZCNT   BSS     1,0
00321  00000 00000     NZP    BSS     1,0
00322 100000           STWD   OCT     100000
00323  04021           PARAM  OCT     4021
00324  77666 77666     SP     ADR     '77666
00325  01020           NMAX   OCT     1020
00326  00000           TYPON  OCT     0
00327  00260           ASCII  OCT     260
00330 177770           M5     OCT     -10
00331  00000 00000     C5     ADR     0
00332  00215           CR     OCT     215
00333  00212           LF     OCT     212
```

```
00334  00000 00000    NXTS   ADR      0
00335   26740                CLR
00336 161100 00436           STA      TEMP3
00337 147076 00435           LA,IX    ADER
00340 131065 00425           AND      AND1
00341 161075 00436           STA      TEMP3
00342  22777 00001           DCX      1
00343  41002 00345           J        *+2
00344  41722 00266           J        SKIP
00345 147070 00435           LA,IX    ADER
00346 131060 00426           AND      AND2
00347 101067 00436           OR       TEMP3
00350 161066 00436           STA      TEMP3
00351  22777 00001           DCX      1
00352  41002 00354           J        *+2
00353  41713 00266           J        SKIP
00354 147061 00435           LA,IX    ADER
00355 131052 00427           AND      AND3
00356 101060 00436           OR       TEMP3
00357 161057 00436           STA      TEMP3
00360  22777 00001           DCX      1
00361  41002 00363           J        *+2
00362  41704 00266           J        SKIP
00363 147052 00435           LA,IX    ADER
00364 131044 00430           AND      AND4
00365 101051 00436           OR       TEMP3
00366 161050 00436           STA      TEMP3
00367  22777 00001           DCX      1
00370  41002 00372           J        *+2
00371  41675 00266           J        SKIP
00372 147043 00435           LA,IX    ADER
00373 131036 00431           AND      AND5
00374 101042 00436           OR       TEMP3
00375 161041 00436           STA      TEMP3
00376  22777 00001           DCX      1
00377  41002 00401           J        *+2
00400  41666 00266           J        SKIP
00401 147034 00435           LA,IX    ADER
00402 131030 00432           AND      AND6
00403 101033 00435           OR       TEMP3
00404 161032 00436           STA      TEMP3
00405  22777 00001           DCX      1
00406  41002 00410           J        *+2
00407  41657 00266           J        SKIP
00410 147025 00435           LA,IX    ADER
00411 131[illegible] [illegible]           AND      AND7
00412 101024 00436           OR       TEMP3
00413 161023 00436           STA      TEMP3
00414  22777 00001           DCX      1
00415  41002 00417           J        *+2
00416  41650 00266           J        SKIP
00417 147016 00435           LA,IX    ADER
00420 131014 00434           AND      AND8
00421 101015 00436           OR       TEMP3
00422  22077 00007           ICX      7
00423 161013 00436           STA      TEMP3
00424  45710 00334           J,I      NXTS
00425  00402          AND1   OCT      402
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

```
00233: 00426  00400        AND2   OCT     400
00234: 00427  01000        AND3   OCT     1000
00235: 00430  03000        AND4   OCT     3000
00236: 00431  12200        AND5   OCT     12200
00237: 00432  54000        AND6   OCT     54000
00238: 00433  64000        AND7   OCT     64000
00239: 00434  20000        AND8   OCT     20000
00240: 00435  XXXXX 00437  ADER   ADR     BNK
00241: 00436  00000 00020  TEMP3  BSS     1,0
00242: 00437        01020  BNK    BSS     528
00243: 01457  00000 00000  DUM    ADR     0
00244:              30000         END     0
```

ABUF1	ØØØ75	REL	NRF
ADER	ØØ435	REL	
AND1	ØØ425	REL	
AND2	ØØ426	REL	
AND3	ØØ427	REL	
AND4	ØØ43Ø	REL	
AND5	ØØ431	REL	
AND6	ØØ432	REL	
AND7	ØØ433	REL	
AND8	ØØ434	REL	
ASCII	ØØ327	REL	
BNK	ØØ437	REL	
BUF1A	ØØ274	REL	NRF
BUF1	ØØ2ØØ	REL	
CR	ØØ332	REL	
C5	ØØ331	REL	
DATA	ØØ161	REL	
DATOR	ØØ177	REL	
DBZ	ØØ264	REL	
DUM	Ø1457	REL	
DZ	ØØ173	REL	NRF
EIGHT	ØØ315	REL	
ERROR	ØØ3Ø1	REL	
FOURT	ØØ316	REL	
GO	ØØ243	REL	
INDEX	ØØ11Ø	REL	
KOT	ØØ213	REL	
LF	ØØ333	REL	
MONE	ØØ333	REL	
MTHRE	ØØ313	REL	
MTWO	ØØ317	REL	
M1	ØØ3Ø2	REL	
M5	ØØ332	REL	
NMAX	ØØ325	REL	
NXTS	ØØ334	REL	
NZP	ØØ321	REL	
OLD	ØØ3Ø7	REL	
PAFAL	ØØ323	REL	
RAUSE	ØØ122	REL	
PAS	ØØ3Ø5	REL	
PRNT	ØØ275	REL	
SCT	ØØ312	REL	
SKIP	ØØ266	REL	
SKP	ØØ334	REL	
SPACE	ØØ254	REL	
SPCE	ØØ313	REL	
SP	ØØ324	REL	
STUL	ØØ322	REL	
TEMP	ØØ3Ø6	REL	
TEMP3	ØØ436	REL	
TOK	ØØ222	REL	
TPO	ØØ234	REL	
TSTAT	ØØ273	REL	
TYPON	ØØ326	REL	
TYPWD	ØØ133	REL	
UPDT	ØØ154	REL	
WPL	ØØ311	REL	
WRITE	ØØ136	REL	

```
      ZCNT      ØØ32Ø   REL
M←    ZERO      ØØ314   REL
```

WLTD2

```
                                 * E DOUGHERTY  8-27-74
                                 *
                                 * WLTDØ
                                 *
                                 * SAMPLE AT 9.8 MICRO S AND
                                 * CONDENSE CNDS AT A TIME
                                 * WRITE ON ALL FOUR TRACKS OF DISK
                                 *
                                 ****************************************
ØØØØØ              ØØØØØ                  REL       Ø
ØØØØØ              Ø1Ø2Ø        BBNK      BSS       52Ø
Ø1Ø2Ø  ØØØØØ       ØØØØØ        DDUM      ADR       Ø
Ø1Ø21  XXXXX       ØØØØØ        BUFF      ADR       BBNK
Ø1Ø22  14107Ø      Ø1112                  LA        STWD
Ø1Ø23  26722                              ES
Ø1Ø24  141Ø67      Ø1113        ST        LA        PMAS
Ø1Ø25  161Ø67      Ø1114                  STA       SAMP
Ø1Ø26  5ØØ71       Ø1117        A         LX        NMAX
Ø1Ø27  141Ø65      Ø1114                  LA        SAMP
Ø1Ø3Ø  241ØØ                              SAE
Ø1Ø31  41Ø15       Ø1Ø46                  J         CCL
Ø1Ø32  141Ø63      Ø1115        CL        LA        CNDS
Ø1Ø33  161Ø63      Ø1116                  STA       CX
Ø1Ø34  2674Ø                              CLR
Ø1Ø35  167Ø64      Ø1121                  STA,IX    ADER
Ø1Ø36  ØØØØ7       ØØØØ7        RD        DI        7
Ø1Ø37  1Ø7Ø62      Ø1121                  OR,IX     ADER
Ø1Ø4Ø  167Ø61      Ø1121                  STA,IX    ADER
Ø1Ø41  71Ø55       Ø1116                  AOM       CX
Ø1Ø42  41774       Ø1Ø36                  J         RD
Ø1Ø43  22777       ØØØØ1                  DCX       1
Ø1Ø44  41766       Ø1Ø32                  J         CL
Ø1Ø45  41Ø15       Ø1Ø62                  J         DONE
Ø1Ø46  141Ø47      Ø1115        CCL       LA        CNDS
Ø1Ø47  161Ø47      Ø1116                  STA       CX
Ø1Ø5Ø  2674Ø                              CLR
Ø1Ø51  16775Ø      Ø1Ø21                  STA,IX    BUFF
Ø1Ø52  ØØØØ7       ØØØØ7        RRD       DI        7
Ø1Ø53  1Ø7746      Ø1Ø21                  OR,IX     BUFF
Ø1Ø54  167745      Ø1Ø21                  STA,IX    BUFF
Ø1Ø55  71Ø41       Ø1116                  AOM       CX
Ø1Ø56  41774       Ø1Ø52                  J         RRD
Ø1Ø57  22777       ØØØØ1                  DCX       1
Ø1Ø6Ø  41766       Ø1Ø46                  J         CCL
Ø1Ø61  41Ø16       Ø1Ø77                  J         DDONE
Ø1Ø62  2454Ø                    DONE      SMI
Ø1Ø63  141Ø26      Ø1111                  LA        PARAM
Ø1Ø64  165Ø24      Ø111Ø                  STA,I     SP
Ø1Ø65  27Ø2Ø       ØØØ2Ø                  T         16
Ø1Ø66  XXXXX       Ø1122                  ADR       BNA
Ø1Ø67  XXXXX       ØØ141                  ADR       DUM-1
Ø1Ø7Ø  41Ø17       Ø11[illegible]         J         ERROR
Ø1Ø71  71Ø23       Ø1114        OTHER     AOM       SAMP
Ø1Ø72  41734       Ø1Ø26                  J         A
Ø1Ø73  71Ø16       Ø1111                  AOM       PARAM
Ø1Ø74  71Ø24       Ø112Ø                  AOM       TRACT
Ø1Ø75  41727       Ø1Ø24                  J         ST
Ø1Ø76  252Ø        ØØØØ7                  P         7
```

```
00059: 01077  24540              DDONE  SMI
00060: 01100 141011 01111               LA     ,PARAM
00061: 01101 165007 01110               STA,I   SP
00062: 01102  27020 00020               T       16
00063: 01103  XXXXX [illegible]         ADR     BBNK
00064: 01104  XXXXX 01017               ADR     DDUM-1
00065: 01105  41[illegible] 01107       J       ERROR
00066: 01106  41763 01071               J       OTHER
00067: 01107  25001 00001        ERROR  P       1
00068: 01110  77666 77666        SP     ADR     '77666
00069: 01111  04021              PARAM  OCT     4021
00070: 01112 100000              STWD   OCT     100000
00071: 01113 177406              PNAS   DEC     -250
00072: 01114        00001        SAMP   BSS     1
00073: 01115 177744              CNDS   DEC     -28
00074: 01116        00001        CX     BSS     1
00075: 01117  01020              NMAX   OCT     1020
00076: 01120 177774              TRKCT  DEC     -4
00077: 01121  XXXXX 01122        ADBR   ADR     BNK
00078: 01122        01020        BNK    BSS     528
00079: 02142  00000 00000        DUM    ADR     0
00080:              00000               END     0
```

ADER	01121	REL
A	01026	REL
BENK	00000	REL
BNK	01122	REL
BUFF	01021	REL
CCL	01046	REL
CL	01032	REL
CNDS	01115	REL
CX	01116	REL
DDONE	01077	REL
DDUM	01020	REL
DONE	01062	REL
DUM	02142	REL
ERROR	01107	REL
NMAX	01117	REL
OTHER	01271	REL
PARAM	01111	REL
PMAS	01113	REL
RD	01036	REL
RFD	01052	REL
SAMP	01114	REL
SP	01110	REL
STWD	01112	REL
ST	01024	REL
TRKCT	01120	REL

E 002
G
A
P

ARF2

```
                        * THIS PROGRAM FOR BAD D/A
                        *
                        * 12/13/74
                        *
                        * START AT 1111
                        * ROGRAM TO
                        * PROGRAM TO WRITE WHALE DATA ON A STRIP
                        * CHART RECORDER VIA D/A CONVERTES
                        *
                        * CORRECTS FOR SKEW 1504 TO 1513
                        * EIGHT IS # OF 0'S RQR'D FOR A 0 WRD
                        * FOURT "  "   "   " DOUBLE 0 WRD
                        * TWENT "  "   "   "  TRIP 0 WRD
                        *
                        * TO RERUN SET 1101 T0 176766
                        * :::::::::::::::::::::::::::::::::::
                        *
                        *
00000              00000          REL      0
00000              00074   BUF1   BSS      60
00074  00000 00000         BUF1A  BSS      1,0
00075  XXXXX 00000         ABUF1  ADR      BUF1
00076  77666 77666         SP     ADR      '77666
00077  04021               PARAM  OCT      4021
00100 100002               STWD   OCT      100002
00101 174616 74616         ABC    BSS      1,-1650
00102  25000 00000         OVER   P        0
00103  25007 00007         ERROR  P        7
00104 177704               M60    DEC      -60
00105  00000 00000         CTP    BSS      1,0
00106 177755               M19    DEC      -19
00107 177776               M2     DEC      -2
00110  00002               TWO    DEC      2
00111 141262 00373                LA       MONE
00112 161260 00372                STA      NZP
00113 141765 00100                LA       STWD
00114  26700                      ES
00115  24544                      SMI
00116 141761 00077                LA       PARAM
00117 165757 00076                STA,I    SP
                        * READ 520 WRDS FROM DISK
00120  71761 00101         INDEX  ADM      ABC
00121  41002 00123                J        TT
00122  41760 00102                J        OVER
00123  27021 00021         TT     T        17
00124  XXXXX 00573                ADR      BNK
00125  XXXXX 01612                ADR      DUM-1
00126  41755 00103                J        ERROR
                        * SELECT CONTINOUS OR PAUSE
00127  23440               SSWC   SSW      C
00130  25002 00002                P        2
00131  23401                      SSW      R
00132  41766 00120                J        INDEX
00133 141751 00104                LA       M60
00134 161751 00105                STA      CTP
00135 141740 00075                LA       ABUF1
00136 161736 00074                STA      BUF1A
00137  26740                      CLF
```

```
00140 161136 00276          STA      ZCNT
00141  53136 00277          LX       NMAX
00142  61232 00374 FILBUF   L        CDNSE
00143 165731 00074          STA,I    BUF1A
00144  71730 00074          AOM      BUF1A
00145  71740 03105          AOM      CTP
00146  41002 00150          J        *+2
00147  41004 00153          J        *+4
00150  71222 00372          AOM      NZP
00151  41772 00143          J        FILBUF+1
00152  41772 00142          J        FILBUF
00153  26740                CLR
00154 161130 00304          STA      TEMP
00155 161123 00300          STA      N0
00156 161123 00301          STA      N=
00157 161124 00303          STA      N>
00160 161122 00302          STA      N<
00161  53116 00277          LX       NMAX
00162 141724 00106          LA       N19
00163 161007 00372          STA      NZP
00164 141723 00107          LA       NP
00165 161120 00305          STA      SEQ
00166 141707 00075          LA       BUF1
00167 151721 00110          A        TWO
00170 161704 00074          STA      BUF1A
00171  71703 00074 AGN      AOM      BUF1A
00172 145702 00074          LA,I     BUF1A
00173 121114 00307          C        ZERO
00174  27410                SE
00175  41002 00177          J        *+2
00176  71102 00300          AOM      N0
00177 121105 00304          C        TEMP
00200  27410                SE
00201  41002 00203          J        *+2
00202  71077 00301          AOM      N=
00203 121101 00304          C        TEMP
00204  27402                SG
00205  41002 00207          J        *+2
00206  71075 00303          AOM      N>
00207 121075 00304          C        TEMP
00210  27404                SL
00211  41002 00213          J        *+2
00212  71070 00302          AOM      N<
00213 161071 00304          STA      TEMP
00214  71060 00074          AOM      BUF1A
00215  71057 00074          AOM      BUF1A
00216  71154 00372          AOM      NZP
00217  41752 00171          J        AGN
                   * DETERMINE SEQUENCE C,T,P
00220 141060 00300          LA       N0
00221 121334 00555          C        FOUR
00222  27402                SG
00223  41002 00225          J        *+2
00224  41021 00245          J        A
00225 141054 00301          LA       N=
00226 121330 00556          C        TEN
00227  27402                SG
00230  41002 00232          J        *+2
```

```
00231  41012 00243               J      B
00232 141051 00303               LA     N>
00233 121324 00557               C      D13
00234  27402                     SG
00235  41002 00237               J      *+2
00236  41006 00244               J      C
00237 141043 00302               LA     N<
00240 121320 00560               C      SIX
00241  27402                     SG
00242  41002 00244               J      C
00243  71042 00305        D      AOM    SEQ
00244  71041 00305        C      AOM    SEQ
00245  26740              A      CLR
00246  26740                     CLR
00247 161027 00276               STA    ZCNT
00250 141025 00555               LA     FOUR
00251 161310 00561               STA    DAN
00252 141121 00373               LA     MONE
00253 161117 00372               STA    NZP
                    * NOW ALLIGNED
                    * START PLOTTING
00254 141306 00562               LA     THREE
00255  05476 00076               DF     '76
00256 141623 00101               LA     ABC
00257  24100                     SAE
00260  41003 00263               J      EVON
00261 141026 00307               LA     ZERO
00262  41002 00264               J      EVENT
00263 141011 00274        EVON   LA     EVMAP
00264  03076 10076        EVENT  DO     '76
00265 141274 00561        PLOT   LA     DAN
00266 121027 00275               C      SEVEN
00267  27410                     SE
00270  41022 00312               J      DAC
00271 141264 00555               LA     FOUR
00272 161207 00561               STA    DAN
00273  41067 00362               J      RTC
00274  77400              EVMAP  OCT    77400
00275  00007              SEVEN  DEC    7
00276  00000 00000        ZCNT   BSS    1,0
00277  01020              NMAX   OCT    1020
00300  00000 00000        NB     BSS    1,0
00301  00000 00000        N=     BSS    1,0
00302  00000 00000        N<     BSS    1,0
00303  00000 00000        N>     BSS    1,0
00304  00000 00000        TEMP   BSS    1,0
00305  00000 00000        SEQ    BSS    1,0
00306  XXXXX 00120        AINDEX ADR    INDEX
00307  00000              ZERO   OCT    0
00310  05076 00076        DAC    DF     '76
00311  71001 00372               AOM    NZP
00312  41003 00315               J      *+3
00313  61061 00374               L      CONSE
00314 151040 00554               STA    TEMP2
00315 141770 00305               LA     SEQ
00316 121771 00307               C      ZERO
00317  27406                     SNE
00320  41005 00325               J      T
```

```
00321  26740                     CLR
00322  71763 00305               AOM      SEQ
00323  41765 00310               J        DAC
00324  41764 00310               J        DAC
00325 141234 00561               LA       DAN
00326 121227 00555               C        FOUR
00327  27410                     SE
00330  41017 00347               J        PRES
00331 141223 00554               LA       TEMP2
00332 121755 00377               C        ZERO
00333  27406                     SNE
00334  41003 00337               J        *+3
00335 161203 00547               STA      TEMP4
00336  41004 00342               J        TOUT
00337 141201 00547               LA       TEMP4
00340 131214 00554               STA      TEMP2
00341  41001 00342               J        TOUT
00342 141212 00554     TOUT      LA       TEMP2
00343 101210 00553               SE       LIMIT
00344 161210 00554               STA      TEMP2
00345  41011 00356               J        OUT
00346  [illegible]     FIVE      DEC      5
00347 121777 00346     PRES      C        FIVE
00350  27410                     SE
00351  41005 00356               J        OUT
00352 141202 00554               LA       TEMP2
00353  20120                     TCA
00354 161200 00554               STA      TEMP2
00355  41001 00356               J        OUT
00356 141176 00554     OUT       LA       TEMP2
00357  30276 00076               DO       '76
00360  71201 00561               AOM      DAN
00361  41764 00265               J        PLOT
                       * WAIT FOR CHART RECORDER
00362 141201 00563     RTC       LA       WIND
00363  25040 00040               DF       '40
00364  02040 00040     CLOCK     DI       '40
00365  20200                     OCA
00366 121176 00564               C        TIM
00367  27414                     SLE
00370  41774 00364               J        CLOCK
                       * GET NEXT WORD
00371  41674 00265               J        PLOT
00372  00000 00000     NZP       BSS      1,0
00373 177777           MONE      OCT      -1
                       *
                       * CONDENSE DATA SUBRUOTINE
                       *
00374  00000 00000     CDNSE     ADR      0
00375 141776 00373               LA       MONE
00376 161774 00372               STA      NZP
00377  26740                     CLR
00400 161704 00304               STA      TEMP
00401 141772 00373               LA       MONE
00402 161163 00565               STA      SKP
00403  26740           NXTS      CLR
00404 161145 00551               STA      TEMP3
00405 147161 00566               LA,IX    ADER
```

```
00406 131133 00541          AND      AND1
00407 161142 00551          STA      TEMP3
00410  22777 00001          DCX      1
00411  41002 00413          J        *+2
00412  41506 00120          J        INDEX
00413 147153 00566          LA,IX    ADER
00414 131152 00566          AND      ADER
00415 131125 00542          AND      AND2
00416 121133 00551          OR       TEMP3
00417 161132 00551          STA      TEMP3
00420  22777 00001          DCX      1
00421  41002 00423          J        *+2
00422  45664 00326          J,I      AINDEX
00423 147143 00566          LA,IX    ADER
00424 131117 00543          AND      AND3
00425 121124 00551          OR       TEMP3
00426 161123 00551          STA      TEMP3
00427  22777 00001          DCX      1
00430  41002 00432          J        *+2
00431  45655 00326          J,I      AINDEX
00432 147134 00566          LA,IX    ADER
00433 131111 00544          AND      AND4
00434 121115 00551          OR       TEMP3
00435 161114 00551          STA      TEMP3
00436  22777 00001          DCX      1
00437  41002 00441          J        *+2
00440  45646 00326          J,I      AINDEX
00441 147125 00566          LA,IX    ADER
00442 131103 00545          AND      AND5
00443 121106 00551          OR       TEMP3
00444 161105 00551          STA      TEMP3
00445  22777 00001          DCX      1
00446  41002 00450          J        *+2
00447  45637 00326          J,I      AINDEX
00450 147116 00566          LA,IX    ADER
00451 131075 00546          AND      AND6
00452 121077 00551          OR       TEMP3
00453 161076 00551          STA      TEMP3
00454  22777 00001          DCX      1
00455  41002 00457          J        *+2
00456  45630 00326          J,I      AINDEX
00457 147107 00566          LA,IX    ADER
00460 131067 00547          AND      AND7
00461 121072 00551          OR       TEMP3
00462 161067 00551          STA      TEMP3
00463  22777 00001          DCX      1
00464  41002 00466          J        *+2
00465  45621 00326          J,I      AINDEX
00466 147100 00566          LA,IX    ADER
00467 131061 00550          AND      AND8
00470 121061 00551          OR       TEMP3
00471  22007 00007          ICX      7
00472 161057 00551          STA      TEMP3
00473 121614 00307          C        ZERO
00474  27412                SE
00475  41015 00512          J        DATA
                   * DETERMINE # OF 0S IN DATA
00476 141600 00276          LA       ZCNT
```

```
00477   71577 00276                 AOM     ZCNT
00500  121607 00307                 C       ZERO
00501   27410                       SE
00502   41005 00507                 J       UPDT
00503  141601 00304                 LA      TEMP
00504   22777 00001                 DCX     1
00505   45667 00374                 J,I     CDNSE
00506   41003 00511                 J       *+3
00507   22777 00001         UPDT    DCX     1
00510   41673 00403                 J       NXTS
00511   45575 00306                 J,I     AINDEX
00512  141564 00276         DATA    LA      ZCNT
00513  121254 00567                 C       EIGHT
00514   27412                       SGE
00515   41015 00532                 J       DATOR
00516  141252 00570                 LA      MTHREE
00517  161653 00372                 STA     NZP
00520  141556 00276                 LA      ZCNT
00521  121250 00571                 C       FOURT
00522   27412                       SGE
00523   71647 00372                 AOM     NZP
00524  121246 00572                 C       TWENT
00525   27412                       SGE
00526   71644 00372                 AOM     NZP
00527   26740               DZ      CLF
00530  161546 00276                 STA     ZCNT
00531   45643 00374                 J,I     CDNSE
00532   26740               DATOR   CLF
00533  161543 00276                 STA     ZCNT
00534  141015 00551                 LA      TEMP3
00535  121547 00304                 OR      TEMP
00536  161546 00304                 STA     TEMP
00537   41750 00507                 J       UPDT
00540   00000 00003         TEMP4   BSS     1,3
00541   00400               AND1    OCT     400
00542   03000               AND2    OCT     3000
00543   10200               AND3    OCT     10200
00544   64020               AND4    OCT     64020
00545   00000               AND5    OCT     0
00546   00000               AND6    OCT     0
00547   00002               AND7    OCT     2
00550   00000               AND8    OCT     0
00551   00000 00000         TEMP3   BSS     1,0
00552   00001               ONE     DEC     1
00553   20000               EADBT   OCT     20000
00554   00000 00000         TEMP2   BSS     1,0
00555   00004               FOUR    DEC     4
00556   00005               TEN     DEC     5
00557   00015               D13     DEC     13
00560   00006               SIX     DEC     6
00561   00000 00000         DAN     BSS     1,0
00562   00003               THREE   DEC     3
00563   44444               WIND    OCT     44444
00564   00012               TIM     DEC     10
00565   00000 00000         SKP     BSS     1,0
00566   XXXXX 00573         ADER    ADP     BUK
00567   00005               EIGHT   DEC     5
00570  177775               MTHREE  DEC     -3
```

```
00349: 00571  00012          FOURT  DEC     10
00350: 00572  00017          TWENT  DEC     15
00351: 00573         01020   BNK    BSS     528
00352: 01613  00000  00000   DUM    ADR     0
00353:               00000          END     0
```

ABC	00101	REL	
ABUF1	00075	REL	
ADER	00566	REL	
AGN	00171	REL	
AINDEX	00306	REL	
AND1	00541	REL	
AND2	00542	REL	
AND3	00543	REL	
AND4	00544	REL	
AND5	00545	REL	
AND6	00546	REL	
AND7	00547	REL	
AND8	00550	REL	
A	00245	REL	
BALDT	00553	REL	
BNK	00573	REL	
BUF1A	00074	REL	
BUF1	00000	REL	
B	00243	REL	
CONSL	00374	REL	
CLOCK	00364	REL	
CTP	00105	REL	
C	00244	REL	
DAN	00561	REL	
DAC	00310	REL	
DATA	00512	REL	
DATOR	00532	REL	
DUM	01613	REL	
DZ	00527	REL	NRF
D13	00557	REL	
EIGHT	00567	REL	
ERROR	00103	REL	
EVMAR	00274	REL	
EVCN	00233	REL	
EVENT	00264	REL	
FILBUF	00142	REL	
FIVE	00546	REL	
FOUNT	00571	REL	
FOUR	00555	REL	
INDEX	00120	REL	
MONE	00373	REL	
MTHREE	00570	REL	
M19	00106	REL	
M2	00107	REL	
M60	00104	REL	
NMAX	00277	REL	
NXTS	00403	REL	
NZP	00372	REL	
N0	00322	REL	
N<	00302	REL	
N=	00301	REL	
N>	00303	REL	
ONE	00552	REL	NRF
OUT	00356	REL	
OVER	00102	REL	
PARAM	00077	REL	
PLOT	00265	REL	
PRLS	00347	REL	

RTC	ØØ362	REL	
SEQ	ØØ3Ø5	REL	
SEVEN	ØØ275	REL	
SIX	ØØ56Ø	REL	
SKP	ØØ565	REL	
SP	ØØØ76	REL	
SSWC	ØØ127	REL	NRF
STWD	ØØ1ØØ	REL	
TEMP	ØØ324	REL	
TEMP2	ØØ554	REL	
TEMP3	ØØ551	REL	
TEMP4	ØØ54Ø	REL	
TEN	ØØ556	REL	
THREE	ØØ562	REL	
TIN	ØØ564	REL	
TOUT	ØØ342	REL	
TT	ØØ123	REL	
TWO	ØØ11Ø	REL	
TWENT	ØØ57Ø	REL	
T	ØØ325	REL	
UPLT	ØØ567	REL	
WIND	ØØ563	REL	
ZCNT	ØØ276	REL	
ZERO	ØØ327	REL	