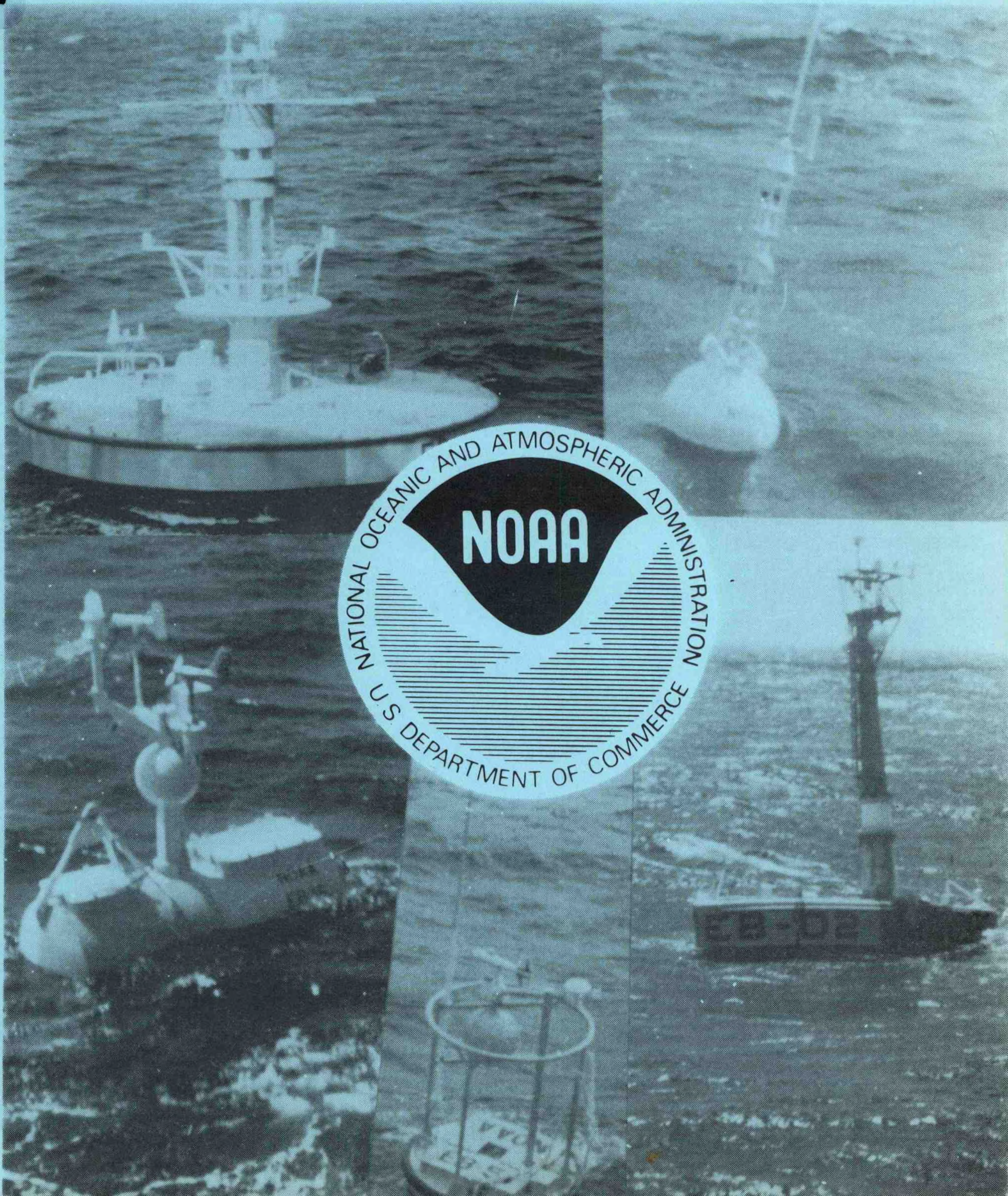
# PRACTICAL EXPERIENCE WITH BUOYS

## DEVELOPED BY
## THE NOAA DATA BUOY OFFICE

NOVEMBER
1973




U.S. DEPARTMENT
OF COMMERCE
National Oceanic
and Atmospheric
Administration
National Ocean
Survey
Office of Marine
Technology
NOAA Data Buoy
Office

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## REVISION RECORD

| Revision No. | Date | Title and/or Brief Description | | | |
|---|---|---|---|---|---|
| 1 | Nov 1973 | Revised Pages: | | | |
| | | 2-2 | 4.2-4 | 4.5-3 | 4.5-17 |
| | | 2-9 | 4.2-5 | 4.5-4 | 4.6-1 |
| | | 2-11 | 4.2-3a | 4.5-5 | 4.6-2 |
| | | 2-14 | 4.3-10 | 4.5-6 | 4.6-4 |
| | | 2-15 | 4.3-11 | 4.5-7 | 4.6-9 |
| | | 2-16 | 4.3-12 | 4.5-8 | 4.6-14 |
| | | 2-17 | 4.4-60 | 4.5-9 | 4.6-17 |
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## 1.0 INTRODUCTION

### 1.1 BACKGROUND

In March, 1966, the Ocean Engineering Panel of the Interagency Committee on Oceanography, noting the many individual data buoy development programs underway, recommended that the Coast Guard manage a feasibility study of a consolidated national buoy system. The study was completed October, 1967, and in November, 1967, the National Council for Marine Research Resources and Engineering Development requested that the Coast Guard undertake the necessary development effort. The National Data Buoy Development Project was thus established. The primary objective of NDBC's program as conceived initially was the establishment of a very extensive network of sophisticated High Capability Environmental Data buoys capable of operating in severe environments and delivering a large variety of data in sophisticated reporting modes. A secondary objective was to provide smaller buoys of less sophisticated design to meet special needs of Users.

On October 3, 1970, the National Oceanic and Atmospheric Administration (NOAA) was formed within the U. S. Department of Commerce and the functions of the National Data Buoy Development Project were transferred from the Coast Guard to NOAA and the name changed to NDBC. After the first year of operation under NOAA, a reassessment of National priorities and User interests led to a shift in emphasis away from large future network deployments in the 1980's to a more immediate fulfillment of current and near term National needs. Subsequent reorganizations of NOAA functions resulted in redesignation of the NDBC as the NOAA Data Buoy Office (NDBO). The NOAA Data Buoy Office is now an element of the Office of Marine Technology, National Ocean Survey and is located in Bay Saint Louis, Mississippi, at the NASA Mississippi Test Facility.

### 1.2 NDBO MISSION

In order to improve environmental data buoy technology the NDBO performs systematic research, development, test and evaluation of a number of data buoys with sensors, power supplies, hull sizes and forms, and data processing and communication systems tailored to meet specific needs. The Office provides the capability to support a series of data buoys to meet short-term measurement needs for research programs and NOAA's long-term operational needs in the marine and weather areas. In addition the office provides a technical advisory capability to serve national interests.

## 1.3 CURRENT PROGRAMS

NDBO is currently in the process of pursuing two types of data buoys on two separate programs: (1) a small Drifting Research Buoy (DRB) for special applications which is already under development by NOVA University and (2) an Environmental Prototype Buoy.

### 1.3.1 DRIFTING RESEARCH BUOYS

The DRB program is illustrative of NDBO's commitment to provide timely support in meeting special needs of the scientific community and to apply evolving technology where practical. An assessment of scientific experiments through 1978 shows a potential requirement of several hundred DRB types of buoys.

### 1.3.2 ENVIRONMENTAL PROTOTYPE BUOY

NDBO is currently involved in planning for the procurement of an Environmental Prototype Buoy as part of the program for addressing NOAA's long-term operational needs in the marine and weather areas. The principal characteristics of this buoy will be high reliability, low life cycle costs, sensor complement of modest accuracy and provisions to facilitate efficient maintenance at sea. It will be capable of efficient deployment and operation in the range of marine environments found in the coastal areas of the Atlantic and Pacific Oceans, the Gulf of Mexico and the Gulf of Alaska. The required parameters for measurement and ordered priority are: wind direction and speed, air pressure, air temperature, significant wave height and period, sea surface temperature, and subsurface temperature.

Based upon extensive test experience with numerous classes of buoys, NDBO believes that the technology is in hand to satisfy the requirements of an Environmental Prototype Buoy. The task is primarily that of combining essentially available subsystems with corrections as needed and with appropriate interface designs to produce an effective, reliable, low cost buoy system. Based on the experience with buoy systems to date it can be stated that:

- Buoy hull and mooring systems exist which have withstood the expected environments and operated satisfactorily.
- Buoy electronics systems, including communications, data processing and sensors, exist which have automatically acquired the needed data and relayed it ashore.
- Buoy power systems exist which have provided the quality and reliability of the electrical energy required for the several electronic and auxiliary systems on the buoy.

In systems evaluated by NDBO to date, these successes have often been independent of each other in many cases. However, the technologies involved have been demonstrated, at least insofar as performance is involved. Delivery of a buoy featuring reduced initial and operating cost, increased reliability, proper integration and adequate testing is the challenge under this program.

## 1.4 DOCUMENT OVERVIEW

This document presents a comprehensive overview of experience gained by the NDBO through prior buoy procurements and years of testing. It is provided as a bank of information which has been obtained as a result of a substantial amount of development, state of the art sensor investigations, and considerable at-sea testing and evaluation. The practical experience which has been gained is a result of at-sea experience with several types of buoy systems.

An overview of the buoy systems which were evaluated is first presented. Then, overall system performance is addressed, with a quantitized summary of hardware reliability. This includes a breakdown of buoy failures by subsystem and buoy type for pre-deployment, at-sea operations and post-deployment accelerated testing on LCB's, and a review of system performance in delivery of messages to the National Weather Service (NWS).

System logistical support at sea and on shore are described and analyzed, including the HF communication stations and land line links. Available facilities and equipment are also described.

Each buoy subsystem is described in detail and an analysis of its performance is presented. Where possible, guidelines and favored approaches to attaining successful subsystems are suggested.

The guidelines and approaches contained in this document are strictly based upon NDBO experience and do not encompass all possibilities. From what NDBO has done in the past, these approaches appear to yield the best results.

## 1.5 BUOY SYSTEMS

During the past several years the NDBO has funded the development of environmental data buoys which automatically obtain meteorological and oceanographic data at their locations, encode the data, and transmit it to shore communications centers. This development effort has resulted in five buoy systems - two High Capability Buoys (HCB) and three Limited Capability Buoys (LCB). These five systems are described in the following paragraphs.

### 1.5.1 Engineering Evaluation Phase (EEP) High Capability Buoy (HCB)

The engineering phase, forty foot, discus-hulled, 100 ton displacement buoys were chosen as platforms for evaluation of advanced state-of-the-art sensors and buoy components. These buoys were integrated by General Dynamics in cooperation with Westinghouse Electric Corporation who had responsibility for the sensor system.

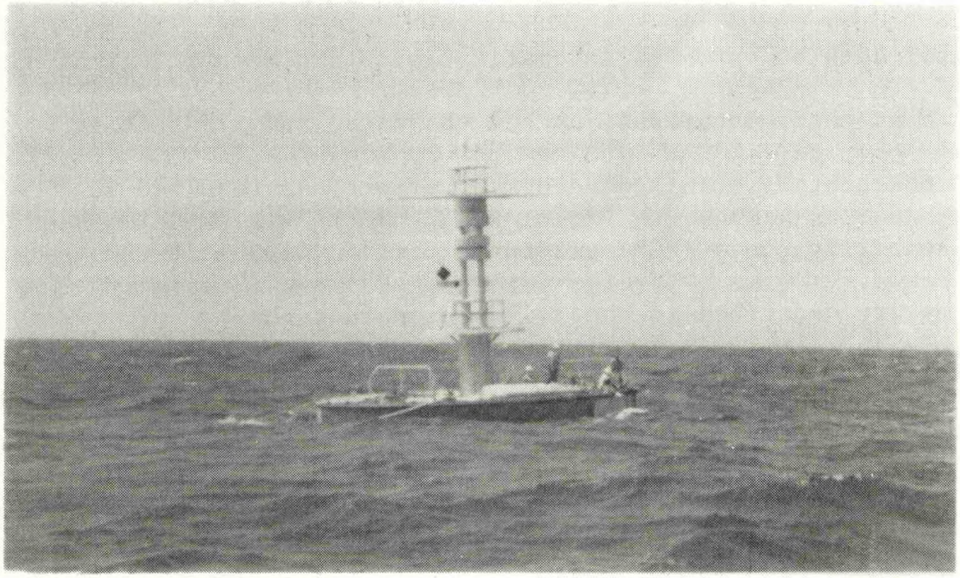
Three of these buoys and a similar one which was a forerunner of the EEP (XERB-1) are presently deployed: One in Atlantic Ocean approximately 125 miles east of Norfolk, Virginia, one in the Gulf of Alaska and two in the Gulf of Mexico.

The characteristics of the EEP buoys are shown in Figure 1.2-1; measurement specifications are shown in Table 1.2-1.

### 1.5.2 Deep-Keeled Environmental Buoy

The Deep-Keel Hull (DKH) buoy was designed as an ocean platform to evaluate the effects of the unique hull form on environmental data gathering. Initial

Figure 1.2-1
BUOY FACT SHEET
ENGINEERING EVALUATION PHASE
HIGH CAPABILITY BUOY
EEP-HCB



CONTRACTORS

General Dynamics - Systems Integration Contractor
Westinghouse Electric Corporation - Sensor System Contractor

STATUS AND APPLICATION

Deployment of six High Capability Buoys began in June, 1972. These buoys return the basic environmental measurements - water temperature and pressure, salinity, current speed and direction, air temperature and pressure - and provide useful experience in practical operations and in systematic data collection, processing and dissemination. The data that are collected are furnished to the National Weather Service at regular intervals.

PHYSICAL CHARACTERISTICS

40' Discus
50 Tons Dry/100 Tons Ballasted
5M and 10M Meteorological Sensors
Hull Mounted Oceanographics Sensor
Oceanographic Sensors to a Depth of 500M
Semi-Taut Moored to Depth of 20,000 ft.
Survival Environment
- Current 6.2 KTS.
- Wind 155 KTS.
- Wave Height (Significant) 45 ft.

DESIGN PERFORMANCE CHARACTERISTICS

One Year on Station
Variable Data Collection Times With Interrogation Capabilities
Programmable Via Radio From Shore Communication Station
Any Three of Six Communications Frequency Between 4 and 22 MHz

## METEOROLOGICAL AND OCEANOGRAPHIC SENSORS FOR HCB'S

### EEP MEASUREMENT SPECIFICATIONS

| PARAMETER | RANGE OF MEASUREMENT | MAXIMUM ALLOWABLE ERROR (RMS) [1] | LEVELS (METERS) [3] |
|---|---|---|---|
| **METEOROLOGICAL** | | | |
| Global Radiation | 0 to 2 Langleys/Minute<br>.25 to 4.0 Microns | 0.05 Langleys/Minute | 10 Meters |
| Infra-Red Radiation | 0 to 1 Langleys/Minute<br>4.0 to 40 Microns | 0.05 Langleys/Minute | 10 Meters |
| Precipitation Rate | 0 to 20 Centimeter/Hour | 0.02 Centimeter/Hour or 1 percent | 10 Meters |
| Air Temperature | -10 to 40° Celsius | 0.5° Celsius | 5-10 Meters |
| Air Pressure | 900 to 1100 Millibar | 1.0 Millibar | 5-10 Meters |
| Dew Point | -10 to 40° Celsius | 0.5° Celsius | 5-10 Meters |
| Wind Velocity - N/S | 0 to 80 Meters/Second | 0.5 Meters/Second or 5 percent of value [2] | |
| Wind Velocity - E/W | 0 to 80 Meters/Second | 3 Degrees [2] | 5-10 Meters |
| **OCEANOGRAPHIC** | | | |
| Water Temperature | 0 to 40° Celsius | 0.06° Celsius | 13 Levels Down to 500 Meters |
| Salinity | 20 to 40 Parts Per Thousand (0/00) | 0.03/0/00 | 13 Levels Down to 500 Meters |
| Current Velocity - N/S | 0 to 3.0 Meters/Second | 0.02 or 3 Percent Meters/Second [2] | 13 Levels Down to 500 Meters |
| Current Velocity - E/W | 0 to 3.0 Meters/Second | 10 Degrees [2] | 13 Levels Down to 500 Meters |
| Water Pressure | 0 to 55 Kilogram/Centimeter [2] | 0.5 Kilogram/Centimeter [2] | 13 Levels Down to 500 Meters |
| Sound Speed | 1410 to 1580 Meters/Second | 0.3 Meters/Second | 1 Level Between 0 and 500 Meters |

1. Maximum allowable system errors shown include sensor, ocean platform system, HF radio link and shore communication station errors.

2. Errors are given for magnitude and direction.

3. The 13 levels for all oceanographic parameters except sound speed will be 1, 10, 20, 30, 50, 75, 100, 150, 200, 250, 300, 400, and 500 meters.

TABLE 1.2-1

instrumentation consists of engineering sensors to measure buoy motion, hull and mooring dynamics, one level of meteorological sensors and three levels of oceanographic sensors.

The characteristics of the DKH buoy are shown in Figure 1.2-2; measurement specifications correspond to those for the EEP buoys.

The DKH was deployed adjacent to an EEP buoy (EB-10) approximately 200 miles south of Mobile, Alabama but has now been returned to MTF for retrofit prior to deployment off the West Coast of the United States. Data from these different buoys are now being analyzed to determine the effects of the hull shape.

1.5.3 Limited Capability Buoys (LCB's)

The LCB program was originally conceived to evaluate the potential of relatively small buoys to meet special needs of users. The program resulted in tests of four small buoy configurations. These configurations were intended to measure a few important parameters that define environmental phenomena of interest. Two of these smaller buoys were to be moored; two were designed as drifters, with position locating systems.

The characteristics of the LCB's are shown in Figures 1.2-3 through 1.2-6.

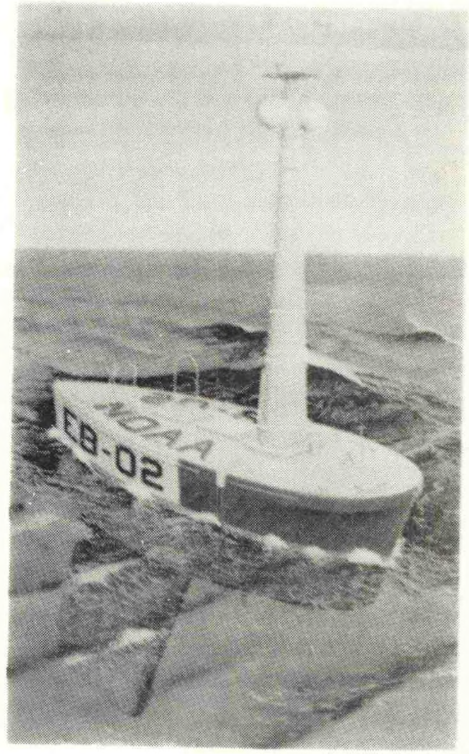
The LCB's have been subjected to a test and evaluation phase, including several deployments in the Gulf of Mexico, drift tests, shallow mooring tests and extensive accelerated reliability testing.

# BUOY FACT SHEET

MFG.: Lockheed Missiles and Space Company

TYPE: DKH/HCB (Deep-Keeled Hull High Capability Buoy)

BUOY CONFIGURATION: Boat-Hull




HULL:

| | | |
|---|---|---|
| Length on Axis | 29 ft. 6 in. | |
| Beam | 9 ft. 7 in. | |
| Draft | | |
| Keel Deployed | | 20 ft. 6 in. |
| Keel Retracted | | 12 ft. 3 in. |
| Mast Height | 27 ft. 3 in. | |
| Displacement | 52,300 lbs. | |

MOORING:

Single Point, Semi-Taut Depths to 20,000

POWER SYSTEM:

Two (2) independent diesel alternator sets
3 KW each
255 days at 1500 watts load

SENSORS:

| | | |
|---|---|---|
| METEOROLOGICAL: | Wind Speed<br>Direction<br>Temperature-Pressure | Precipitation Rate<br>Dew Point<br>Global Radiation |
| OCEANOGRAPHIC: | Current Speed &<br>Direction<br>Temperature<br>Pressure | Salinity<br>Sound Velocity<br>Wave Height |

DATA PROCESSING:

Ruggedized Mil Spec Central Processing Unit and Peripherals with up to 32K of Core

COMMUNICATIONS:

3 Channel, High Frequency Operating From 4 to 22 Mhz

ENVIRONMENT: Current 6.2 KTS
Wind 155 Kts
Wave Height (Significant) 45 ft.

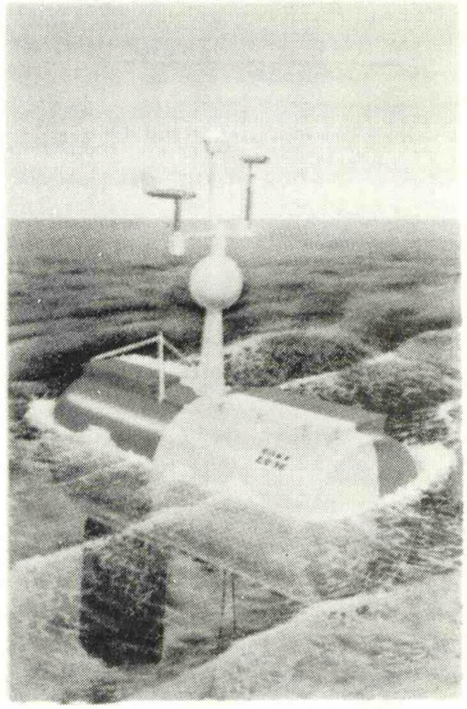
Figure 1.2-2

# BUOY FACT SHEET

MFG: Lockheed Missiles and Space Company

TYPE: MLCB (Moored Limited Capability Buoy)

BUOY CONFIGURATION: Horizontal Cylinder With Keel and Mast



HULL:

| | |
|---|---|
| Length | 11 ft. 3 in. |
| Diameter | 4 ft. 6 in. |
| Draft | 7 ft. 5 in. |
| Mast Height Above Waterline | 11 ft. 7 in. |
| Displacement | 5600 lbs. |

MOORING:

Taut Mooring System Depths to 24,000 ft.
Slack Mooring Utilized for Shallow Applications

POWER SYSTEM:

Zinc-Air Primary Batteries
6 Months Duration
36 KWH

SENSORS: METEOROLOGICAL: Wind Speed & Direction
Temperature
Pressure

OCEANOGRAPHIC: Temperatures to 600 ft.

DATA PROCESSING:

- Hardwired system.
- Parameters sampled ten minutes out of every hour.
- Synoptic reports every six hours.
- Interrogation capability.

COMMUNICATIONS:

3 Channel, High Frequency 4 to 22 Mhz Direct to Shore Station Or UHF To Satellite

ENVIRONMENT: Current 4.0 KTS.
Wind 100 KTS.
Wave Height 45 Ft.
Ice 5 In. On Exposed Surfaces

AUXILIARY SYSTEMS: Navigation Warning Light
Radar Reflector

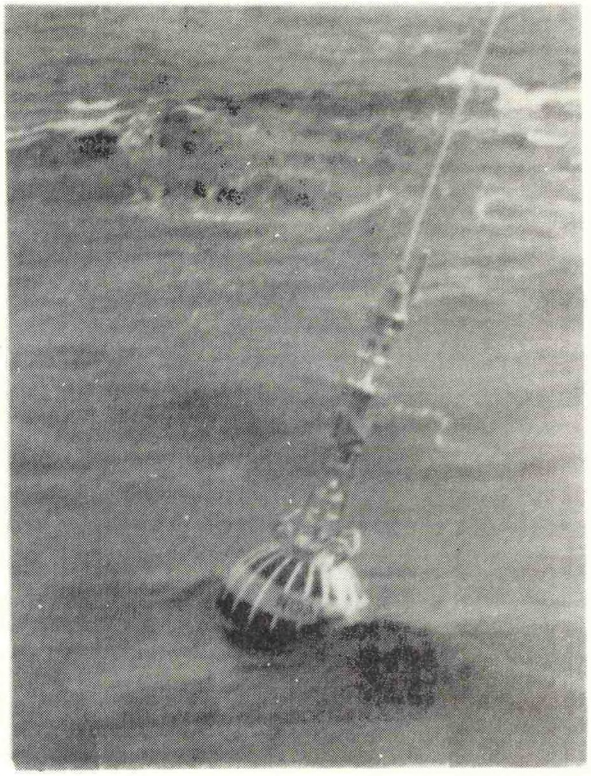
Figure 1.2-3

# BUOY FACT SHEET

MFG: General Electric

TYPE: MLCB (Moored Limited Capability Buoy)

BUOY CONFIGURATION: "LIGHT BULB"-Sphere Bolted to Cylinder-Aluminum Constructi(



HULL:

| | |
|---|---|
| Diameter | 46 Inch Sphere<br>25 Inch Cylinder<br>(Below Sphere) |
| Weight | 1600 pounds |
| Height | 32 feet (includes antenna) |

MOORING:

- Two Stage With Subsurface Float
- Lower Section Taut Moored
- Mooring line data line above sub-surface float, semi-taut

POWER SYSTEM:

Alkaline Manganese Dioxide Batteries
4 months @ 7.5 KWH Minimum

SENSORS:

| | | |
|---|---|---|
| | METEOROLOGICAL: | Air Pressure<br>Air Temperature<br>Wind Speed & Direction |
| | OCEANOGRAPHIC: | Water Pressure (at 200 meters)<br>Water Temperature (2 to 200 meters depth) |

DATA PROCESSING:

- Hardwired system.
- Parameters sampled ten minutes out of every hour.
- Synoptic reports every six hours.
- Interrogation capability.

COMMUNICATIONS:

2 Channel, High Frequency 4 to 12 MHz Direct to Shore Station Or UHF To Satellite

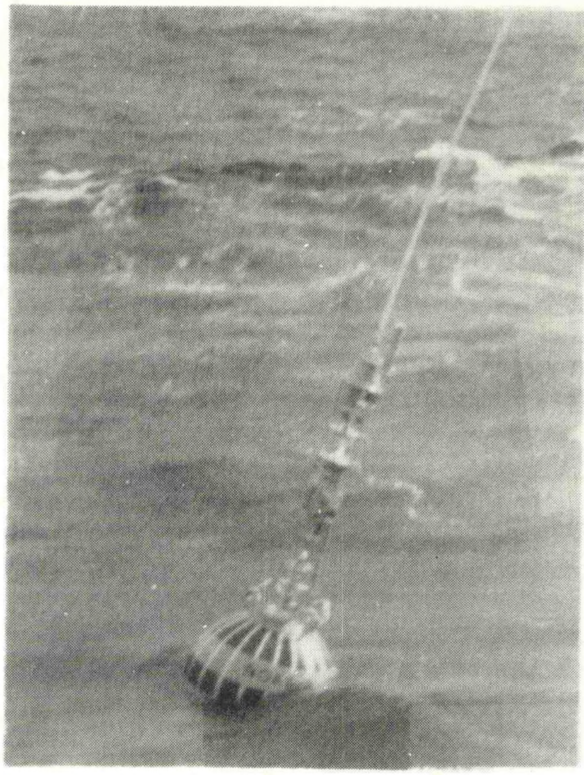
ENVIRONMENT: Current 4.0 KTS. Wind 100 KTS. Wave Height 45 Ft. Ice 5 In. On Exposed Surfaces

AUXILIARY SYSTEMS: Navigation Warning Light
Radar Reflector

Figure 1.2-4

## BUOY FACT SHEET

MFG: General Electric



TYPE: DLCB (Drifting Limited Capability Buoy)

BUOY CONFIGURATION: "LIGHT BULB"-Sphere Bolted to Cylinder-Aluminum Construction

HULL:

| | |
|---|---|
| Diameter | 46 Inch Sphere<br>25 Inch Cylinder (Below Sphere) |
| Weight | 1600 pounds |
| Height | 32 feet (includes antenna) |

POWER SYSTEM:

Alkaline Manganese Dioxide Batteries
4 months @ 7.5 KWH Minimum

SENSORS: METEOROLOGICAL: Air Pressure
Air Temperature
Wind Speed & Direction

OCEANOGRAPHIC: Water Temperature

DATA PROCESSING:

- Hardwired system.
- Parameters sampled ten minutes out of every hour.
- Synoptic reports every six hours.
- Interrogation capability.

COMMUNICATIONS:

2 Channel, High Frequency 4 to 12 MHz Direct to Shore Station Or UHF To Satellite

ENVIRONMENT: Current 4.0 KTS.
Wind 100 KTS.
Wave Height 45 Ft.
Ice 5 In. On Exposed Surfaces

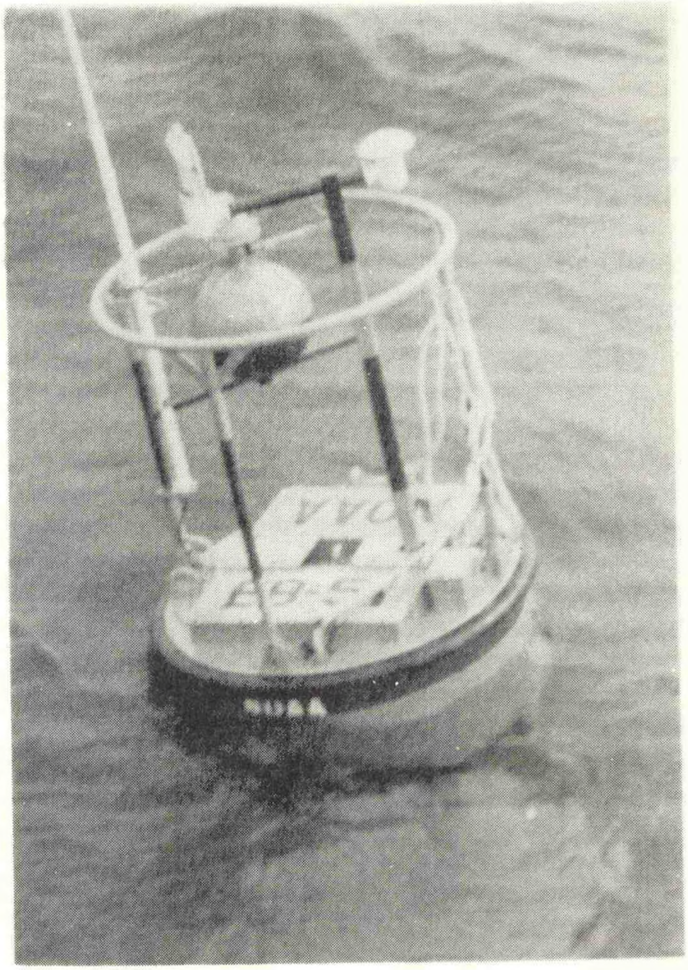
POSITION LOCATION SYSTEM:

OMEGA phase difference hyperbolic radio navigation system.
NAVY NAVIGATION SATELLITE SYSTEM

AUXILIARY SYSTEMS: Navigation Warning Light
Radar Reflector

Figure 1.2-5

## BUOY FACT SHEET



MFG: MAGNAVOX

TYPE: DLCB (Drifting Limited Capability Buoy)

BUOY CONFIGURATION: Hatbox With Telescoping Ballast

HULL:

Diameter 66 in.

Height 116 in. (Pre-Deployment, Including Superstructure)

Height 436-5/8 in. (Deployed, including antenna-railing to ballast 20 ft.)

POWER SYSTEM:

Carbon Zinc Battery Cells With Nickel-Cadmium Peak Load Secondary Batteries
6 Months Duration

SENSORS: METEOROLOGICAL:

Air Temperature
Air Pressure
Wind Speed & Direction

OCEANOGRAPHIC: Water Temperature

DATA PROCESSING:

- Hardwired system.
- Parameters sampled ten minutes out of every hour.
- Synoptic reports every six hours.
- Interrogation capability.

COMMUNICATIONS:

3 Channel, High Frequency, Frequency "HOPPING" Scheme Direct to Shore Station Or UHF To Satellite

ENVIRONMENT: Current 4.0 KTS.
Wind 100 KTS.
Wave Height 45 Ft.
Ice 5 In. On Exposed Surfaces

POSITION LOCATION SYSTEM: OMEGA phase difference hyperbolic radio navigation system.
NAVY NAVIGATION SATELLITE SYSTEM

AUXILIARY SYSTEMS: Navigation Warning Light
Radar Reflector

Figure 1.2-6

## 2.0 EXPERIENCED RELIABILITY-INTRODUCTION

The purpose of this section is the presentation of information about the reliability experience gained by NDBO in the field of environmental measuring and reporting buoys. Experience has been gained as the result of two modes of operations: 1) Deployed test operation; 2) Non-deployed accelerated test operation. Experience information is presented in the following sections on the EEP deployed mode of operation and the LCB deployed mode of operation and the LCB deployed and non-deployed accelerated test modes of operation.

Data used were obtained mainly from the Buoy Status Reports and the Failure Reports.

### 2.1 HCB HISTORIES

A history of the operation of the HCB's as impacted by catastrophic failures is illustrated by a time plot of the up and down times of the buoys. A catastrophic failure in this context refers to any buoy associated problem which results in the failure to receive any usable data from the buoy. Figures 2-1 through 2-5 are such plots for EB-01, 02, 03, 10 and 12 respectively. The codes on the figures refer to the event and status information obtained from Operations reports.

EB-01, in the time interval October 7, 1972 to September 15, 1973, experienced six (6) catastrophic failures. The mean operating time between these failures is thirty-one days.

EB-02, in the time interval April 4, 1973 to September 15, 1973, experienced four (4) catastrophic failures. The mean operating time between these failures is twenty-eight days.

EB-03, in the time interval August 28, 1972 to September 15, 1973, experienced six (6) catastrophic failures. The mean operating time between these failures is thirty days.

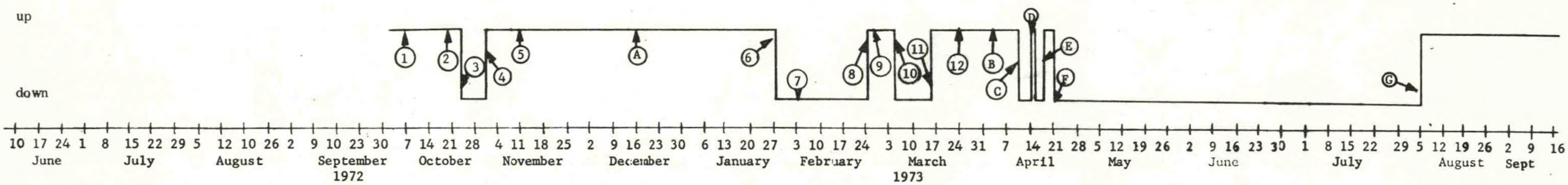
EB-10 in the time interval June 16, 1972 to September 15, 1973, experienced ten (10) catastrophic failures. The mean operating time between failures is 30.4 days.

EB-12 had reliability improvement changes incorporated after acceptance and prior to deployment on 22 June. In the interval April 6 to May 27, 1973, testing at MTF was interrupted to make these changes. This accounts for the downtimes of Figure 2-5. Bit error rates (BER) on board the buoy started to contaminate reports early in August. On September 9, the BER became too high to allow automatic data reduction at the Shore Communication Station.

In addition to catastrophic buoy failures, there are a number of reasons data is not received and reported to NWS. Among these reasons are:

1) Buoy degradation failures
2) Ionospheric perturbation
3) SCS equipment failure or error
4) Operator error
5) SCS to NWS communication link failure

Figure 2-6 indicates the composite percent of data from deployed buoys which actually was sent to NWS. This results from both catastrophic and non-catastrophic failures. The catastrophic failures are also indicated on the lower part of this Figure.




EB-01

1) Buoy Deployed - Hook Dropped 2100 Z 10-7-72
- Tensiometer A Intermittent from time of Anchor Drop
- Current Sensor not Activated

2) Tensiometer B apparently failed FR____ 10/20/72
- Accelerometer 7H Failed FR 1051 10/18/72

3) No Response from buoy after 0000Z 10/23/72
EB-01 Visited by USCGC MADRONA
- Accel. Ckt. BRKR Found Tripped - Accel. Removed
- Current Meter Ckt. Brkr. turned on

4) Buoy Restored on 2100 Z 10/31/72
- Replaced Inverter Power Supply - No FR
- A Stathem Accelerometer was installed

5) 5 Meter Met Data Intermittent
- Compass #1 became erratic FR 1053

6) Lost all Met Data 0900 Z 1/29/73

7) EB-01 Stopped Xmitting all Data on 2/3/73 1200 Z FR 1058

8) Buoy Restored to Operations 2/25/73
- Replaced CPU - 1 & 2 and Memory Cards
- Installed ROM

9) Engine A "No Start" in event word 1 @ 0600 Z 2/26/73 Crankcase Temp. Zeros FR 1059

10) +10 VDC Ref. Voltage went to 15.0VDC
- 2100 Z Synoptic Data Could not be retrieved
- A/D Data retrieved @ 2120 Z - FR 1059

11) Buoy Operation Restored 3/14/73
- Complete Engine Overhaul - See FR 1059
- Removed Defective Current Sensor

12) Compass #2 FLUX GATE Failed FR 1076
S/N 3H Output erratic

A) Current Sensor Failed 12/15/72 FR 1061

B) Data Indicates Secondary O & I Lite Failure FR________

C) Buoy Failed to Respond to Shore Commands 0600 Z 4/10/73
FR 1078 HFC Failed

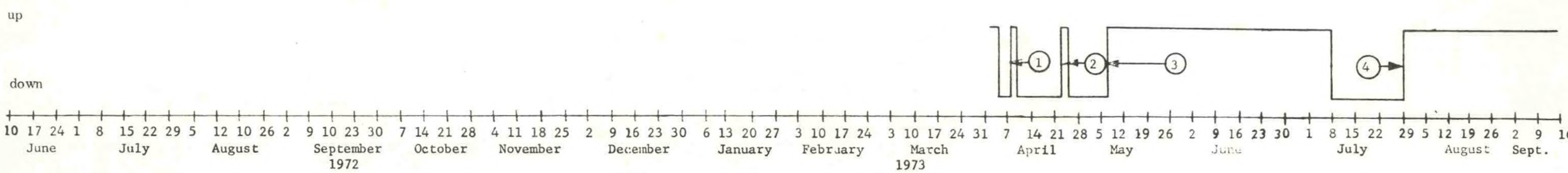
D) Buoy Restored to Operation 4/13/73 1100 EST
- Cleaned HFC Connector J7 - Moisture Contaminated
Sprayed w/water Disp. Aerosol & Packed W/OC-4
- Buoy Failed Again @ 1400 EST FR 1079

E) Buoy Restored to Operation 4/17/73 2300 Est
- Reloaded Program & Adjusted Computer Voltages
- Replaced Compass (FLUX GATE) 3H with 11H

F) Buoy Failed to Respond to Shore Command as of 0900 Z 4/19/73 FR 1082

G) DPS- Time of Year Clock replaced

FIGURE 2-1 - EB-01 HISTORY OF CATASTROPHIC FAILURE - REPAIR CYCLES




EB-02

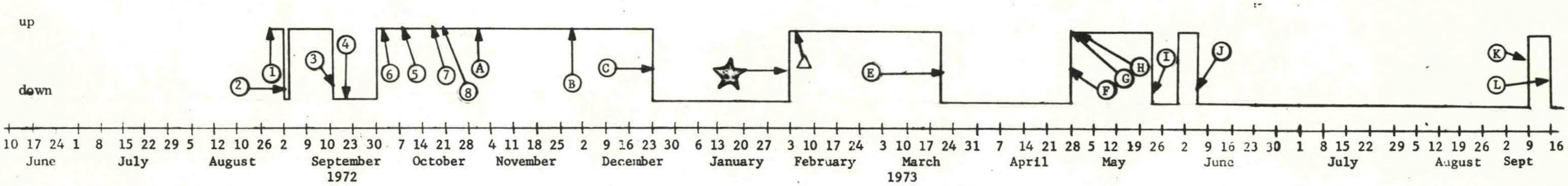
1) Fuel System FR 1635

2) Fuel System FR 1638

3) Fuel System FR 1643

4) Fuel System No FR yet

FIGURE 2-2 - EB-02 HISTORY OF CATASTROPHIC FAILURE - REPAIR CYCLES




EB-03

1) EB-03 DD250 28 Aug. 1972

2) DPS Failure - T of Y Clock/Cable FR 1010

3) Mooring Line Parted - 1st Attempt @ Mooring FR 1021
   - Battery Charger Failed FR 1011

4) Buoy Taken under Tow - Back to Kodiak
   - O & I Lights Failed FR 1029

5) Buoy Deployed 2nd Time - Anchor Dropped 0547 Z 7 October
   - Tensiometer chan "A" Failed FR 1030

6) Accelerometer Failed S/N 3H FR 1026 Replacement S/N 1 H Failed Upon Installation FR 1027 (No Spare)
   - Repaired O & I Light Failure
   - GD Air Temperature 2 - 6° Low FR 1031

7) Eng/Gen #1 Oil Temperature Failed FR 1032

8) O & I Lights Failed FR 1033
   Restored on 2/3/73

A) FLUX-GATE Compass S/N 1H Failed FR 1042

B) +10 Volt Reference Supply Failed FR 1048
   - Readings on most A to D Data Channels Bad
   - Met Data not affected

C) DPS Failure - FR 1052
   - Last Data Frame 12/23/72
   - Lost all Communications 1/2/73

★ Operation Restored 2/3/73 - New Computer Installed & ROM Installed

△ All WEC 5 Meter Met Data lost on 2/5/73

△ Heave Output From Acceler. Bad 2/4/73 FR 1063

D) Engine #1 Oil Pressure Erratic - Failure ?

E) Data Proc. System Failed FR 1062 2200 Z 3/20/73

F) Replaced Digital Computer with S/N 007 (New Reliability Mods)
   - Replaced Power Control Drwr w/new MOP's
   - Installed 2540401-006 Wave Height Processor
   - Installed New - Oil Accelerometer
   - Installed New ROM & T of Y Clock Assemblies

G) Engine #1 Failed 4/29/73 FR 1083 - Noise appears to fail either engine when primary

H) DPS Failure - Program Bombed 2300 Z 5/2/73
   FR _____ - Restored to Operation via SCS by Reprogramming Computer - Appears to be Power Control Problem.

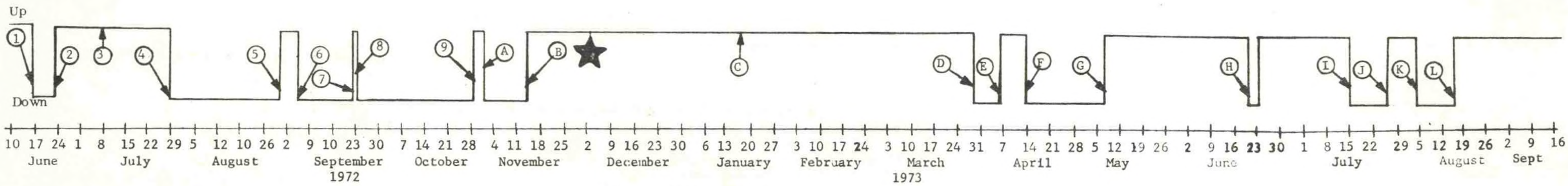
I) Power Control FR 1083

J) DPS FR 1319

K) DPS replaced
   Suspect Shipment Damage

L) DPS failed - Suspect shipping damage

FIGURE 2-3 - EB-03 HISTORY OF CATASTROPHIC FAILURE - REPAIR CYCLES




EB-10

DEPLOYED 16 JUNE 1972

1) DPS failed 2300Z 6/16/72
+5 Volt Reg. FR 1000

2) Operation restored 6/23/72
- Tensiometer failed FR 1002
- Paint peeling FR 1001

3) Gyro-stab Compass H5 failed
7/10/72 FR 1008

4) DPS failed 7/28/72 1100Z
C31 out of Tol. in Comm. & cont. FR 1017

5) Operation restored 8/30/72
- Flux GATE Compass 4H installed

6) DPS failure 9/04/72 FR 1022
Data Bit 1 always "1" E36 in C&C

7) Restored to Operation 9/20/72

8) Data Processing System failed 9/21/72
No response from Buoy FR 1036, 1037
& 1041

9) Operation restored 10/29/72 1300
- Replaced computer and installed complete new set P.C. Cards
- Replaced Engine Controller Board Assy FR 1038

A) OPS Failure 11/01/72 1800Z FR 1047
T of Y Clock Shifted - Time & Synoptic Specs
Reset by Miami SCS - Operation Restored 11/13/72 1700Z

B) Engine Controller Failure Noticed After Buoy Restored to Operation - Intermittent Engine Exercises FR 1070
Occurs approximately every 291 Hours.

★ - Intermittent Flood Indications Begins

C) Data Ceased to be Recorded on Mag Tape 1/17/73 -
Tape Units Full FR 1055
- Flood Indication Still Intermittent
- Flux GATE Compass Failed FR 1056

D) DPS Failure 1500 Z 3/28/73 FR 1069

E) Operation Restored 4/6/73 1700 Z
- DPS Computer and new set of BDS.
- ROM Installed
- Spare Compass Failed Upon Installation because of Faulty Connector - See FR 1056
- Engine #2 would not shut down. #1 would not start
Replaced Fuel Starvation Valves FR 1071
- Replaced Leaky Engine #2 Lube Oil Hose FR 1072
- Installed new Acceler. - No Failure FR 1073
- Installed New Power Control - No Fail FR 1074
- K35 Failed in Comm/Cont Assembly FR 1077
- Engine Cont. Disconnected From DPS - Random noise, etc.

F) Buoy Ceased to Respond to any Shore Commands 4/15/73 1200 Z FR 1081

G) Repair DPS 4/6

H) DPS No FR

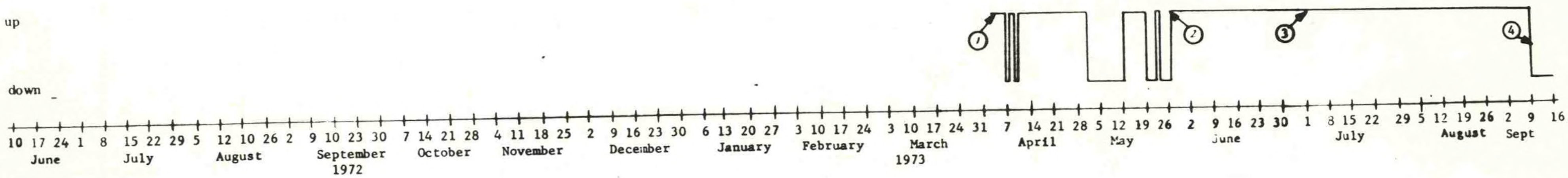
I) Engine Failures No FR

J) Engines Repaired

K) DPS mfg problem

L) DPS repaired

FIGURE 2-4 - EB-10 HISTORY OF CATASTROPHIC FAILURE - REPAIR CYCLES




EB-12

1) - 2) - Test Period

3) - Deployed 6/29

4) - BER too high

FIGURE 2-5. - EB-12 HISTORY OF REPORTING AND NON-REPORTING PERIODS

* See Text for explanation of down periods

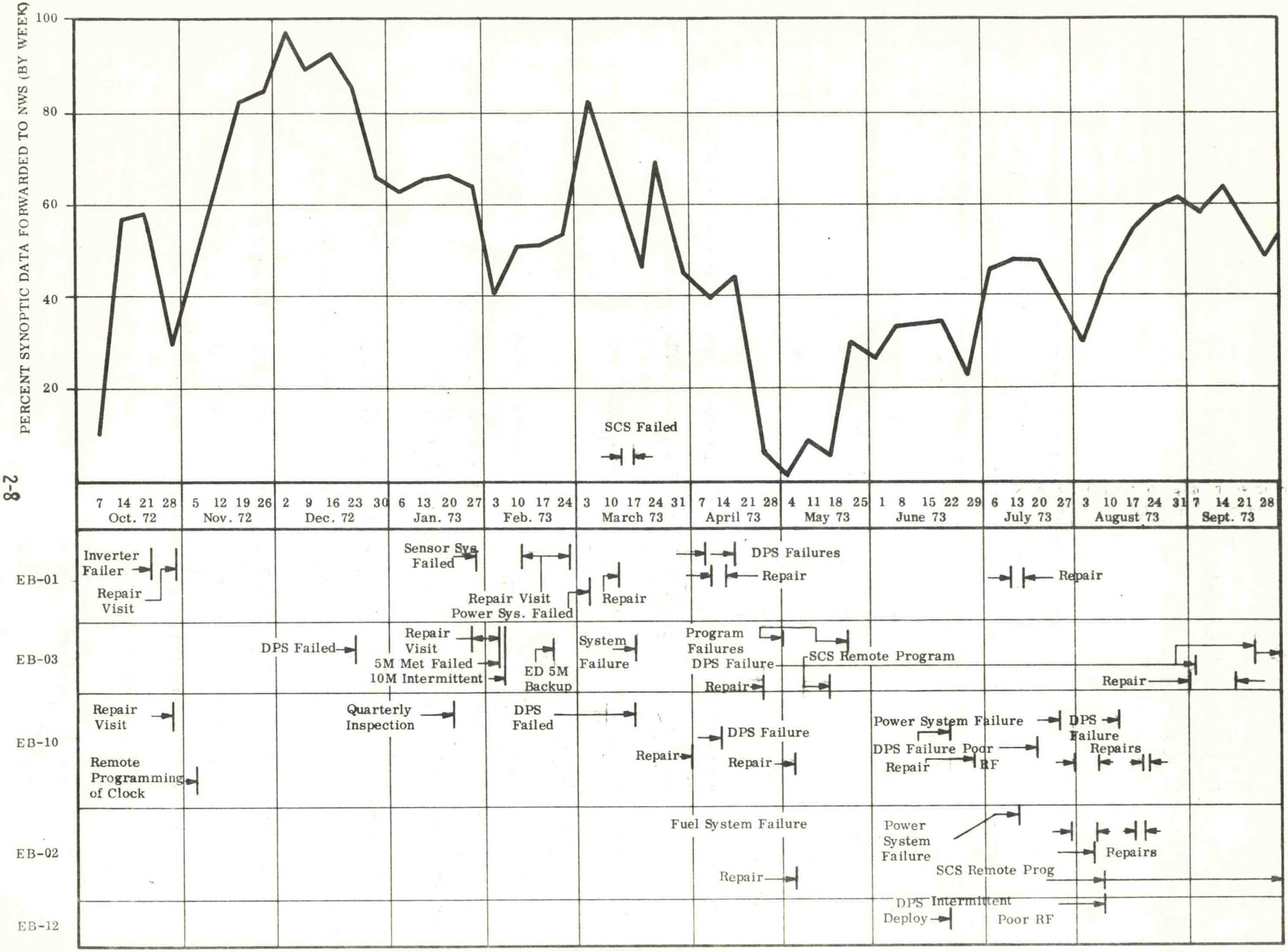



Figure 2-6. OPS Performance

The subsystem hardware failures experienced by EEP buoys which have been catastrophic are tabulated in Figure 2-7.

| | EB-01 | EB-02 | EB-03 | EB-10 |
|---|---|---|---|---|
| Mooring | | | 1 | |
| DPS | 3 | | 5 | 9 |
| HFC | 1 | | | |
| Sensor | 0 | | | |
| Power | 2* | 4 | 1 | 1 |

FIGURE 2-7. - TABULATION OF HCB CATASTROPHIC FAILURES

EB-12 had its first catastrophic failure early in September; a noise problem corrected by a design change.

A summary of both catastrophic and non-catastrophic Failure Reports written against the HCB subsystem covering the post acceptance period is tabulated in Figure 2-8. Some of these were written prior to deployment.

The Data Processing and Power Systems are serial system. The total number of failures for these two systems indicate areas requiring improvement.

The sensor system also has a large number of Failure Reports written against it. A number of these reports were not failures but represented replacements for testing and engineering chages authorized by NDBO. A more detailed discussion of sensor performance is included in another part of this document.

* No FR written on one failure

| | 01 | 02 | 03 | 10 | 12 | Bench | Total |
|---|---|---|---|---|---|---|---|
| Data Processing System | 4 | | 6 | 15 | 2 | 9 | 35 |
| Hull and Superstructure | | | 1 | 4 | 1 | | 5 |
| Mooring System | | | 3 | | | | 3 |
| Power System | 1 | 12 | 6 | 6 | 2 | 1 | 29 |
| Communication System | 1 | 1 | | | | | 2 |
| Sensor System | 16 | 15 | 15 | 6 | | 11 | 63 |
| Auxiliary System | | 3 | 3 | | | | 6 |
| Software | | 2 | 1 | | | | 3 |

FIGURE 2-8. - A TABULATION OF POST ACCEPTANCE FR's FOR HCB's BY SUBSYSTEM

It must be emphasized that a list in Figure 2-8 also contains Failure Reports which reflect problems which occurred because of unskilled handling, design inadequacies and software problems. In addition non serious failures are included. For example, the Power System Failure Reports include gage failures faulty fuel plumbing, failed sensors, and battery charger failures. None of these are failures of the diesel generator.

Figure 2-8 is presented to indicate the subsystem problems which required varying degrees of attention even though some of the problems could be considered minor or nuisance problems. In fact, only one out of six of the Failure Reports represents a catastrophic failure.

## 2.2 LCB HISTORIES

The LCB's have much shorter deployed histories than the HCB's. Initially there were to be five drifting and five moored buoys in the test program. As the program developed some of the drifters were outfitted with a mooring system (tether) and additional data (more than just a short drift test) was obtained.

### 2.2.1 MOORED LCB HISTORIES

Figure 2-9 depicts the up-down cycles for the moored LCB's. This includes the effect of the communications link and the SCS. A buoy is considered down if no useful data is recorded at the SCS.

EB-31 operated 75 days and 55% of the expected data was received. Subsequently, the mooring parted and this buoy was lost.

EB-32 operated about 113 days and 44% of the expected data was received.

EB-36 operated 9 days and 75% of the expected data was received.

EB-37 was launched in June after about two weeks its mooring parted and the buoy began to drift. Seventy-five (75%) of the expected data was received during the moored time.

EB-38 was never deployed. It has been subjected to accelerated testing as have other MLCB's upon retrieval.

### 2.2.2 DRIFTING LCB HISTORIES

The histories of the drifting LCB's are made up of four (4) activities as follows:

1. Drift Tests
2. Moored Tests
3. AOML (modified drift tests)
4. Accelerated Testing

Not all of the DLCB's were tested in each of these four tests.

EB-51 was subjected to a drift test from January 21 to January 27, 1973. After return to MTF it was subjected to accelerated testing. Lat in May it was modified

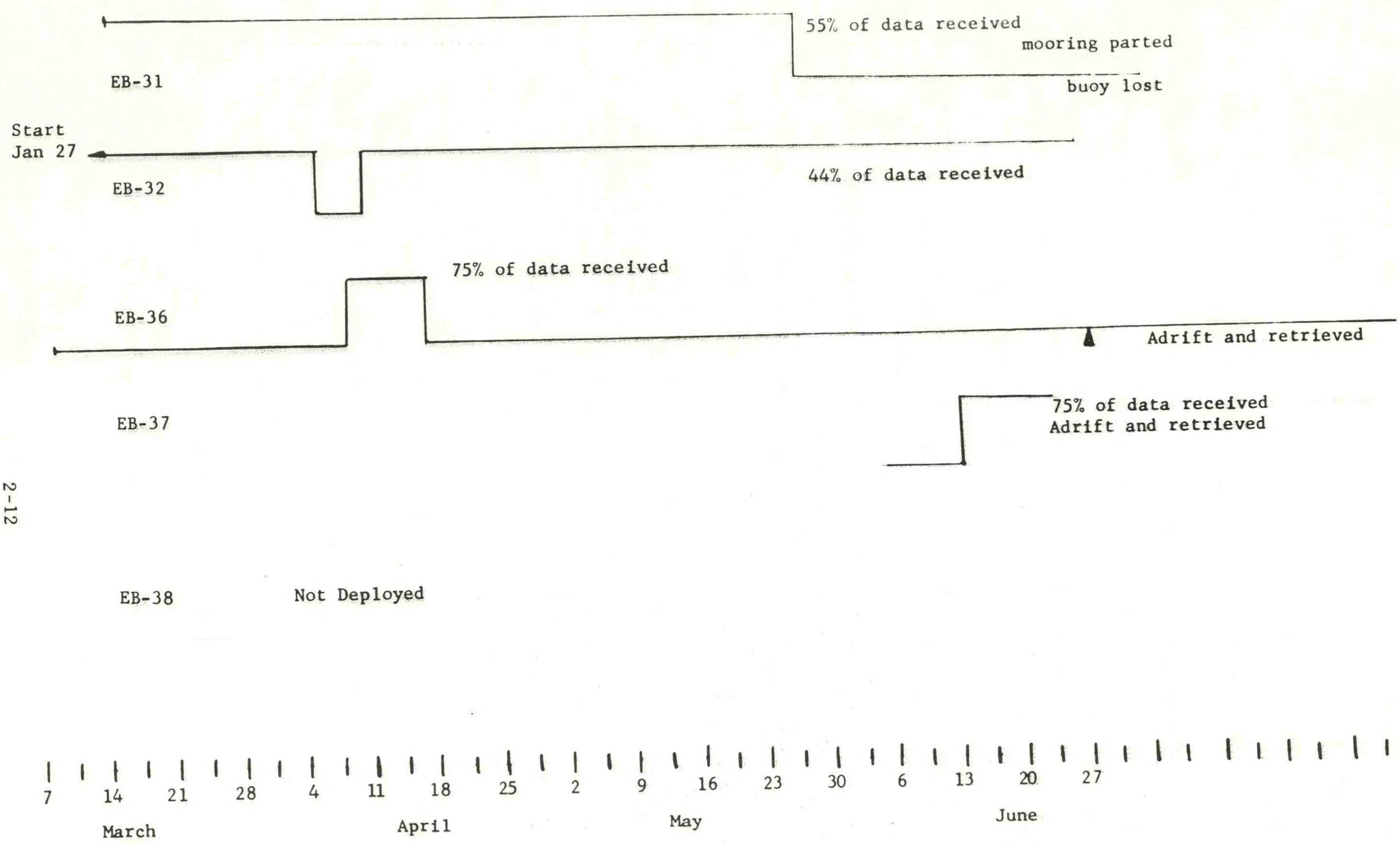



FIGURE 2-9.- DEPLOYED HISTORY OF MLCB's

(addition of drag device) to participate in the AOML tests. After retrieval from the AOML test accelerated testing resumed.

EB-52 was shallow moored on February 22, 1973 and reported data until April 20, 1973, a total of 57 days. Average return during deployment was 79%. After retrieval on June 11, it was returned to MTF, carefully examined and refurbished for accelerated testing.

EB-53 was shallow moored on March 7, 1973 and retrieval by a fishing boat was effected on April 1, after the mooring line parted. Sixty percent of the expected data was received during that period. After refurbishment accelerated testing began. In late May the buoy was modified to participate in the AOML tests. After the AOML tests from June 8, 1973 to June 15, 1973 this buoy was returned to accelerated testing.

EB-61 was shallow moored February 21, 1973 and operated until May 18, a total of 87 days. During this period 63% of expected data was received by the SCS. This buoy was retrieved on June 11, returned to MTF and has been subjected to temperature cycling testing. After refurbishment accelerated testing began.

EB-62 was drift tested along with EB-51 from January 21, 1973 until January 27, 1973. EB-62 replaced EB-32 and operated for two days, reporting 59% of the expected data. EB-32 was returned and prepared for the AOML test. After return to MTBF it was refurbished and put into the accelerated testing program.

## 2.3 TEST RESULTS

### 2.3.1 DRIFTING TEST

Position fixing data received from the deployed drifting buoys were compared to the position data derived by the tracking ship. The conclusion drawn from the results of the test are that at the current development of the systems, the NNSS is preferable to OMEGA. Difficulty in maintaining lane counts using the OMEGA SYSTEM and the marginal ability to establish a position in a weak signal environment are contributing factors to the conclusion.

### 2.3.2 MOORED TESTS

Four of the LCB's, EB-31, 36, 37 and 53 parted mooring lines and drifted. EB-31 has not been retrieved and is currently missing. EB-36 washed ashore near Palm Beach, Florida and Eb-37 near Galveston, Texas. EB-53 was towed into Pascagoula, Mississippi by a fishing boat. EB-53 was not designed originally as a moored buoy and the mooring system should be considered as a NDBO designed tether. There is also some doubt about the nature of the EB-53 tether failure. It is possible that the line was cut accidentally. Figure 2-11 tabulates reliability experience during the moored tests. Time of deployment covers the time span useful data was received at the SCS.

### 2.3.3 AOML TEST

EB-51, EB-53 and EB-62 participated in the AOML test from June 8 to June 15, 1973. Unfortunately, the EB-62 antenna was damaged during deployment and EB-51 and EB-53 OMEGA systems did not operate successfully. Data was obtained on buoy drift patterns by the PFS aboard the test ship, Virginia Key.

### 2.3.4 ACCELERATED TESTING

Figure 2-10 summarizes the time each buoy type was on accelerated test

| SUBSYSTEM | MFG | TEST DAYS | EQUIV. DAYS | # FAIL | 75% CON. $MTBF_{LL}$ (1) |
|---|---|---|---|---|---|
| COMM (Xmitter) | G | 162 | 1944 | 1 | 722 |
| | L | 164 | 2952 | 4 | 496* |
| | M | 297 | 2160 | 1 | 802 |
| DPS | G | 162 | 2754 | 2 | 703 |
| | L | 164 | 3132 | 3 | 613 |
| | M | 297 | 2014 | 3 | 394 |
| SENSOR | G | 162 | 162 | 0 | 120 |
| | L | 136 | 272 | 0 | 196 |
| | M | 244 | 488 | 1 | 181 |
| POWER | G | 162 | 486 | 0 | 350 |
| | L | 164 | 707 | 0 | 510 |
| | M | 297 | 939 | 0 | 677 |

FIGURE 2-10 - ACCELERATED TESTING SUMMARY

(1) $MTBF_{LL}$ in days, one sided confidence interval, based on fixed time test termination

* Three failures were in parallel redundant paths.

G - GE

L - Lockheed

M - Magnavox

and the equivalent time for each subsystem. The equivalent time is based on the powered time of each subsystem used in an eight times a day synoptic reporting mode requiring one transmission on one frequency for each report and data collection once per hour.

Figure 2-11 is a tabulation of the deployed experience for each buoy subsystem. Figure 2-12 combines the deployed data and accelerated test data to include the results of all the post acceptance experience with LCB's.

## 2.4 DISCUSSION OF LCB TEST RESULTS

The following results are based on the combined deployed and accelerated testing results. Evaluation is based on MTBF for each subsystem.

### 2.4.1 COMMUNICATIONS

The Magnavox communications subsystem is the best communications subsystem among the three types tested.

### 2.4.2 DATA PROCESSING SYSTEM

The results of testing on Data Processing Subsystems (three types tested) indicated that the General Electric DPS exhibited the best reliability characteristics.

### 2.4.3 SENSOR SUBSYSTEM

Magnavox sensor subsystems exhibited the best reliability among those tested. Lockheed's sensor subsystem has had a relatively large number of failures during a short exposure period.

### 2.4.4 POWER SYSTEM

The GE power system proved best in this category. It has experienced no failures. Lockheed after a design change has experienced no power failures.

| SUBSYSTEM | MFG. | TEST DAYS | EQUIV. DAYS | # FAIL | 75% CON. $MTBF_{LL}$ (1) |
|---|---|---|---|---|---|
| COMM. (XMITER) | G | 280 | 392 | 1 | 145 |
| | L | 21 | 31 | 0 | 22.4 |
| | M | 83 | 70 | 0 | 50.6 |
| DPS | G | 280 | 363 | 0 | 262 |
| | L | 21 | 35 | 0 | 25.3 |
| | M | 83 | 105 | 0 | 38 |
| SENSOR | G | 280 | 280 | 1 | 104 |
| | L | 21 | 21 | 5 | 2.8 |
| | M | 83 | 83 | 0 | 60.0 |
| POWER | G | 280 | 545 | 0 | 393 |
| | L | 21 | 23 | 0 | 16.6 |
| | M | 83 | 118 | 1 | 44 |
| HULL & SS | G | 280 | 280 | 2 | 71.5 |
| | L | 21 | 21 | 0 | 15.2 |
| | M | 83 | 83 | 0 | 60.0 |
| MOORING | G | 280 | 280 | 1 | 104 |
| | L | 21 | 21 | 2 | 5.4 |
| | M | 83 | 83 | 1 | 31 |

FIGURE 2-11 - DEPLOYED TESTING SUMMARY

(1) $MTBF_{LL}$ in days, one sided confidence interval, based on fixed time test termination

G - GE
L - Lockheed
M - Magnavox

| SUBSYSTEM | MFG. | EQUIV. DAYS | # FAIL | 75% CON. $MTBF_{LL}$ (1) |
|---|---|---|---|---|
| COMM. (XMITER) | G | 2336 | 2 | 596 |
| | L | 2983 | 4 | 501* |
| | M | 2230 | 1 | 828 |
| DPS | G | 3117 | 2 | 795 |
| | L | 3167 | 3 | 620 |
| | M | 2119 | 3 | 415 |
| SENSOR | G | 458 | 1 | 170 |
| | L | 293 | 5 | 40 |
| | M | 571 | 1 | 212 |
| POWER | G | 1031 | 0 | 744 |
| | L | 730 | 0 | 527 |
| | M | 1057 | 1 | 393 |
| HULL & SS | G | 280 | 2 | 71.5 |
| | L | 21 | 0 | 15.2 |
| | M | 83 | 0 | 60.0 |
| MOORING | G | 280 | 1 | 104 |
| | L | 21 | 2 | 5.4 |
| | M | 83 | 1 | 31 |

FIGURE 2-12 - COMBINED ACCELERATED AND DEPLOYED SUMMARY

(1) $MTBF_{LL}$ in days, one sided confidence interval, based on fixed time test termination.

* Three failures were in parallel redundant paths.

G - GE

L - Lockheed

M - Magnavox

2.4.5 HULL AND SS

This includes the Navigation Light. Magnavox, with a shorter exposure than GE, has experienced no failures. However, GE emerges with a 71.5 day MTBF.... 11.5 days longer than Magnavox.

2.4.6 MOORING

GE with the longest exposure among those tested is better by a factor of three over the next highest, Magnavox. However, it must be remembered that the Magnavox mooring system was an add on thether system not in the original design. Lockheed (temporarily) lost both of its deployed buoys as the result of mooring failures.

## 3.0 SYSTEM LOGISTIC SUPPORT

### 3.1 At-Sea Operations

Over the past fifteen months of NDBO deployed buoy operations, a variety of Coast Guard Cutters have been utilized for transporting, deploying, maintaining, and recovering buoys from various locations in the oceans surrounding the United States (See Table 3.1-1). In most instances, these operations were conducted successfully the first time with each buoy. This was due, in part, to the planning and discipline imposed by the definition of all mission aspects through a document called Field Test Instruction, prepared by NDBO prior to the mission with the help of Contractors involved in the mission. Experience gained at sea with the unique characteristics of each type of buoy provided for improved performance in subsequent operations. It is hoped that this background of experience can be utilized in the development of new buoys to improve the efficiency of the various buoy operations and overall system reliability.

The following discussions of at-sea operations touch upon many aspects of hulls, moorings, and buoy subsystems. More detailed discussions of these appear in Section 4 of this document.

#### 3.1.1 Transport Operations

The EEP disc hulls have been towed over long distances at speeds up to ten knots with the speed limited by the tow line tension rather than by buoy dynamics. During these tows, the buoy was either unballasted or ballasted with a slightly bow up attitude, and the length of the tow has varied from 500 to 1500 feet with no significant change in characteristics.

The experience with the DKH buoy has been limited to the one trip from Gulfport to its deployment site. During this tow, speeds up to six knots were achieved with satisfactory performance. Beyond that speed, the buoy commenced to roll and yaw.

TABLE 3.1-1

NDBO AT-SEA OPERATIONS SUMMARY

JUNE 14, 1972 TO JULY 31, 1973

| Agency | Ship Days | No. Of Ships |
|---|---|---|
| 5th Coast Guard District | 36 | 5 |
| 8th Coast Guard District | 121 | 3 |
| 13th Coast Guard District | 12 | 1 |
| 17th Coast Guard District | 18 | 2 |
| NOAA AOML | 11 | 1 |
| University of Miami | 11 | 2 |
| Total Coast Guard | 187 | 11 |
| Total | 209 | 13 |

TABLE 3.1-1 CONTINUED

NDBO AT SEA OPERATIONS

| BUOY | ACTIVITY | SUPPORT SHIP | TRIP DATES (INC.) | REMARKS |
|---|---|---|---|---|
| EB-10 | Deploy | ACUSHNET | June 14 - 17, 1972 | |
| EB-10 | Repair | ACUSHNET | June 22 - 26, 1972 | DPS Failure |
| EB-10 | Data Quality | ACUSHNET | July 9 - 12, 1972 | Sensor System |
| EB-03 | Deploy | YOCONA | September 4 - 15, 1972 | Mooring Failure |
| EB-10 | Repair | ACUSHNET | August 29 - Sept.1, 1972 | DPS Failure |
| EB-10 | Repair | ACUSHNET | September 18 - 22, 1972 | DPS Failure |
| EB-03 | Redeploy | CITRUS | October 3 - 8, 1972 | |
| EB-01 | Deploy | CHEROKEE | October 4 - 8, 1972 | |
| EB-01 | Ocean Data | TUCUMCARI | October 16, 1972 | Abort - WX |
| EB-01 | Ocean Data | MADRONA | October 21 - 23, 1972 | |
| EB-10 | Repair (Quarterly Inspection) | DEPENDABLE | October 24 - 30, 1972 | DPS Failure |
| EB-01 | Repair | CHEROKEE | October 30 - Nov.1, 1972 | Power System |
| EB-32 | MLDL Test | ACUSHNET | December 8 - 9, 1972 | |
| EB-10 | Inspection | ACUSHNET | January 9, 1973 | Flooding Alarm |
| EB-10 | Quarterly Inspection | ACUSHNET | January 22 - 28, 1973 | Combined Operations |
| EB-32 | Deploy | SALVIA | January 22 - 28, 1973 | |
| EB-51 | Drift Test | SALVIA/ACUSHNET | January 22 - 28, 1973 | |
| EB-62 | Drift Test | SALVIA/ACUSHNET | January 22 - 28, 1973 | |
| EB-03 | Repair | CITRUS | January 29 - Feb.4, 1973 | DPS Failure<br>Sensor System |
| EB-01 | Repair | CHEROKEE | February 12 - 17, 1973 | Sensor System<br>DPS Failure; Abort WX |
| EB-01 | Repair | CONIFER | February 22 - 26, 1973 | DPS - Sensor System |
| EB-35 | Deploy | SALVIA | February 21 - 24, 1973 | Abort |
| EB-32 | Deploy | SALVIA | February 21 - 24, 1973 | |
| EB-31 | Deploy | SALVIA | February 21 - 24, 1973 | |
| EB-01 | Repair | CHILULA | March 12 - 17, 1973 | Power System |

TABLE 3.1-1 CONTINUED

NDBO AT SEA OPERATIONS (CONTINUED)

| BUOY | ACTIVITY | SUPPORT SHIP | TRIP DATES (INC.) | REMARKS |
|---|---|---|---|---|
| EB-31 | Deploy | SALVIA | March 7 - 11, 1973 | EB-31 Adrift in Atlantic |
| EB-36 | Deploy | SALVIA | March 7 - 11, 1973 | EB-53 Adrift and recovered March 30. |
| EB-53 | Deploy | SALVIA | March 7 - 11, 1973 | Returned to MTF Apr.5 |
| EB-02 | Deploy | ACUSHNET | March 20 - 24, 1973 | |
| EB-02 | Repair | ACUSHNET | April 1 - 10, 1973 | Power System (Unsuccessful) |
| EB-10 | Repair | ACUSHNET | April 1 - 10, 1973 | DPS |
| EB-36 | Repair | ACUSHNET | April 1 - 10, 1973 | Antenna |
| EB-01 | Repair | MADRONA | April 12 - 14, 1973 | DPS; Abort - WX |
| | | CONIFER | April 15 - 18, 1973 | |
| EB-02 | Repair | SALVIA | April 22 - 27, 1973 | EB-02 Power System (Unsuccessful) |
| EB-32 | Replace | SALVIA | April 22 - 27, 1973 | |
| EB-03 | Repair | CONFIDENCE | April 24 - 28, 1973 | DPS Sensor System |
| GATE | Deploy | R. V. Columbus Iselin | April 23 - May 3, 1973 | Radar Buoy - NSF Univ. of Miami - Mooring In-Line Sensor Mech. Fail - Failed May 3 |
| EB-02 | Repair | ACUSHNET | May 6 - 13, 1973 | Power System |
| EB-10 | Repair | ACUSHNET | May 6 - 13, 1973 | DPS |
| EB-32 | Repair | ACUSHNET | May 6 - 13, 1973 | Met Sensor |
| EB-02 | Repair | ACUSHNET | June 4 - 9, 1973 | Power System |
| EB-32 | Repair | ACUSHNET | June 4 - 9, 1973 | Met Sensors |
| EB-36 | Recover | SALVIA | June 8 - 18, 1973 | EB-36 not on station - found off West Palm Beach Fla. Returned to MTF June 27. (HOLLY HOCK) |
| EB-37 | Deploy | SALVIA | June 8 - 18, 1973 | EB-37 not on station June 28. Found drifting-Returned to MTF July 11. (GENTIAN) |
| EB-51 | Drift Test | SALVIA/VIRGINIA KEY | June 8 - 18, 1973 | |
| EB-52 | Recover | SALVIA | June 8 - 18, 1973 | |
| EB-53 | Drift Test | SALVIA/VIRGINIA KEY | June 8 - 18, 1973 | |
| EB-61 | Recover | SALVIA | June 8 - 18, 1973 | |
| EB-62 | Drift Test | SALVIA/VIRGINIA KEY | June 8 - 18, 1973 | |
| | | | | Combined Operations with AOML |

TABLE 3.1-1 CONTINUED

NDBO AT-SEA OPERATIONS (CONTINUED)

| BUOY | ACTIVITY | SUPPORT SHIP | TRIP DATES (INC.) | REMARKS |
|---|---|---|---|---|
| EB-12 | Deploy | ACUSHNET | June 18 - 25, 1973 | DPS |
| EB-10 | Repair | ACUSHNET | June 18 - 25, 1973 | DPS |
| EB-32 | Recover | SALVIA | July 9 - 12, 1973 | |
| EB-02 | Repair | ACUSHNET | July 23 - 30, 1973 | Power System |
| EB-10 | Repair | ACUSHNET | July 23 - 30, 1973 | DPS/Power System |
| MCS | Use | ACUSHNET | July 23 - 30, 1973 | Test No. 1 |
| GATE | Deploy | R. V. James M. Gillis | July 25 - August , 1973 | Radar Buoys - NSF Univ. of Miami |
| EB-01 | Repair/refurbish | CHEROKEE | July 31 - August 6, 1973 | DPS |
| EB-02 | Repair | ACUSHNET | August 13 - August 15,1973 | Wind Sensor-Unsuccessful |
| EB-10 | Repair | ACUSHNET | August 13 - August 15,1973 | DPS |
| EB-03 | Repair/refurbish | CITRUS | August 22 | DPS |

TABLE 3.1-1 CONTINUED

When long distance transport of the EEP buoys has been required, they have been carried as deck cargo on commercial ships. This method is effective, but extremely costly, and utilized only where no towing arrangement is available.

Transport of all LCB's to their deployment sites was accomplished on board Coast Guard buoy tenders with the buoys as deck cargo. All LCB's were transported in timber cradles, except for the Magnavox buoy, which can be conveniently stood on the deck unsupported. All of the LCB's proved to be much more delicate than Aid to Navigation buoys customarily handled by the buoy tenders. Each buoy was equipped with HF communications antenna extending about twenty feet above the mast and meteorological sensors which are installed at the edge of the space envelope of the buoy. Both types of equipment are subject to contact with the ship's structure during handling operations.

3.1.2 Deployment Operations

Deployment of the large buoys has been conducted in each case by deploying the buoy, the mooring line and then the anchor last. This procedure was conducted six times in deep water. There has been only one instance in which a large buoy was not satisfactorily moored. It has been postulated that this was due to the following causes. The deploying ship maneuvered in such a way as to put a loop in the mooring line before the anchor was dropped. As the anchor descended, that portion of the line nearest the anchor probably ran over the rest of the line and actually cut the line by friction. This failure caused a three week delay in deployment and required a completely new mooring assembly, except for the 700 feet of line immediately beneath the buoy.

Most of the deployments of high capability buoys utilized ships that were not equipped with a large crane, as, for example, with EB-02 and EB-12 deployments. This required considerable manhandling of the equipment, but was accomplished successfully. In these cases the mooring line data line for the buoy was faked out on the deck of the buoy, along with the sea return ground plate to permit these elements to be more easily manhandled over the side. A crane is expected to be available in the winter of 1974 for installation on the ACUSHNET to simplify the deployment operations. With that equipment, plus the installed roller chock at the stern and multiple capstans, the retrieval and deployment of ocean sensors on the mooring line data line under tension can be accomplished in a straight forward manner.

Due to Coast Guard experience in handling various classes of loads at sea, deployments of the General Electric and Magnavox drifting buoys were accomplished with relative ease from the deck of the buoy tender. The 20 foot HF antenna is susceptible to damage if the buoy rotates under the crane. To protect against this, the buoy must be hoisted at an attitude off the vertical and then tag lines must maintain the direction of the antenna away from the crane boom. To minimize the opportunity for damage, the buoy should be lifted from the deck and deployed in the water in the minimum time possible. During the transition from the stowed position to the angled-out attitude for deployment, the buoys are also subject to dragging along the deck and bumping into various obstructions - all potentially damaging to the buoy. These operations have been performed fairly well, despite the difficulties inherent in restraint of two to four thousand pound buoys aboard a rolling ship.

Deployment of the General Electric and Lockheed moored LCB's provided additional complications. The GE buoy deployment was a two-stage operation. First, the buoy itself and its 1500 foot upper tether line (which had been faked out on deck) was deployed manually. Secondly, the subsurface float/anchor assembly was deployed. This required a two point lift to put the assembly in a specified thirty degree anchor down attitude. During the first deployment, the lower attachment point broke free first, causing the assembly to descend into the water in a vertical position. Fortunately, this had no adverse effect on the deployment. This first GE mooring maintained the buoy on station for 113 days. Following recovery, it appeared that the final lockup arrangement on the anchor cable assembly had not functioned, but a secondary braking system had maintained the subsurface float at the proper depth. During the second deployment, all went as planned. However, the buoy subsequently broke loose and has not been recovered. It is postulated that the subsurface float remains on station. If so, it cannot be recovered in any practical manner because its release mechanism requires a hundred amp pulse fed in through the buoy tether line.

The Lockheed buoy design incorporates a self-deploying oceanographic data line in addition to a mooring line, both attached to the bottom of the buoy hull. The oceanographic data line is stored in a container under the hull and release is initiated by salt water corrosion of restraining links. The anchoring system consists of a dead weight box assembly and a light weight anchor to prevent lateral dragging. The box is a five foot cube with a bottom slab of steel weighing approximately 5,000 pounds. The sheet metal sides of the box provide a cavity for storage of the nylon mooring line. In deploying this buoy, the buoy itself was launched first and then the anchor box was lowered and released into the water with the mooring line paying out from the box as the box descended. Two deployments were made with this arrangement, in 1,000 and in 12,000 feet of water. Both of these moorings failed and are discussed elsewhere in this report. Also, the data line was released prematurely in both deployment operations due to corrosion link failure. This resulted in immediate abortion of the oceanographic sensor deployment.

Two Magnavox buoys and one GE buoy were moored in relatively shallow water (between 300 and 700 feet) off the west coast of Florida. These buoys were moored on fiber lines with 2500 pound navy anchors. The vertical line load on the GE buoys was reduced by adding bouyant spheres at various points along the line. Since the Magnavox buoys were never intended (as designed) to be moored, an auxiliary surface float was provided to support the weight of the mooring line. In all of these cases, the buoy, the mooring line, and finally the anchor were deployed in that order. The GE buoy and one Magnavox buoy survived on station until they were recovered as scheduled (shown in Table 3.1-1). The second Magnavox buoy was apparently cut loose by the propeller of a ship that passed between the buoy and the surface float. The buoy was discovered adrift and recovered while the surface float and mooring line were lost. Moorings for the other Magnavox buoy and the GE buoy were both hauled up and recovered completely.

### 3.1.3 At-Sea Maintenance

There are three broad options available for maintenance of data buoys:

- Go aboard the buoy and perform the required work.
- Haul the buoy aboard ship and perform maintenance.

- Replace the buoy with another one and return faulty buoy to port.

The first option applies to the large buoy and has been utilized extensively by NDBO. The second option is applicable for smaller buoys and has also been utilized to a limited extent. The third option is feasible for large and small buoys but generally applies only to the latter because the high costs of inventory, as well as transportation, tend to eliminate its practicality for large buoys. All at sea repair and maintenance depend upon accurate diagnosis of problems and replacement by line replaceable units (LRU's).

Small Buoy Experience

Because the LCB's were intended to fulfill specialized functions requiring only limited performance, the LCB Test Program did not include extensive at-sea maintenance and deployment durations. The LCB design concept was based upon minimal repair at sea, generally confined to exchange of readily accessible components, which was performed aboard the support ship or from a small workboat alongside the deployed buoy. Hauling out a buoy on a slack mooring is practical and was accomplished when a complete changeout of the GE mast assembly was required. However, taut or semi-taut moorings do not lend themselves to the aboard ship operation and small work boats are required. In those cases where minor repairs were required top-side, the small boat went alongside the buoys and personnel worked from the boat.

Large Buoy Maintenance

The EEP and DKH buoys have been maintained at sea by working aboard the buoys. Although the U. S. C. G. Cutter ACUSHNET will eventually be outfitted to support operations by mechanically attaching to the buoy, operations to date have required transport of men and materials via small work boats. The original EEP concept was to facilitate movement of personnel and material by having LRU's weigh no more than 35 pounds. However, actual components packaged in portable carrying cases are weighing two or three times that limiting weight. This not only increases the difficulty of at-sea maintenance operations, but renders it quite dangerous. The buoys are similar to small ships in an open ocean. Their motion is considerable and seldom corresponds to the motion of the small workboats. Apart from the need to effectively transfer men and materials, it is also important to limit the exposure time on board the buoy due to human factors. The combination of motion in a confined environment together with the odor of diesel exhausts is particularly conducive to the onset of seasickness and resultant sub-par performance of personnel.

Despite the difficulties encountered and the severe environment, maintenance and repair at sea on the large buoys has been successfully accomplished on each visit. Lack of adequate spares has seldom been a problem. On the occasion when a significant piece of equipment, specifically a data processing system, had to be replaced, the equipment was flown out by Coast Guard helicopter. Major problems associated with maintenance of large buoys at sea have included:

- Transfer of equipment and personnel is difficult and dangerous.
- Timely diagnosis of problems in the on-board environment is a formidable task.

- Repair elements and test equipment get considerable exposure to the damaging effects of marine atmosphere prior to installation.
- Effective working hours aboard the buoys are constrained by weather conditions and sea state.
- Protective clothing and gear, e.g., life jackets, wet suits, etc. reduce personnel efficiency.

### 3.1.4 Buoy Recovery

Buoy recovery is in general an extension of the maintenance procedure. The large buoys are each equipped with an acoustic release which is fairly reliable but quite expensive. So far in the EEP program, actual recovery has not been accomplished using this particular equipment. EB-01 was recovered from the Atlantic deployment site by cutting the line near the bottom with a pressure actuated explosive line cutter. This was accomplished quite successfully and at minimum cost. A line cutter installed in the subsurface float was used to successfully release the moored GE buoy which was recovered. This was the only time this system was utilized.

### 3.1.5 Successes During At-Sea Operations

The major success from all operations so far can be characterized by the fact that all major tasks have been accomplished as planned except when limited by weather or unanticipated equipment failures. The ship support provided by the Coast Guard has always been dependable; the ship's forces have assisted at every opportunity and have contributed significantly to the overall success of these operations. In addition, no one from the support ship or Data Buoy Office has been seriously hurt during any of these activities.

### 3.1.6 General Comments

The NDBO has initiated action to reduce the hazards encountered in transferring men and material to the large buoys for at-sea maintenance. The Coast Guard Cutter ACUSHNET has been equipped with a trailer hitch type device which will eventually be used to connect the ship directly to the buoys. When used in conjunction with two lateral stabilizing lines, the buoy-ship combination will be fixed in surge, yaw and sway but will have relative motion in pitch, roll and heave. This equipment has not been utilized as yet, since it requires a crane to connect the hitch to the buoy. Installation of a crane on the ACUSHNET is scheduled for the winter of 1974. It is envisioned that this system, when used, will allow direct transfer of test equipment, personnel and repair parts without the inconvenience and danger involved in using small workboats. The strength of the mooring line on the buoys will limit the use of the buoy-ship connection system to operation in light environments.

The use of on-the-ship maintenance of small buoys by hauling on the buoy without disconnecting it's mooring line is limited to slack moorings, for which it can be accomplished without much difficulty. The tension in the line can be monitored and the ship can usually hold position adequately. As in all cases, this procedure is limited by the severity of ambient weather conditions. For taut or semi-taut moorings, the ship would, in all likelihood, overstress the relatively light mooring line by becoming part of it's active load.

### 3.1.7 Summary of Problems

- The presence of the HF antenna and meteorological sensors on buoys that are hoisted by a crane present handling problems involving potential contact of the buoy elements with the crane.

- The lack of a crane for handling the trailer hitch assembly and the ocean sensors on the mooring line data lines has limited operations with large buoys at sea, both in the deployment phase and in the maintenance and repair visits.
- Transferring of equipment from ships to small boats and small boats to buoys is cumbersome, dangerous and exposes equipment and personnel to damaging situations.
- When deploying or recovering a buoy with a crane, the timing of the operation is very critical in order to minimize impacts caused by wave slap on the buoy or cable jerk from ship's roll motion.
- A major safety consideration involves personnel contact with an HF antenna during a transmission period. If work on the antenna is required, positive steps must be taken to prevent shock.
- When working on-board buoys, there is a danger of a large "one in a million" wave of breaking over the buoy and causing considerable damage to internal active equipment. This occurred on EB-01 requiring complete replacement of the Data Processing System.

### 3.1.8 Recommendations

- If the buoy must be maintained at sea, design the buoy for complete plug-in/bolt-in interchange of all active elements.
- With the help of an experienced photographer, obtain a clear record of all notable events. This will be of assistance for

archival records and analysis of repair effectiveness, as well as for training.

- Provide the support ship with complete technical manuals, including maintenance procedures, system description, and handling procedures.
- Design the buoy with the understanding that it will be exposed to particularly rough handling during transit ashore and at sea, and during deployment and recovery.
- When equipment is exchanged on board a buoy, document this change immediately rather than at some convenient time at a later date.
- At the first convenient time after concluding the mission, document all activities.

## 3.2 LOGISTICS AND MAINTENANCE SUPPORT

The following information is supplied as a guide in answering questions that may be raised in the areas of logistics and maintenance support. This information describes briefly how NDBO has done business at MTF where all integration and delivery has taken place in the past on previous data buoy programs. It is recognized that this does not cover logistics for integration and delivery at other locations. Such programs will require a re-definition of NDBO support of this type.

Certain facilities and services have been provided to contractors at no cost by NDBO. These are as follows:

1. A support ship (USCGC Acushnet) to service buoys with facilities for personnel, spares and support equipment.
2. A System Support Station (MTF) for shop maintenance of buoy LRU's, including standard electronic test equipment.
3. Spares and equipment storage at the MTF to provision the support ship and to support base maintenance activities.
4. System Support Station facilities to permit buoy refurbishment at regular intervals.
5. Communication station facilities (USCG Miami Radio Station) to house operating and maintenance equipment required for data collection.
6. Other facilities of the MTF as required, such as space and facilities for a Bench Test Unit.

### 3.2.1 Support Ship

The support ship visits buoys on a regularly scheduled basis and when directed by the Operations and Test Division to accomplish maintenance. The ship is provisioned with spare unit equipments, consumables, and test equipment necessary to accomplish the scheduled and unscheduled maintenance. Contractor and USCG personnel assigned to support ship perform the buoy maintenance.

The support ship task has been assigned to the USCGC Acushnet for Gulf of Mexico operations. The primary tasks include buoy deployment, scheduled visits, unscheduled maintenance trips and recovery. A limited spare parts inventory is carried on the ship. Normally platform spares will be stocked for units that are not monitored by the SCS. Spares for those units monitored by the SCS are loaded aboard based on fault localization accomplished ashore.

Space and electrical power are provided for buoy handling and deployment equipment used for the towing of a buoy platform to a deployment site. The support ship has the capability to transfer a buoy to and from the NASA Tug Clermont. The Clermont tows the buoy from the MTF tothe rendezous location and back to MTF when required for repair.

At times, ships of opportunity are used.

The support ships have proven capabilities to support buoys from the small LCB type to the 40' diameter disc type.

3.2.2 Mississippi Test Facility

Shop-level maintenance of the buoys is performed by the System Support Station located at MTF, Bay St. Louis, Mississippi, Building 3203. All corrective and preventive maintenance tasks identified as shop level are performed at MTF utilizing authorized buoy spares repair parts and test equipment. Equipment modifications and buoy overhaul are also accomplished at this location. Support from local sources as well as from the contractor are available depending on technical, schedule and economic considerations.

Office space is provided for buoy contractors and other personnel supporting the NDBO. The following is a listing of the facilities provided by MTF.

Stowage space

Bonded storage space and local transportation services

Supply support including material control and inventory capability

Maintenance areas

Standards and calibration facilities

Dockside area for installation of equipment within the hull

Dockside predeployment test area

System bench test area

Office space

Document storage and reproduction services

Working space in Building 3203 and at the adjacent Dockside-Stage Storage Basin at MTF have been assigned to the Buoy Program. The system integration/subsystem tests and 1000 hour acceptance tests have been performed at MTF with the platform afloat dockside. The space layouts in Building 3203 and the dockside area are shown in Figures 3.2-1 and 3.2-2.

The MTF and NOIC have performed pre and post-deployment calibration of oceanographic sensors and maintained the associated records. The meteorological sensors have been calibrated at the test equipment pool by the operating contractor.

### 3.2.3 Depot/Factory Facilities

The contractor provides factory support to the field activities on a demand basis, and provides on-site technical assistance related to equipment maintenance. Depot level corrective and preventive maintenance, including equipment modification, overhaul and refurbishment are performed by the contractor as required during the entire contract period.

The contractors' factories provide depot level support facilities for the Buoy Program. This depot level support includes subcontractors when required. All special purpose test equipment is available to accomplish performance evaluation both for fault isolation and verification of repair action. Failure analysis laboratory capability is available as described in the Failure Analysis Plan. This laboratory can support electronic and mechanical failure analysis including IC and contact failures. Harness assemblies have been listed as LRU spares; however, the factory production capability should be available for repair as necessary.

Buoy hull and mooring components are normally repaired and refurbished at MTF. Government furnished equipment is returned to NASA/MTF for repair or replacement.

### 3.2.4 Shore Communication Station (SCS)

Maintenance personnel and facilities are available at the Shore Communications Station for on-site and shop level maintenance of communications station equipment dedicated to data buoy operations.

Indications of equipment malfunctions are reported to on-site contractor personnel by USCG operator personnel who are monitoring equipment operation and status. Contractor personnel perform the equipment trouble-shooting, module interchange, and check-out tasks necessary to restore the system to its operational state. At scheduled periodic intervals preventive maintenance is performed on the operating equipment by the contractor.

The SCS is located at an existing USCG station equipped with HF communications facilities. The equipment has been modified to include suitable data processor and necessary peripheral equipment to meet buoy requirements. The regular operation of the equipment will be handled by USCG station personnel with basic maintenance and troubleshooting functions performed by contractor technicians. The following is a listing of the data buoy support facilities provided at the Shore Communication Station:

1. Storage space for spare parts for communication and data processing system
2. Space for test and calibration equipment
3. Office space for USCG and contractor personnel
4. Electrical power
5. Air conditioning

### 3.2.5 Transportation

Transportation associated with the Buoy Program involves movement of the complete buoy, electronic equipment, support equipment and spare parts to and from the contractor's plant, the MTF, the SCS, Gulfport, Mississippi, and the Gulf of Mexico. Transportation methods include land, sea and air.

From Contractor's Plant to the MTF and SCS

Shipments involve the transportation of:

- Complete data buoys
- Sensors
- Spares and repair parts
- Bulk consumables
- Explosive devices
- Tools and test equipment

- Personnel
- Communications equipment
- Data processing equipment (and data cards, tapes, etc.)
- Special handling devices

Local Transportation at MTF

Local transportation at the Mississippi Test Facility involves:

- Transportation of equipment, material and spare parts between the MTF warehouse and Building 3203
- Special transportation of explosive devices
- Personnel
- Sensors, test equipment and other devices to and from the calibration lab
- Data to and from the data processing centers

MTF to Gulfport, Mississippi

The complete data buoys can be towed to Gulfport by the NASA tugboat Clermont for transfer to the USCGC Acushnet for deployment.

Buoy Deployment

The USCGC Acushnet assumes transportation/deployment responsibility for complete data buoys when they are delivered at the rendezvous point by the NASA tugboat. The USCGC Acushnet also transports contractor deployment and/or maintenance personnel, spare parts, replacement equipment, supplies and maintenance equipment to, from and between buoys after deployment in the Gulf of Mexico and will retrieve and transport complete buoys back to Gulfport. Maintenance of the NASA tugboat and the USCGC Acushnet is in accordance with existing NASA and USCG maintenance policies, respectively.

3.2.6 Handling Equipment

Handling equipment includes devices for lifting, towing, blocking, etc., of the complete data buoy and equipment installed aboard the buoy. Special handling equipment is identified and the logistic support aspects of such equipment is defined by the contractors. These handling devices may be located at the MTF, on board the tugboat, dockside at Gulfport, or on board the Acushnet and include:

- Mobilizer and prime mover to move buoys up the ramp to Building 3203 and return
- Devices in Building 3203 such as hoists, jacks, stands, and dollies for handling buoys
- Devices in the MTF shop for special handling of buoy equipment and subsystems
- Equipment aboard the Acushnet for towing, deploying, securing, and handling such as winches, hoists, and dinghies.

3.2.7 Packing

Preservation and packing methods are selected by the contractor to insure protection of the items against natural and induced environments considering the item's fragility, forces produced in transportation, handling and in climatic conditions. Packaging and identification is in accordance with the best commercial practices, utilizing military and other government specifications for guidance. Marking and containing identification is specified by NDBO.

3.2.8 Shipping

All shipments of supply items are made on government bills of lading or parcel post indicia on forms and labels to be provided by the government. Shipments are made by air, rail, truck, or water, depending on the requirements for the item being shipped.

General Shipping Information (See Figures 3 and 4)

1. Location of the Mississippi Test Facility - Southwest corner of Mississippi. Highway distance to closest towns and facilities are as follows:

   a. Picayune, Mississippi, 14 miles north

   b. Bay St. Louis, Mississippi, 22 miles southeast

   c. Slidell, Louisiana, 21 miles west

   d. New Orleans, Louisiana, 57 miles southwest

   e. New Orleans, Louisiana, Airport, 70 miles southwest

   f. Michoud, Louisiana, 41 miles southwest

   g. Gulfport, Mississippi, 36 miles southeast

2. Consignment instructions

   All shipments are consigned to: Transportation Officer, NASA/MTF, Warehouse Building 2204.

3. Marking

   All shipments are marked to the attention of an individual or function. Bills of lading indicate content of shipment.

4. Shipping and Receiving Facilities for Freight and Passengers

   a. Rail

      Government trackage connects with the Southern Railway System. Switching is performed by the support contractor as needed. End location ramp is available. Passenger stations are Picayune, Mississippi, or Slidell and New Orleans, Louisian.

b. Water

Internal canal system at MTF connecting with the East Pearl River. NASA owned tug available for internal movement of barges.

c. Air

(1) Moisant Field, New Orleans, Louisiana (MSY - Frequent passenger and freight schedules, pickup and delivery of air freight shipments is provided)

(2) Gulfport, Mississippi (GFP - limited passenger and freight schedules)

(3) Picayune, Mississippi (PCU - charter service only)

d. Bus

Picayune or Bay St. Louis, Mississippi

e. Freight

(1) Rail - carload, Mississippi Test Facility, Mississippi LCL, Picayune, Mississippi (note: subject to 6000 pounds minimum)

(2) Motor, express, bus and air - Mississippi Test Facility, Mississippi

Identification of Shipment

The NDBO must be notified in advance of all shipments of all materials, regardless of destination. Shippers must forward a copy of each bill of lading, packing list, and DD-250 to the NDBO within 24 hours after they are completed.

These documents must arrive at the NDBO as far in advance of the shipment as possible to facilitate planning for receipt, storage, etc.

They will be forwarded by air mail to the following address:

NOAA Data Buoy Office

Mississippi Test Facility

Bay St. Louis, Mississippi 39520

Attention: R. E. Cagle, Building 3203, Ext. 3456

Shipping Addresses

Material, spares and repair parts provided for the Buoy Program are shipped to:

NOAA Data Buoy Office

Mississippi Test Facility

Bay St. Louis, Mississippi 39520

Attention: R. E. Cagle, Building 3203, Ext. 3456

Shipments to the SCS are addressed as follows:

U. S. Coast Guard Primary Radio Station Miami

168th Street and 117th Avenue, SW

Perrine, Florida 33157

3.2.9 Data Processing Services at MTF

Data from the buoys will be transmitted by the buoys to the SCS eight times daily at three hour intervals. This data is then transmitted to MTF where it is processed once each day. Two copies of the processed data received each 24 hours are available for analysis. One copy will be made available to the Prototype Buoy Contractor's representative stationed at MTF.

3.2.10 General Services Available at MTF

In addition to the available facilities and capabilities detailed in the foregoing pages, the following general services are available on site at MTF to contractor:

1. On-site NASA taxi service
2. NASA motor vehicle pool
3. In-coming and out-going mail service
4. Federal Telephone Service

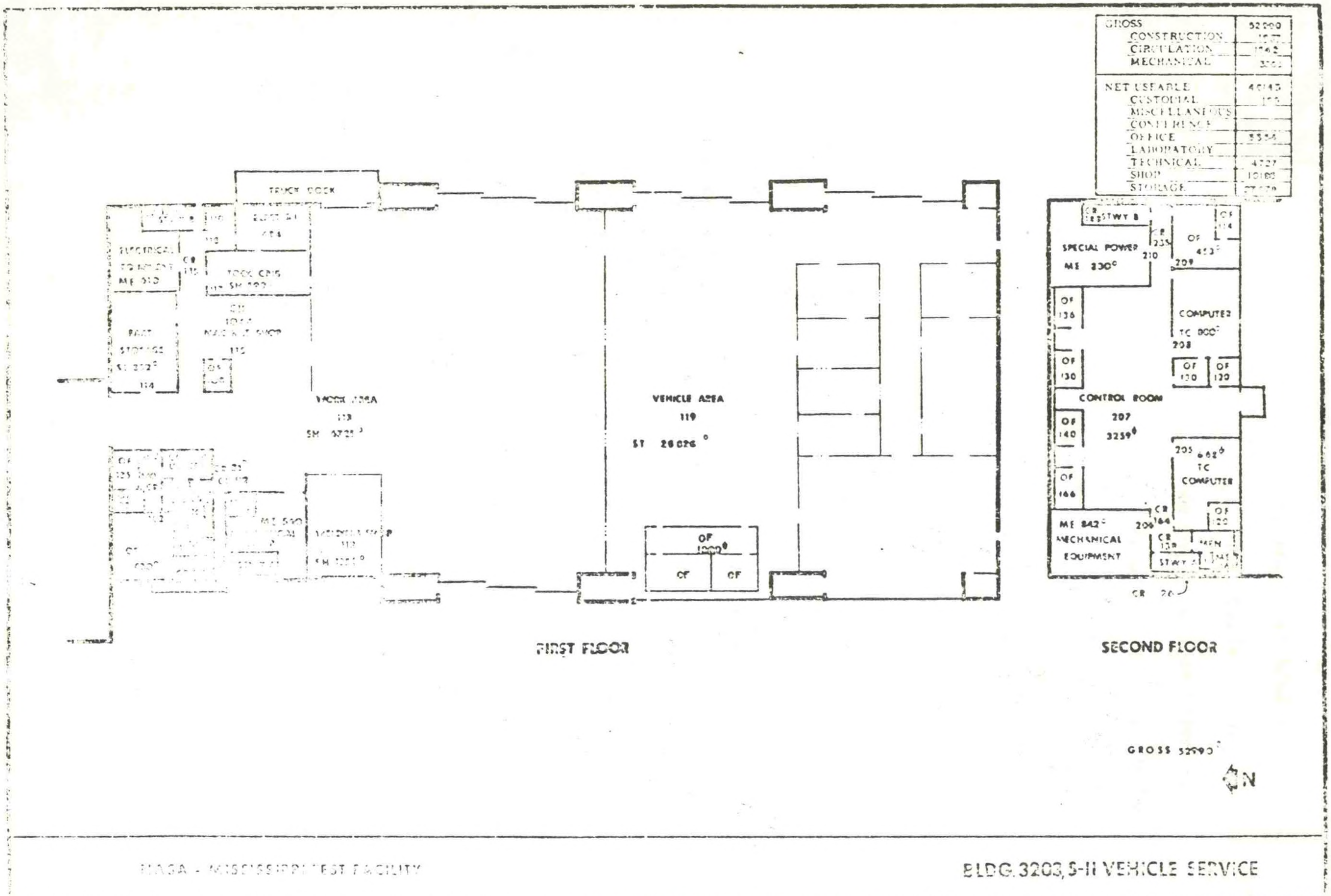

GROSS
CONSTRUCTION
CIRCULATION
MECHANICAL
NET USEABLE
CUSTODIAL
MISCELLANEOUS
CONFERENCE
OFFICE
LABORATORY
TECHNICAL
SHOP
STORAGE
TRUCK DOCK
ELECTRICAL
TOOL CRIB
PART STORAGE
VEHICLE AREA
119
ST 28026
OF
FIRST FLOOR
SPECIAL POWER
ME 230
COMPUTER
TC 800
CONTROL ROOM
207
3259
TC COMPUTER
MECHANICAL EQUIPMENT
ME 842
SECOND FLOOR
GROSS 52990
N
NASA - MISSISSIPPI TEST FACILITY
BLDG. 3203, S-II VEHICLE SERVICE

FIGURE 3.2-1

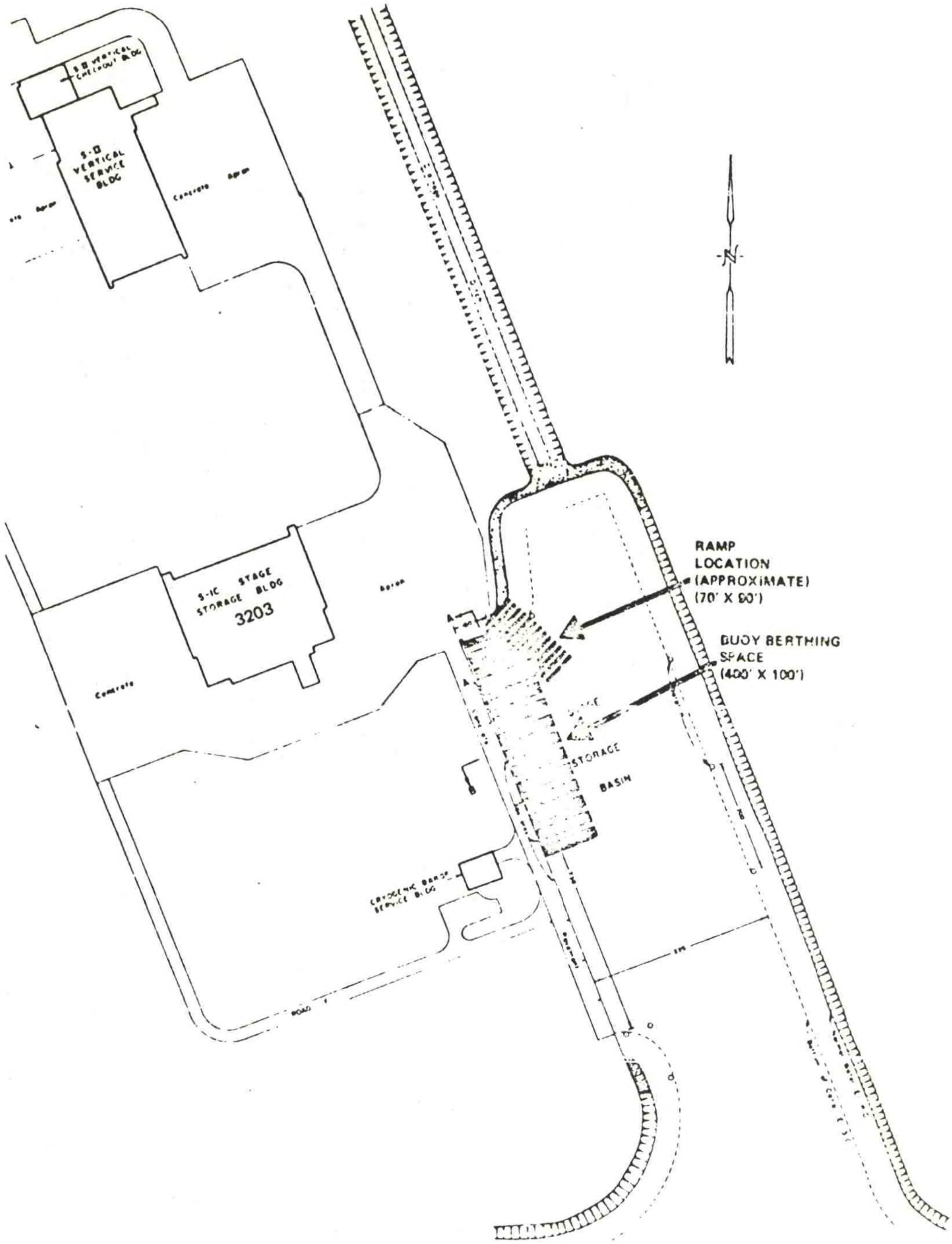



FIGURE 3.2-2 Ramp Location and Buoy Berthing Space

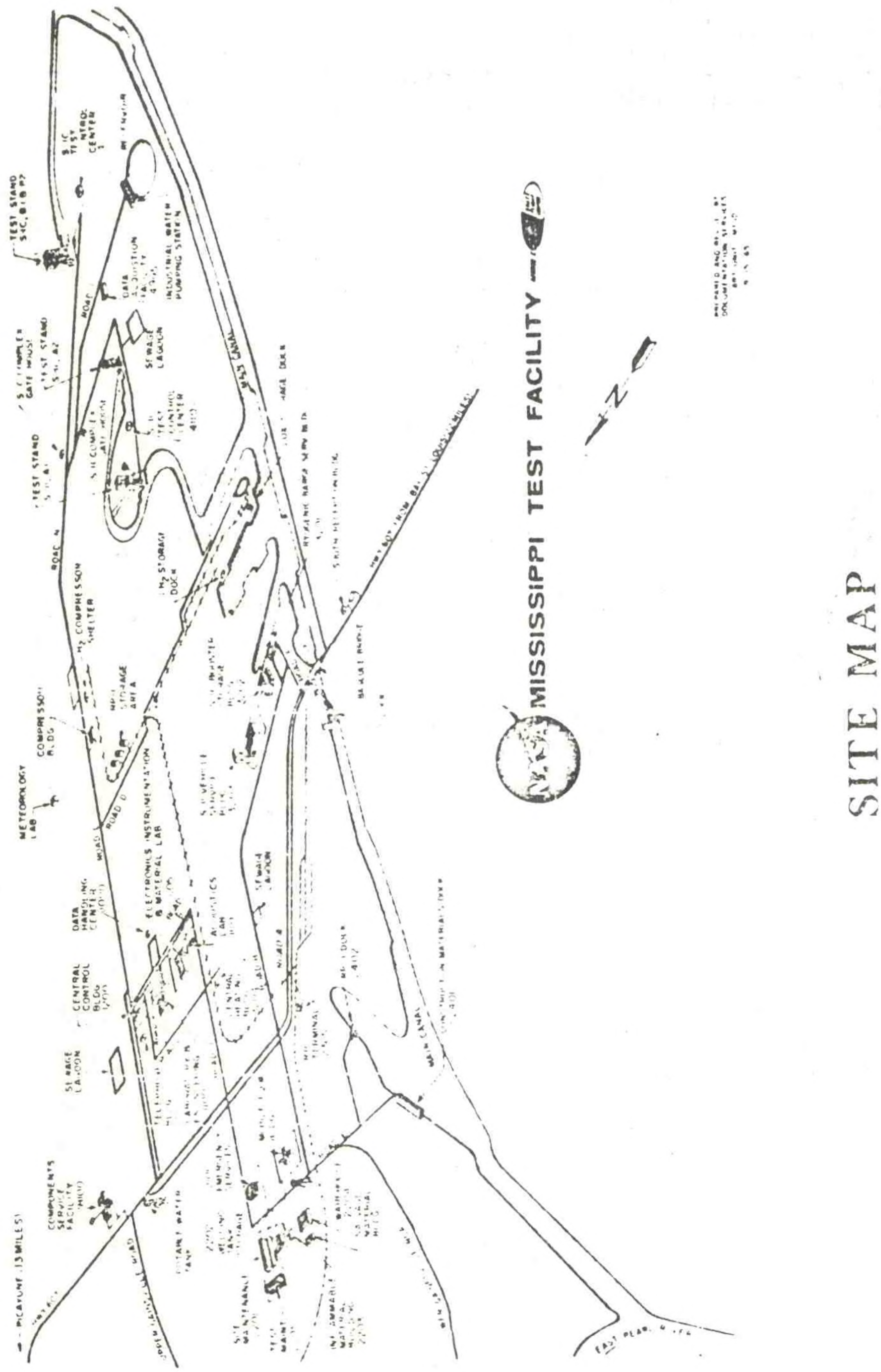



FIGURE 3.2-3

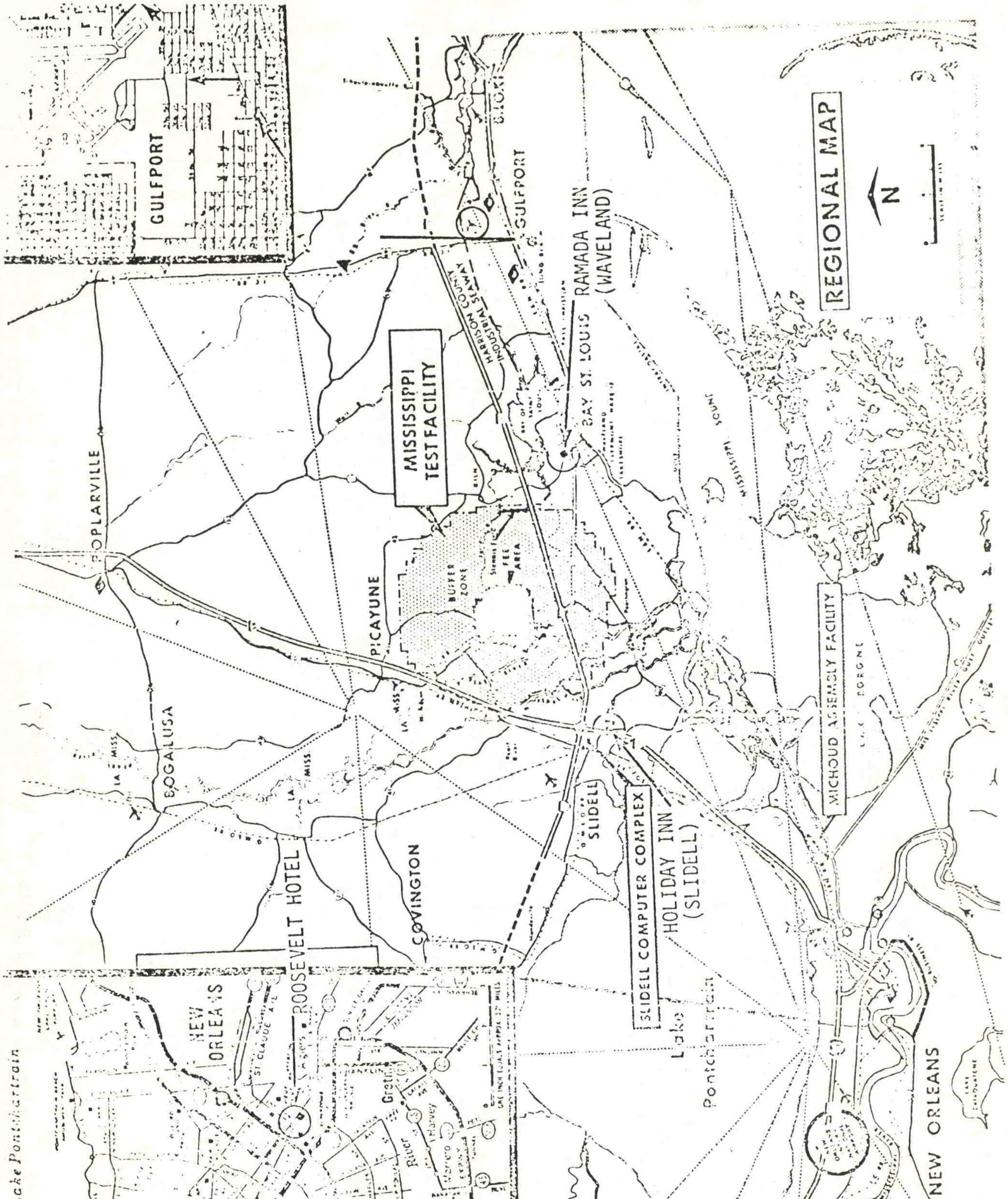

REGIONAL MAP
N
GULFPORT
BILOXI
POPLARVILLE
MISSISSIPPI TEST FACILITY
HARRISON COUNTY INDUSTRIAL SEAWAY
RAMADA INN (WAVELAND)
BAY ST LOUIS
PICAYUNE
BUFFER ZONE
FEE AREA
MISSISSIPPI SOUND
BOGALUSA
ROOSEVELT HOTEL
COVINGTON
SLIDELL
SLIDELL COMPUTER COMPLEX
HOLIDAY INN (SLIDELL)
MICHOUD ASSEMBLY FACILITY
Lake Pontchartrain
NEW ORLEANS
Gretna
Harvey
Mississippi River

FIGURE 3.2-4

## 3.3 SHORE COMMUNICATION STATIONS

The shore communication station's role in the gathering of data from environmental buoys is discussed in Section 4.6 (Communication Subsystem Experience). Background information on the stations is included in Appendix 3.3-1, which described the operation and major equipment complement at the Miami Shore Communication Station, and Appendix 3.3-2 which describes the current methodology for communicating with buoys in the Gulf of Alaska.

## 4.0 SUBSYSTEM PERFORMANCE

All of the NDBO moored Buoy Systems can be subdivided into six basic subsystems:

- Hull
- Mooring
- Power
- Sensor
- Data Processor
- Communications

These will now be discussed in the light of experience gained with them in developmental and operational NDBO projects to date.

# 4.1 HULL EXPERIENCE

## 4.1.1 DESIGN AND PERFORMANCE

### 4.1.1.1 HYDRODYNAMIC CONSIDERATIONS

The hull provides the platform which supports the other subsystems. It must provide sufficient space for the electronic and power system payloads and structure for mounting of sensors and other equipment at the required locations. It must also provide adequate buoyancy to support the total system weight and anticipated mooring loads, while retaining sufficient reserve buoyancy for survival in the worst environmental conditions expected. It should satisfy operational motion limitations and provide sufficient dynamic stability to prevent capsizing under storm conditions.

All of the above factors, as well as design requirements and constraints imposed by logistic and handling considerations, should be considered in determining the optimal hull configuration. Wind drag of the exposed structure, current drag of the hull, size and shape of the hull, and mooring tension are inter-dependent parameters which must be defined. Theoretical and empirical data relative to drag of various shapes are readily available in the literature. Definition of reserve buoyancy and hull volume requirements to meet specified environmental conditions can be accomplished using a dynamic mathematical model.

Hull shape is critical in determining motion response to waves. Buoys are usually divided into two classes, surface followers and surface piercers, although designs may combine the characteristics of these classes to some degree. Surface followers have relatively large waterplane areas and tend to have close coupling to the wave, particularly in heave. The motion amplitude-frequency response curve of surface followers usually has a rather broad resonance, indicating measurable response over the entire operating range but without a marked resonance.

Surface piercing buoys have relatively small waterplane areas and are typified by the spar buoy. This class may exhibit low motion response over a wide range of frequencies but shows a significant resonance. This resonance may well affect sensor performance and limit survivability. A length on the order of a quarter of the wave length of the longest waves expected in the operational environment is required to preclude undesirable resonant responses. The small waterplane makes it difficult to provide adequate reserve buoyancy for mooring loads and static stability to maintain a vertical axis in significant winds or currents.

The requirement to measure wave height in conjunction with the survival requirements will probably make it advantageous to have close coupling to the wave in heave.

Pitch response is important for normal operation and for survivability. A number of hull shapes have been tested as scale models to determine response spectra which are shown in Figures 4.1-1 and 4.1-2. Pitch and roll in the operating range should be minimized in order to minimize sensor errors. The 10 meter sensor height causes a high degree of coupling between pitch and horizontal motion of mast-head sensors.

Pitch response under severe environments is also important. For example, scale model tests indicate that the thick discus is susceptable to capsizing in breaking waves whose height is of the order of 1 to 1-1/2 times the buoy diameter or more with some random capsizing at smaller ratios. These tests also indicate that for small surface following buoys, e.g., discus or horizontal cylinder, lowering the center of gravity by use of ballast below

FIGURE 4.1-1

HEAVE SPECTRAL RESPONSE

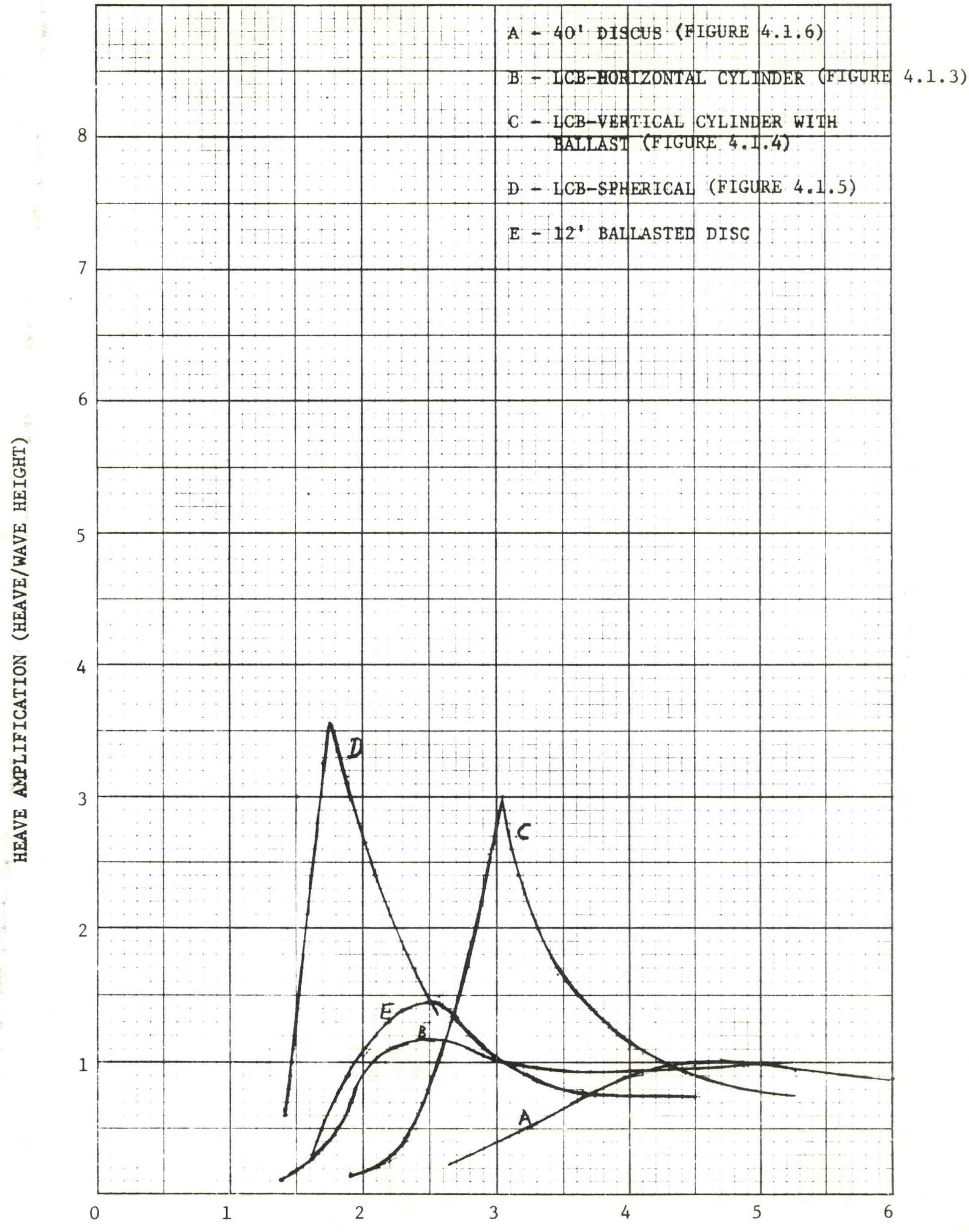
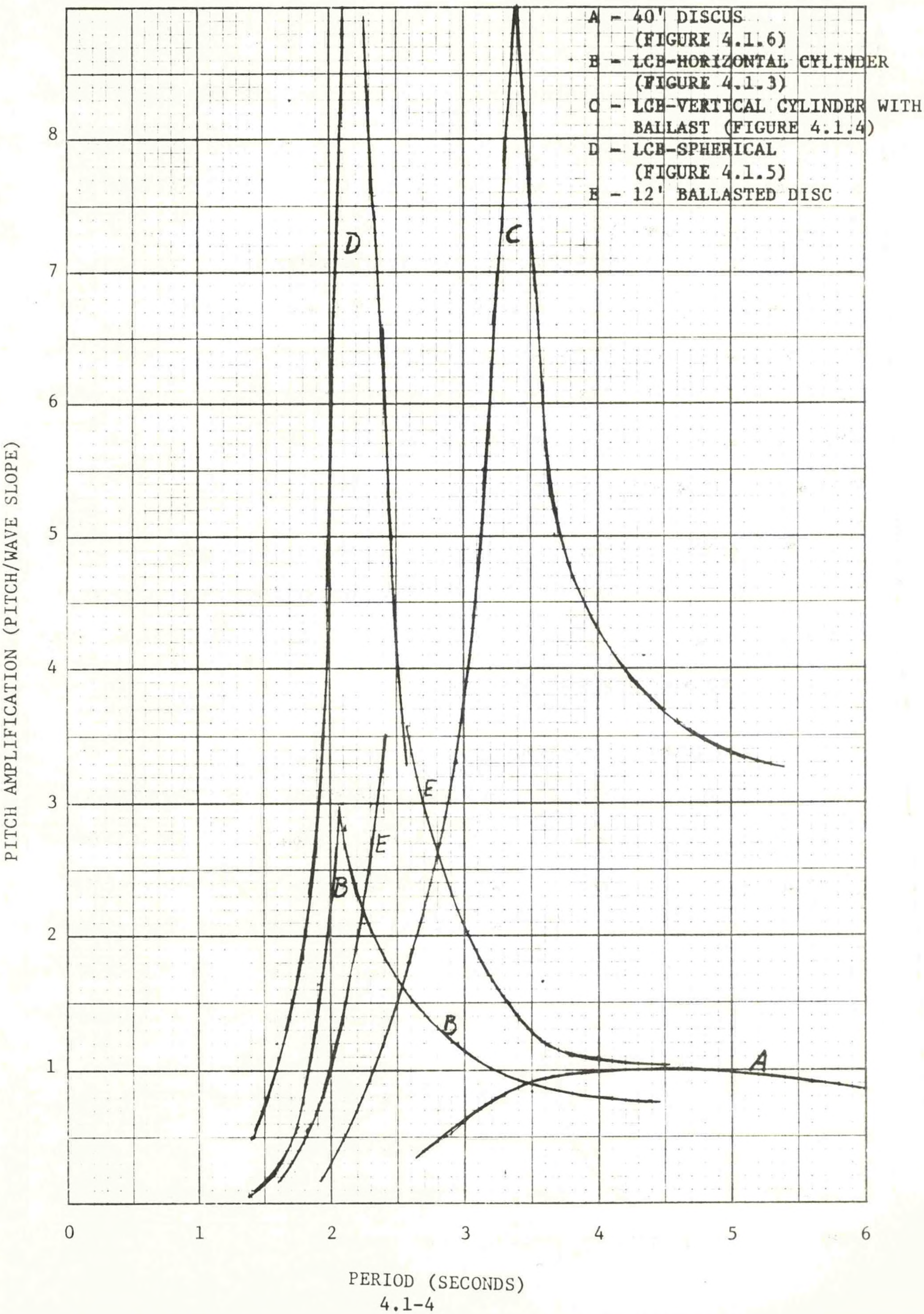


FIGURE 4.1-2

PITCH SPECTRAL RESPONSE



the hull may extend the range of survivability by increasing the wave height required to produce capsizing. Ballasting, however, may result in aliasing of sensor data due to increased pitch and roll response and/or nutation during normal operations.

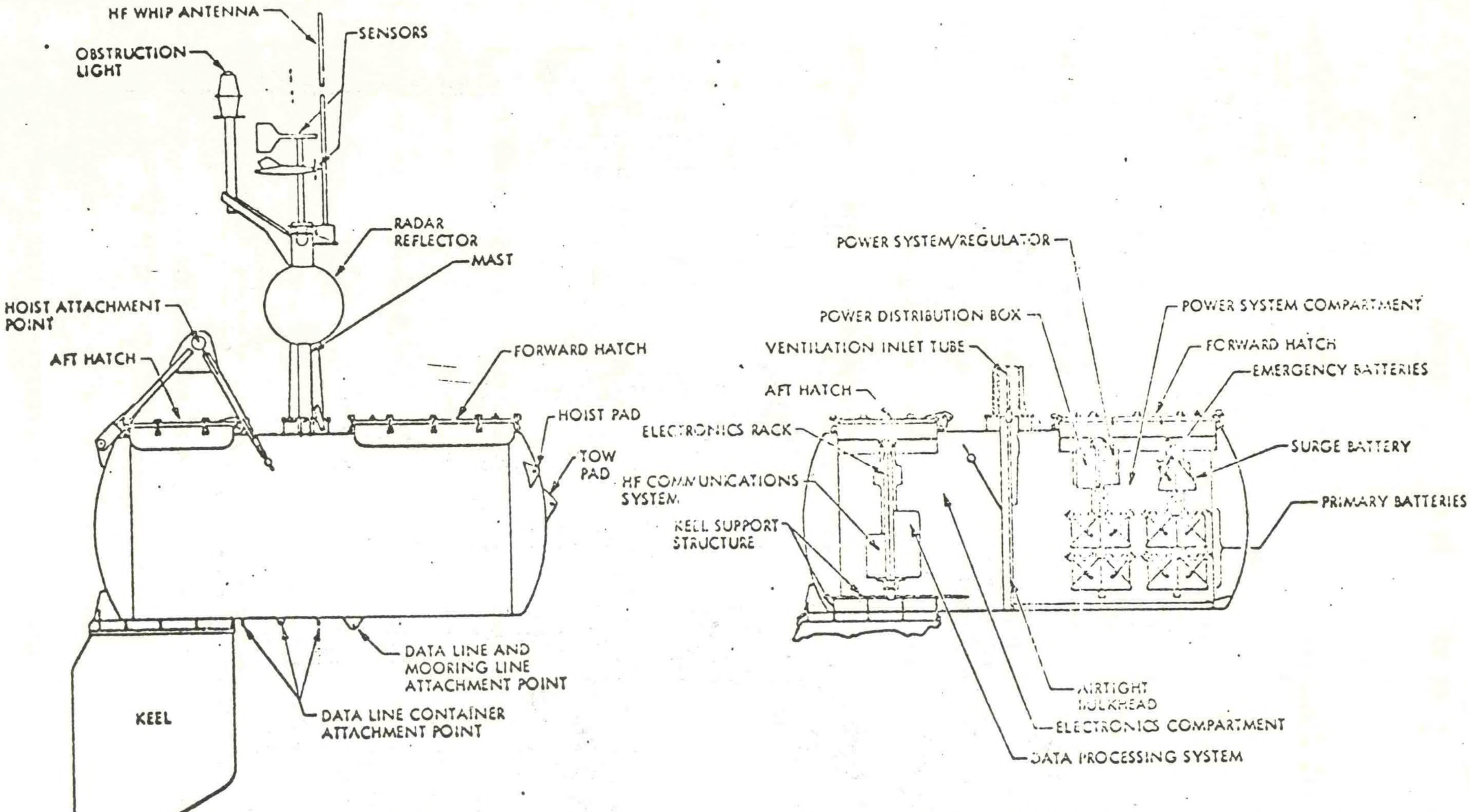
Surface following response may be achieved with a boat shaped hull, e.g., Figure 4.1.7, as well as with axisymmetric shapes such as the discus. However, roll characteristics are as important as pitch. If the buoy has a preferred axis, coupling between wave direction and buoy heading together with the roll response spectrum must be such that acceptable motion limits result.

#### 4.1.1.2 EXISTING SYSTEMS

Five major hull designs have been procured by NDBO. Sketches of these designs are shown in Figures 4.1-3 through 4.1-7 with supplementary technical details given in Table 4.1-1.

#### 4.1.1.3 DEPLOYMENT EXPERIENCE

The operational aspects of NDBO experience are discussed in Section 3.1. NDBO buoys have been exposed to a variety of environments in actual service. However, not all of the NDBO buoys have been exposed to all environments required of the prototype buoy. The large thick discus, which has been widely deployed, exhibits wave follower response with minimal hull motion effects on sensors. The deep-keeled boat type hull is somewhat responsive in pitch at the higher frequencies. The small deck area and low freeboard make manned maintenance difficult. Both of these types of large buoys have been successfully towed at speeds of 8 knots. All of the small LCB's, to varying degrees, respond actively to high frequency chop, as might be expected from their response spectra.




(a) External Arrangement

(b) Internal Arrangement

General Arrangement of MLCB

FIGURE 4.1-3

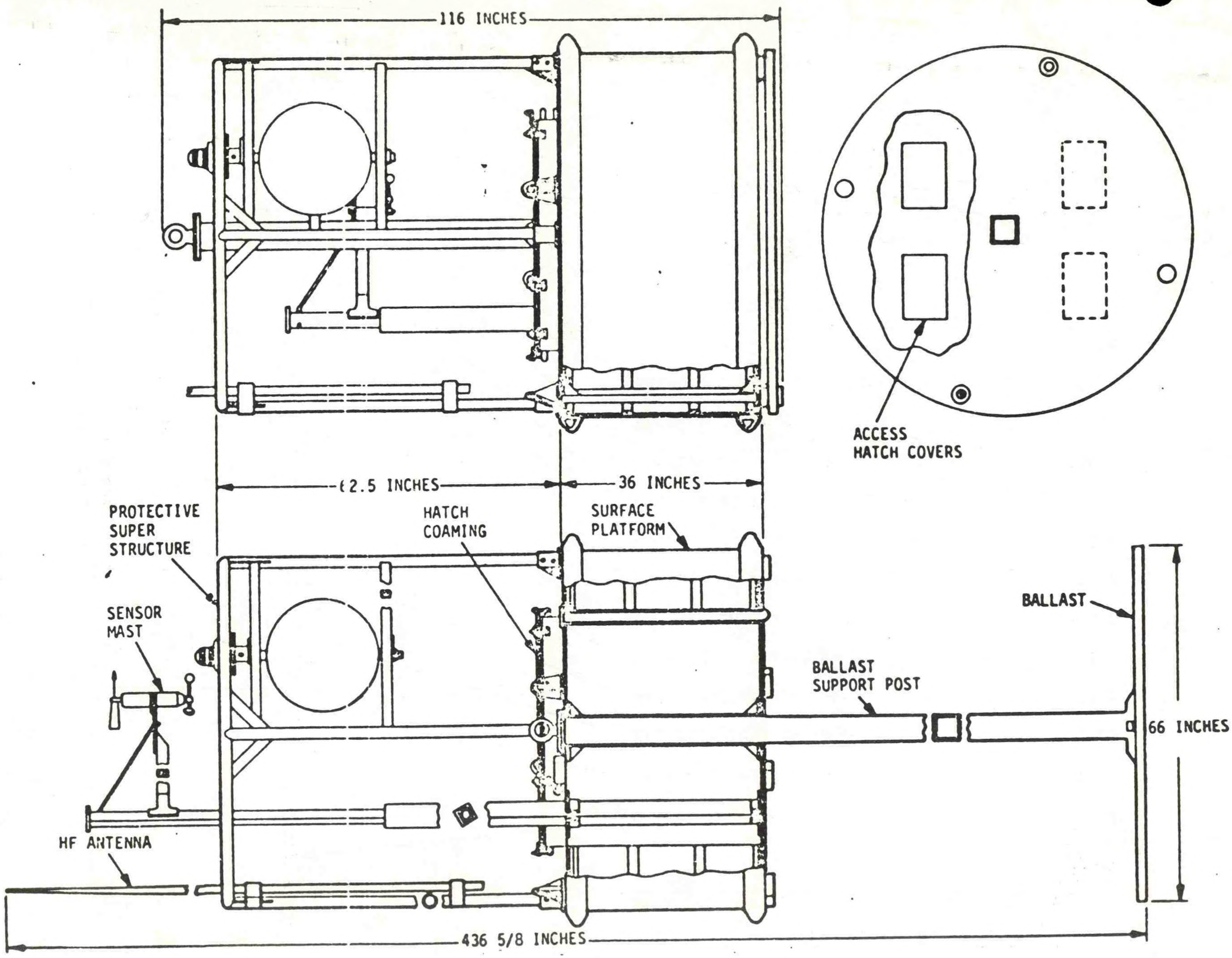
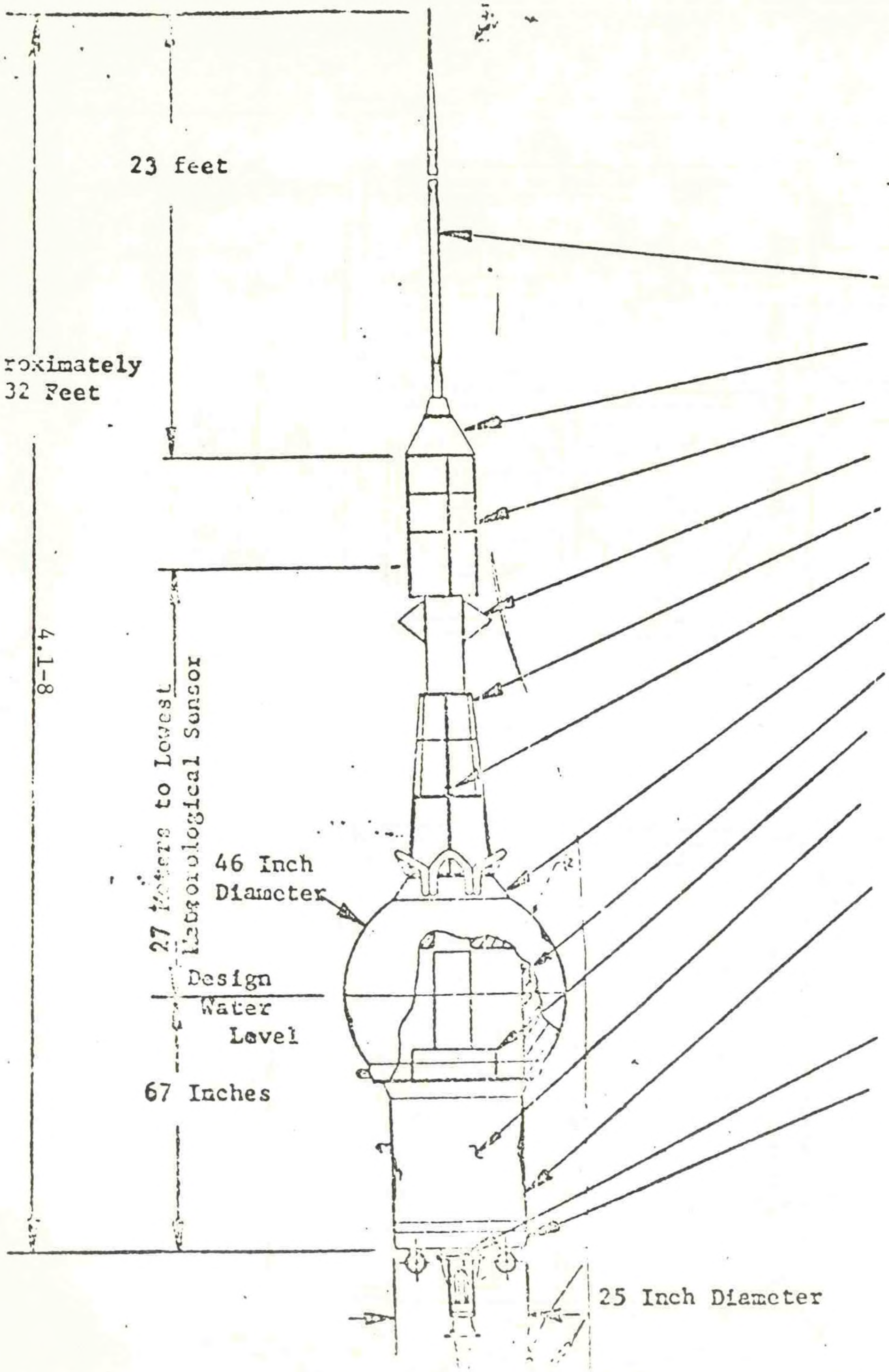



Figure 4.1-4. Vertical Cylinder With Ballast Disc

EB 51 EB 52 EB 53




MASS PROPERTIES SUMMARY - HF CONFIGURATION

| | Weight (Lbs.) |
|---|---|
| HF Antenna | 11.0 |
| Antenna Coupler | 12.5 |
| Meterological Package | 43.5 |
| Radar Reflectors | 2.6 |
| Lower Mast Structure | 22.4 |
| Navigation Light | 3.0 |
| Sphere Assembly Structure | 246.2 |
| Foam | 51.1 |
| Electrical Equipment & Shelf | 100.0 |
| Battery | 220.0 |
| Battery Ballast | 210.0 |
| Battery Compartment Structure | 192.2 |
| Fasteners | 20.0 |
| Electrical Cables | 25.0 |
| Cable Support Fitting | 19.2 |
| Counterweight | 339.8 |
| Growth & Contingency Allowance | 100.0 |
| | 1618.5 |

FIGURE 4.1-5

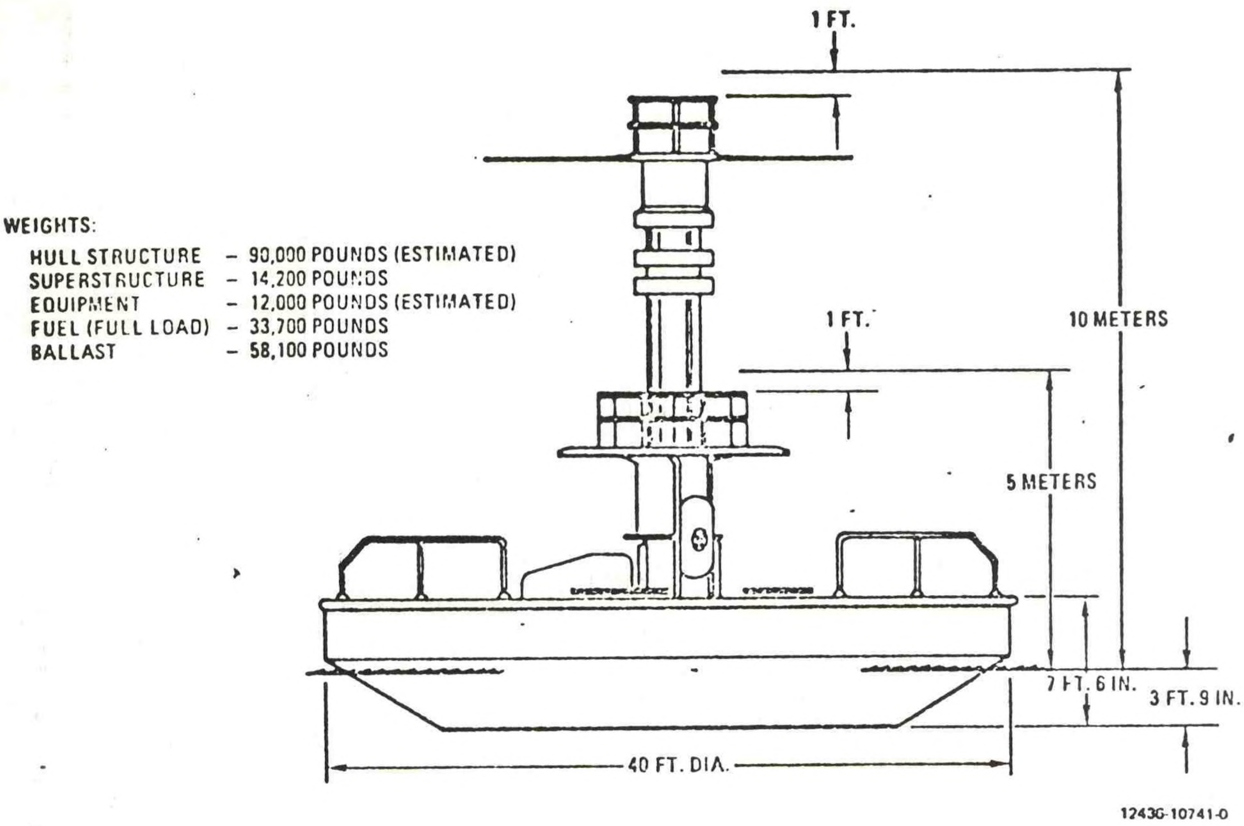
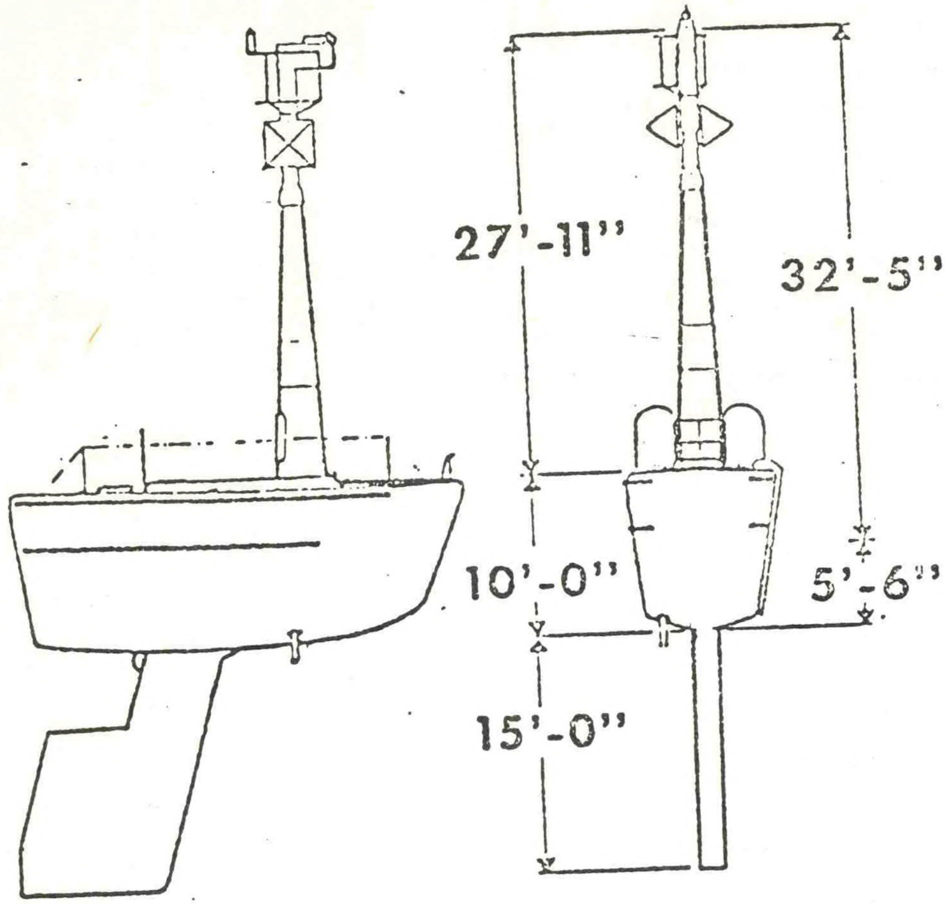

WEIGHTS:
HULL STRUCTURE – 90,000 POUNDS (ESTIMATED)
SUPERSTRUCTURE – 14,200 POUNDS
EQUIPMENT – 12,000 POUNDS (ESTIMATED)
FUEL (FULL LOAD) – 33,700 POUNDS
BALLAST – 58,100 POUNDS
1 FT.
1 FT.
10 METERS
5 METERS
7 FT. 6 IN.
3 FT. 9 IN.
40 FT. DIA.
12436-10741-0

FIGURE 4.1-6




DEEP KEEL HULL

FIGURE 4.1-7

| | TYPE | LENGTH | BEAM | HEIGHT | WEIGHT | MATERIAL | MOORING TYPE | MOORING MATERIAL | ANCHORING TECHNIQUE |
|---|---|---|---|---|---|---|---|---|---|
| EB-02 | Boat, Deep Keel | 29' | 9'6" | 10' | 52,400 lbs | Steel | Slack | 2" Nylon | Anchor Last, non-automatic |
| EB-03, 10-15 | Thick Discus | 40' | 40' | 7'6" | 100 Tons | Steel | Slack | 2-1/15" Nylon | Anchor Last, non-automatic |
| EB-31, 32 | Sphere with vertical cylinder | 3'10" | 3'10" | 6.11' | 1500 lbs | Aluminum | TAUT (Subsurface float) SLACK (Float to buoy) | 9/32" Steel 1-1/3" Polypropylene 1" Dacron | Anchor Last semi-automatic deployment |
| EB-61, 62 | Sphere with vertical cylinder | 3'10" | 3'10" | 6.11' | 1500 lbs | Aluminum | ← Drifting Buoy → | | |
| EB-36-38 | Horizontal cylinder with keel | 11'3" | 4'6" | 4'6" | 5667 lbs | Steel | Taut (Deep) | 5/8" Nylon | Semi-automat deployment |
| EB-51-53 | Vertical cylinder with ballast disc | 5'6" | 5'6" | 3' | 3270 lbs | Aluminum | ← Drifting Buoy → | | |

BUOY HULL CHARACTERISTICS

Table 4.1-1

NDBO operational experience does not include any complete hull failures such as sinking or capsizing. Other users, however, have had discs of 16 ft. diameter capsize in the North Pacific.

4.1.2 FAILURE AND REPAIR

NDBO experience with buoy hulls includes deployment of large discus hulls in Atlantic, Pacific, and Gulf of Mexico waters for both protracted and short periods. The EB-01 hull has been in service for approximately 10 years. No catastrophic hull failures have been experienced, even though the buoy has been involved in three collisions. However, there have been component and material problems, failures in paint or coating systems, damage in handling or deployment, and operational delays caused by excessive buoy motion which forced delays in repair operations. Examples of failures which have been observed are as follows:

EB-01, East Coast, October 1972 to present

- Hull damage due to three collisions with support ship
- Extensive paint peeling from sides, deck
- Corrosion around hatches and fittings
- Several instances when unable to carry out repairs due to heavy weather

EB-02, Gulf of Mexico, March 1973 to present

- Pressure transducer broken off by cribbing during transport
- Nitrogen blanket for fuel tank leaked off
- Engine fuel system clogged
- Slight corrosion observed in underwater inspection

EB-03, Gulf of Alaska, October 1972 to present

- Paint rubbed from cruciforms by cables during transport
- Rust pits observed on topside fittings
- Green slime observed on sides above chine
- Mooring windlass control handle broken
- Unable to board for repair operations due to heavy seas

EB-10, Gulf of Mexico, June 1972 to present

- Rust observed on hatch coamings, hinges, fittings
- Hatch cover leaked and required insertion of foam rubber gasket for sealing
- Slight corrosion observed in underwater inspection
- Sea too rough for repair operations

EB-32, Gulf of Mexico, January to July 1973

- Paint peeled and deteriorated
- Whip antenna broke off - probably excessive motion
- Lost nitrogen purge

EB-36, Gulf of Mexico, March 7 1973 - June 14 1973

- Antenna missing after period of deployment

### 4.1.3 DESIGN

Design decisions result from the application of specified design requirements, guidelines, and assumptions as well as the design approach. NDBO experience with buoys developed and deployed to date serves to substantiate many criteria used in the past. Analysis of deficiencies experienced indicates the need to revise others. The following guidelines are used by NDBO in hull design.

4.1.3.1 PERFORMANCE CRITERIA

The structural design should provide sufficient strength to meet maximum loads imposed by wind, waves, mooring, deployment and handling, and should include the effect of cyclic stresses or fatigue. Allowable loads used should be conservative since long life is expected.

The superstructure provides mechanical support for the meteorological sensors. The dimensions of the sensor platform or mounting bars should be sufficient to permit adequate separation of sensors from each other and the superstructure as required to avoid interference effects. The design of sensor supporting members should minimize effects on sensor operation and accuracy. The mechanical stability of the superstructure, the mounting means for the wind velocity sensor, and the mounting means for the wind sensor compass should be such as to establish and maintain mechanical alignment between these sensors within the required accuracy after replacement of either sensor.

Cables between sensors and hull compartments should be run within the superstructure, thereby minimizing the number and length of external cables and fittings. The number of bulkhead penetrations should be minimized and they should be properly designed and located to avoid deleterious effects on structural and watertight integrity. Exposed connectors should be eliminated or minimized and all cables should be replaceable without soldering or welding.

The design should minimize wind and wave loading transmitted to the mooring, as well as motion affecting sensor and antenna performance. It should provide adequate vertical stability while intact and while in a damaged condition. The hull should be subdivided into compartments and watertight integrity should be maintained between compartments in the operational configuration. The number and size of compartments should be such as to limit stability degradation if flooding occurs. The buoy design should minimize the probability of total loss of the buoy as a result of flooding through effective use of compartmentation or use of foam flotation material. The hull should be configured for ease of fabrication, repair, modification, and replacement of equipment modules.

4.1.3.2 MATERIALS AND PROCESSES

The expected cost of acquisition and deployment of these prototype buoys is such that the useful life of the hull should be at least fifteen (15) years with a goal of twenty (20) years.

Materials conforming to appropriate government or industry specifications or standards should be used and should be of the type, grade and quality which experience and/or tests have demonstrated to be suitable for the purpose intended and for marine applications. For example, MIL-S-20166A and QQ-A-250 are acceptable general specifications if mild steel or aluminum, respectively, are the chosen materials. The use of magnetic materials in the vicinity of sensors subject to magnetic interference should be avoided.

Prudent selection of materials should be made in order to combat the effects of galvanic corrosion. Ideally, dissimilar metals should not be placed in direct contact with one another. When this is not possible, coupled metals should be chosen that are listed closely together in the galvanic series in seawater or they should be electrically isolated. In these circumstances, design considerations should include good practices such as the selection of favorable anode to cathode area ratios and placement of the more noble materials in the more critical areas.

All materials which are not inherently corrosion resistant should be finished with a proven preventive treatment or known protective coating system to minimize the effects of exposure to both atmospheric and marine environments. Protective coatings subject to cracking, peeling, or sealing with age or with extremes of atmospheric conditions should not be used. Experience has shown that the lack of compatibility of the individual coats (prime, tie, and top)has led to system failure. A prime consideration in the selection of a coating system is the degree of latitude in ambient conditions during application. Quite often the paints must be applied in less than ideal conditions. The surface preparation method selected should provide a proper and compatible match with the protective coatings used. Generally, initial protective finishes should be applied to individual parts prior to assembly. MIL-P-23236 (Paint coating systems, ship steel tank, fuel and salt water ballast), and its QPL, although not a requirement, are considered acceptable guidelines for coating systems. Crevice corrosion should be prevented by proper sealing of crevices or use of flanged connections insulated with a dielectric medium that leaves no voids between the flange faces.

Materials subject to continuous or intermittent immersion in sea water should be resistant to corrosion and marine fouling, or should have an external surface treatment or coating which is effective in inhibiting corrosion and marine fouling in sea water. The surface treatment, or the coating, should have a service interval not less than two years and must be compatible with the base metal.

Non-metallic materials should be resistant to lubricants, hydraulic fluids, oil, chemicals, and all other environmental conditions likely to be encountered in service. Materials which provide a nutrient medium for fungi shall not be used unless suitably treated.

Electrical connectors should be carefully selected and specified to assure maximum reliability and life. In view of the severe service environment, the requirements of MIL-C-24217 are considered appropriate. Open face tightness of 10,000 psi on both sides and capability of field installation are desirable characteristics.

#### 4.1.3.3 SERVICING ASPECTS

Provisions for handling the buoy during outfitting deployment and maintenance should be incorporated. A sufficient number of fittings should be provided to facilitate handling of weights and equipment at sea. Fittings should allow handling and launching without the necessity for special handling fixtures, if possible. The strength of fittings and lifting eyes must be consistent with buoy weight and with dynamic forces that can be experienced during handling operations.

Provisions for deployment must be incorporated in the buoy. Experience has shown this to be a very critical operation. Facility and speed of accomplishment without damage to buoy, superstructure, or topside equipment is vital. The potential for damage to the buoy should be minimized. Design of the hull should include this characteristic and deployment procedures should be defined in parallel with the design. If towing is required, performance of the hull as a towed body in a seaway should be considered. Towing should be possible at speeds up to eight knots in ten foot seas. Retrieval should be practical in seas up to ten feet also.

Maintenance operations should be feasible at sea in waves up to ten feet. Maintenance at sea should be limited to minor repairs, replacement of sensors and faulty modules, and replenishment of items which are degraded or consumed; major structural repairs should only be accomplished at a shore depot.

The entrance of sea spray or rain through exterior ports should be prevented by the port design and access arrangement or by special attachment which is designed for use during maintenance.

## 4.2 MOORING EXPERIENCE

### 4.2.1 DESIGN AND PERFORMANCE

#### 4.2.1.1 ANALYTICAL CONSIDERATIONS

The function of the mooring system is to limit the buoy excursion from some fixed position. To accomplish this, the hull and mooring as a system must be stable and be able to survive the maximum environments specified. Factors affecting mooring performance include cable size, construction, length, and weight; size, shape, and weight of terminations and other cable attachments; anchor type and size; bottom conditions; current profile; as well as buoy size and motion characteristics.

In general, cost increases as excursion limits are decreased. However, a scope greater than 1.4:1 for deep moorings is not generally warranted and only increases mooring costs. Smaller watch circles may be achieved by increasing mooring line tension to attain a taut moor (which is vertical in the absence of environmental forces) or by using multiple leg moors. The NDBO requirements do not normally justify substantially increasing cost to achieve a small watch circle for a meteorological buoy.

Mathematical models have been developed to perform static and dynamic analyses of buoy mooring systems to determine buoy excursion and mooring line tension and motions. However, in a severe environmental condition, the buoy excursion and mooring line responses may be large. Subsequently, the mooring line may be permanently elongated relative to the starting conditions. Moreover, ocean currents may not be steady but continuously shift direction and change speed. Thus, a mooring cannot remain in static equilibrium with the current and must continuously seek a new equilibrium configuration. To some degree the changing wind plays a role in the motion of the moored buoy system. A further problem exists relative to unsteady hydrodynamic drag forces on a mooring line, which cannot be accurately predicted at this time. For these reasons, due to the lack of accurate viscoelastic coefficients, and because the available mathematical models have not been fully validated through comparison with experimental data, conservative interpretation of results is required when analytical models are used in the design process.

4.2.1.2 EXISTING SYSTEMS

The design configurations of the mooring systems for the six principal moored buoy types developed and deployed by NDBO today are shown in Figures 4.2-1 through 4.2-5.

4.2.2 FAILURE AND REPAIR

NDBO experience with buoy moorings is summarized in Table 4.2-1. It includes four large discus buoys, one large boat type, and seven smaller buoys, in water depths ranging from 120 feet to 13,800 feet. Moorings for the large disc buoys have survived for periods up to three years. Indeed, the only failure with a large buoy mooring occurred during deployment and was caused by a procedural error. Failures have been observed in smaller mooring lines for different reasons, apparently including fishbite and cutting by propeller. A summary of the observed mooring failures follows:

EB-03

Failure occurred during deployment when the line crossed over itself. Localized melting of nylon resulted from friction generated by the lower mooring line running over the upper mooring line. Approximately 80% of the line at the failure point appeared to have been melted; the remaining 20% appeared to have failed in tension.

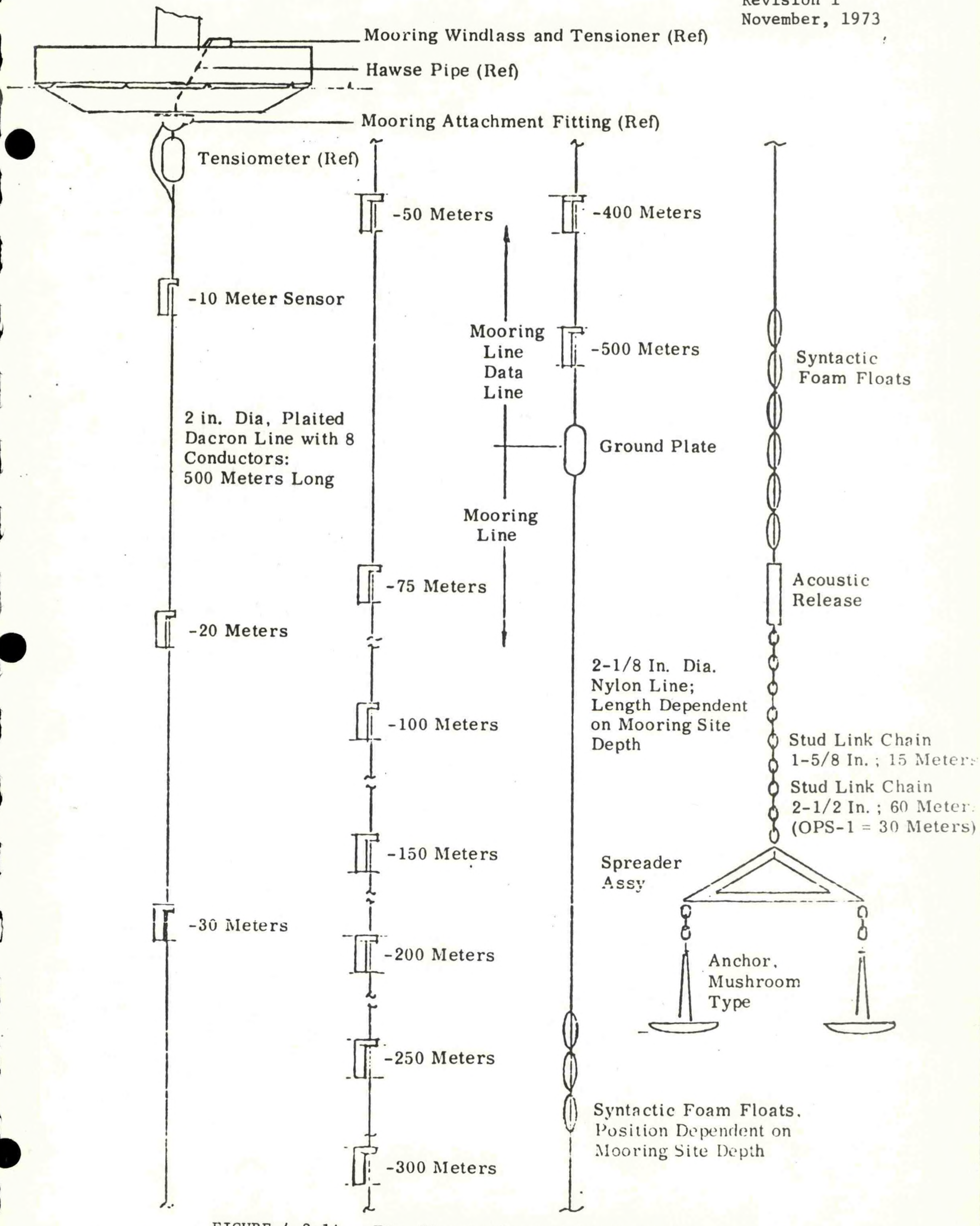
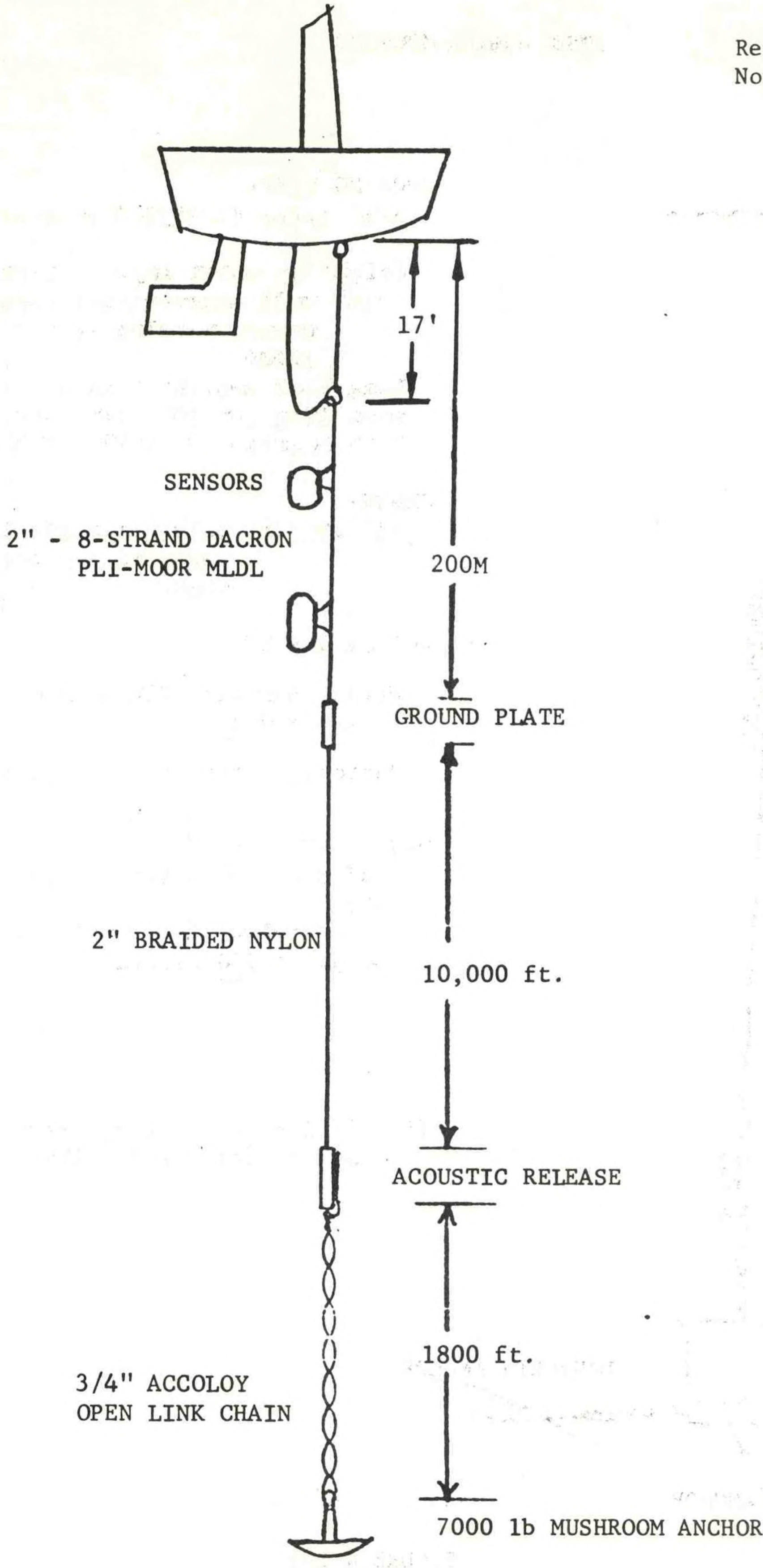


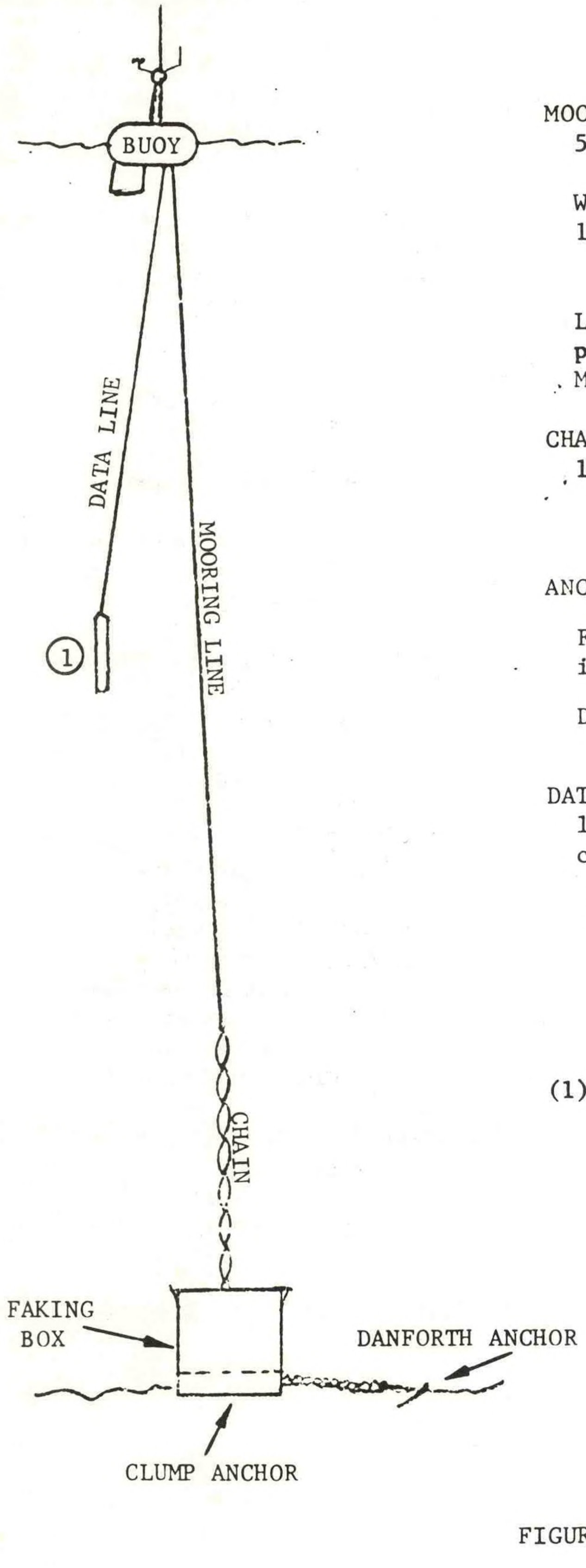

FIGURE 4.2-1A. EEP Mooring System Arrangement




MOORING CONFIGURATION FOR DKH BUOY

Figure 4.2-1B

LMSC - MLCB MOORING




MOORING LINE-
5/8" nylon (modified type of nylon line)

Weight in water approx. zero
1/16" wall polyurethane vented sheath covers mooring line from buoy down to 1500M
Length of mooring line determined at site providing for 10% taut moor
MANUFACTURED BY SAMSON CORDAGE CO.

CHAIN-
10' of 7/8" galvanized steel chain connecting mooring line to anchor

ANCHOR SYSTEM -

Faking Box With Clump Anchor - Wt. in Air 5000#

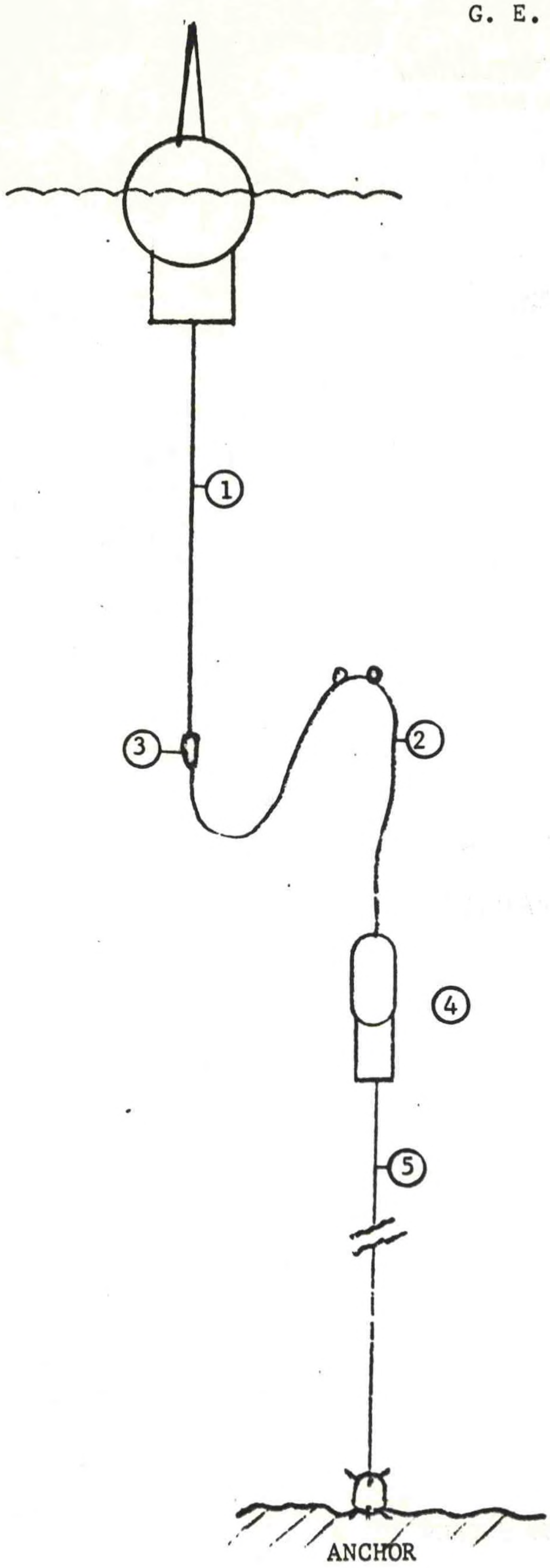
Danforth Anchor - Wt. in Air 40#

DATA LINE
1/8" dia. galvanized steel strand cable
1/16" polyurethane outer sheathing
Length = 200 meters

(1) 3" dia. x 56" long weight
wt. in water = 100 lbs

FIGURE 4.2-2

G. E. - MLCB MOORING




* (1) UPPER (MLDL) MOORING LINE DATA LINE
1" dia. 3 Strand twisted dacron line. Each strand contains 1 electrical conductor.
650' in length - strength 19,940#.
Contains Five Oceanographic Temperature Sensors Inductively Coupled To Electrical Conductors.

* (2) LOWER MLDL
1.12" dia. 3 strand polypropylene rope with three electrical conductors
950' in length -Strength 17,200#.
Contains One Oceanographic Temperature Sensor
Two Floats - buoyancy 14 lbs. each

(3) QUICK RELEASE COUPLING - connects upper with lower MLDL

(4) SUBFLOAT AND WINCH AND FRAME ASSY
Buoyancy 4300 lbs.
Subfloat - 55" dia. cylinder with hemispherical ends
Overall Length - 110"

(5) LOWER MOORING LINE - (taut moor)
9/32" dia. galvanized improved plow steel (1x7)
24000 ft. in length (variable)
Weight in water = 3290 lbs.
Weight in air = 3940 lbs.
½" chain - welded steel coil, short, link, galvanized 25' chain
Mean Break Strength - 11,000#

ANCHOR - dead weight cast iron with four flukes
weight in air = 3500 lbs
weight in water - 3000 lbs

* MANUFACTURED BY COLUMBIAN ROPE COMPANY

FIGURE 4.2-3

NDBO RADAR REFLECTOR/
MARKER BUOY

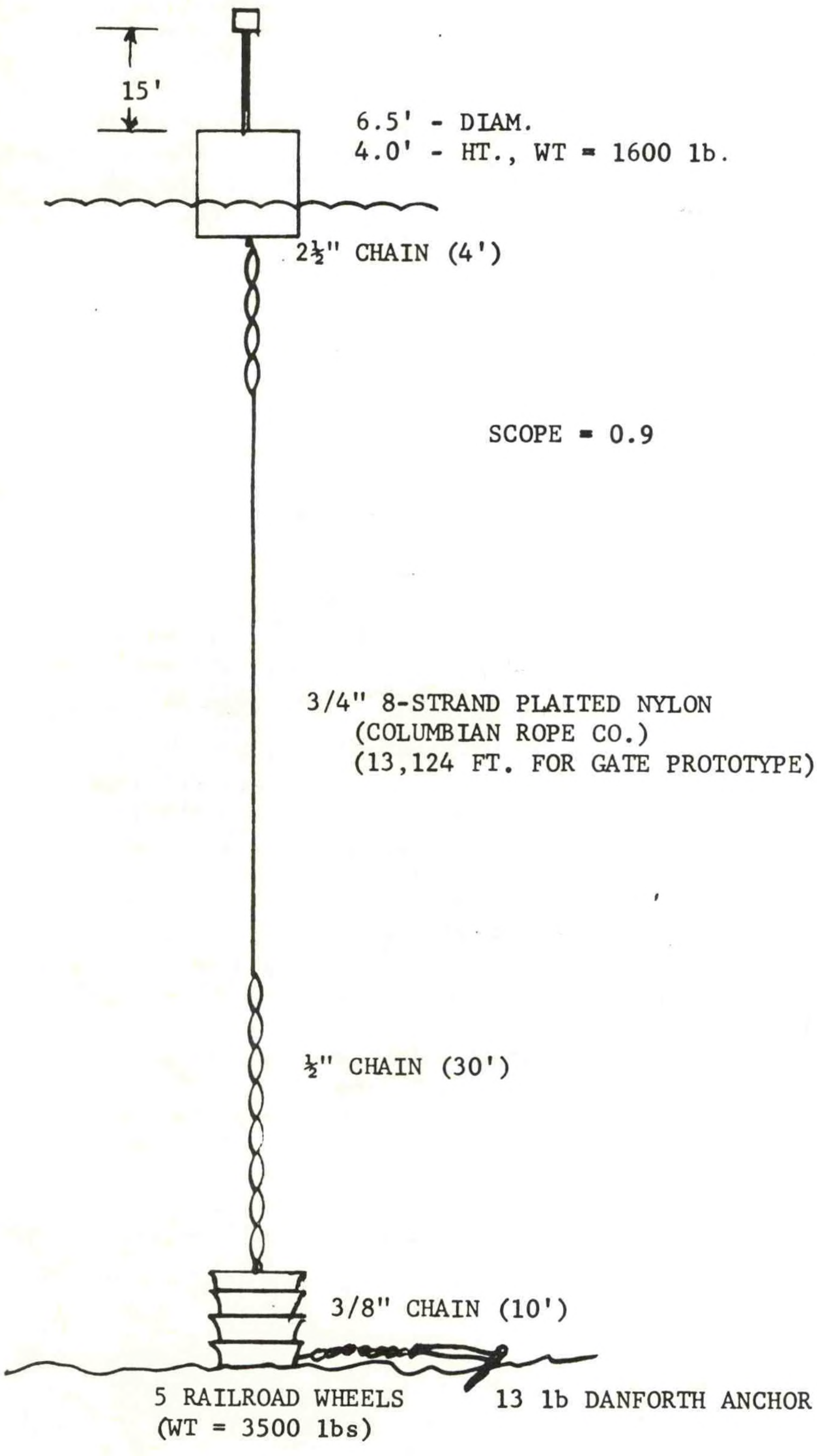
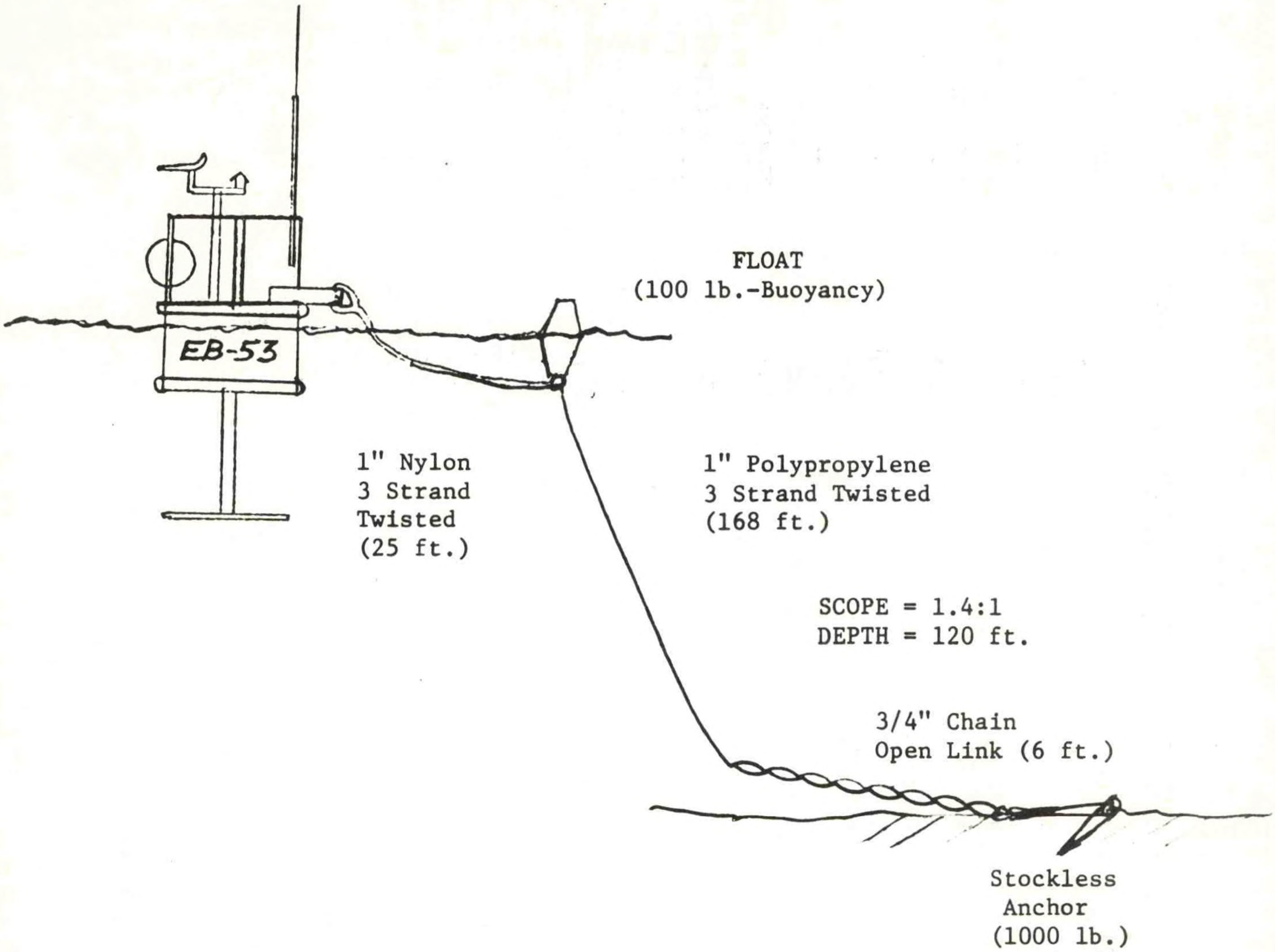



FIGURE 4.2-4




MAGNAVOX DLCB SPECIAL MOORING CONFIGURATION

(Moored Off Mobile Bay)

FIGURE 4.2-5

| BUOY | MFG. | LOCATION | DEPTH | DEPLOYED | RETRIEVED | MOORING FAILURE | CAUSE OF MOORING FAILURE |
|---|---|---|---|---|---|---|---|
| EB-01 | EDD | EAST COAST | 10,000' | 10/10/72* | -- | NONE | -- |
| EB-02 | LMSC | GULF OF MEXICO | 8,400' | 3/23/73 | -- | NONE | -- |
| EB-03 | EDD | GULF OF ALASKA | 13,800'<br>13,800' | 9/10/72<br>10/7/72 | 9/10/72<br>-- | YES<br>NONE | DEPLOYMENT TECH.<br>-- |
| EB-10 | EDD | GULF OF MEXICO | 8,400' | 6/16/72 | -- | NONE | -- |
| EB-12 | EDD | GULF OF MEXICO | 10,400' | 6/22/73 | -- | NONE | -- |
| EB-31 | GE | GULF OF MEXICO | 10,800' | 3/8/73 | MISSING | YES | UNKNOWN |
| EB-32 | GE | GULF OF MEXICO | 8,400' | 1/24/73 | 7/10/73 | NONE | (LINE SCUFFED AT THIMBLE) |
| EB-36 | LMSC | GULF OF MEXICO | 990' | 3/7/73 | 6/14/73 | YES | PROBABLE FISHBITE |
| EB-37 | LMSC | GULF OF MEXICO | 5,500' | 6/14/73 | 6/30/73 | YES | PROBABLE SCUFF & TENSION |
| EB-52 | MAG. | GULF OF MEXICO | 300' | 2/22/73 | 6/11/73 | NONE | -- |
| EB-53 | MAG. | GULF OF MEXICO | 120' | 3/7/73 | 3/31/73 | YES | TETHER LINE CUT BY FISHING BOAT |
| EB-61 | GE | GULF OF MEXICO | 600' | 2/21/73 | 6/11/73 | NONE | -- |
| RADAR MARKER BUOY | NDBO | FLORIDA COAST | 2500' | 6/ /73 | 6/ /73 | -- | CURRENT METER BROKE |

TABLE 4.2-1

*Mooring previously used for about two years

EB-31

The buoy has not been recovered. Cause of the mooring failure is unknown.

EB-32

Impending failure. Two strands of the line were severed, cause not fully determinable but possibly by barnacles.

EB-36

The buoy was moored in 990 feet west of Tampa, Florida, with scope of 1.0 using a 5/8" Samson single-braided nylon sheathed with a 1/16" polyurethane jacket for fishbite protection. The buoy was found to be missing after about two months on station and was recovered a month later off Lake Worth, Florida. The buoy had about forty feet of mooring line attached. The line showed evidence of fishbite and also of tensile failure. It appeared that the mooring line was initially weakened by fishbite through the outer sheathing. The mooring line then proceeded to fail progressively in tension.

EB-37

The buoy was taut moored in 5500 feet of water in the Gulf of Mexico using a 5/8" Samson single-braided nylon sheathed with a 1/16" polyurethane jacket. The mooring line failed after one day. The line showed scuffing and had failed in tension.

EB-53

The buoy was moored south of Mobile Bay in 120 feet of water using 168 feet of 1" polypropylene mooring line to a float with a 25-foot tether of 1" nylon. The buoy was moored for 23 days prior to failure. When recovered, 24 feet of nylon was still attached. The end was badly torn and tangled. The failure was attributed to entanglement with the propeller of a fishing boat which had crossed over the tether line and float.

### 4.2.3 DESIGN GUIDANCE

The following comments result from analyses of the failures and successes observed in NDBO operations with buoy moorings. They represent a few selected points that merit design emphasis and not a complete set of design criteria used by NDBO.

#### 4.2.3.1 ENDURANCE

The ability of the mooring to perform for the specified period is vital. This involves not only the required strength to withstand the expected loads, but also the capability to resist the additional hazards imposed by the environment. These include attacks by fish or mollusks. Experience accumulated by Woods Hole Oceanographic Institute and NDBO indicates that fishbite can be a significant risk but that the frequency of occurrence is dependent on geographic location and physical size of the mooring. The mooring line and/or its protective coating should be adequate to provide a high degree of assurance against failure.

#### 4.2.3.2 DEPLOYMENT AND RETRIEVAL

Damage to buoys and appendages has been sustained in deployment operations. Design of the mooring system should facilitate accomplishment of these operations in moderate seas with minimum hazard and should also minimize the time required and amount of personnel interaction. Deployment procedures should be designed to eliminate the likelihood of causing mooring failures as well.

4.2.3.3 MOORING LINE SCOPE

Use of a small scope for the purpose of producing a very small watch circle is not required if it results in increased cost or reduced mooring life. For buoys in deep water (10,000 ft.) no significant reduction in mooring line tension is obtained for scopes larger than 1.3. In shallower deep water moorings, a scope greater than 1.4 tends to induce design complications to avoid bottom chafing and entanglement. Bottom chain is required to alleviate snap loads in shallow water.

4.2.3.4 MATERIALS

Materials conforming to appropriate government or industry specifications or standards should be used. They should be of a type, grade, and quality which experience and/or tests have demonstrated to be suitable for the purpose intended and for marine applications.

Selection of mooring line material is very important. Reliability and cost effectiveness should be the governing criteria.

Synthetic mooring lines are compliant and non-corrosible but subject to fishbite damage. The creep, elasticity, and density characteristics of various synthetics differ. Polypropylene is buoyant, with a density of 0.9. The buoyancy tends to reduce the mooring force on the buoy and ensure that the mooring line does not pile up on the bottom during periods of slack current or wind. However, polypropylene exhibits large creep at moderate tension and is not generally recommended for that reason. Nylon has a density of 1.14, a slightly negative buoyancy. It has predictable elastic and creep properties and the permanent elongation and creep are not excessive at moderate loads. Dacron is denser than nylon (1.38) and has lower working elasticity. Its working length is the most predictable of the common synthetic rope fibers. These materials can be provided as twisted ropes or in braided or plaited constructions exhibiting torque-free characteristics or jacketed parallel fiber ropes. Twisted construction is not recommended because of the tendency to twist upon deployment. Double braid construction is considered superior to single braid construction.

Wire rope has high strength-to-drag ratio but also high density. It is more resistant to fishbite damage than synthetics, but subject to corrosion. Aluminum or zinc coatings will retard galvanic corrosion and plastic jackets will provide corrosion protection. Torque-balanced construction is available which reduces the propensity for kink formation. Use of steel cable allows significantly higher tension and reduced buoy excursion.

4.2.3.5 CORROSION RESISTANCE

All materials which are not inherently corrosion resistant should be finished with a proven preventive treatment or protective coating to minimize the effects of exposure to both atmospheric and marine environments. Protective coatings subject to cracking, peeling, or scaling with age or with extremes of atmospheric conditions should not be used. The surface preparation method selected should provide a proper and compatible match with any protective coatings used. Generally, initial protective finishes should be applied to individual parts prior to assembly.

Crevice corrosion should be prevented by proper sealing of crevices or use of flanged connections insulated with a dielectric medium that leaves no voids between the flange faces.

4.2.3.6 GROUND TACKLE OR ANCHOR

The selection of ground tackle depends upon the expected tension at the anchor and the direction of this force. NAVFAC DM-26, Design Manual, Harbor and Coastal Structures provides guidance for anchors and chain.

Moorings with large scope may use conventional anchors which exhibit maximum holding power at angles close to the horizontal. A clump or heavy chain ahead of the anchor is recommended to assure a horizontal pull on the anchor. The Danforth anchor is light in air, but has horizontal holding power in mud which can be up to fifty times the anchor weight and in a sand bottom which can be up to three hundred times the anchor weight. A special anchor for a Taut Moor is the Stimson anchor. It is designed to slip into the bottom by the arrangement of the three support chains. This anchor has probably the best holding power to weight ratio of any anchor for a taut moor.

Deployment involves carrying the anchor aboard the support ship to the desired station and then launching and dropping the anchor. Use of support ships with no crane has complicated this operation; but successful deployments have been made by the use of two mushroom anchors with a spreader bar for the forty foot disc and a single mushroom anchor for the Deep Keeled Hull. The anchors were mounted on a swing support on the ship for transport; a gravity launch occurred when the swing support was tripped.

4.2.3.7 ANCHOR RELEASE

It is usually desirable to release the anchor of a surface mooring before retrieval to reduce the line tension during hauling. A corroded or otherwise weakened mooring line may part if the additional weight of the anchor is present during the retrieval operation. Devices available to disconnect the anchor from the mooring line include explosive cable cutter (knife and burst) and acoustic/mechanical releases.

An effective acoustically operated release must be secure from random sources of acoustic energy such as surface waves, fish, ships, and seismic disturbances and yet must recognize a specific command signal in this noisy environment. In addition, thermal gradients and multi-paths conspire to mask and distort command signals sent to the release. It is often useful to incorporate a sound source, such as a pinger, into the release package which energizes when the release activates, signalling successful release. Intelligent design and high reliability are most important for this critical component of the mooring system. Acoustic release devices are battery operated and are therefore suitable only for applications involving a maximum deployment of two years.

NDBO has successfully used explosive cable cutters to release EB-32 and EB-01. Current designs include acoustic releases, but no attempt has been made to date to operate one.

## 4.3 POWER SUBSYSTEMS EXPERIENCE

### 4.3.1 DESCRIPTION OF NDBO SUBSYSTEM HARDWARE DESIGNS

Two basic types of power systems are presently used by NDBO in their data buoys; diesel electric generators for the large buoys and primary batteries for the small buoys.

#### 4.3.1.1 LARGE BUOYS

##### 4.3.1.1.1 ED - EEP BUOY POWER SYSTEM

The EEP power system consists of two diesel engine driven AC generators, an engine controller, two battery chargers, three batteries, a power distribution panel, an engine lubrication system, a fuel system and a fuel tank pressurization system. A simplified schematic diagram of the system is shown in Figure 4.3-1.

One diesel engine driven generator supplies all the electrical power requirements of the buoy. The other unit functions as a standby unit in case of failure of the on-line unit. The output of the generator is 120 VAC, single phase, and supplies power to the AC Bus for various AC loads in addition to two battery chargers.

The output of each battery charger is used to float charge a set of 28 VDC lead acid batteries and to supply power to its DC bus. The two DC busses are tied together through the contacts of the AC power failure relay.

During normal operation, the DC load is supplied by battery chargers with the batteries accommodating peak loads that exceed the 25 amp capacity of the charger. The on-line power plant is continuously monitored by the engine controller to assure that AC power output is maintanined within specified

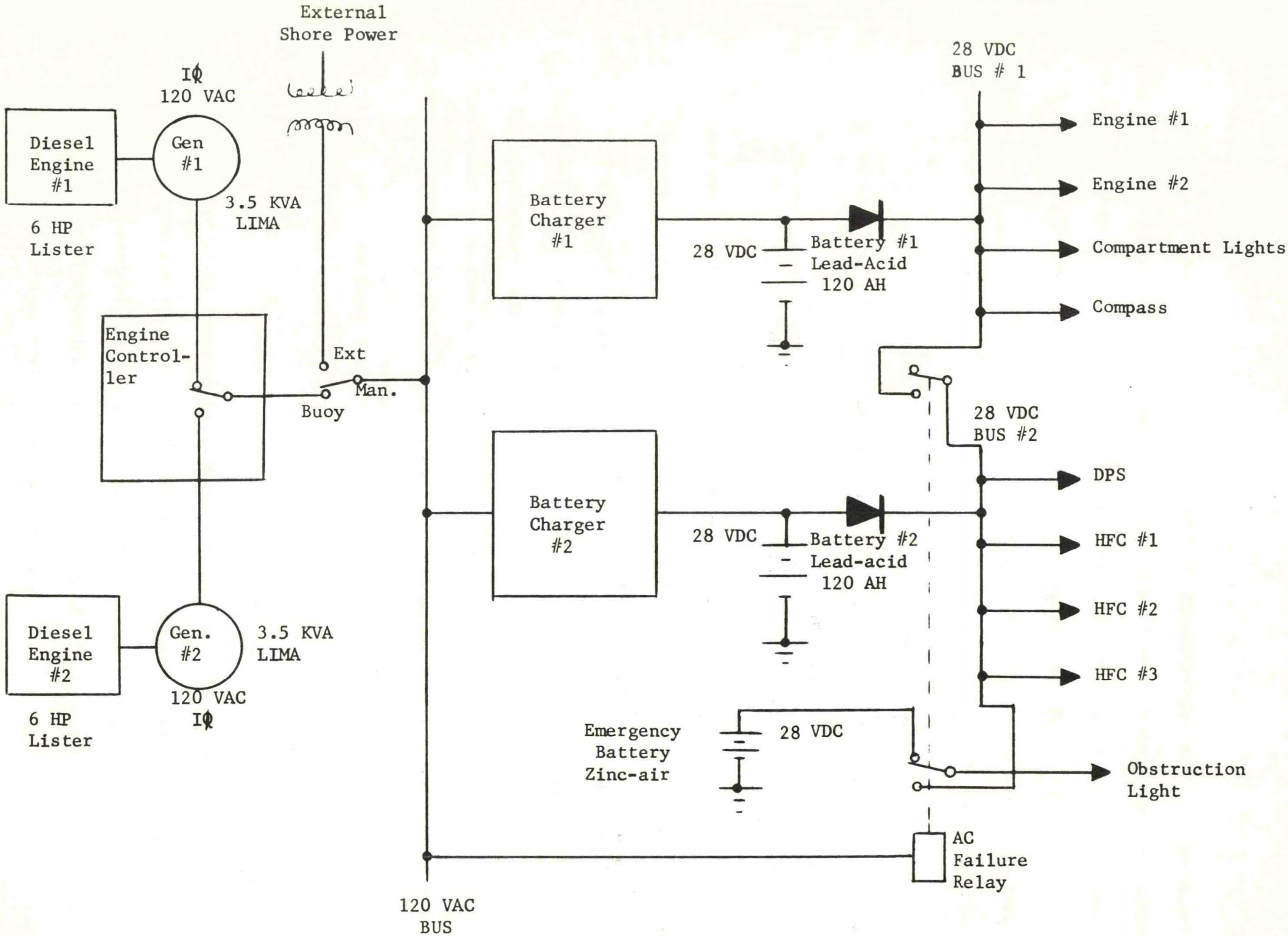



Figure 4.3-1. ED-EEP Power System - Simplified Schematic

requirements. The engine controller is a solid-state unit capable of automatic and manual operation in both a local (buoy) and a remote control (DPS) mode. Protection, monitoring, starting and engine test controls are included in the controller. If the AC power fails, the failure is sensed by the engine controller and the standby diesel engine generator is started and switched into the AC bus.

If both generators fail, the AC power failure relay separates the two DC busses so that each battery supplies its own bus until its charge is depleted. In this emergency mode the obstruction light is switched to the emergency 28 VDC battery. The emergency battery is a zinc-air primary battery.

The lubricating oil and fuel are filtered and the fuel system has a coalescent to remove water. The fuel tanks are pressurized with nitrogen to prevent the entry of water vapor and to eliminate the presence of oxygen.

4.3.1.1.2 LMSC- DKH BUOY POWER SYSTEM

The DKH power system consists of two diesel engine driven AC generators, an engine controller, three batteries, a power distribution panel, an engine lubrication system, a fuel system and a fuel tank pressurization system. A simplified schematic diagram of the system is shown in Figure 4.3-2.

Although the DKH power system operates in the same basic manner as the EEP system, there are some major differences. The output of the DKH generator is 24 VAC, 3 phase, and supplies power to the AC bus for its AC loads through a step up transformer. The generator also supplies its DC power directly to the DC bus through its 3 phase, full wave rectifiers. This output which is a low ripple 28 VDC is also used to float charge the 28 VDC lead acid batteries associated with the generator on the line and the emergency batteries.

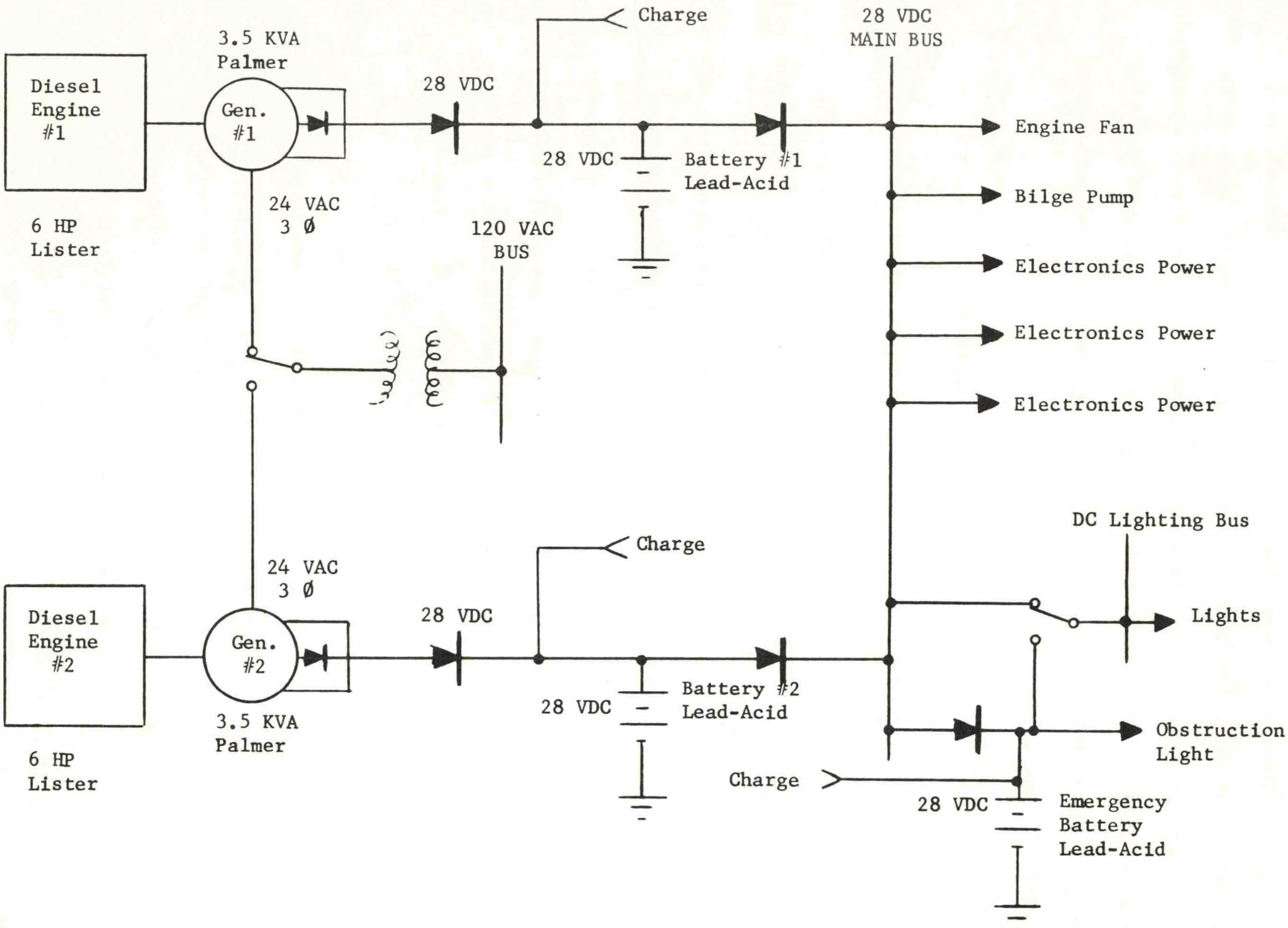



Figure 4.3-2. LMSC-DKH Power System - Simplified Schematic

One generator operates at a time while the other one is in a standby mode. The on-line generator is monitored by the solid state engine controller. A failure of output voltage or oil pressure is sensed by the engine controller which causes the standby generator to be started. The DPS is programmed to switch generators every 14 days.

4.3.1.2 SMALL BUOYS

4.3.1.2.1 GE - LCB BUOY POWER SYSTEM

The GE - LCB power system consists of two sets of batteries and the battery control electronics. A simplified schematic diagram of the system is shown in Figure 4.3-3. The two sets of batteries consist of the primary power supply, which provides the power for the entire buoy mission, and the emergency power supply, which is used to power the navigation light after the prime power is depleted. All of the batteries are alkaline manganese dioxide rechargeable dry cells.

The prime power supply operates as a step - boost power system with three boosts, one 4.5 VDC and two 1.5 VDC. The major portion of the prime power supply batteries are connected for an output of 30 VDC (nominal). The battery voltage is sensed during the high current drain while the buoy is transmitting data. If during the 25 second transmission the voltage drops to 24 VDC the battery control electronics senses the drop and 3 seconds after the transmission is completed it switches a 4.5 VDC group of cells, boost 1, in series to increase the prime power voltage. This cycle is repeated for 2 more groups of cells, boost 2 and boost 3, each containing cells at 1.5 VDC. When the voltage drops to 24 VDC the 4th time the mission of the buoy can no longer be performed and the navigation light is switched to the emergency power source.

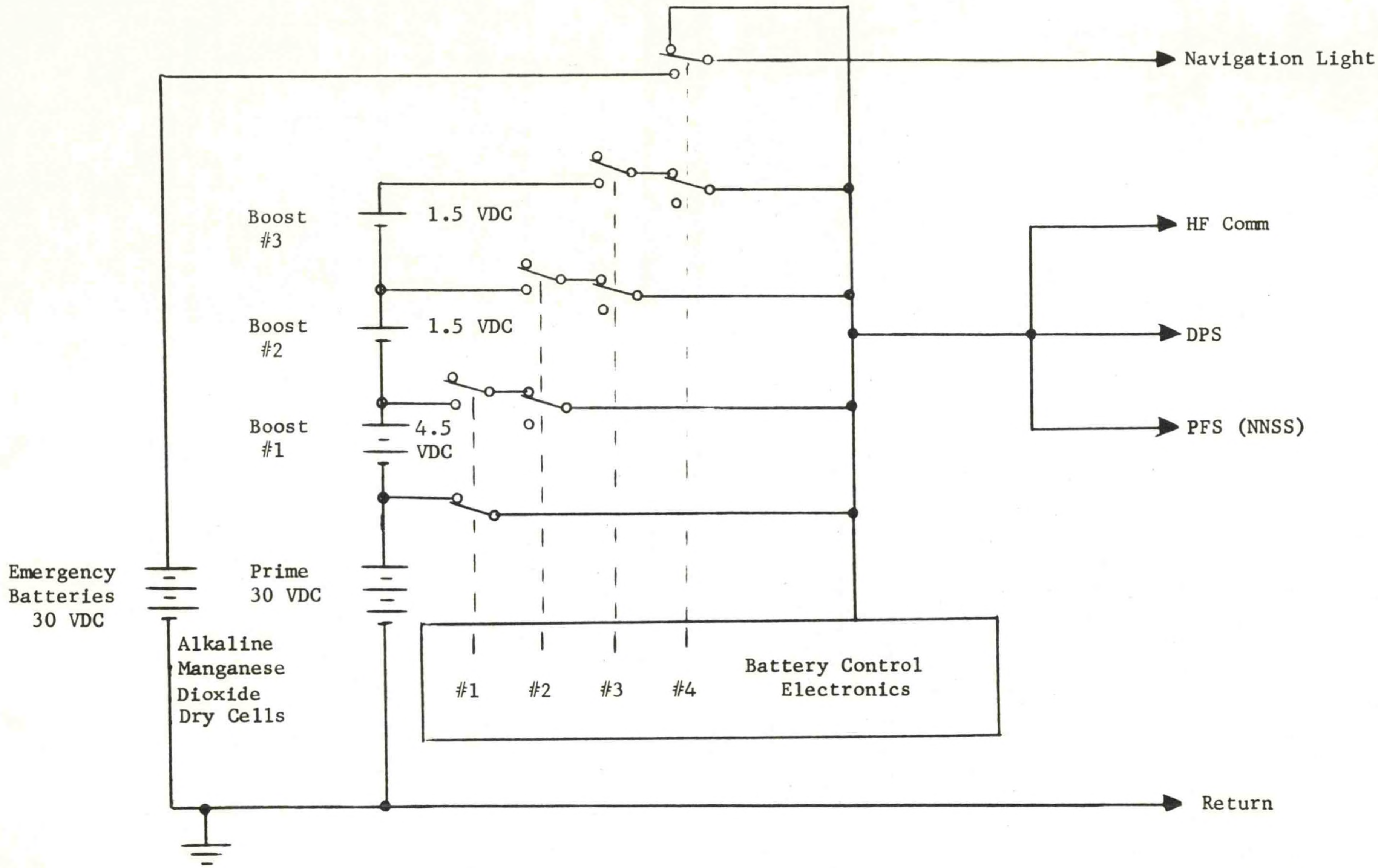



Figure 4.3-3. GE-LCB Power System - Simplified Schematic (Drifter)

Although the batteries are a rechargeable type, they are not suitable for recharge when used as primary batteries and completely discharged.

Regulated and unregulated ± 14 volt dc power required for the Data Processor System is supplied by a DC/DC converter/regulator which is a part of the Data Processor.

4.3.1.2.2 LMSC - LCB BUOY POWER SUPPLY

The LMSC - LCB power system consists of three sets of batteries, a voltage regulator, and a battery charger. A simplified schematic diagram of the system is shown in Figure 4.3-4. The three sets of batteries consist of one set for the primary power, one set for emergency power, and one set of rechargeable batteries for the peak load power required by the HF transmitter.

The primary batteries are zinc-air non-rechargeable. The peak load batteries are rechargeable nickel-cadmium dry cells while the emergency battery is rechargeable lead-acid with low self discharge characteristics.

Power for the Data Processor and other electronic equipment is obtained from the ± 14 volt regulator.

4.3.1.2.3 MAGNAVOX - LCB BUOY POWER SYSTEM

The Magnavox - LCB power system consists of four sets of batteries, a voltage regulator, and a battery charger. A simplified schematic diagram of the system is shown in Figure 4.3-5. The four sets of batteries consist of two sets for the primary power (high voltage and low voltage), one set for emergency power, and one set of rechargeable batteries for the peak load power required by the HF transmitter. The rechargeable peak load batteries are Nickel-Cadmium dry cells while all other batteries are carbon-zinc dry cells.

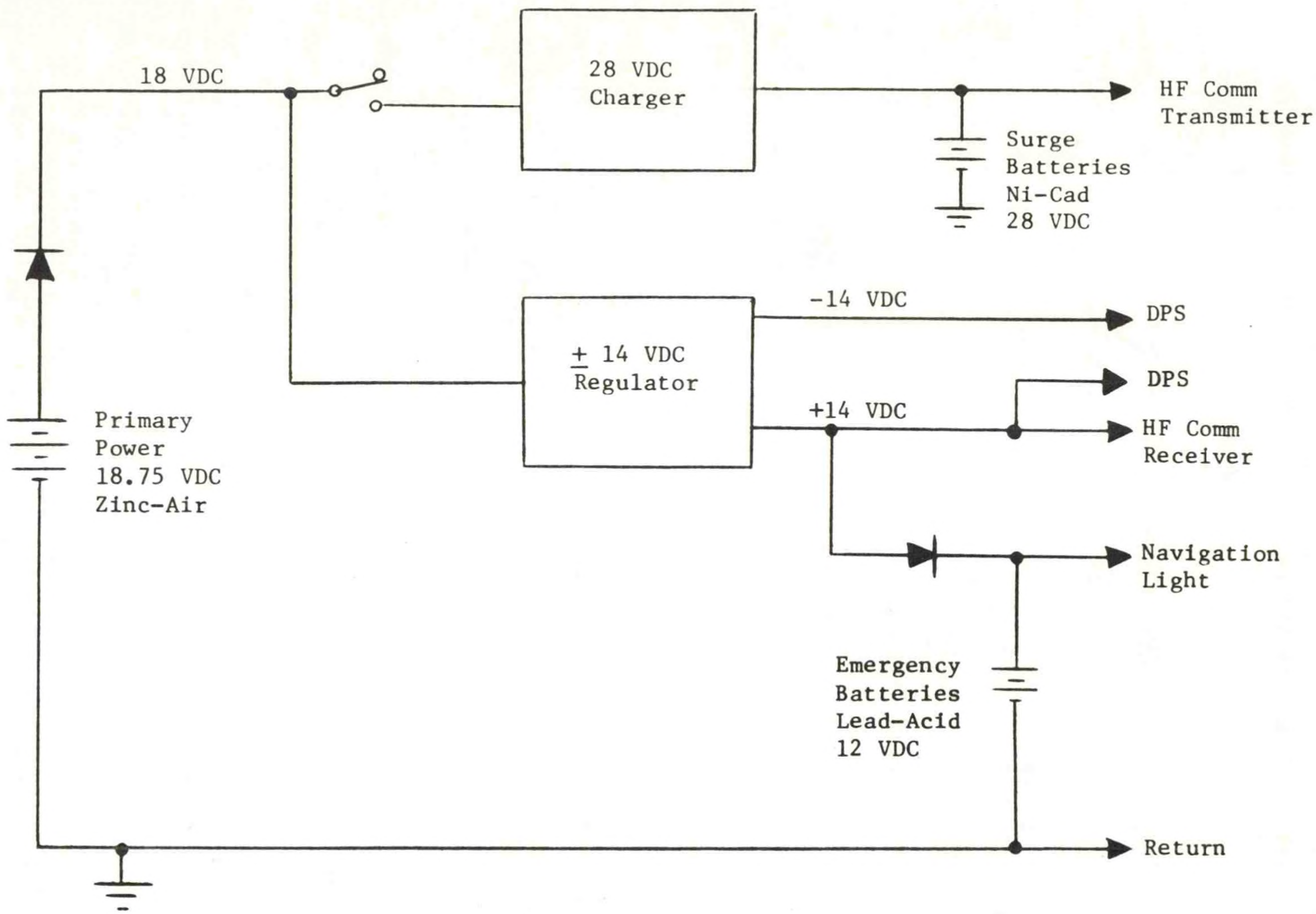



Figure 4.3-4. LMSC - LCB Power System - Simplified Schematic

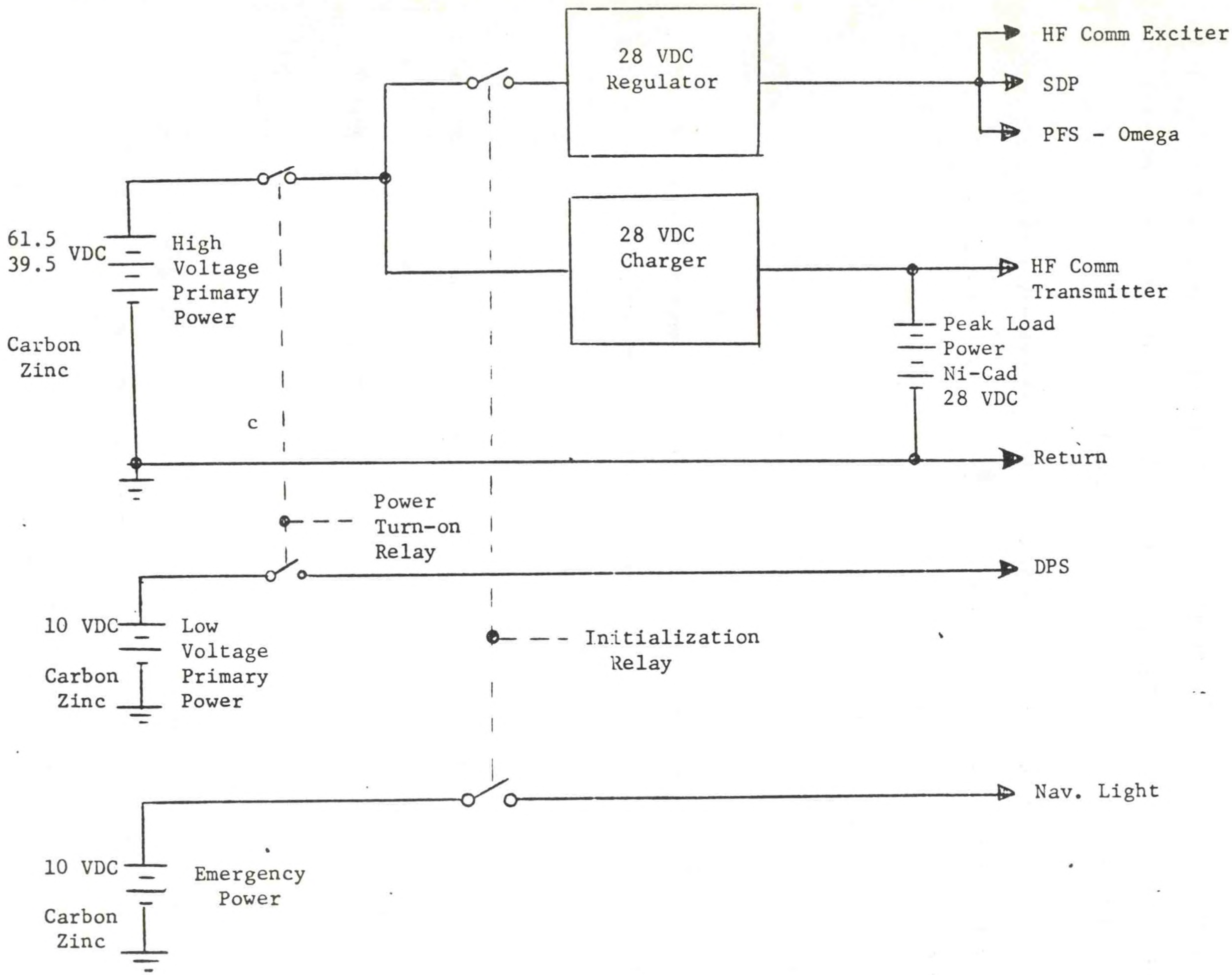



Figure 4.3-5. Magnavox - LCB Power System - Simplified Schematic

Since the peak load batteries are rechargeable from the primary high voltage supply, and since the emergency batteries are used only for the navigation light, the power required to perform the buoy's primary mission is obtained from the two primary battery supplies.

The emergency battery is sized with enough power to continue to operate the navigation light for at least 30 days after the primary batteries are depleted.

4.3.1.3 OTHER POWER SYSTEMS

4.3.1.3.1 LIQUID FUELED THERMO ELECTRIC GENERATOR

A 300 watt liquid fueled (diesel) thermo electric generator (LFTEG) has been developed by NDBO. This power system has not been installed in any buoy systems and very little experience has been gathered to date.

4.3.1.3.2 SOLAR CELLS

Some limited testing will be done by NDBO within the next year with existing solar cells on our 40 ft. concrete discus buoy. Use of solar cells on buoys has been very limited and there is little data available to support their use.

4.3.1.3.3 FUEL CELLS

Consideration has been given to the use of Integral Fuel Cells but to date we have no experience with this type of power.

4.3.2 PERFORMANCE BASED ON EXPERIENCE

4.3.2.1 LARGE BUOYS

4.3.2.1.1 DIESEL ENGINE

The large 40-foot discus buoys and large boat hull buoys are powered by diesel engine generators. Very good reliability has been achieved by operating the engines at low speed and by careful filtering of the fuel and lube oil. The crank case of these diesel engines is operated dry; engine lubrication is supplied from a 25-gallon lube oil sump. The fuel system is operated with a nitrogen blanket with a slight pressure above atmosphere to avoid condensation of moisture in the tanks. This system has been successful and we have not had a problem with bacterial growth in the fuel as long as the nitrogen blanket has remained intact. In such a system an over-pressure relief value is necessary and it must be a low pressure and relatively sensitive device. In one instance a relief value failed which resulted in loss of the blanket and caused bacteria and fungus growth in the fuel. The resulting sludge and slime was bad enough to plug the filter and shut the engine down in a few weeks. There is some evidence, however, that comparable results could be had by adding a biocide and eliminating condensation with a silicagel drier for the asperated air. In any event, generous size filters are considered a necessity in both the fuel and lube oil system.

Failures in the diesel engine generator systems have been in the area of engine controls and spurious commands from the DPS rather than in the basic engine. Simple rugged controls are highly desirable.

4.3.2.1.2 GENERATOR

Two general types of generators have been used, permanent magnet field and wound field. Some minor problems have been encountered with the voltage regulator for the wound field type. The permanent magnet type generator is less subject to failure, but the voltage regulation is not as good.

Single-phase generators have been used where battery chargers have been used to charge the batteries. Three-phase generators have been used since the low ripple from the three-phase rectifier allows direct float of the battery on the line.

4.3.2.1.3 STORAGE BATTERY

Lead-calcium storage batteries have been used for conditions requiring low self-discharge. These batteries, however, do not have the cycling capability that the common lead-antimony batteries have.

4.3.2.1.4 BATTERY CHARGING

SCR-controlled battery chargers have caused considerable trouble in small signal circuits by generating voltage transients, both on the A.C. bus and the D.C. bus. Direct battery charging with rectified three-phase current has been successful. Speed and voltage droop characteristics of the small generating system appear to allow this type of charging.

4.3.2.2 SMALL BUOYS

4.3.2.2.1 PRIMARY BATTERIES

Rechargeable alkaline manganese dioxide batteries have been used successfully as primary batteries, without recharging. The temperature characteristic of these batteries is good, but the cost is high. Carbon-zinc dry cells are more economical, but the low temperature characteristics prohibit their use in northern latitudes. Zinc-air batteries have favorable power density and cost, but require ventilation.

Leakage of electrolyte has been experienced with the zinc-air batteries when tipped on their side for extended periods, in particular, during overland transportation to and from the deploying ship. In one case the electrolyte leaked through the seal of the battery case. In another case, after a period of deployment, the electrolyte leaked out of the vented filler cap when transported on its side back from the ship. A vendor improved filler cap may reduce this tendency to leak.

Some problems have also been experienced with the carbon-zinc dry cells due to vibration and shock during overland transportation where the batteries vibrated out of their normal insulated mounting. Continued vibration caused the paint to wear the bare metal battery case then made contact with the hull and the energy was depleted due to an accidental leakage path from the battery, to case, to ground.

#### 4.3.2.2.2 SECONDARY SURGE BATTERIES

Heavy surge loads imposed by the transmitter have been supplied by nickel cadmium batteries charged from the primary battery. These require charging equipment, and in general, output regulator equipment. Some trouble has been experienced with these devices and it is considered desirable to eliminate them if the primary battery can be made large enough to supply surge currents.

### 4.3.2.3 GENERAL

#### 4.3.2.3.1 CABLES AND CONNECTORS

Corrosion of exterior connectors, and moisture in both internal and external connectors has been a problem. Insufficient tightening of the connector is believed to be a contributing cause where weather-proof connectors have been used. Replacement of these connectors has been a problem. Cables are generally installed in conduit and connectors have to be installed after the cables are run. This is standard practice ashore but it is not practical on buoys at sea.

Cable installation should be such that replacement cables with installed connectors can be installed at sea. An alternate would be installation of spare universal-type cables and connectors. See Appendix 4.3-1 for further details on connector problems experienced.

4.3.2.3.2 TRANSIENT VOLTAGE SURGES

Transient voltages have been a major source of trouble on buoys. The proximity of small signal circuits to power circuits make it imperative that transients should be eliminated wherever possible. A major source of transients is relay and contactor coils. Semiconductor surge suppressors have been found to be very effective in eliminating transients from this source. Another effective method of reducing interference from transients is separating the power supply so that small signal equipment is supplied from a source isolated from the source supplying power loads.

4.3.2.3.3 GROUNDING

The power system should be grounded to the buoy hull/sea water at a single point. Failure to do this has given trouble with ground loops and electrical noise induced in signal circuits. The signal system should also be grounded at a single point and should not have any of its ground circuitry common to power ground conductors. The communications system should also have its single point ground and its circuitry should be separate from all other ground circuits. Generous size ground wire tends to reduce transferred noise.

There have been no lightning grounds used on steel hull buoys and no known problems have arisen from this.

4.3.2.3.4 SPECIAL POWER SUPPLIES

So called power supplies providing special voltages to electronic gear have been a large source of trouble. Marginal design in the transistors and heat dissipation equipment has contributed largely to failures of these components. Coordination of equipment operating voltages and the primary power supply voltage would reduce reliance upon voltage conversion equipment, improve the reliability, and reduce the power loss.

4.3.3 APPROACHES

The primary role of the power system in the environmental buoy is to supply all of the primary power requirements for the Sensor, Data Processor, and Communication Systems for the mission of the buoy. An important consideration in the design of the power system is the requirements for special voltages, or power supplies, and regulation for the various subsystems. One of the most important design tasks of the power system is the elimination of unnecessary sub-power supplies and assuring the reliability of the remaining ones.

Although the diesel engines and generators of the large buoys have operated with little trouble, the associated electronic controls and remote controls via the computer system have given considerable trouble. Also transients caused by the control system have caused problems in the logic circuit of the Data Processor System. By having reduced load requirements in the future buoy systems a less complex power system can be used.

An approach to the design which should be given strong consideration is the use of large capacity primary batteries with a minimum of converters, regulators, and battery chargers. Where these devices are required they should be of a minimum complexity and cost, but with a high degree of reliability. Consideration should be given to isolating the power for the Data Processing System to the extent that spikes or transients of the power system or other systems will not cause erroneous logic signals ot appear.

In the design of battery systems the problem of disposal should be kept in mind. Almost all batteries contain Mercury in some form and degree. Dumping the depleted batteries at sea is consequently forbidden. Even disposal in land fill is not allowed in some states.

It should be noted that there has been difficulty experienced with some kinds of air depolarized batteries in buoys. High humidity and inadequate case venting may be contributing causes.

Other problem areas to consider in the initial design concept are the selection of proper connectors (when needed) and the proper routing of signal and power return circuits.

Mil-spec connectors such as MIL-C-5015 or MIL-C-22992 should be considered, but more important is the selection of a connector to meet the requirements of its environment.

Consideration should be given to the requirements of MIL-STD-1310 for grounding of all equipments.

Appendix 4.3-2 consists of a table of characteristics of the three types of primary batteries used on the small buoys.

Appendix 4.3-3 is a report on the power requirements and power profile for one of the small buoys.

## 4.4 SENSOR SUBSYSTEM

### 4.4.1 INTRODUCTION

The Sensor Subsystem of the Prototype Buoy is defined as the set of basic transducers and signal conditioning equipment required to sense changes in the physical environment for the identified measurands and transform the transducer responses into electrical signals of known relationship to the physical changes. Furthermore, the electrical signals shall be normalized to facilitate direct acceptance and processing by a digital data processing system on board the buoy. The definition of a transducer, as used herein, is a device that senses a change in a physical measurand and converts this change into a representative electrical signal. A sensor is defined as consisting of a transducer and its associated signal conditioning electronics and mechanical structure.

The Sensor Subsystem on the Prototype Buoy will include Meteorological and Oceanographic Sensors. Meteorological Sensors are Wind Speed and Direction, Air Temperature, and Air Pressure. Oceanographic Sensors are Surface Water Temperature, Subsurface Water Temperature and Sea State. The frequency of data acquisition and the duration of the acquisition period will be controlled externally or from within the Sensor System. Accuracy of a sensor is its ability to sense the physical phenomenon and provide a true electrical representation of this phenomenon at the output. Detail requirements for the system accuracies and the environmental ranges over which the sensors must operate within these accuracies are included in the System Specification for the Prototype Buoy.

In the design of the Sensor Subsystem for the Prototype Buoy, the contractor will be free to use existing sensor hardware designs when they meet the objectives of his overall system. A detail description of all pertinent NDBO hardware is given in the following paragraphs.

4.4.1.1 NDBO HARDWARE

Sensor Subsystems in use on NDBO buoys have several things in common. They are not self-initiating, but must be interrogated by command from a digital data processing system. They must be at ready to respond immediately upon interrogation. Depending on the remoteness of the sensor from the DPS and the scheme used for communication between the sensor and the DPS, they must be capable of recognizing and interpreting a command. In general, a sensor consists of a basic transducer with appropriate linearization network, analog signal conditioning circuits, A/D converter, and a store and forward on command. Since more than one measurement is usually involved, the use of common data channels or serial processing is used which requires time multiplex switching of measurement signals. Flexibility is sometimes added to allow interrogation of one particular sensor or a specific group of sensors. The interrogating signals are transmitted in a coded format by telemetry up or down link. This requires that decoders be located in the remote sensor package. The HCB sensor subsystem uses Phase Shift Keying (PSK) modulation for transmission of commands and data. One of the moored LCB's uses power switching for command coding, and data is transmitted by the variable frequency from a voltage-to-frequency oscillator.

The sensor subsystem installed on the Engineering Experimental Phase (EEP) High Capability Buoy (HCB) includes a Meteorological Sensor System and an Oceanographic Sensor System. Measurements are taken at the 5 and 10-meter meteorological levels and at the air-sea interface and twelve Oceanographic levels to 500 meter depth. All sensors interface with the Data Processing System (DPS) through a Sensor Deck Unit (SDU). Sensor address and data are serially shifted to and from the sensors, in NRZ format for the meteorological sensors and in NRZI format for the inductively coupled oceanographic sensors. The SDU provides sensor power, control, interrogation, timing and data store and forward on command.

The Oceanographic Sensors interface directly with the SDU, in the case of hull mounted sensor, or via the Mooring Line Data Line (MLDL), in the case of inductively coupled sensors. The inductively coupled sensors are powered by an internal 12-V battery which is trickle charged. The hull mounted sensor, however, is hard wired directly to the SDU and is powered by +12-VDC from the SDU.

Information exchange between the SDU and the inductively coupled oceanographic sensors, and power to trickle charge the battery, are accomplished by up-link and down-link telemetry signals on one or more of the eight electrical conductors in the MLDL. The oceanographic sensors include the transducers, signal conditioning electronics and control and decoding circuits to receive and interpret commands, sense and signal condition data, and transmit the conditioned data to the SDU. The Meteorological Sensors include separate sensor electronics units on each of the meteorological levels. These units include signal conditioning electronics and control and decoding similar to the oceanographic sensors.

The Deep Keel Hull (DKH) Buoy utilizes the same Sensor Subsystem as the EEP buoys. However, only the 10-meter level has meteorological sensors installed.

The Limited Capability Buoy (LCB) includes a Sensor Subsystem for meteorological and oceanographic measurements. Drifting LCB's measure wind, air temperature, air pressure above water, and surface water temperature. Moored LCB's measure the same measurands as the drifting LCB's and also sub-surface water temperature at six levels down to 200 meters. The moored LCB's also measure water pressure at the 200-meter level.

Meteorological sensors on the LCB's are mounted at approximately two meters above the water surface. The Lockheed Moored LCB's have a separate data line which interfaces the water temperature and pressure transducers to the buoy electronics by individual electrical conductors in the data line. The General Electric Moored LCB's have a mooring line data line with three electrical conductors which interfaces the water temperature and pressure transducers to the buoy electronics with inductive couplers at the transducer housings. A block diagram and detail description of each of these Sensor Subsystems is included in the following paragraphs. Table I is a matrix which identifies all transducers/sensors in the NDBO inventory with pertinent details on vendors, types, buoys and locations where installed, etc.

(Entries = Manufacturer-Sensor Type/Level[s])

15 August 1973

| | SEVERE ENVIRONMENT BUOYS | | | | | | MODERATE ENVIRONMENT BUOYS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BUOY NUMBER: | EB-01 | EB-02 | EB-03 | EB-10 | EB-12 | EB-13 | EB-31 | EB-32 | EB-36 | EB-37 | EB-38 | EB-51 | EB-52 | EB-53 | EB-61 | EB-62 |
| CONTRACTOR: | GD | LMSC | GD | GD | GD | GD | GE | GE | LMSC | LMSC | LMSC | MAG | MAG | MAG | GE | GE |
| METEOROLOGICAL MEASUREMENTS | | | | | | | | | | | | | | | | |
| 1. Wind Direction | W-VS/* | W-VS/10 | W-VS/*<br>GD-AE/5 | W-VS/* | W-VS/* | W-VS/* | EG-FGC/2 | EG-GFC/2 | WM-IG/2 | WM-IG/2 | WM-IG/2 | J-VS/2 | J-VS/2 | J-VS/2 | EG-FGC/2 | EG-FGC/2 |
| 2. Wind Speed | W-VS/* | W-VS/10 | W-VS/*<br>GD-AE/5 | W-VS/* | W-VS/* | W-VS/* | EG-FGC/2 | EG-FGC/2 | WM/IG/2 | WM-IG/2 | WM-IG/2 | J-VS/2 | J-VS/2 | J-VS/2 | EG-FGC/2 | EG-FGC/2 |
| 3. Air Pressure | W-CD/* | W-CD/10 | W-CD/*<br>GD-AP/5 | W-CD/* | W-CD/* | W-CD/* | S-AP/2 | S-AP/2 | G-DT/2 | G-DT/2 | G-DT/2 | R-CD/2 | R-CD/2 | R-CD/2 | S-AP/2 | S-AP/2 |
| 4. Air Temperature | W-PTR/* | W-PTR/10 | W-PTR/*<br>GD-PTM/5 | W-PTR/* | W-PTR/* | W-PTR/* | Y-T/2 | Y-T/2 | F-T/2 | F-T/2 | F-T/2 | Y-T/2 | Y-T/2 | Y-T/2 | Y-T/2 | Y-T/2 |
| 5. Dewpoint Temperature | W-SC/* | W-SC/10 | W-SC/*<br>GD-TCM/5 | W-SC/* | W-SC/* | W-SC/* | | | | | | | | | | |
| 6. Precipitation | W-D/15 | W-D/10 | W-D/10 | W-D/10 | W-D/10 | W-D/10 | | | | | | | | | | |
| 7. Global Radiation (IR) | W-T/8 | | W-T/10 | W-T/10 | W-T/10 | W-T/10 | | | | | | | | | | |
| 8. Global Radiation (Visual) | W-T/10 | | W-T/10 | W-T/10 | W-T/10 | W-T/10 | | | | | | | | | | |
| OCEANOGRAPHIC MEASUREMENTS | | | | | | | | | | | | | | | | |
| 1. Wave Height | K-A/H** | L-TS/H | HU-A(SD)/H *** | HU-A/H ** | HU-A/H ** | SH-A(SD)/H *** | | | | | | | | | | |
| 2. Water Temperature | GD-PTM/H | W-PTR/+ | W-PTR/H | | W-PTR/++ | W-PTR/@ | Y-T/# | Y-T/# | F-T/## | F-T/## | F-T/## | Y-T/H | Y-T/H | Y-T/H | Y-T/H | Y-T/H |
| 3. Current Direction | GD-V/H | W-V/+ | W-V/H | | W-V/++ | W-V/@ | | | | | | | | | | |
| 4. Current Speed | GD-SR/H | | | | | | | | | | | | | | | |
| 5. Conductivity ▪ | | W-ICT/+ | W-ICT/H | | W-ICT/++ | W-ICT/@ | | | | | | | | | | |
| 6. Water Pressure | | W-SG/+ | W-SG/H | | W-SG/++ | W-SG/@ | EG-SG/200 | EG-SG/200 | CEC-SG/200 | CEC-SG/200 | CEC-SG/200 | | | | | |

* 5, 10 meters above sea level.

** Buoy Acceleration Measurement System Only.

*** Wave Period is Derived

▪ Salinity is Derived

LEGEND FOR SEVERE ENVIRONMENT BUOYS

MANUFACTURER

GD: General Dynamics
HU: Humphrey
K: Kistler Accelerometer
L: Lockheed
SH: Schaevitz Accelerometer
W: Westinghouse

Type

A: Accelerometer (SD): Strapped Down
AE: Aerovane (Bendix) with flux gate compass (Humphrey)
AP: Aneroid Potentiometer (Sostman)
CD: Variable Capacitance Diaphragm (Rosemount)
D: Volumetric Dumping (Westinghouse)
ICT: Inductively Coupled Transformer (Plessey)
PTM: Platinum Resistance Thermometer (MIL STD)
PTR: Platinum Resistance Thermometer (Rosemount)
SC: Sapphire Crystal (Transonics)
SG: Bonded Strain Gauge - Standard Control
SR: Savonius Rotor
T: Thermopile
TCM: Thermoeletrically Cooled Mirror (EG&G)
TS: Tucker System-Accelerometer and Pressure Transducer
V: Vane
VS: Vortex S[illegible]ng (J-TEC) Anemometer with Magnavox Flux Gate Compass

LEGEND FOR MODERATE ENVIRONMENT BUOYS

MANUFACTURER/TYPE

CEC-SG: Consolidated Electrodynamics Corp./Strain Gauge, Standard Control
EG-FGC: EG&G/3-Cup Anemometer with Bar Magnet Compass
F-T: Fenwall/Thermistor
G-DT: Gulton/Linear Variable Differential Transformer
J-VS: J-TEC/Vortex Shedding Anemometer with Flux Gate Compass (Magnavox)
R-CD: Rosemount/Variable Capacitance Diaphragm
S-AP: Sostman/Aneroid Potentiometer
WM-IG: Weather Measure/Impeller Generator, Bar Magnet (Humphrey)
Y-T: Yellow Springs/Thermistor

LEVELS (DEPTHS IN METERS)

H: In or On Buoy Hull
+: H, 50, 100
++: H, 50, 100, 150, 250, 500
@: H, 30, 50, 100, 150, 200, 300
#: H, 10, 20, 50, 100, 200
##: 2, 10, 20, 50, 100, 200

TABLE 4.4-1

### 4.4.2 SENSOR DESCRIPTIONS

The physical and electrical details for each meteorological and oceanographic sensor currently in the NDBO inventory are given in the following paragraphs. These descriptions are limited to those sensors which perform the measurements of environmental parameters of interest for the prototype buoy. Our intent in describing the general functioning of these sensors is to familiarize the potential bidder with information on the techniques and designs being utilized in hardware in which we have had considerable operational and testing experience. These are certainly not the only techniques that have been successful and are not necessarily the optimum configurations. We shall also point out, in the next sections, areas where NDBO has experienced problems that have affected the reliability, performance and cost of these sensors.

#### 4.4.2.1 AIR TEMPERATURE SENSORS

4.4.2.1.1 One configuration of air temperature sensor used on the High Capability Buoy (HCB) is shown in the block diagram of Figure 4.4-1. Two temperature transducers provide temperature measurements at two heights from the mean water surface. One is housed in the Dew Point and Temperature Transducer Assembly at the five-meter level and the other is housed in the Dew Point, Temperature and Global Radiation Transducer Assembly at the ten-meter level. Each of these assemblies contains a small aspirator fan to draw the outside air through the transducer housing. The housing provides shielding from the direct rays of the sun and is painted white.

The air temperature sensor uses a platinum resistance temperature sensing element which forms a leg of a Wheatstone bridge. A bridge amplifier amplifies and conditions the analog voltage before being multiplexed into an

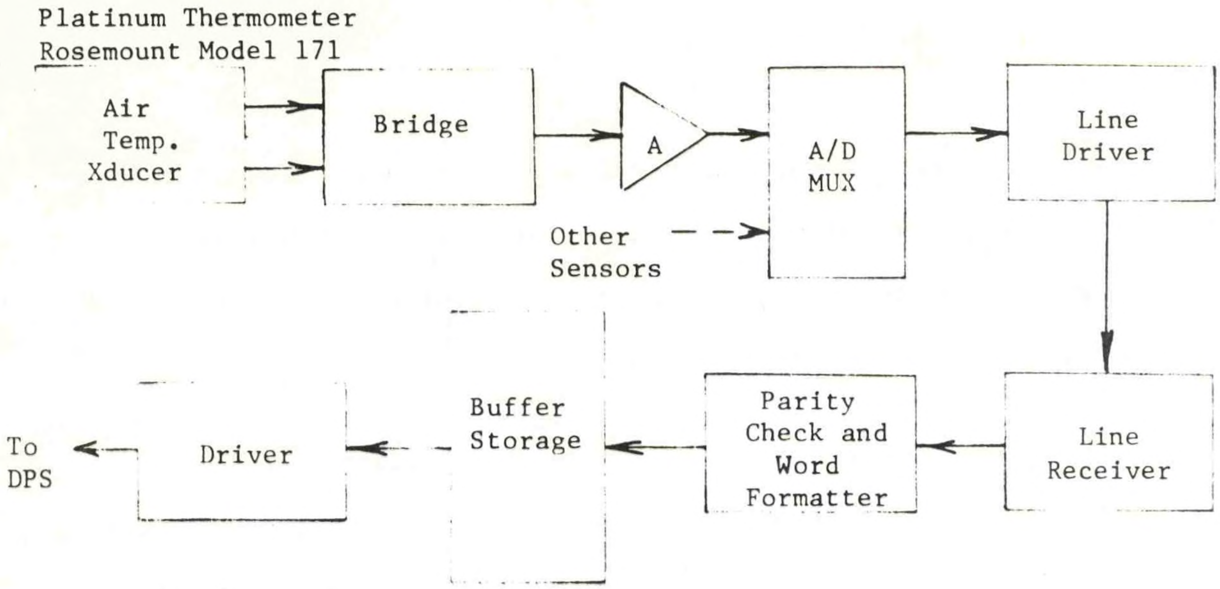



Figure 4.4-1. HCB Air Temperature Sensor Block Diagram

A/D converter. The resulting digital signal which represents the air temperature is transmitted by a driver from the meteorological electronics assembly to the Sensor Deck Unit for storage and transfer. The operational range of the temperature sensor is -10°C to +40°C, with an accuracy of ±0.20°C.

4.4.2.1.2 An air temperture sensor shown in the block diagram of Figure 4.4-2 is in use on one of the Limited Capability Buoys (LCB). The air temperature transducer assembly consists of a thermistor composite bead (2-thermistors) potted into an aluminum block with thermally conducting epoxy and mounted to a Delrin block for thermal isolation. A radiation shield attached to the Delrin isolating block provides physical protection and shielding from radiation, wind, and water spray. Air is allowed to pass by the thermistor sensing block through holes in the shield. The shield is painted white to reduce its own temperature rise due to radiation and subsequent effects on the temperature sensor. The air temperature transducer assembly is mounted within a cage assembly approximately two meters above the mean water line of the buoy.

A Zener diode controlled reference dc voltage is applied to the temperature bridge which has the thermistor temperature transducer for one leg. The thermistor composite transducer provides a linear voltage output versus temperature over the range of -10 to +40°C. The bridge amplifier converts the thermistor output to an analog voltage of from 0 to 5 volts corresponding to the range of -10 to +40°C. This output voltage is presented at one input of the DC multiplexer at all times the system is energized. The multiplexer is controlled by signals received from the data encoding subsystem and switches the air temperature analog voltage to a high impedance buffer amplifier input to the voltage-to-frequency converter. The voltage-to-frequency converter generates

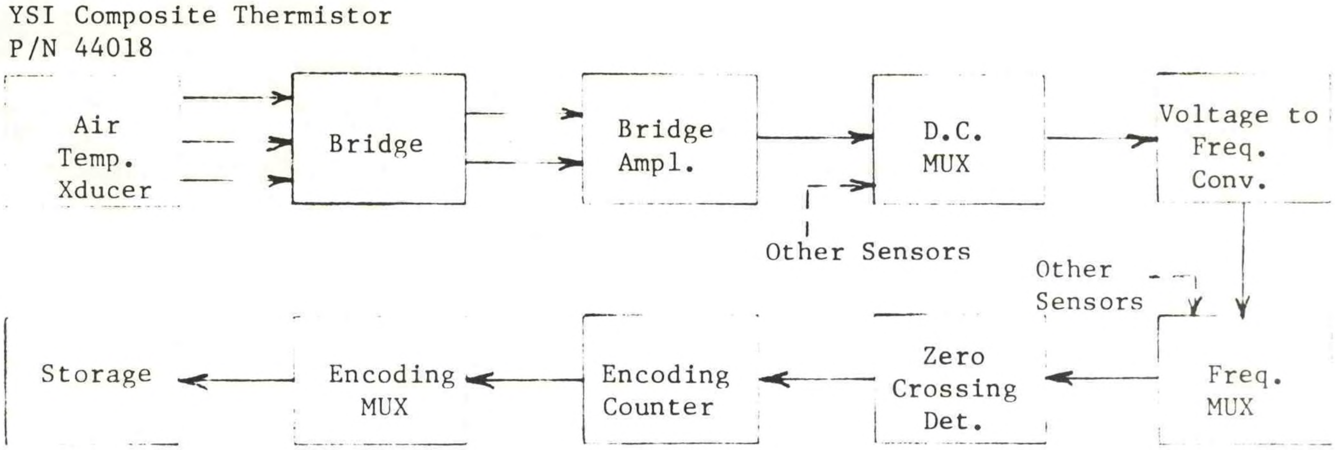



Figure 4.4-2. LCB Air Temperature Sensor Block Diagram

a symmetrical square wave whose frequency ranges from 960 to 4800 Hz, and is proportional to the air temperature. This square wave is transmitted to the data encoding subsystem where it is multiplexed to a detector and counted. It is then multiplexed and shifted into storage in a serial word format.

4.4.2.1.3 Another LCB air temperature sensor shown in Figure 4.4-3 employs two separate transducers. Two bead thermistor composites sense ambient air temperature. One is exposed and is located within air baffles under a solar radiation shield in the top of the Meteorological Sensor Package (MSP). The exposed thermistor has a short time constant slightly greater than one second. The output of this thermistor is sampled and digitally averaged for approximately 10 minutes in order to average the temperature over the acquisition period. The other thermistor is encapsulated within the base that holds the exposed unit. The potting compound provides "thermal mass" and yields a nominal 10 minute time constant. The output of this thermistor is sampled only once during the 10 minute acquisition period since the long time constant of the transducer provides averaging of air temperature.

The thermistor temperature transducers are sequentially switched by the MUX into a Wheatstone bridge. The bridge amplifier output is 0 to +10Vdc which linearly corresponds to $-10^{o}C$ and $+40^{o}C$, respectively. The air temperature signal to be digitally averaged is switched by a MUX to the A/D converter. During the 10 minute acquisition period the air temperature signal is sampled every four seconds. At the conclusion of the sampling period the air temperature is averaged by truncation as the accumulator output is gated into storage.

4.4.2.1.4 Figure 4.4-4 is a functional block diagram of another LCB air temperature sensor. The air temperature thermistor is housed in a knurled aluminum probe for mounting purposes. The thermistor probe assembly is then installed in

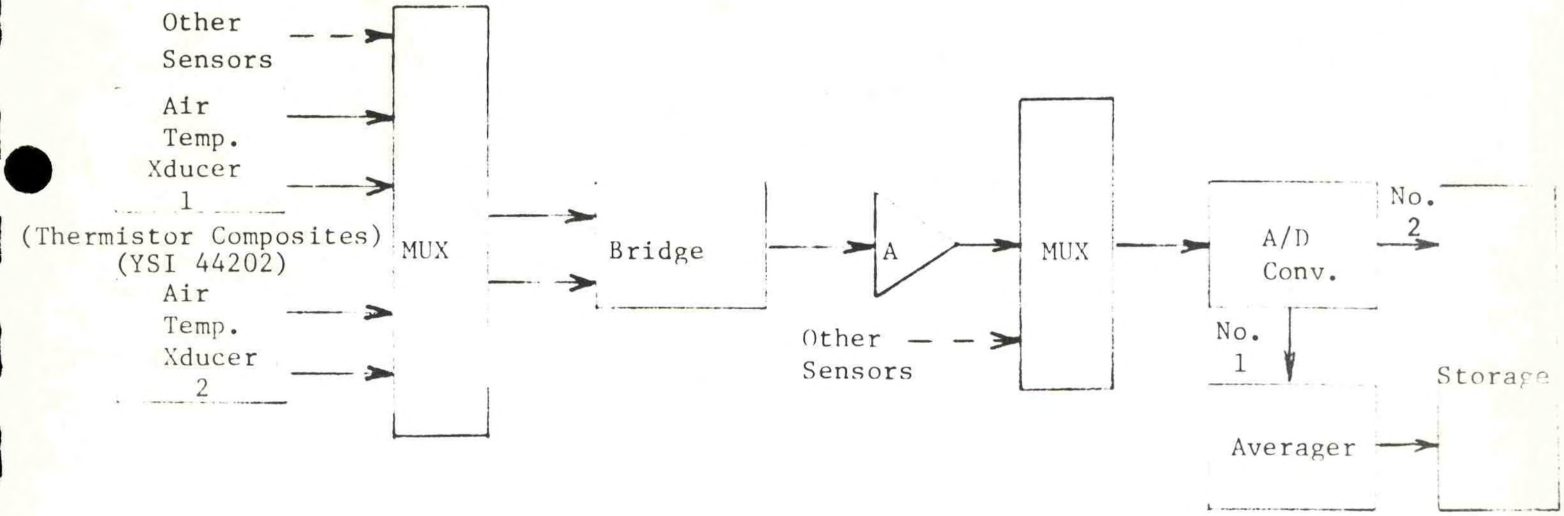



Figure 4.4-3. LCB Air Temperature Sensor Block Diagram

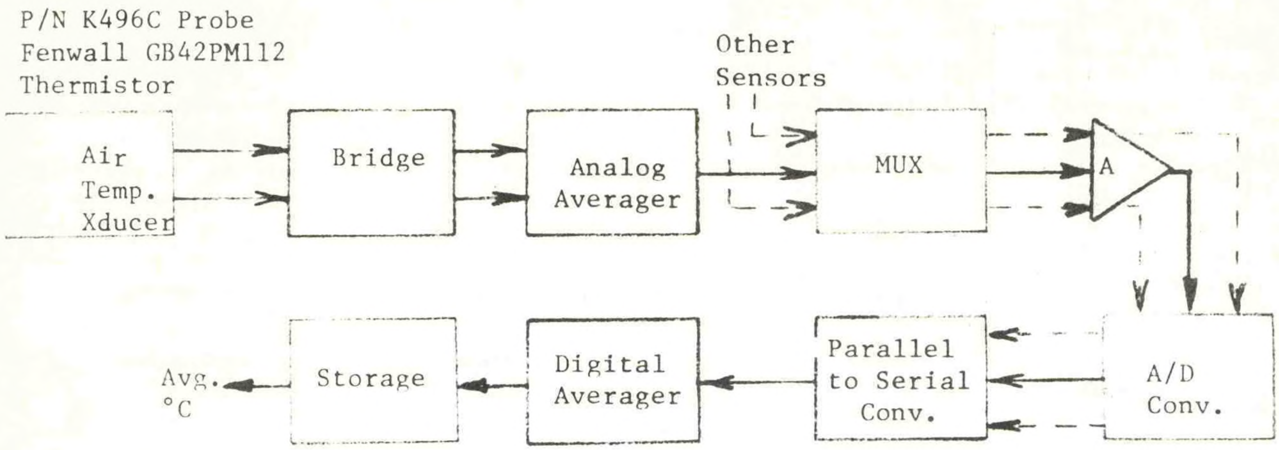



Figure 4.4-4. LCB Air Temperature Sensor Block Diagram

a phenolic adaptor and secured with Tra-Cast, completely filling the adapter and also covering the thermistor tips with at least 0.125 in. epoxy. The potted assembly is installed in an aspirated vane temperature shield. The aspirated vane is mounted on a crossarm support of the buoy mast at approximately two meters above the water level. It keeps the concentric shield elements pointed into the prevailing wind to provide flow of ambient air over the temperature transducer. The time constant of the transducer is increased to 10 seconds by covering the exposed tip of the thermistor with epoxy. This provides averaging to minimize the effects of natural variability and buoy motion on the measured data prior to being digitally averaged. Data from the analog averager is switched by the MUX to a final amplifier which has the proper gain to increase the voltage range to 0 to 10 volts as required by the parallel A/D converter. The A/D converter samples each input every 4.8 seconds. These samples are accumulated until 128 have occurred, at which time they are averaged by truncation and the results is stored in a memory register. The operating range of the air temperature transducer is -10 to +40°C.

4.4.2.2 AIR PRESSURE SENSORS

4.4.2.2.1 The air pressure is sensed and measured at two levels on the EEP HCB, 5 meters and 10 meters above the sea surface. A functional block diagram of the system is shown in Figure 4.4-5.

The Air Pressure Sensor contains two elements, the pressure sensing capsule and the signal conditioning electronics, both housed in the Meteorological Sensor Electronics assembly. A capacitive pressure gage in which capacitance controls the frequency of an oscillator is used for the measurement. Capacitance changes developed by the pressure sensing capsule are detected

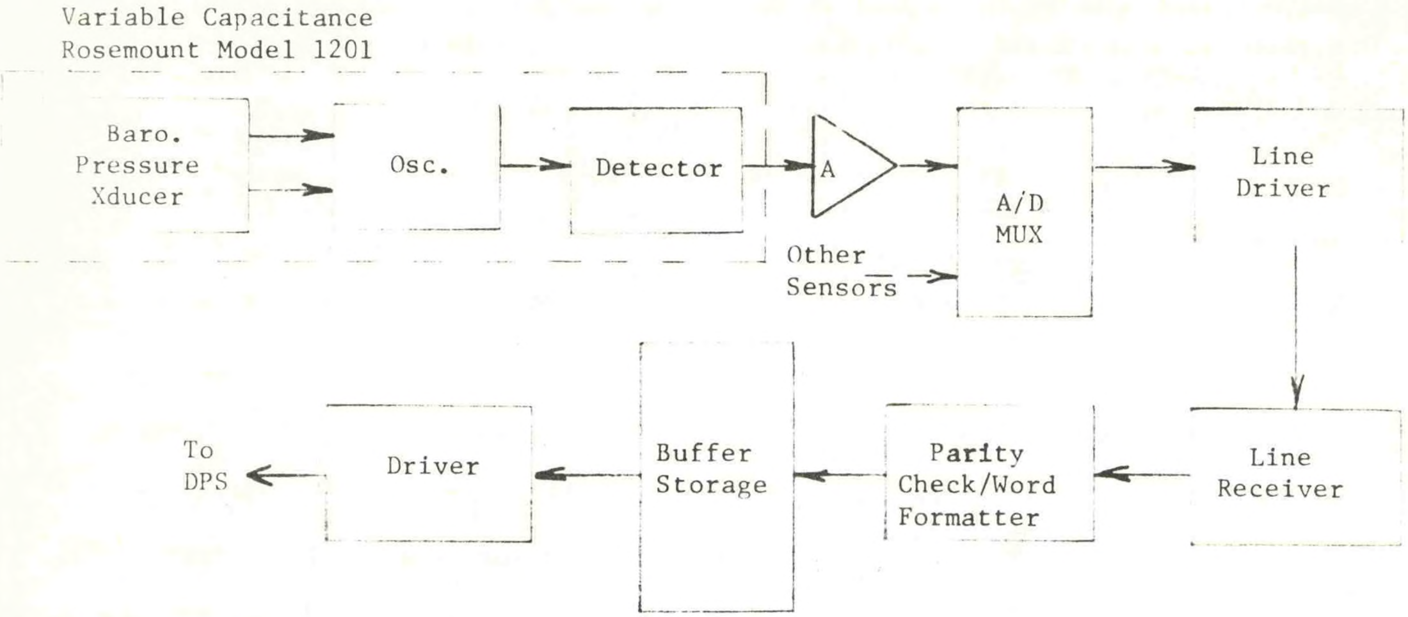



Figure 4.4-5 . HCB Barometric Pressure Sensor Block Diagram

and operated upon by the signal conditioning electronics such that a high level D. C. voltage proportional to pressure is obtained. This voltage is multiplexed into an A/D converter, and the resulting digital signal is transferred to the Sensor Deck Unit via line driver where it is formatted for storage and transfer. When sensed in the 900 to 1100 millibar range, air pressure is measured to an RMS accuracy of 0.61 millibars in this system.

4.4.2.2.2 Figure 4.4-6 is a block diagram of one type pressure sensor in use on an LCB. The pressure transducer is the same type and model as on the HCB. The transducer is located inside a Meteorological Sensor Package (MSP) with its pressure port protruding through the lower bulkhead. The electronics within the transducer package detect and condition the oscillator signal to provide a 0 to +4 Vdc output for absolute (barometric) pressures from 900 to 1100 mbars, respectively. The output voltage is linear with pressure. A circular PC board in the lower half of the MSP contains an operational amplifier circuit to provide a 0 to +10 Vdc output which represents pressures from 900 to 1100 mbars. During the 10-minute acquisition period the air pressure is sampled every four seconds. At the completion of the sampling period the 128 samples are averaged by truncation when the accumulator output is gated into the storage register.

4.4.2.2.3 Another configuration air pressure sensor being used on an LCB is shown in Figure 4.4-7. The air pressure sensor is a linear variable differential transformer (LVDT) designed to measure absolute pressure within the 900 to 1100 mbar range. The LVDT air pressure unit is mounted on a sensor crossarm support bracket at approximately two meters above the water surface. When installed the pressure port is oriented away from the normal buoy heading. Sea water entering the sensing port will drain out the same way due to normal

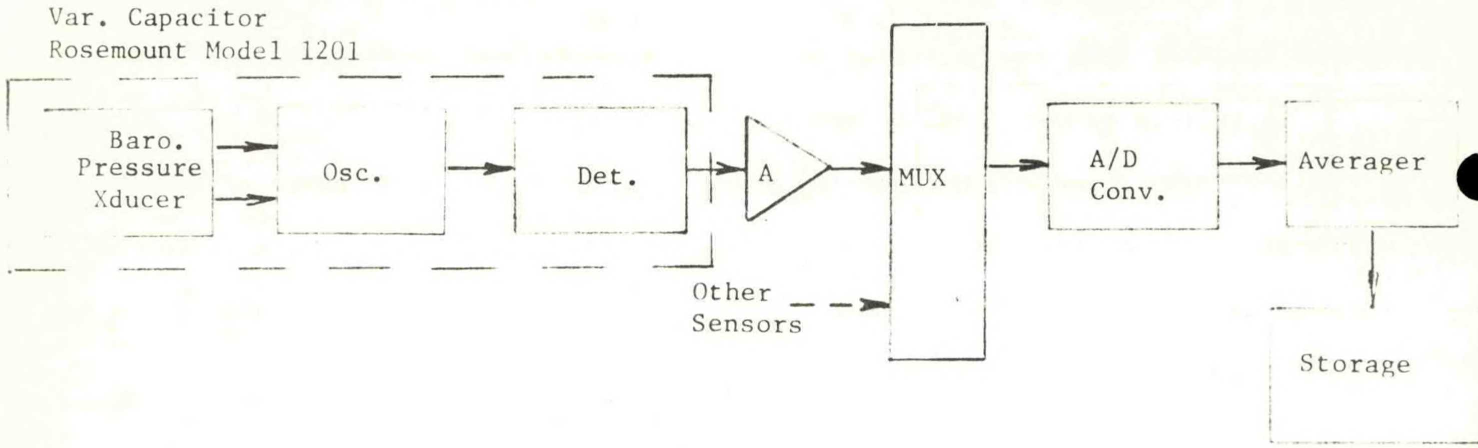



Figure 4.4-6. LCB Barometric Pressure Transducer Block Diagram

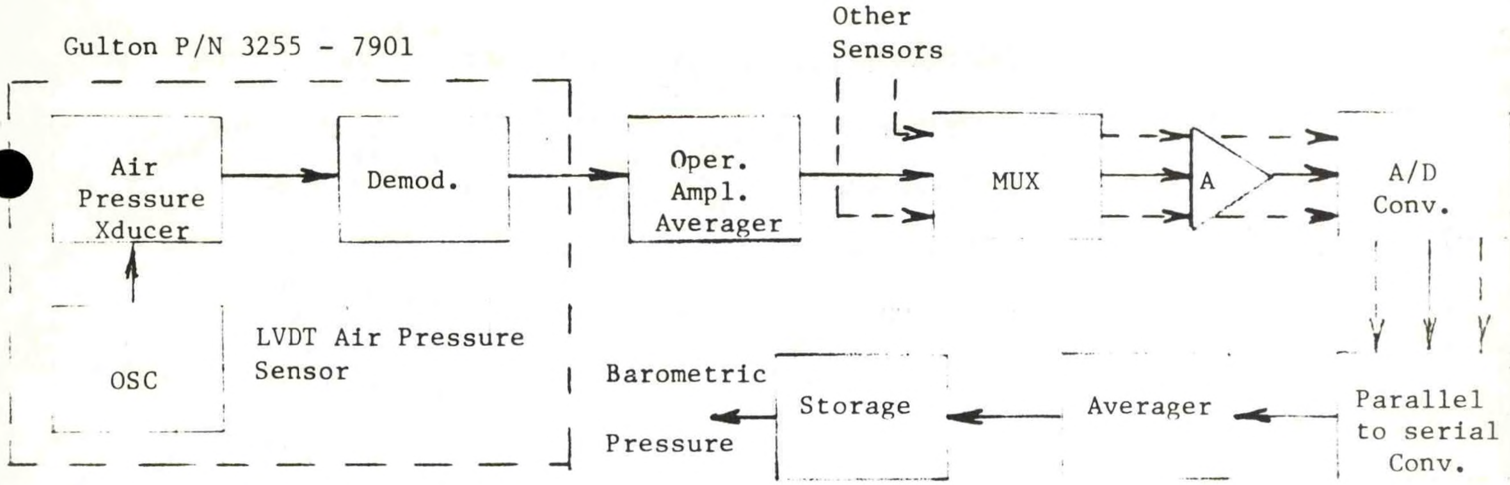



Figure 4.4-7. LCB Air Pressure Sensor Block Diagram

motion of the buoy and the horizontal mounting attitude of the sensor. The sensing element which is exposed to ambient is made of corrosion resistant Inconel 718. Pressure differentials caused by wind gusting and wave slap will be short-term phenomena and will be filtered out along with buoy motion and other natural variability effects that take place. Since the inherent time constant of the transducer is 5 msec, these short-term effects will be filtered out by a combination of analog averaging in the conditioning circuitry plus digital averaging in the DPS. The analog averaging is accomplished by integrating the output signal to impose a time constant of approximately 10 seconds.

The small analog signal, after being normalized, is switched through COS/MOS switches in the MUX to the A/D converter. The signal is sampled every 4.8 seconds and accumulated. After 128 samples are taken the data is averaged by truncation when shifted into the storage register.

4.4.2.2.4 A third type air pressure transducer being used on LCBs is shown in Figure 4.4-8. The air pressure transducer is a potentiometric device which is driven by an aneroid barometer. The unit is mounted at the topmost part of the Meteorological Sensor Subassembly at approximately two meters above the water surface. Inlet pressure to the transducer is through a special inlet assembly which is designed to protect the transducer diaphragm from high pressure during submergence and from the direct environment. This assembly also provides a long inlet tube which utilizes part of the met sensor cage assembly together with a ball check valve to damp out short gusts due to pitot tube effect and platform motion. The air inlet tube contains a replaceable time constant slug for changing the time constant, if desired. The slug normally used provides a three minute time constant.

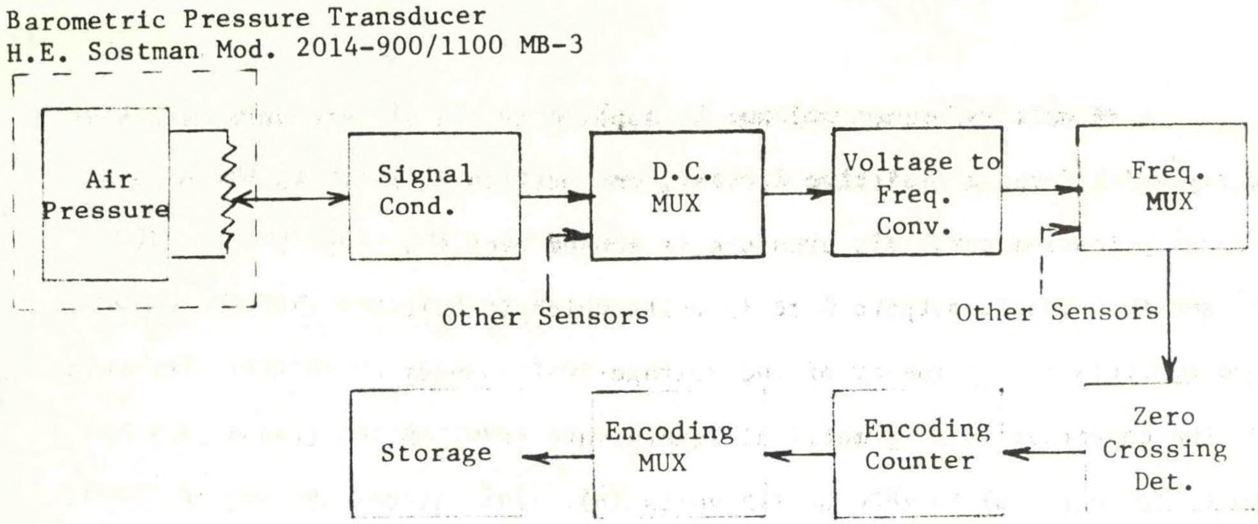



Figure 4.4-8 . LCB Barometric Pressure Sensor Block Diagram

A +8 volt reference voltage is applied to the air pressure measuring circuitry which forms a resistive divider, one portion of which is the pressure transducer potentiometer. Air pressure is sensed over the range 900 to 1100 mbars, and the circuit outputs 0 to +5 volts which is switched through the DC MUX and controls the frequency of the voltage-to-frequency converter. The output of the converter is a symmetrical square wave covering the frequency range of 960 Hz (0 volts in) to 4800 Hz (+5 volts in). This signal is coupled through a frequency MUX to the pulse detection, counting, encoding and storage circuitry in the data encoding subsystem.

4.4.2.3 WIND SPEED AND DIRECTION SENSORS

4.4.2.3.1 The HCB Wind Speed and Heading Sensor Assembly consists of a wind vane, flux-gate compass (magnetometer), and a wind speed sensor. The wind vane keeps the sensor aligned into the wind. The magnetometer detects the magnetic field components of the earth relative to the wind direction. The wind speed sensor, a vortex shedding anemometer, measures the wind speed magnitude and produces an output proportional to the speed. Two of these assemblies are employed, one at the 5-meter level and the other at the 10-meter level. A functional block diagram is shown in Figure 4.4-9.

The operation of the wind speed sensor is shown functionally in Figure 4.4-9. The sensor uses a patented vortex sensing technique in which a rod is used to generate a vortex street, which modulates an acoustic beam behind the rod. The modulation is detected, processed, and outputed as a pulse train. The transmitter generates the acoustic beam, and a receiver accepts the vortex modulated beam. The output of the receiver is amplified, AM detected and filtered to remove the RF carrier. The resulting signal is then filtered and fed to a Schmitt trigger through an OR gate. The Schmitt trigger output is a pulse train which represents wind velocity. A driver transmits the pulse train to each channel of the component resolver multiplier.

The flux-gate compass employs a saturable toroidol transformer consisting of a primary and two sets of secondary coils each wound in opposition to minimize the fundamental frequency at the output and to maximize the second harmonic. A sinusoidol voltage drives the primary winding. With no external magnetic field (including the earth's magnetic field) the output of each set of secondary windings is zero. However, since the earth's magnetic field is present, the output voltage of a particular set of windings is not zero, and a

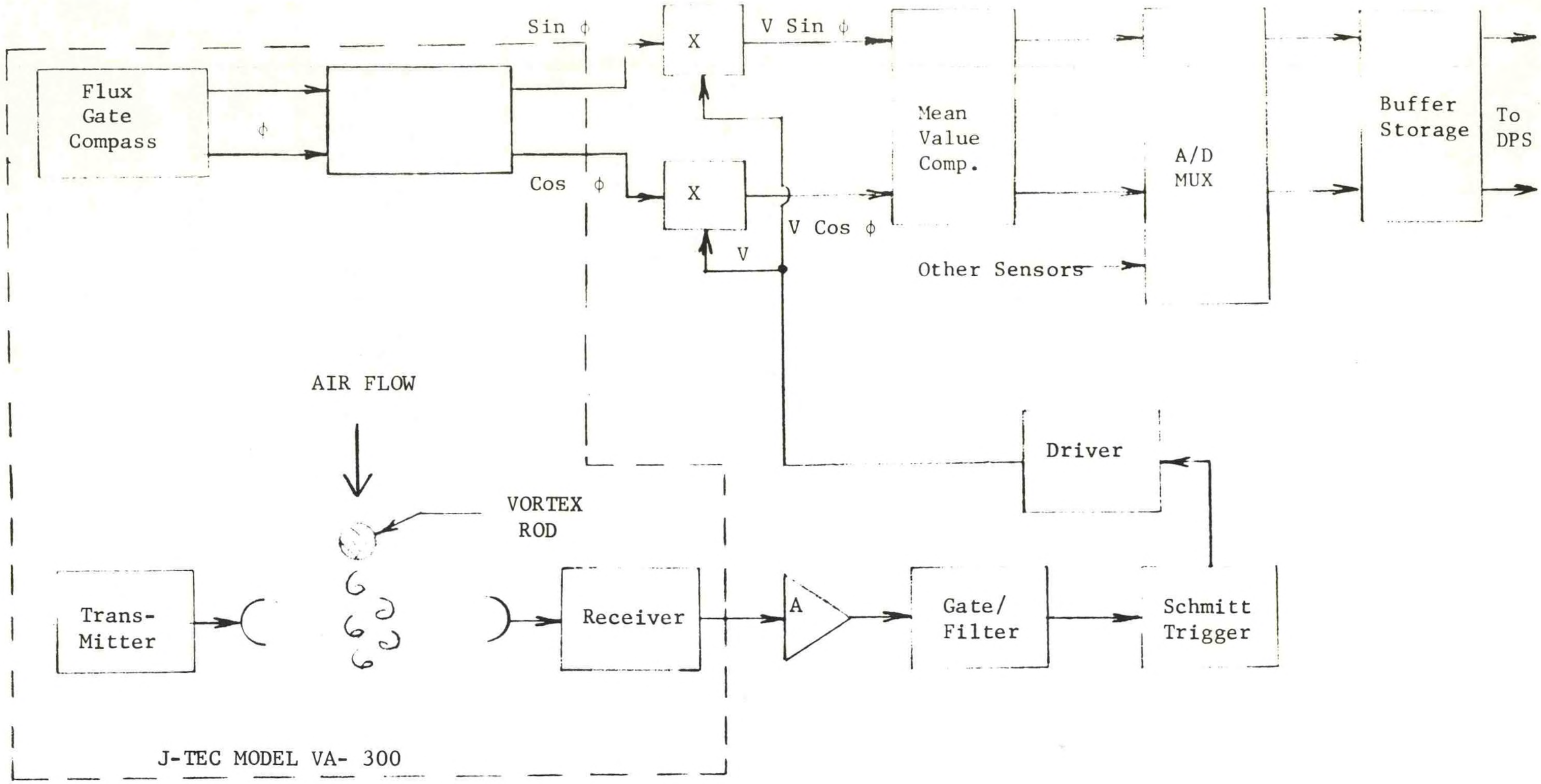



FIGURE 4.4-9. HCB WIND SPEED AND DIRECTION SENSOR BLOCK DIAGRAM

second harmonics voltage of the excitation voltage, at a level which depends upon compass orientation to magnetic North, appears across each set of secondary windings. This output voltage follows a cosine law in direction making possible the use of the flux-gate toroid as a compass. Since two sets of secondary windings are placed at right angles to each other they provide a unique method to distinguish the actual angle and quadrant.

The wind vane of the anemometer is coupled to the magnetic compass so the output of the compass is actually proportional to the angle Ø between the vane and magnetic North. A component resolver resolves this angle into the sine and cosine of the angle. The wind velocity and these East and North components are multiplied and are used to compute the mean values of the instantaneous East and North wind components. These components of East and North wind are computed for wind velocity 0 to 80 m/sec and from 0 to 360 degrees in direction. The wind components are transferred to the SDU for storage and transfer to the DPS where averaging is done.

4.4.2.3.2 Wind speed and direction on one LCB is provided by the Wind Component Resolution and Averaging Sensor shown in the block diagram of Figure 4.4-10. As on the HCB, this sensor uses a vortex shedding anemometer flux-gate compass to sense wind velocity and direction. The Wind Sensor Package (WSP) is basically a J-Tec, Model VA-300, shedding vortex anemometer with the lower housing modified to accept a Magnavox magnetometer. The WSP is mounted on the LCB sensor mast cross-arm approximately two meters from the water surface.

The magnetometer output signal (2400 Hz, 1 volt RMS minimum) is processed through a zero-crossing detector providing a 0 to +5 Vdc output square wave. A Wind Processor board contains the sine/cosine, read only memory (ROM), the Wind North and Wind East accumulating counters and associated control logic.

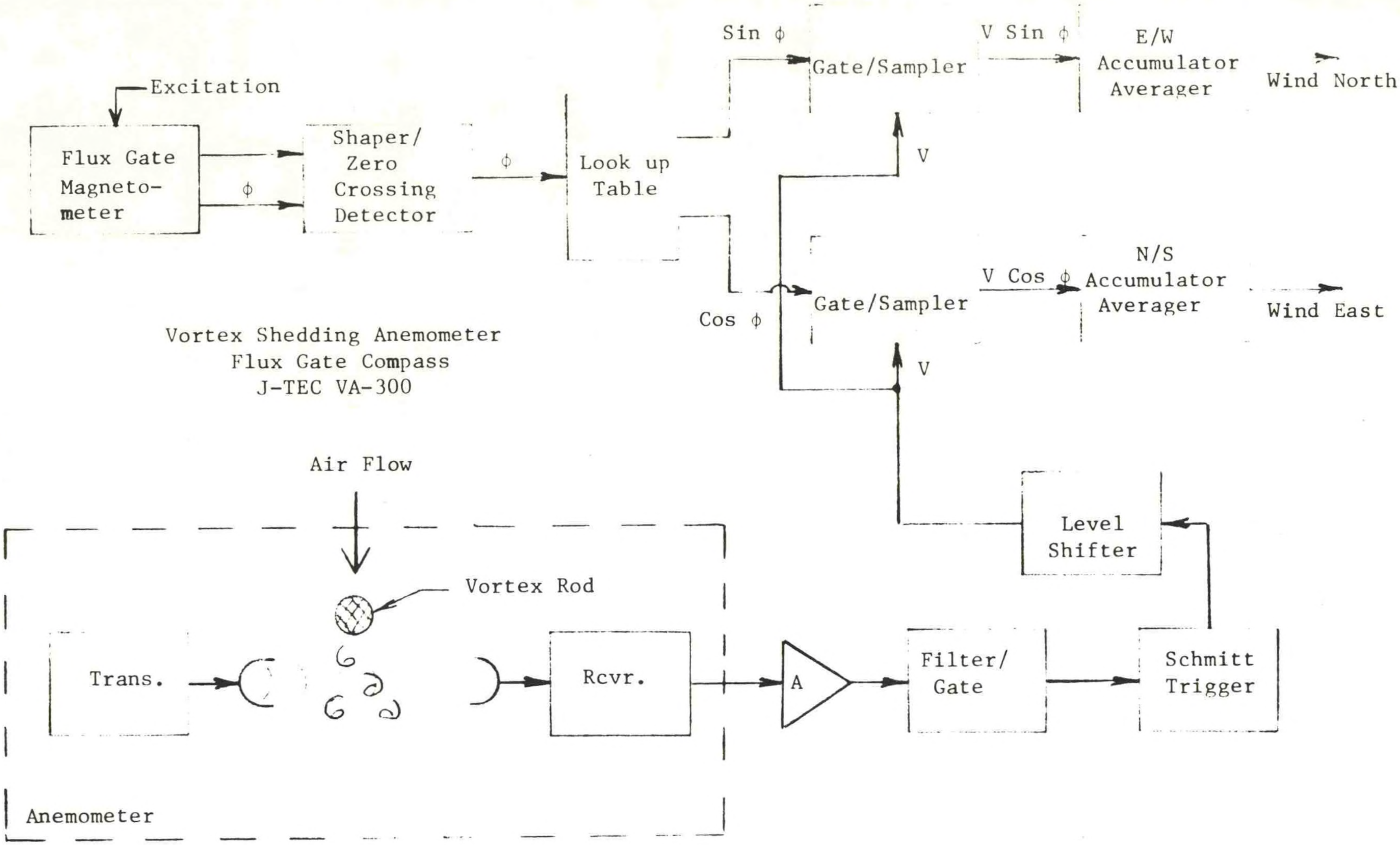



Figure 4.4-10. LCB Wind Component Resolution and Averaging Sensor Block Diagram

The ROM is power switched by the wind program control. The ROM input is the output of the segment counter on the Data Programmer board. This input is a binary magnitude which is a function of the quadrant displacement of the magnetometer. The ROM is first powered for about 27 milliseconds during which the 8-bit sine or cosine function is delay gated into the Wind North decrementing counter. Similarly, the Wind East segment is translated to an equivalent sine or cosine value and entered into the Wind East decrementing counter.

The Wind North and East 21-bit accumulating counters have their most significant bit set during reset time. During the 10-minute acquisition period 512 wind samples are taken, and the sample components stored in the decrementing counters are clocked down by the 2400-Hz clock. This creates a time gate to their respective accumulators. During this time gate the accumulators are either incremented or decremented depending upon the resolved magnetometer quadrant. These accumulators are clocked by the rate pulses from the wind anemometer. The resultant is the Cartesian resolution of Wind North = V sin Ø and Wind East = V cos Ø, where V is the anemometer magnitude and Ø is the magnetometer displacement counterclockwise from magnetic East.

At the conclusion of the acquisition period the accumulators will contain the sum value of 512 samples of Wind North and East. At acquisition time when these values are read into memory, the accumulator output are effectively averaged by dividing by 512. This is accomplished by offset gating the 21 bit accumulators 9 binary positions and reading out only the higher order 12 bits. This data is gated onto the data bus by program control at the appropriate time for entry into memory. The wind speed sensor senses wind over the range 0 to 80 m/sec and produces average north and east vector outputs from 0 to 360 degrees.

4.4.2.3.3 The Wind Speed and Direction Sensor shown in the block diagram of Figure 4.4.-11 is another type used on LCB. This sensor is part of the integrated

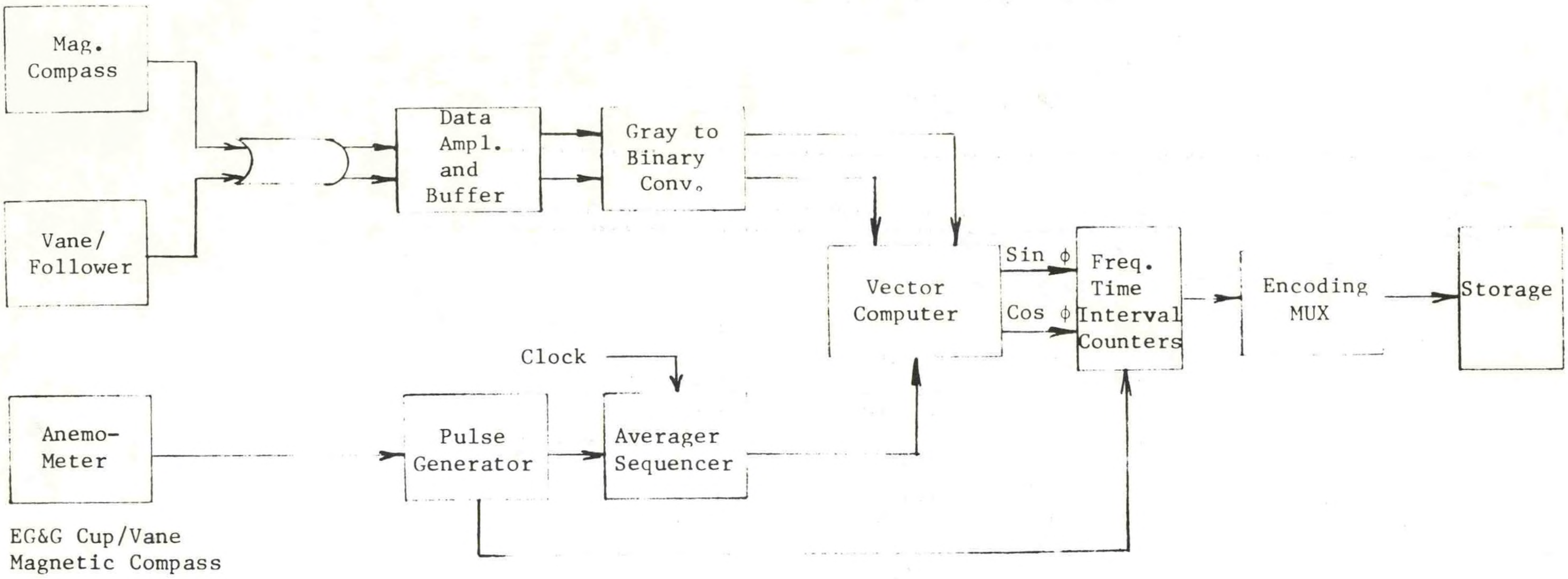



Figure 4.4-11 LCB Vector Averaging Anemometer Block Diagram

Meteorological Sensor (MS) and consists of a three cup anemometer to measure wind speed, and a separate vane/vane follower assembly whose electrical output is digital. The sensor senses and outputs North and East Wind vectors over the range 0 to 50 m/sec and at angles 0 to 360 degrees. The wind and direction transducers are located approximately two meters above the water surface.

Each revolution of the 3-cup anemometer is sensed by a dry reed switch which is activated by a small permanent magnet attached to the anemometer shaft. Each switch closure triggers a single-shot multivibrator which is used to control the vector wind computation; one computation occurring for each revolution of the anemometer. The vane follower is constructed with two pairs of balanced magnets mounted on the same shaft. One pair is used to couple to the vane magnets and the other pair is used to eliminate compass offset errors resulting from the first pair. Also attached to the vane follower shaft is a circular gray code encoding disc which allows optical readout of wind direction from an LED array and photo transsistor. The compass assembly is constructed much like the vane follower and uses a balanced pair of permanent magnets to couple the compass angle to a ring containing a Gray code disk. The compass angle is read out optically in the same manner as the wind vane angle and the angle Ø between these two angles is used to compute the wind vectors. Power from the data encoding subsystem is present at all times to the Vector Averaging Anemometer, however, the control and power circuitry is such that computations only take place when allowed to do so by the data encoding subsystem. With this design, 10 minutes out of every hour are spent performing computations. When allowed to compute by the data encoding subsystem, the VAA will perform a computation for each revolution of the three-cup anemometer. Each switch closure triggers a single-shot multivibrator which turns on the computer ON/OFF control. The vector computation is performed for each revolution of the anemometer for a period of 10 minutes once each hour. The data that is accumulated during this 10 minute averaging period is stored in 16-bit shift registers, one each for the anemometer, one for the North and one for the East. Under the control of the Data Encoding Subsystem, a shift clock is generated at the end of the 10-minute averaging period to shift this data serially down into the Data Encoding Subsystem and into the 480 bit memory for storage prior to readout to the Data Processing Subsystem.

4.4.2.3.4 Another configuration used on an LCB for measuring Wind Speed and Direction is shown in the functional block diagram of Figure 4.4-12. The wind speed transducer is a Weather Measure W101-P Skyvane Wind Sensor modified to facilitate mechanical integration with a north seeker and to provide the required electrical output for wind speed. The unit is a impeller-driven vane type device of fiberglass-reinforced construction 30 in. high by 27.5 in. long. The primary modification is extension of the output shaft to enable integration with the north seeking device. The north seeker is a Humphrey, Inc. Model NS06-0201-1 Magnetic Azimuth Indicator complete with a modified slip ring assembly. This modification consists of an extension to the output shaft with a mating adapter to enable coupling to the wind speed sensor. Both the Weather Measure and Humphrey units are mounted on the buoy mast crossarm bracket at approximately two meters above the water surface.

Wind speed is measured with a four-blade, 14-in., fiberglass-reinforced impeller that drives an AC generator mounted inside the vane body. The unit has been modified to adapt to a Humphrey sin/cos resolver and to provide a DC voltage output. The two units are coupled together mechanically by a shaft and electrically through a slipring assembly. By this coupling, the north-seeker housing is free to rotate with the wind direction sensor, and the output of the resolver gives the difference in angle between wind direction and magnetic north. The wind speed output is provided by amplitude variations of the DC output voltage,

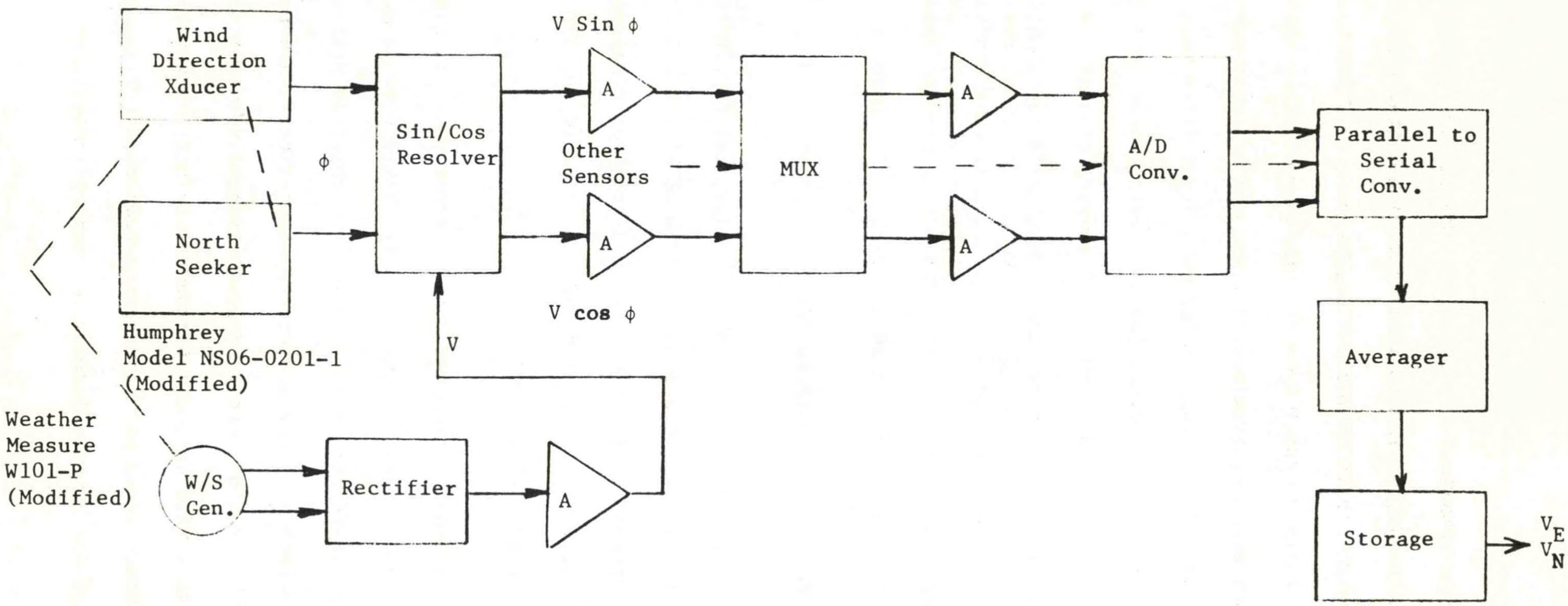



Figure 4.4-12 LCB Wind Speed and Direction Sensor Block Diagram

while the angle output is in component form, sin/cos. Operational amplifiers buffer and amplify the small analog signals derived from the transducers. The normalized data is switched through COS/MOS analog switches to a final amplifier which increases the voltage range to the 0 to +10 volts required by the Analog to Digital converter. Both the analog switch unit and the A/D converter are controlled by logic signals arriving from the DPS Data Acquisition logic. Averaging is accomplished by summing 128 samples from each channel and then dividing by 128. This is performed in a single bit summing circuit and a storage register which stores the temporary sums. When the data is shifted out of this register a 7-bit truncation occurs which results in a division by 128. The resulting sums are transferred into two memory storage registers. Wind speed is sensed over the range of 0 to 80 m/sec at angles 0 to $360^{\circ}$.

4.4.2.4 ALTERNATE METEOROLOGICAL SENSOR PACKAGE

4.4.2.4.1 An alternate design of an integrated Meteorological Sensor Package (MSP) for one of the LCBs is shown in the block diagram of Figure 4.4-13. This MSP is functionally interchangeable with the sensors described in Paragraphs 4.4.2.1.3, 4.4.2.2.2, and 4.4.2.3.2. A single MSP was supplied to NDBO by Honeywell and has undergone extensive testing on an LCB.

The MSP employs a 3-cup anemometer with a vane-mounted flux-gate magnetometer to sense wind speed and direction over the range 0 to 50 m/sec and 0 to 360 degrees. Temperature is sensed by a thermistor which is protected by a solar shield that is asperated to reduce radiated heat effects. Temperature is sensed over the range -10 to $+40^{\circ}C$. Air pressure is sensed over the range 700 to 1100 mbars by a Gulton LVDT Unit which is mounted in the lower half of the MSP housing. The pressure input port is protected from direct sea water by means of a ball float check and an intermediate hermetically sealed cavity

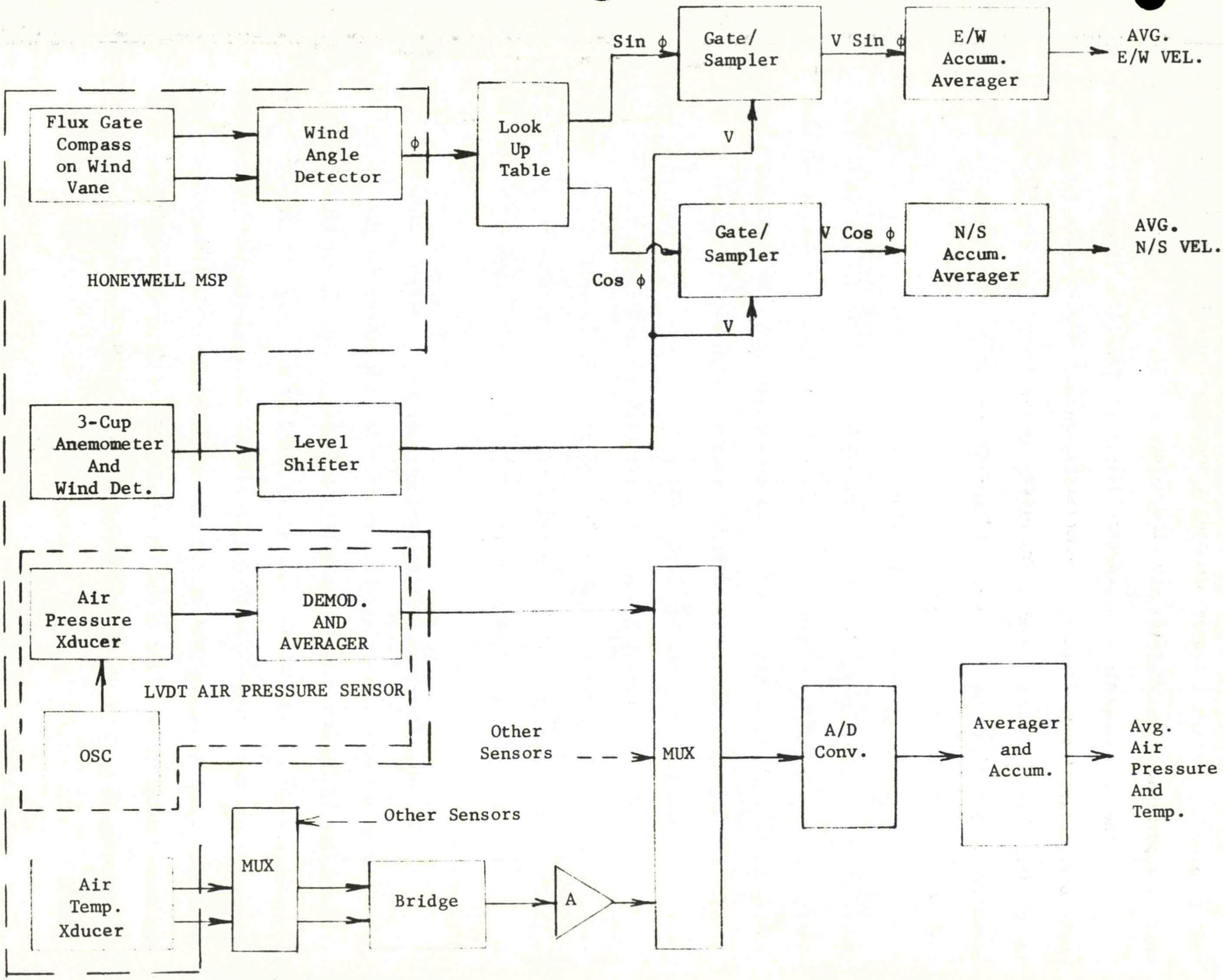



Figure 4.4-13. Alternate LCB Wind, Air Temperature and Barometric Pressure Sensor Block Diagram

designed to transmit air pressure to the aneroid bellows sensing element. The MSP is very compact and is flange mounted at the end of a strut on the buoy sensor mast at approximately two meters above the water surface.

The air temperature transducer includes a precision linearization network to linearize the resistance vs temperature curve. This network is connected as one leg of a Wheatstone bridge. The bridge output is voltage and impedance conditioned by a high quality, linear-integrated amplifier and multiplexed to the A/D converter for further processing.

A functional block diagram of the Linear Variable Differential Transducer (LVDT) is shown in Figure 4.4-13. The basic sensor is an aneroid bellows operating into the LVDT. Output of the LVDT is demodulated and scaled and then averaged for a period of 100 seconds. The time constant of the averaging amplifier is 13.6 seconds which reduces the effects of wave motion and other rapid changes in pressure on the output of the pressure sensor.

The wind sensor is a cup anemometer with a vane-mounted flux-gate magnetometer. The anemometer speed pickoff is accomplished optically, utilizing a L.E.D. illumination and a photo sensitive transistor to receive the returned pulse. The device is very linear and provides one pulse for each 0.13 meter of wind movement.

The wind direction sensing system consists of co-axial flux-gate magnetometer and wind vane, fixed with respect to each other, but free to rotate with respect to the MSP frame. Electrical connection between the flux-gate magnetometer and the electronics is made by means of a rotary transformer. This scheme allows the derivation of wind direction versus magnetic north (Ø angle) directly. A 512-Hz square wave drives the magnetometer. The output signal from the magnetometer is twice the input frequency, and is filtered and shaped prior to comparing it back to the drive frequency. This is accomplished by a zero crossing detector. The results provide a time gate output proportional to angle Ø. Thus, the output of the MSP wind sensor consists of a series of pulses with PRR proportional to wind speed, plus a series of time gates each of which has a length proportional to the angle Ø. These signals are used to compute average E/W and N/S wind vectors in the same way as described in Paragraph 4.4.2.3.2.

4.4.2.5 SURFACE WATER TEMPERATURE SENSORS

4.4.2.5.1 Measurement of surface water temperature on the High Capability Buoys (HCB) is made by a temperature sensor which is part of the Hull Mounted Oceanographic Sensor (HMOS). The HMOS is deployed through a well in the buoy and protrudes from the bottom of the buoy approximately two meters below the water surface.

The temperature transducer is a high purity platnium wire whose resistance change is directly proportional to the change in surrounding temperature. The operating range of the transducer is -2 to +40°C, with an accuracy to within 0.06°C. As in the HCB air temperature sensor (Paragraph 4.4.2.1.1), the platinum wire resistor forms a leg of a Wheatstone bridge, as shown in Figure 4.4-14. The bridge amplifier amplifies and conditions the analog voltage before it is multiplexed into the A/D converter. The resulting digital word, which represents water temperature, is transmitted by direct wire data-link to the SDU for further processing and temporary storage.

4.4.2.5.2 Figure 4.4-15 is a block diagram of one surface water temperature sensor used on an LCB. The hull mounted temperature assembly is fastened 0.6 meters below the buoy design water line. The assembly utilizes a Delrin thermal isolator which is inserted into the buoy hull. An O-ring is inserted in the groove provided in the thermal isolator and seals against the buoy hull. A lock nut inside the hull completes the assembly. A YSI thermistor composite (two thermistors on one glass bead) is inserted through the thermal isolator and into the aluminum sensing tip and is secured with thermally conducting epoxy. The thermally isolating mounting block prevents heat conduction between the sensor and buoy hull.

The response of the sensor to temperature variations is controlled by

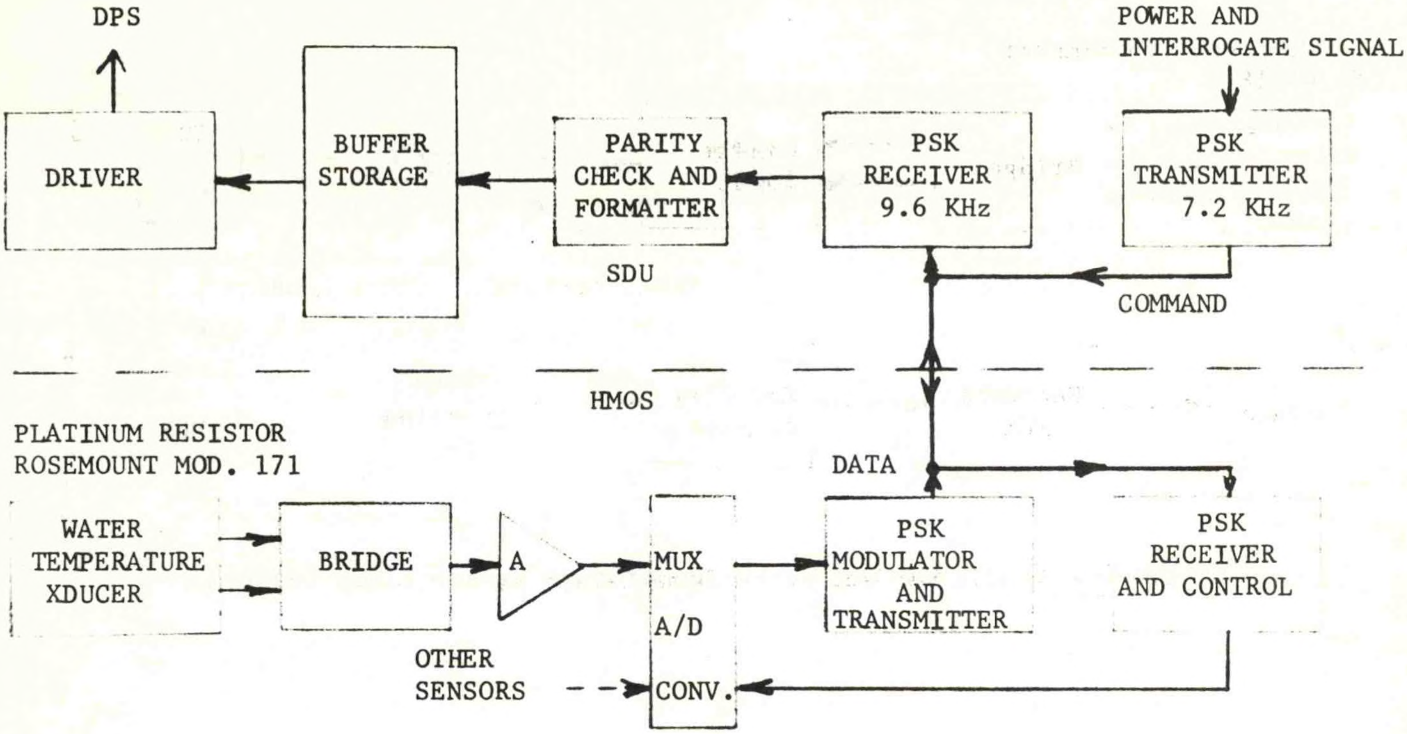



FIGURE 4.4-14 HCB SURFACE WATER TEMPERATURE SENSOR BLOCK DIAGRAM

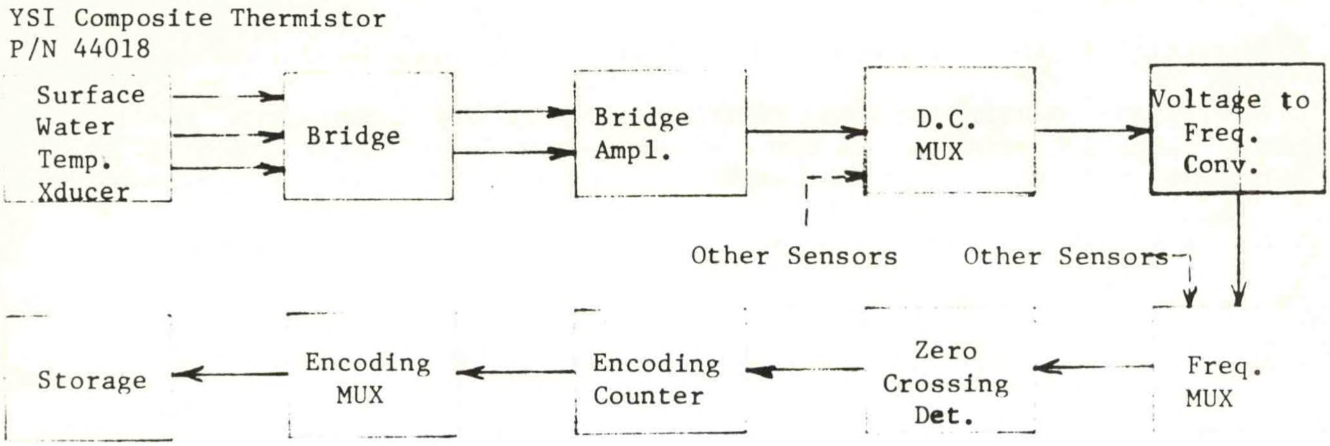



Figure 4.4-15 LCB Surface Water Temperature Sensor Block Diagram

a protective sleeve fastened over the transducer, and includes a liner of open cell urethane foam. Water enters the foam area through holes in the sleeve and acts as a thermal conductor to temperature change. This arrangement effectively retards the temperature flow to the sensing tip and produces a time constant for the sensor of three minutes. The shield also is designed to reflect direct radiant energy from the sun although the sensor is protected by the mounting ring of the battery canister.

The thermistor leads, fed through the buoy hull, are connected via appropriate connectors to the signal conditioning electronics located within the data encoding subsystem. A temperature bridge and bridge amplifier are used to generate a 0 to 5 volt ac analog signal proportional to surface water temperature of -2 to +40$^{\circ}$C. This signal is converted, counted and encoded, and the resulting digital word representing surface water temperature is temporarily stored for further processing.

4.4.2.5.3 A different mounting technique for the surface water temperature sensor is employed on the LCB unit shown on the block diagram of Figure 4.4-16. In this case, the temperature transducer is mounted on the tip of a long tube which protrudes through a small well in the buoy and is secured by bolts on the buoy deck. An integral cable and connector exits at the tubing flange and mates with a connector on the coaming of the electronics compartment. This feature allows the assembly to be mounted and serviced from the top of the buoy.

The temperature sensing element consists of a bead thermistor and precision linearizing resistor encapsulated in a Delrin housing. The combination of housing material and epoxy potting compound provide "thermal mass" to yield a nominal 10-minute time constant in water. A single Wheatstone bridge is used for all thermistor transducers on the buoy; multiplex switches implement this capability. The output of the bridge for the surface water temperature sensor

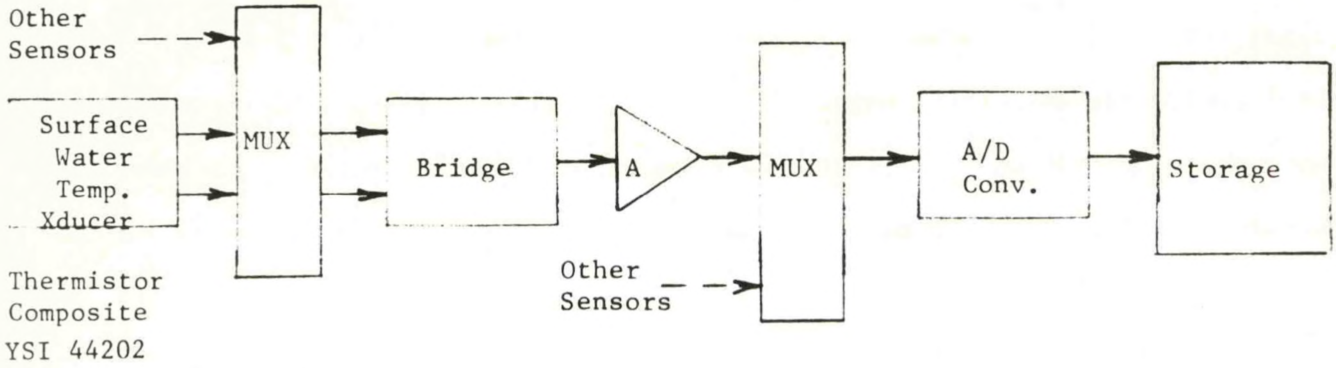



Figure 4.4-16. LCB Surface Water Temperature Sensor Block Diagram

is 0 to +10 Vdc corresponding to $-10^{o}C$ to $+40^{o}C$, respectively, and is linear over the temperature range. The surface water temperature sensor is sampled once during the data acquisition period since the long time constant provides temperature averaging.

4.4.2.5.4 Surface water temperature and subsurface water temperature are sensed on a moored LCB by thermistors embedded in a data line cable. For the surface water measurement, the thermistor is located approximately two meters below the water surface. A block diagram of this sensor is shown in Figure 4.4-17.

Since surface wave motion will be manifested as vertical thermistor movement through temperature gradients, a method of filtering out this modulation is required. The inherent time constant of the thermistor itself is much too short to be of any value; therefore, a suitable time constant is imposed by utilizing thermal damping. The thermistors are potted in the data line. This technique gives an imposed sensor time constant in the neighborhood of 90 seconds. The thermistor selected is a glass-encapsulated Fenwall Electronics Oceanographic Iso-Curve (type GB4ZMM182) with a stability of $0.05^{o}C/yr$ change maximum, specifically designed for oceanographic use. Resistance is precision matched to a standard resistance-temperature curve and is predictable accurately at any given point to $\pm 0.1^{o}C$ over the temperature range of $-2^{o}$ to $+40^{o}C$. Implantation and potting of the thermistors in the data line provides protection against seawater penetration, and an external polyurethane jacket offers fishbite protection.

Data from the analog averager is switched by the MUX to a final amplifier which increases the voltage range to 0 to +10 volts as required by the parallel A/D converter. The A/D converter samples each input every 4.8 seconds. These samples are accumulated until 128 samples have been taken, at which time an average is produced by truncation when the data is shifted to a memory register for further processing and temporary storage.

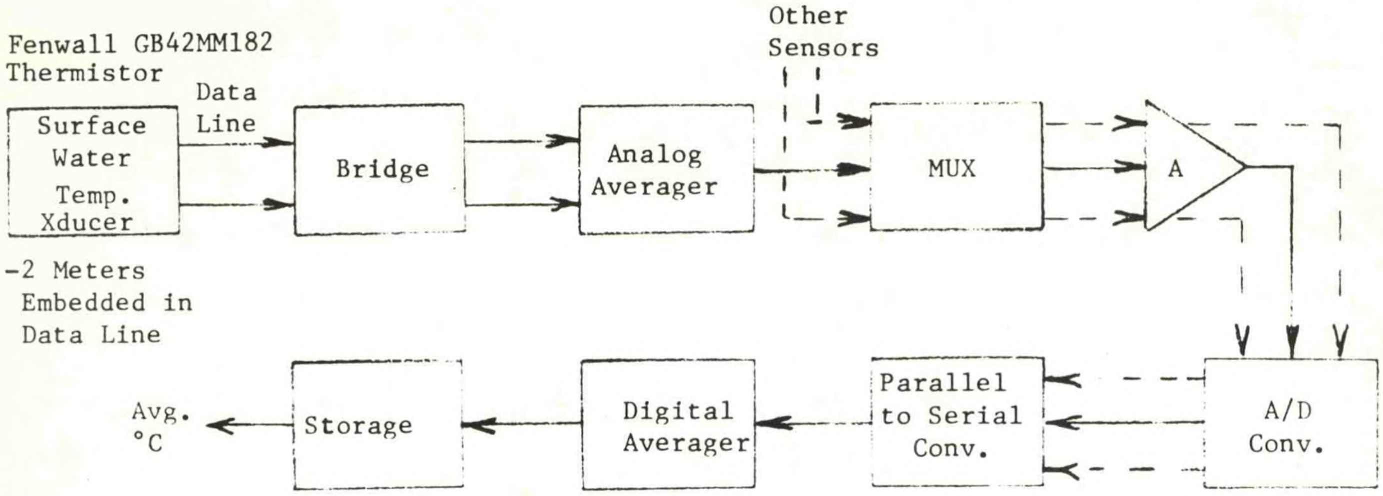



Figure 4.4-17 LCB Surface Water Temperature Sensor Block Diagram

4.4.2.6 SUBSURFACE WATER TEMPERATURE SENSORS

4.4.2.6.1 Subsurface water temperature is one of the measurands which the HCB Oceanographic Sensors measure. These measurements are taken at various levels from near the surface to a depth of 500 meters. The Oceanographic Sensor operation is identical to the HMOS described in Paragraph 4.4.2.5.1 except the sensor is located on the mooring line data line (MLDL) and uses inductive couplings to interrogate and transfer data through the MLDL between the sensors and the SDU in the buoy. Figure 4.4-18 is a functional block diagram of the subsurface water temperature sensor.

An Oceanographic Sensor consists of a single pressure housing which contains the electronics and transducers necessary for oceanographic data sampling and collection. The sensor electronics perform power control and address control functions in response to the Sensor Deck Unit (SDU) commands and interrogations which are in form of 7.2-KHz Phase Shift Keyed (PSK) MLDL down-link signals. The sensor electronics also convert, level shift, and condition the analog transducer outputs into digital data, which is modulated and Phase Shift Keyed in a 9.6-KHz carrier on the up-link to the SDU. Once the data reaches the SDU it is conditioned, processed and temporarily stored the same as the surface temperature data.

4.4.2.6.2 One of the moored LCBs also uses inductive coupling of subsurface water temperature and pressure (at the lowest level only) to the surface buoy through an MLDL. A block diagram of these sensors is shown in Figure 4.4-19. Two small oceanographic sensors are used to measure temperature and pressure only. These are separate units but, except for the basic transducers, utilize almost identical (the sensor code wired differently) signal conditioning and data transfer schemes.

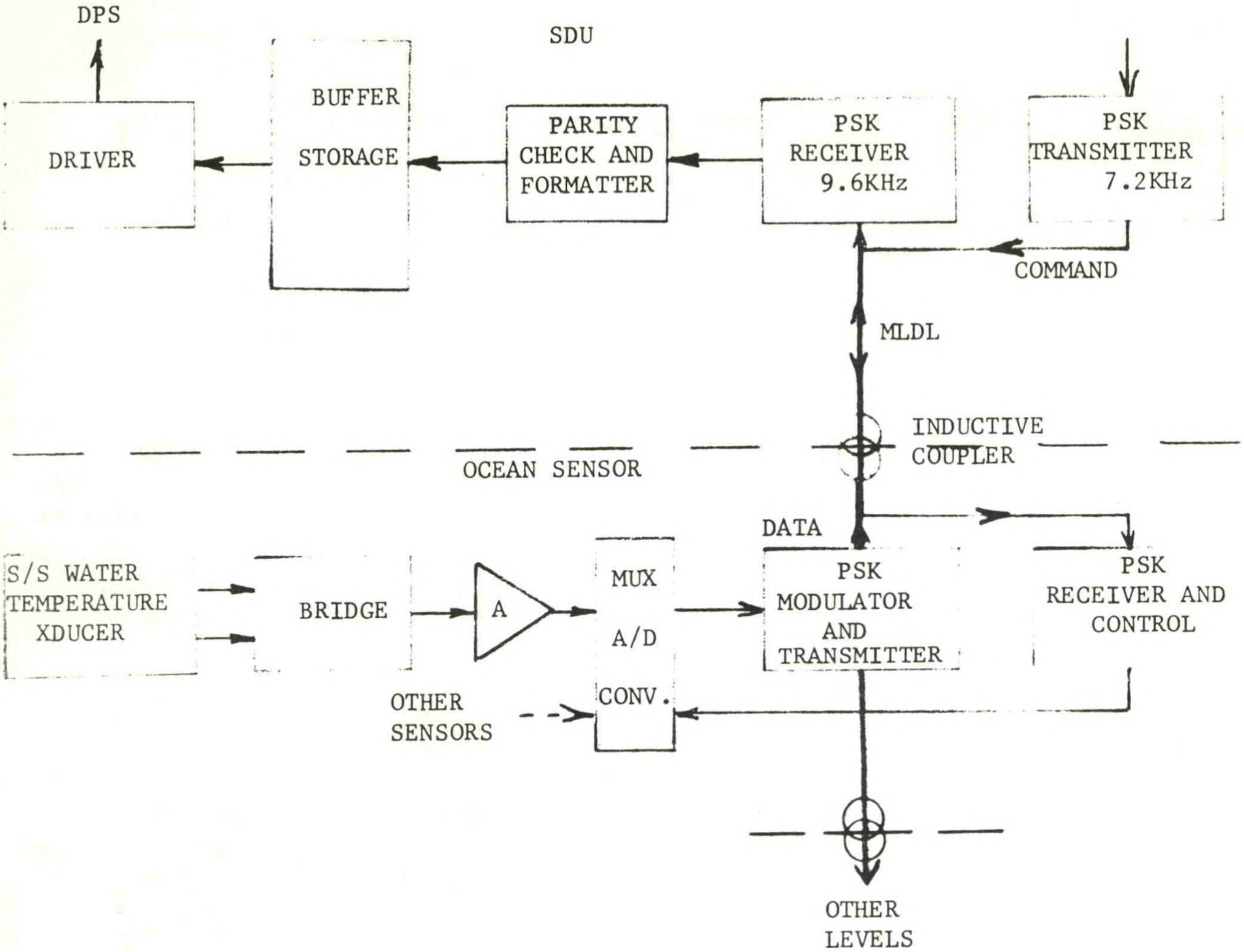



FIGURE 4.4-18 - HCB SUBSURFACE WATER TEMPERATURE SENSORS BLOCK DIAGRAM

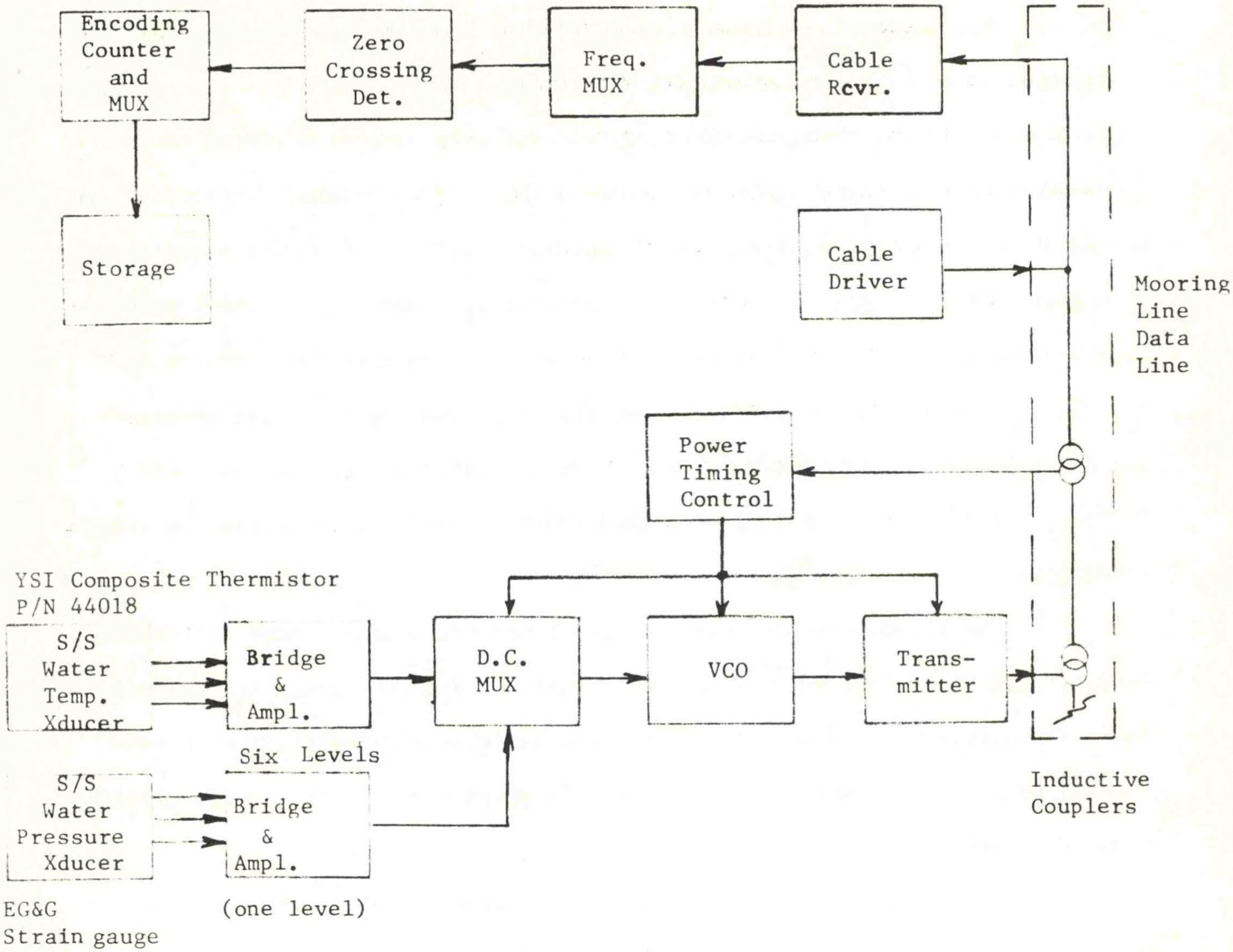



Figure 4.4-19. LCB Subsurface Temperature and Pressure Sensor Block Diagram

The subsurface sensors have solid core inductive couplers and are designed to thread over the mooring line data line (MLDL) which has electrical conductors inside the synthetic fiber strands. Either a composite thermistor for temperature or a strain guage for pressure with their associated electronics are housed in the pressure-proof can and encapsulated with solid urethane coating. When a temperature sensor is made the thermistor is bonded to the steel pressure container with thermally conductive epoxy cement. When a pressure sensor is made the strain gage is properly aligned with a pressure port in the container and epoxy bonded. After connection to the electronics on circular PC boards, the sensor electronics are encased with Sylgard, a flexible, repairable potting material.

The YSI thermistor composite for temperature measurement will sense temperatures from -2 to +40$^{o}$C. The transducer has a three minute time constant thereby reducing the influence of short term variations affecting the instantaneous temperature measurements. The strain gauge pressure transducer measures water pressure over the range 0 to 322 psi.

Power, in the form of a 10kHz square wave, is transmitted down the MLDL and is coupled into the sensors by the inductive couplers. The decoding logic circuitry in the sensor is designed so a given sensor may be turned on to take data by varying the on and off times of the applied power signal. When a sensor decodes the incoming signal, it turns on power to its transmitter and voltage controlled oscillator, and initiates data acquisition. Voltage from the temperature or pressure bridge is multiplexed to the VCO and controls its output frequency. The output of the voltage controlled oscillator, which follows the analog input voltage from the transducer, covers the range of 960 to 4800 Hz for a 0 to +5 volts input. The output of the transmitter when it is energized drives the transmit core which induces a frequency into the mooring cable, this signal is detected at the surface by the cable receiver and is counted to determine the value of the pressure or temperature signal. This value is encoded and multiplexed into a storage register for further processing. Water temperature is measured at six levels down to 200 meters. Pressure is measured only at 200 meters. No digital averaging is done on these measurands.

4.4.2.6.3 A different approach to measuring subsurface water temperature and pressure is used on another moored LCB. A block diagram of the subsurface sensor system is included in Figure 4.4-20.

In this system a separate data line is used, and the interconnections between the buoy and the sensors are by individual pairs of wires. These wires are spirally wound around a steel inner cable. At the appropriate depth a temperature or pressure transducer is embedded into the cable. Six temperature transducers are used between 50 meters and 200 meters below surface. Pressure is measured only at the 200 meter level.

Water temperature sensing is done by thermistors in the exact manner as described in Paragraph 4.4.2.5.4 for the surface temperature measurement. Each subsurface level has its own transducer and signal conditioning circuit and feeds into a common parallel MUX in the DPS for digitizing, averaging and storage.

The water pressure transducer used is a CEC/Transducer Division of Bell and Howell Type 4-306-0155, 500 psia unit. The transducer converts fluid pressures on the diaphragm of the instrument to a controlled strain in an excited Wheatstone bridge of strain guage windings in which all four arms are active. The output signal is a linear function of the pressure applied to the diaphragm. The output signal from this transducer is further amplified and

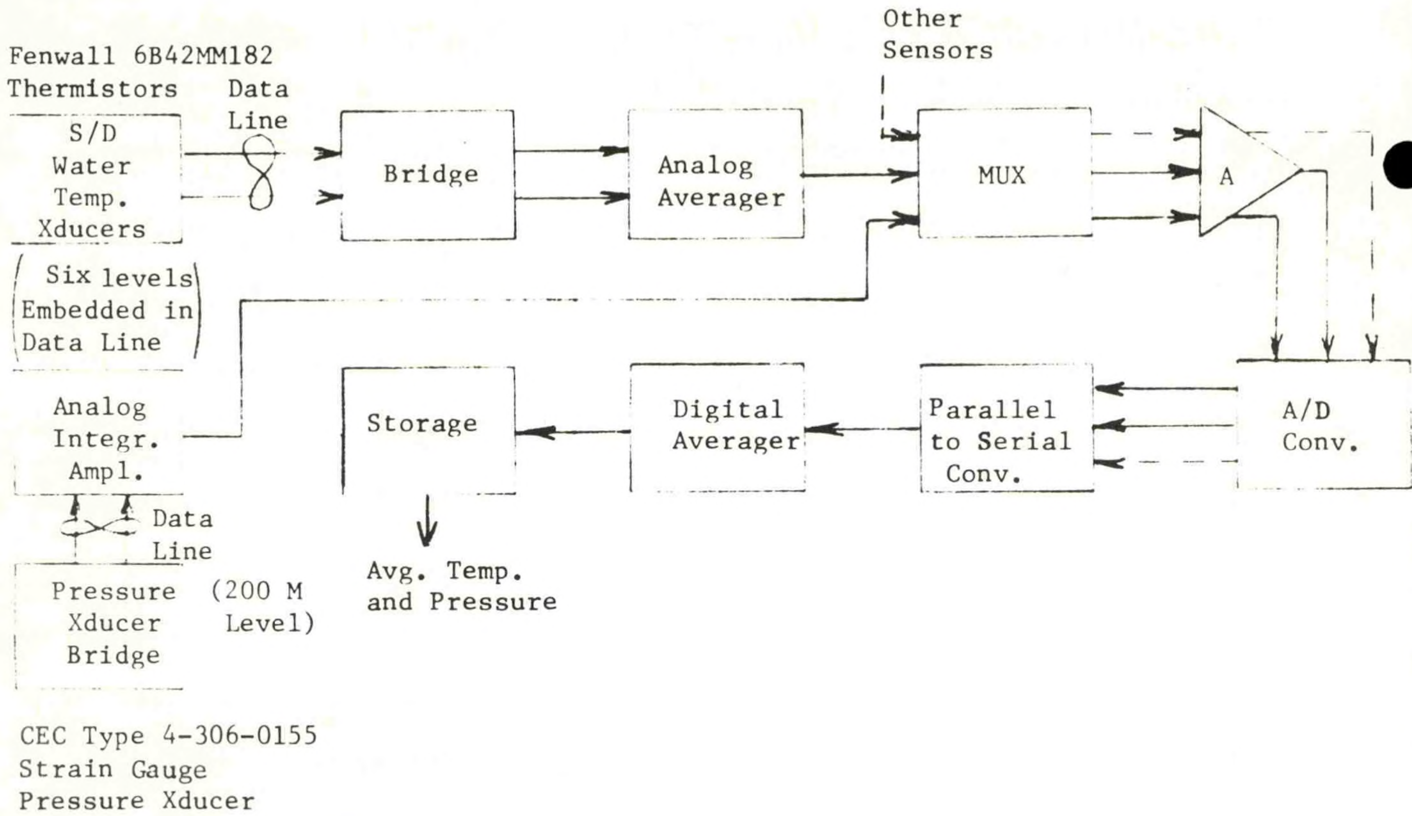



Figure 4.4-20. LCB Subsurface Water Temperature and Pressure Sensors Block Diagram

integrated prior to multiplexing. The amplification and integration serves a dual purpose: First, to normalize the output signal to the multiplexer; and, second, to impose an approximate 10-sec time constant on the output signal. Since the inherent time constant of the transducer is 5 msec, some analog filtering prior to digital averaging in the DPS is necessary to remove the high frequency effects of buoy motion/wave action which, although attenuated at the 200-m depth due to elasticity and inertia of the data line, could cause aliasing of the output.

4.4.3 PERFORMANCE OF SENSOR HARDWARE

4.4.3.1 Considerable operational time has been logged on the High Capability Buoys and on some of the Limited Capability Buoys. In addition to the predeployment checkout and deployed operation, burn-in and accelerated life testing have been accomplished at MTF. A detail accounting of the test and operational exposure and failure history of each NDBO buoy is given in Section II, Systems Reliability Summary.

4.4.3.2 In order to put failures of the sensor subsystems into proper prespective, a listing is included below of the total units which make up the hardware that is either in service or is being used for spares and support. An inventory of HCB units which are of interest for possible application in the Prototype buoy follows:

| HCB Sensor Units | Quantity Delivered |
|---|---|
| Wind Speed and Direction Sensor | 19 |
| Met Sensor Electronics | 19 |
| Met Sensor Electronics/Pressure Transducer | 8 |
| Dew Point and Temperature Transducer Assembly | 9 |
| Dew Point, Temperature, Global Radiation Transducer Assembly | 10 |
| Sensor Deck Unit | 11 |
| Ocean Sensors | 50 |

Of the sixty-three HCB sensor failures reported from all causes, approximately 40% of the verified failures were outright component failures. The balance were attributed to design deficiencies, shipping/handling procedures, directed change-outs, etc. Significantly, approximately ten percent were caused by damage received in handling and shipping. Outright component failures are broken down approximately as follows: Met Sensor Electronics - 50%, SDU - 25%, Met Sensor Electronics/Pressure Transducer - 20%, others combined - 5%. Wind Speed and Direction sensor failures are mainly attributed to shipping/handling and procedural errors. However, it is to be noted that high rate of failure of the met electronics and SDU also affect the ability of the Wind Speed/Direction sensor to deliver valid data. Major failures in the SDU also affect the ability of the ocean sensors to deliver data. In the case of ocean sensors, our success to data has not been acceptable. Complete analysis to determine each failure is difficult because of the difficulty of recovering the ocean sensors from a deployed buoy. Approximately 25% of all ocean sensors delivered have had failure reports written against them. These potential failures are being analyzed to determine a specific cause. It appears that many of these were a result of operation/procedure errors and not outright component failures. The procedure for properly matching the MLDL impedance to the SDU/ocean sensor interface has been a particularly troublesome area. Consistent responses from deployed ocean sensors have not been achieved to date.

The following is a list of the sensor components that were delivered on the Limited Capability Buoys and bench systems.

| Mfg. | LCB Sensor Units | Qty. Delivered |
|---|---|---|
| General Electric | Meteorological Sensor Package (Includes air temp., air pressure and wind sensors) | 5 |
| | Data Encoding Subsystem | 5 |
| | Hull Mounted Water Temperature Sensor | 5 |
| | MLDL with Inductive Coupled Water Temperature and Pressure Sensors | 2 sets |

| Mfg. | LCB Sensor Units | Qty. Delivered |
|---|---|---|
| Lockheed | Air Temperature Sensor | 4 |
| | Air Pressure Sensor | 4 |
| | Wind Speed and Direction Sensor | 4 |
| | Data Line with potted Water Temperature and pressure transducers | 4 |
| | Note: Part of signal conditioning electronics is located in the DPS | |
| Magnavox | Meteorological Sensor Package (Includes air temperature and pressure and deluge sensors) | 4 |
| | Honeywell MSP (Includes air temperature and pressure, wind, and deluge sensors.) | 1 |
| | Wind Sensor Package | 4 |
| | Surface Water Temperature Transducer | 4 |
| | Sensor Data Processor | 4 |

From the limited experience during LCB deployed operations and accelerated life testing, no apparent high failure trends have occurred. Of fifteen failures encountered on sensors, approximately one-half have been random type failures. The others have been due to a presistent problem in an air pressure transducer and problems resulting from buoy handling. Buoy handling has taken a heavy toll on LCB met sensors. Specific details of sensor performance are covered in Section II and in the following paragraphs.

4.4.3.3 ASSESSMENT OF SENSOR PERFORMANCE

Our assessment of sensor performance is based on the actual failures encountered, the amount of troublefree operation and other factors. It is important to realize that this assessment in several cases is also based on a low level of experience. However, it is felt that the experience gained to date has provided valuable information on which to base future sensor designs. Each measurement will be discussed below, and observed problems in the sensors will be listed, where applicable.

4.4.3.3.1 WIND SPEED AND DIRECTION

The vortex shedding anemometer and flux-gate compass have provided good wind speed and direction except as affected by the following:

1. Shading from both up-wind and down-wind objects at the EEP HCB 5-meter level has introduced large errors in both magnitude and direction. A special mounting for this sensor was required.
2. Directional errors in compass indication imparted by magnetic materials on the EEP in close proximity to the compass. Compensation for compass deviation is difficult on the buoys.
3. Design and workmanship problems. Electronic packaging required to ruggedize unit; bonding of the acoustic lens requires improvement, exterior finish and paint requires improvement.

The 3-cup/vane/vane follower with magnetic compass sensor data has compared well with reference sources. However, the wind vane has shown a tendency to bind with a slight distortion in the sensor cage assembly, and cannot be readily replaced or repaired. The cage is excellent in preventing damage to the transducers when the buoy is mishandled.

Results from the impeller-driven vane and North Seeker compass configuration have not been good to date. The one unit that was at sea for any length of time bound up in both speed and direction and ceased to function properly. Also, a failure was caused by an oil leak in the North Seeker

4.4.3.3.2 BAROMETRIC PRESSURE

Air pressure sensors using the variable capacitive diaphragm transducers have shown a tendency to drift up to 6 mbars high. Compounding this problem on the EEP buoys has been a sudden jump in pressure when the unit was handled or shaken. A potentiometer used to adjust the unit was found to be too sensitive (low resolution) allowing a slight shock to change its setting significantly. Other problems which might occur on other types of pressure transducers is water entry into the pressure vent blocking air pressure and clogging of the vent filter by salt deposits.

The aneroid potentiometer type air pressure sensors have been reliable and have returned good data.

Results have been good with the Linear Variable Differential Transformer pressure sensor in the Lockheed MLCB and in the Honeywell Met Sensor Package. However, these sensors have seen very limited at-sea time.

#### 4.4.3.3.3 AIR TEMPERATURE

Air temperature measurements have been very satisfactory from both an accuracy and reliability standpoint on the LCBs. The aspirator fan motor in the Global Radiation/Temperature/Dew Point unit on the EEP buoy failed several times invalidating the temperature reading. However, with proper aspiration, the temperature measurement appears to be valid.

#### 4.4.3.3.4 WIND SPEED & DIRECTION/AIR PRESSURE AND TEMPERATURE (HONEYWELL MSP)

This integrated met sensor package has performed very well after initial interface problems were fixed. The unit has undergone testing on a drifting buoy in the Gulf of Mexico and extensive accelerated testing without a failure.

#### 4.4.3.3.5 SURFACE WATER TEMPERATURE

Measurement of surface water temperature is made with a transducer mounted in the Hull Mounted Oceanographic Sensor on the HCB. On two of the LCBs the surface water temperature transducer is mounted directly to the hull below the water line. On a third LCB, the surface water temperature transducer is encapsulated into the data line at two meters below the surface. Each of these schemes except the last, and the transducer types, have worked well. A failure on the Magnavox LCB was a result of a bad connector.

4.4.3.3.6 SUBSURFACE WATER TEMPERATURE

Subsurface water temperature measurements have not been successful on the HCB. EB-03 Ocean Sensor has worked and given data out of calibration. The basic problem has not been in the temperature sensor but in the ability of the ocean sensors to respond and transmit data reliably. Some useable water temperature data has been received from one General Electric LCB, however, a problem has existed in impedance matching the data line to the buoy. No satisfactory results have been obtained from the Lockheed buoys to date. The first data line deployed (EB-36) fouled with the mooring line cutting some of the conductors. The second data line deployed (EB-37) did not deploy satisfactorily.

4.4.3.3.7 SENSOR ELECTRONICS

As noted previously, many of the outright component failures of EEP Sensors have occurred in the met sensor electronics and Sensor Deck Unit. Because of the use of serial data transfer to and from these units, a failure in either one often wipes out all meteorological data which they handle. A failure in the SDU can also wipe out the oceanographic sensor data. A particularly undesirable feature of the EEP sensor subsystem is the interdependence of LRUs on each other. For instance, the Wind Speed and Direction sensor and the met electronics bottle containing the air pressure sensor are a matched set, requiring that both be replaced if one malfunctions.

The sensor electronics for the LCBs have provided very successful operation to date. Two reported failures have affected sensor data. One was a data encoder on EB-62 and the other was a DC/DC converter in the sensor data processor on EB-53.

4.4.4 APPROACHES

4.4.4.1 Information presented herein represents some of the knowledge acquired through experience in the development of sensor systems for NDBO buoys. The discussions on different approaches to the design, fabrication and testing will point out those techniques and procedures that have generally "worked" and also those that have not worked at all or not very well. We will also point out areas of concern which we feel could lead to performance or reliability problems if adopted on the prototype buoy. It is suggested that the bidder carefully review this information to determine its applicability in his proposed design and development of the Sensor Subsystem.

4.4.4.2 As defined earlier in this discussion, the purpose of the Sensor Subsystem is to sense the changes in the environment and to transform the physical responses into electrical signals of known relationship to the physical changes. As noted in the hardware descriptions for the NDBO buoys, this job may be accomplished quite successfully with different transducers and signal conditioning schemes. The challenge is to select the proper set of components and electronics and integrate them into a system that will have a high probability of meeting the reliability and cost objectives of the program.

Relief in the system accuracies of the measurements should provide a desirable cost impact. However, the requirement to provide high system reliability will make necessary a careful and accurate trade-off of cost and predicted or demonstrated performance when selecting the components and schemes for the Sensor Subsystem design. Since Wind Speed and Direction and Barometric Pressure are required data for any successful mission on the prototype buoy, consideration should be given to completely independent, redundant sensors to ensure successful delivery of wind and air pressure data. Redundancy in other sensors, however, must be balanced against costs. A high degree of flexibility in the sensor system usually runs counter to high reliability and low costs. In general, a simple, straight-forward design to meet basic requirements is the way to meet our goals. In the case of the Sensor Subsystem, the proven technology exists to meet these goals. It is felt that no new sensor technology need be developed for the Prototype buoy. Instead, we must concentrate on the development of hardware that has the requisite stability and reliability to meet the data delivery requirements while deployed for long periods of time in the hostile sea environment.

4.4.4.3 Each sensor transducer required on the Sensor Subsystem of the Prototype Buoy is discussed in the following paragraphs. The sensor electronic and mechanical features are also discussed. Where there have been problems or potential problems in the performance, reliability, maintainability and degradation because of the sea environment on deployed NDBO hardware, these will be pointed out. We will indicate approaches which experience has shown will provide improved results over previous methods. Finally, we will point out areas of concern where further analysis and testing or improved precedures can result in considerable improvement in the Prototype Buoy Sensor System.

4.4.4.3.1 Sensor Subsystem Design and Component Selection

4.4.4.3.2 Reliability of sensors is determined for the most part by the circuit components used and how they are packaged and built. The number of circuit components and overall complexity of the circuitry must therefore be held to a minimum. Use of high reliability (Hi-Rel) components is not desirable from a cost standpoint except in very critical applications. By use of proper derating and packaging techniques, standard commercial components are normally adequate to meet reliability requirements. To achieve the reliability, however, burn in of the system is required while electrically and thermally stressing the system.

4.4.4.3.3 A typical sensor subsystem will include a set of transducers with associated signal conditioners providing parallel inputs to a multiplexer and A/D converter. The digital output is transferred bit serial to an accumulator for temporary storage. The data is then forwarded to a data processor on command. This scheme seems simple enough, but can become very complicated when one considers the addressing, sequencing and timing aspects of the operation. In this regard, NDBO has found that the best scheme is the use of a simple interrogation (turn on) command which will cycle through each sensor sequentially in the same order each time and then turn the sensors off after all data has been acquired. In this manner, no elaborate addressing and address detection circuitry are required, and no capability for selection of individual sensors is needed. All data from each transducer is always delivered. Shore processing is then used to sort out and deliver the valid data of interest.

The individual transducers and associated signal conditioning will be discussed in later paragraphs. Certain general considerations of Sensor Subsystem design such as time constants, transfer functions, sampling rates, averaging and general design features will be covered at this point.

The physical configurations and locations of the transducers and electronic packages are extremely important both from the standpoint of data acquisition and for maintenance and servicing. For example, the transducers must be properly designed and located where they will "see" the physical environment to be measured, and not be affected by nearby structures or extraneous effects of a long term or short term nature. At the same time they must not be inaccessible for servicing during repair trips. Quality of data reported is directly related to the response time of a transducer and associated signal processor. In general, the time constant of the transducer shall be such that the output for each sample taken is an <u>independent</u> measurement. This implies that the time constant must be less than the time between samples. For variations of shorter duration (higher frequency) than the TC, the transducer should be designed to provide inherent averaging, so that all higher frequencies would result in an average value. Time constants of related transducers, such as wind speed and wind direction, must be the same; and the wind speed transducer and wind direction transducer should "see" the same volume of air for proper response.

Since many of the physical fluxuations (and noise) are random in nature, it is important that sensor transfer functions be as linear as possible. Non-linearity will cause a bias in the data output which cannot be calibrated out. For transducers using non-linear resistors to sense temperature or pressure changes, the resistance bridge is normally used as a means of linearizing the output. This bridge provides best results when excited with an ac voltage. The transfer functions must be identical for like functional and mechanical units to permit interchanging units during repairs.

A particularly poor feature in the EEP Sensor System is the necessity for matching one LRU with another. For example, a wind speed/direction package is matched to a met sensor electronics bottle requiring replacement of both if the other is bad. Another example is the performance of the met sensors being affected by removal or malfunction of an ocean sensor. This type of system design problem does not enhance reliability and maintenance of the sensor system, and should be eliminated on the prototype buoy design by adequate circuit analysis and testing. It would be desirable to have protective circuitry, such as current limiter, fuse, etc., such that a failure in one function will not cause a failure or prevent proper operation of another function. This will be particularly important for wind and air pressure data on the prototype buoy. It would also be desirable to include provisions to fill the data word for a failed parameter with a pattern of "1" or "0", making sure that data words for other parameters are unaffected.

Sampling of the sensors is normally by command of the Data Processing System. This command may be controlled internally for self-initiated mode or externally by interrogation from shore. The sensor system must be capable of responding each time commanded. The sampling rate is determined by the frequency variation of the measurand. Normally, one sample each 15-30 seconds is adequate. Wind and air pressure require more frequent sampling because of higher frequency variations. Wave height and period may require higher sampling rates depending on the type sensor employed and the buoy response to waves of different frequencies. Provisions should be made to discard the first samples or delay start of sampling until adequate sensor warmup is achieved.

Data averaging is required for wind and air pressure measurements and is highly desirable for all measurements. Because of the problem of maintaining long term stability in analog circuits, digital averaging should be considered. The output from analog transducers should be digitized as for up-stream as practical. Some mechanical averaging may be considered for temperature measurements consistent with natural variability and obtaining a true average value. In the interest of simplicity and cost, NDBO recommends consideration of binary averaging by truncation with the sample size adjustable by powers of two.

Power consumption of the Sensor Subsystem is of importance in meeting the overall power budget of the buoy. With the use of COS/MOS low power logic and prudent care in the design, power consumption should not exceed 10 watts peak. Failures of dc/dc converters in both the EEP and one LCB sensor system point out the need for a close examination of the voltage levels in the buoy with the intent to standardize on voltages as far as practical. By proper standardization, a significant reduction in voltage converters may be possible.

Grounding, shielding and terminations require very careful attention in a data buoy because of transients from power switching, coupled with the low level digital circuitry. This has been well demonstrated by recurring problems on the EEP buoy where digital logic and memory locations were "wiped out" by power transients and r-f noise. In general, an overall system of grounding and shielding must be adapted throughout the buoy. This system should employ a parallel path from each equipment chassis to a common ground terminal in the buoy. Stating it another way, no two pieces of equipment shall be in series on one ground. Care must also be taken in test equipment design to ensure that no equipment shall become floating above this common ground by the insertion of the tester into the circuits. Shielding should be considered for all low level circuits. Shield terminations should be insulated from the chassis except at one common point and should be carried through connectors on a separate pin.

Selection of transducers for the Prototype Buoy must be based on several factors such as cost, availability, actual performance, reliability, etc. NDBO has had considerable experience with various types of transducers deployed on buoys over the past two years. In addition, we have sponsored various industry and government agencies in the development and test evaluation efforts on candidate transducers for use on buoys. Results of these efforts have lead to a recommendation of transducer types which we feel the proposer should consider in making his selection of components for the Sensor Subsystem.

| Measurand | Transducer Type |
|---|---|
| Wind Speed | *Vortex Shedding Anemometer |
| Wind Direction | Wind Vane and Flux-Gate Compass |
| Barometric Pressure | Bonded Strain Gauge |
| Air Temperature | Platinum Resistor |
| Water Surface Temperature | Platinum Resistor |
| Subsurface Temperature | Thermistor Line |
| Subsurface Pressure | Bonded Strain Gauge |
| Wave Height and Period | Double Integration of Vertical Accelerometer Output |

*Assumes that stringent quality controls are implemented to eliminate workmanship failures.

4.4.4.3.4 Packaging

4.4.4.3.5 There are many things to consider by the product design engineer in the manner that elements of the Sensor Subsystem are integrated into functional units. First, a knowledge of the ocean platform configuration that will support the sensors is required. The predicted performance of the platform must also be known so the designer will understand the environment the sensors will see during operation. Space, weight, and power limitations are also required. Maintenance concepts, and maintenance equipment and personnel that will be available during checkout and operation are among the many other considerations that should be understood. All of these together with sensor performance requirements determine the packaging concepts that apply.

The one factor that continues to cause most failures in buoys is their ability to withstand the environment to which they are subjected during deployment. When one compares this environment, say, to the operating environment of an aircraft or a missile, it becomes evident from the relative number of environmental "duty cycles" each must endure that the buoy equipment must be more rugged and durable in order to meet its deployment life. Add to this the effects of the sea water and spray, and sea life, on the equipment, and the task of producing a reliable sensor becomes a formidable one.

Listed below are some of the problems encountered with NDBO hardware that could have been avoided with proper care in packaging design.

1. Necessity for special handing of items such as anemometers, compasses, etc. to prevent internal damage during shipment and handling. A high rate of failures has been experienced on EEP anemometers as a result of internal damage during shipment.

2. Printed circuit boards or modules have "fallen out" of their sockets during deployment. This has occurred on an LCB electronics package, underwater current meters, and wind speed sensor.

Since one major source of failures in sensors has been in interconnections, a trade-off should be made by the bidder to determine the feasibility of hard wiring pc boards instead of using connectors, to improve reliability. This may be feasible since no on-board maintenance of the LRUs is to be done, and the repair effort will be done by highly capable personnel at the bench level. This same argument may be valid in justifying the elimination of as many intercabling connectors as possible since failures of connector pins, potting, etc. has been a major source of trouble on buoys. Connectors, where required, should be located where they have minimum exposure to the sea environment.

It is desirable from a maintenance and growth standpoint to package modules on a parameter type basis to prevent interplay between modules and to allow a complete function to be added or deleted easily. For example, a transducer should have its associated signal conditioning together in one package, where possible. Since the multiplexer and A/D converter are closely related, they should be packaged together.

In general, modularity should be carried to the greatest extent practical consistent with factors such as reliability, ease of maintenance and growth. A good example of proper use of the modularity concept is in the single unit construction of the Honeywell Met Package. It is compact and can be easily serviced. It contains the met transducers and signal conditioning and is interconnected to the data processing electronics inside the buoy by a single connector. Size and weight of sensor packages must be carefully considered, as well as ease of installation and removal. No sensor LRU should exceed 25 pounds, and provisions for quick and safe servicing are essential. Sensor packages on the EEP buoy are generally considered too bulky and heavy for safe handling and servicing at sea. Additional comments on sensor packaging is included under the detail sensor discussions in later paragraphs.

4.4.4.3.6 Environmental Protection

4.4.4.3.7 One of the difficult design tasks for buoys is to make them impervious to the environment. Corrosion, salt deposits and sea growth on or near the sensor transducers can cause failure or severe degradation of performance. Our experience with EEP and LCB buoy deployments has shown that a very short time exposure to the sea can produce surprisingly harsh effects on the equipment. Selection of proper materials and providing proper seals for transducers that are exposed are critical to their survivability. Use of double o-rings and clamps for sealing two plain surfaces has been successful on sensors. Sealing around penetrations for transducers and connectors have been a source for trouble. On the EEP buoy, several failures have occurred because of breakdown of potting used to waterproof connectors. Potting of components in thermistor data lines has also caused considerable troubles and requires that good procedures and care be exercised to obtain good seals. It is always essential to pressure test any potted or sealed unit to verify proper sealing. A good approach to corrosion protection is to start by selecting more high quality plastics such as Lexon or fiberglass materials for exposed surfaces. It is also good practice to avoid use of aluminum as this material is exceptionally susceptible to corrosion if not protected. Where aluminum is selected for met sensors, hard anodized finish covered with a large number of coats of white heat reflective paint has been successful. Westinghouse met sensors use this type finish. Exposed ocean transducer housings require a high grade epoxy finish to withstand the effects of the sea water. It is important to insure that exposed materials in purchased transducers are compatible with buoy mounting surface materials to prevent electrolysis and severe corrosion at and adjacent to the mounting surfaces. Moving parts anemometers tend to bind as a result of corrosive action and salt deposits. One of the moored LCBs (EB-36) froze after a short time at sea so that neither the impeller or wind vane would operate. Another moored LCB (EB-32) had impeller freeze-up but may have been a result of handling damage.

4.4.4.3.8 Buoy Installation and Servicing

4.4.4.3.9 Installation of transducers on the buoy should be guided by two important "don'ts" to be successful:

1. Don't place them where the quality of the data is affected.
2. Don't place them where they cannot be serviced.

Experience on the EEP buoys has shown that almost every transducer has unique problems in this regard. Because the hull and superstructure is ferrous material directional errors are introduced in wind components because of the effect of the disturbed magnetic field on the magnetic compass. Movement of the compass away from the buoy helps the magnetic field problem but causes higher acceleration forces on the compass. These acceleration forces introduce significant directional errors which are amplified by the height above the buoy center of motion. Since these effects are bounding, it is necessary through analysis and experimentation to select the compass mounting so as to minimize the combined error. This task is made easier if a symmetrical configuration about the compass is maintained, and no other devices containing ferrous material are mounted nearby. Compensation of the compass is also less difficult if everything is symmetrical. Our past practice has been to use the center of the superstructure and buoy for cabling, personnel passageways, etc. Instead, consideration ought to be given to reserving the center for compass mountings and for mounting other instruments that require a centerline location for best performance.

Tests on the EEP buoys have shown that local interference in the path of the wind stream both up-stream and down-stream from the wind sensor causes significant errors in wind speed and direction. As a result of these tests the 5-meter wind sensor was moved to a special outboard pod to reduce the effects of shading by the buoy superstructure. To prevent a similar problem on the prototype buoy, a symmetrical installation of the two wind transducers about the buoy center is suggested with the distance between them greater than ten diameters, where the diameter is that of each wind transducer housing or support. It is also suggested that the installation be above all major superstructure. By a symmetrical installation, the effect of buoy motion on the direction vane can also be minimized.

Installation of the air pressure transducer is quite critical because of the pressure port. However, several important considerations can enhance the long term stability and performance of the device.

Problems that should be considered in design of the pressure inlet are:

(1) Water in the pressure inlet can effectively block out the pressure; and,

(2) Water on the sensing element can change the time constant of the device and cause errors. Care must be taken also that any filter in the pressure inlet be located so salt crystals or other matter does not block the line.

The major pressure transducer errors are caused by acceleration and *temperature. Fortunately, both can be minimized by careful mounting of the transducer.

* Unless carefully compensated

The sensing element should be located as close as possible to the buoy center of motion to minimize effects of acceleration. Temperature offset errors can be minimized by heat sinking to a relatively constant temperature structure, such as the bottom of the buoy hull. A good arrangement, then, may be to mount the transducer down low in the buoy hull with pressure piping from above. Carefully designed Pitot tube arrangement on top of the mast piping might be used to transmit pressure down through the inside of the mast. By sinking the unit essentially to the ocean surface temperature, which will be known, a means is available for post data acquisition correction of pressure, if required. A tradeoff, of course,

should be made of the potential technical problems and cost of this arrangement versus the cost of more elaborate compensation for the pressure transducers.

Installation of the air temperature transducer away from heat sources that can affect the ambient air is essential for accurate results. Normally, this requires installation as high as possible. The transducer should not be secured to a large structure where radiated or conducted heat can affect it. It should also be protected from water spray. Since the unit must be asperated for good performance, consideration should be given to making the temperature probe part of the aerovane of the wind sensor.

Because of the potential problems associated with installing the surface water temperature transducer in water below the hull, a new mounting approach should be considered. By mounting the transducer on the inside of the bottom of the buoy and thermally coupling it to the hull at the right location, minimal error should be introduced from the 2 meter water location. Protection from the effects of buoy heat could be provided by well insulating the transducer from the inside. This installation, if feasible, could significally reduce the complexity, cost and risks in obtaining water surface temperature.

Subsurface water temperature sensors integral to the mooring line appear to be the only feasible approach. Separate data lines on EB-36, 37 and 38 LCBs have not been successful from a mechanical standpoint. On EB-36, the first buoy deployed, the data line fouled with the mooring line cutting several conductors. On the next deployment attempt, the data line did not deploy properly.

Accurate measurement of significant wave height and period by integrating vertical acceleration is dependent on being able to accurately sense the vertical motion of the buoy. It is important that the vertical accelerometer be mounted and properly aligned at the buoy center of motion so it will be insensitive to motion in other planes.

4.4.4.3.10 Servicing of the sensors on-board the buoy is usually a difficult task at best. This makes it necessary to provide features that allow fast isolation of failed components and easy access and replacement. Safety is also a very important aspect of servicing a buoy. The NDBO maintenance philosophy is based on the foregoing and essentially calls for minimum maintenance to be performed on-board the buoys, with the major effort going to replacing LRUs and expendibles and making essential adjustments that cannot be made elsewhere.

Servicing of the Sensor Subsystem is particularly hazardous because most of the elements are located above deck or below the buoy. The EEP met sensors consist of many heavy and bulky modules that are secured by J-bolts to the 5 and 10 meter rails or to special extentions. In several cases access to connectors and fasteners makes the task of replacement almost impossible and dangerous to personnel. Consequently, servicing of the sensors is often done hurriedly with the usual risks of leaving a connector loose or some other problem that can cause a later malfunction.

For the Prototype Buoy, the following features should be considered to improved serviceability of the sensors:

1. Built in on-board provisions to read out data from each sensor as an aid to trouble isolation.
2. Digitize a reference word to transmit along with data words. Also make provisions for inserting a pre-programmed known message for separating sensor and other subsystem failures.
3. Bring all test points and adjustments out where they are accessible without special test equipment and PC board extenders, etc.
4. Complete functional and mechanical interchangeability of LRUs without the necessity for recalibration or system adjustment.
5. Design the met sensor platform with servicing in mind.
6. Provide quick disconnect fasteners, access to connectors, access to latching devices, etc, temporary LRU holding provisions, and light, non-cumbersome packages so any LRU may be efficiently replaced by a single maintenance man in relatively rough seas.

4.4.4.3.11 Quality Control

4.4.4.3.12 Most of the NDBO sensor hardware reflects the contractors' efforts to provide a quality product. However, some of the hardware that has been most troublesome shows a lack of quality control. Because of the severe environment that the sensors must withstand, poor workmanship cannot be tolerated. For example, a poor sealing job on a module can cause near complete destruction from entry of salt water. A scratch in the paint surface can cause a crack through which corrosion can begin and greatly reduce the useful life of a sensor. A poor bonding job can cause wind speed acoustic lenses to fall off disabling the wind sensor. All of these incidents have been experienced once or more times on NDBO sensors. To remedy this type of quality problem the supplier must institute a procedure of incremental inspection and testing. In this procedure each PC board, module, LRU and Sensor Subsystem is individually inspected and tested prior to entering the next higher assembly. A period of burn-in should be conducted on each equipment to force any latent failure prior to acceptance testing. At least one representative unit should also undergo environmental testing to assist in uncovering and fixing design problems that bench tests will not detect.

Calibration of the sensors is required to show that the acquired data is reasonable and meanful. The calibration should include five to seven points with a check of both end points of the range. The single point sensor calibration to verify the vendor data for the transducer is not adequate. This has been borne out by an out-of-calibration condition of EEP air pressure sensors. Westinghouse conducted a single point calibration and found the results agreed very well with the vendor calibration data. However, the procedure did not provide for checking the end points which were later found to be out of calibration. Calibration of the transducer and at the sensor level should be traceable to a NBS standard and be within reasonable limits of the standard.

4.4.4.3.13 Development Testing

4.4.4.3.14 The Prototype Buoy is not intended to be a test bed for developing sensors. The sensors must be fully developed and ready for production and installation at delivery of the prototype. Problems identified such as shading of the wind sensors, deviation errors in the flux-gate compass, air pressure inlet design, wave measuring system design, etc. should be resolved by adequate development testing prior to committment for production/installation on the prototype buoy.

4.4.4.4. Transducer and Sensor Electronics Design Considerations

4.4.4.4.1 The following discussions apply to the individual transducers and electronics of the Sensor Subsystem.

4.4.4.4.1.1 WIND SPEED AND DIRECTION

The trend in wind measurements is toward a no-moving-parts device which is less susceptable to hangup, dead band and acceleration problems. However, the NMP device has not yet been developed sufficiently to justify selection for use on the prototype buoy. The vortex-shedding anemometer and wind vane/flux-gate compass appears to be a leading candidate for use since it overcomes some of the disadvantages of the impeller and cup type anemometers. Its performance on the EEP and Magnavox LCB has been very good except for the quality and packaging problems mentioned earlier, which are easily corrected. Parallel brushes on the slip rings would provide redundancy and improve reliability.

Mounting of the wind sensor, as pointed out previously, is critical to its proper performance on the buoy. Early verification of the proposed mounting should be performed for shading errors and magnetic compass errors. An improved mounting arrangement to enhance servicing is highly desirable.

Vector resolution of each wind sample into the north and east components is required before averaging. Digital coordinate resolution appears to be a good technique for accomplishing this. Because of the importance of wind measurement, redundant wind sensors should be considered.

4.4.4.4.1.2 AIR PRESSURE

Capacitive type pressure transducers in use on the EEP and Magnavox LCB have shown a tendency to drift high by up to 6 mb. A pressure offset caused by a vibration of an adjustment potentiometer has also caused errors in the EEP air pressure measurements. Results from tests conducted on resistance bonded strain gauge pressure transducers and their successful application on buoys, indicate that the bonded strain gauge type unit can meet the accuracy and stability requirements for the prototype buoy. Proper design of the pressure inlet and location to minimize acceleration and temperature effects is recommended.

4.4.4.4.1.3 AIR TEMPERATURE

Location of the air temperature probe is not critical. However, care must be taken in designing the enclosure so that the sun and heat from the buoy do not affect the ambient temperature about the transducer. NDBO has found that a properly aspirated housing is required. The fan motor in the EEP aspirated housing has failed on numerous occasions. A motor driven fan is not recommended. Consideration should be given to the advantages of the platinum resistance type transducer.

4.4.4.4.1.4 WATER SURFACE TEMPERATURE

Installation of the water surface temperature sensor inside the buoy was previously discussed. Another advantage of this is to get the transducer away from the sea water and protect it. One of the failures of water surface temperature sensor on an LCB was a result of water leakage past a seal.

4.4.4.4.1.5 SUBSURFACE TEMPERATURE

Inductively coupled ocean sensors on both the EEP buoy and the General Electric MLCB have not performed satisfactorily to date. Additional development of this concept needs to be done before consideration on the meteorological buoy. As indicated previously, the use of a separate data line on the Lockheed MLCB has not been satisfactory at this time. Development of a thermistor line at NDBO has progressed satisfactorily and two configurations have been designed. One is constructed of PVC tubing and nylon tees and filled with oil. Individual wires for each thermistor run through the tubing. Breakouts for the thermistors are provided at the tees, and the thermistors are potted and screwed into the tee. A model of this configuration was fabricated and has been under test in the canal at MTF for 10 months. The thermistor has maintained its watertight integrity during this period. One thermistor failure has occurred.

Another configuration is known as the blocked line design. It consists of a steel center wire with individual conductor pairs for each thermistor spirally wrapped around the steel wire. Breakouts are made at the proper levels and the thermistors are connected and potted to the cable. No model has yet been constructed for this configuration. The latter configuration appears to have great promise and should be considered for the subsurface water temperature sensor.

4.4.4.4.1.6 WAVE MEASUREMENT

Several techniques have been employed to measure waves. The EEP buoys have two systems that are designed to provide various wave parameters. These systems in general are too complicated and have not shown the required reliability and accuracy for application on the prototype buoy.

A simple wave measuring system is presently under development for NDBO by General Dynamics which uses a strapped down vertical accelerometer as a wave sensing element. By double integrating the measured acceleration, information is obtained to compute the significant wave height ($\bar{h}$ 1/3) and period (T). This computation is presently being done with a general purpose computer on the buoy. The bidder should investigate alternate approaches to this computation, including both analog and digital methods using hard wired devices, since no general purpose computer is to be included on the prototype buoy. The strapped down accelerometer system should be considered for application on the prototype buoy.

One of the problems that have contributed to the inability of the wave measuring systems on the EEP buoys to perform reliably has been failures in accelerometers. The key to the simple double integrating system performance could also be the reliability of the vertical accelerometer. Therefore, the bidder should select and specify a highly reliable unit for the prototype buoy.

4.4.4.4.1.7 SENSOR SUBSYSTEM ELECTRONICS

Power considerations dictate the use of low power devices as far as practical in the Sensor Subsystem electronics. The use of COS/MOS circuitry in the existing NDBO sensor systems has been very successful and has resulted in a power reduction of roughly ten to one over conventional TTL circuitry. With proper design precautions COS/MOS devices can provide attractive performance and should be considered for use in the Sensor Subsystem electronics.

Plastic IC's have been used to provide reliable operation by packaging to keep them protected from the ocean environment and burning them in past the infantile high failure period. The designer should use care during breadboarding that the IC's to be used have the same characteristics as production units. During the EEP Sensor System design Westinghouse found that COS/MOS plastic IC's varied from JAN and JAN-TX units and also varied from one manufacturer to another. Another problem encountered with COS/MOS circuits when used as gates is their ability to drift and hang up when one terminal is left on. To overcome this a a scheme must be used to clamp the device off when not in use. With proper care in the design, COS/MOS circuits can be very reliable.

In the sections on System Design, Packaging, and Maintenance Features we discussed the concepts of using standard voltages to reduce the number and complexity of voltage converters, packaging certain functions together for ease of add-on and maintenance, and steps that might be taken in the electronics design to circumvent some of the failures we have experienced in existing NDBO hardware. Another area that should be addressed is the complexity required in the A/D conversion and other circuitry to obtain the accuracies required for the Prototype Buoy. Up to 12-bit resolution is provided on some parameters in the EEP and LCB. It is entirely possible that this could be reduced to as low as 8-bit resolution and still meet the specified requirements.

Vector resolution of wind components is accomplished by several different techniques on existing NDBO hardware. Some of them are extremely complex while others are quite straightforward. We believe that a digital coordinate resolver approach is preferable to an analog or hybrid approach in both simplicity and accuracy.

4.5 DATA PROCESSOR EXPERIENCE

4.5.1 HARDWARE DESCRIPTION

4.5.1.1 LARGE BUOYS

4.5.1.1.1 EDD

The Data Processing System (DPS) is constructed around a general purpose NOVA Computer and acts as a controller and data processor for the integrated operations of the entire buoy including sensors, communications, and power systems. It is able to interpret and act upon a number of different commands with numerous options. The data processor is also able to initiate on-board operations based on built-in specifications by virture of an integral timing system. A block diagram of the data processing system, one of the two non-redundant systems aboard the buoy, is shown in Figure 4.5-1.

4.5.1.1.1.1 FUNCTIONAL OPERATIONS

The data processing system performs five major operating functions. These are:

(1) Control of communication system

(2) Selection of synoptic data acquisition category

(3) Selection of on-line data acquisition category

(4) Processing of data

(5) Storage of data

Each of these major operating functions consist of various logical and arithmetical operations performing the following tasks:

(1) Control of communication system

- Recognition of a command
- Reception and storage of a command
- Interpretation and execution of command
- Operation and control of the buoy transmitter

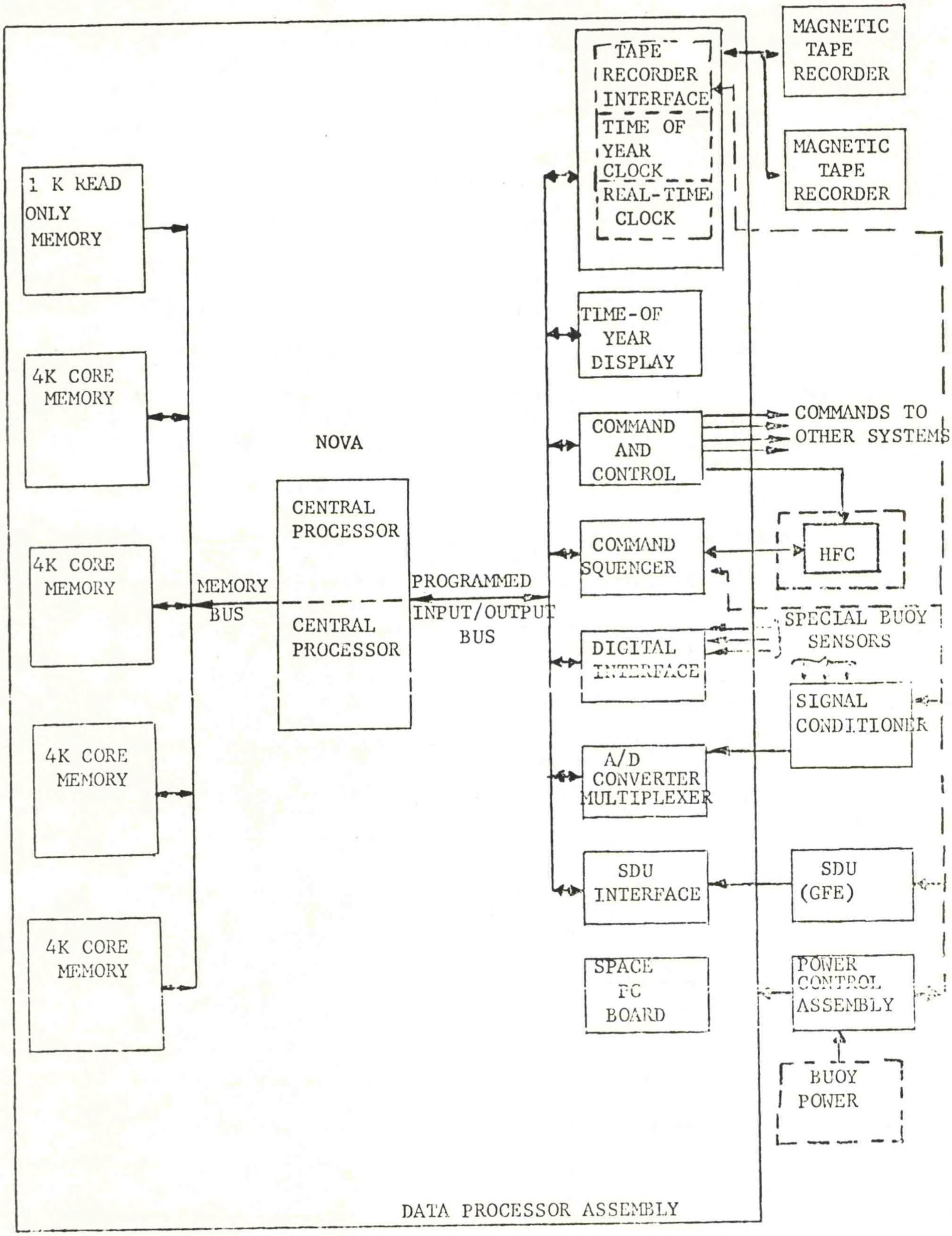



FIGURE 4.5-1 - EDD LARGE BUOY DATA PROCESSOR

(2) Selection of synoptic data acquisition from four categories

- Meteorological data
- Sea State data
- Oceanographic data
- System status data

The DPS is capable of processing any combination of the four categories. The synoptic data sampling specification specifies sampling for each category.

0 = do not sample this category

1 = sample this category each hour

2 = sample this category every 3 hours

3 = sample this category every 6 hours

Either instantaneous or averaged processing may be specified and this option applies to all categories being processed.

(3) Selection of on-line data acquisition from eight categories

- Single channel
- Meteorological data
- Sea state data
- Oceanographic data
- Oceanographic data - Group 1
- Oceanographic data - Group 2
- System status data
- High-volume A/D data

On-line data may be acquired either in an instantaneous mode or an averaged mode.

(4) Processing of data

- Linearization: Since some transducers are nonlinear in their response, data averaging of raw data (including data which has undergone reference corrections) can provide inaccurate results. To provide this linearization, scale factors are stored in the core memory for each parameter. Data scaling and linearization are applied to data as it is processed.
- Special Calculations: Special processing calculations are performed as required to produce transformed parameters, including:

  a) N&E components of wind and current direction

  b) Salinity (from conductivity, pressure and temperature)

  c) Significant wave height

(5) Storage of data

- Buffer storage of raw data
- Digital tape recording of raw data (optional)
- Buffer storage of processed data
- Digital tape recording of processed data

4.5.1.1.1.2 DESCRIPTION

The data processing system consists of a central processing unit, associated memory, floating point software package, a signal conditioner assembly, a power control assembly and two magnetic tape recorders. All the above assemblies are installed in a single cabinet located in the buoy electronics compartment. This cabinet is 26 inches wide, 62 inches high, and 32 inches deep and is capable of being purged with nitrogen.

The general purpose NOVA computer assembly consists of an expansion chassis containing a 1-K non-destruct read-only memory with sixteen-bit words used for communication logic, and four read-write 4-K memory modules each containing sixteen-bit words used for buffer storage and application programs which perform data winnowing, averaging, scaling, formatting and storage before transmission and recording of raw and/or processed data on magnetic tapes.

The signal conditioner assembly provides analog measurement signal conditioning for special buoy sensors. The signal conditioner contains independent power supplies for sensors requiring regulated instrumentation power and for data readout within the assembly. It also provides operational amplifiers for conditioning of analog sensor signals.

The power control assembly contains seven power supplies and five power cycling control relays. The relays are used to control power to other components of the data processor and data processor interface devices.

A real-time digital clock provides reference time with a resolution of one second and a maximum cumulative error of $\pm$ 5 seconds per month. This clock is used as a time reference for both the data sampling interval generator and the process timer.

The sampling interval generator provides the time sequences for the synoptic interval, measurement duration, and sampling duration. It consists of a sixteen-bit word with a resolution of one second and is synchronized exactly with the time-of-year clock. This clock can be preset with appropriate time intervals by the computer.

The process timer is a multipurpose counter which is used by the computer to provide internal time delays independent of computer activity. This counter has a resolution of one part in 256 of the clock frequency. The delays which this counter generates are used in conjunction with the sampling interval generator to provide finer sampling resolution which is synchronized to the time-of-year clock. This time also provides the generation of timing gates for the computer when external devices are operated.

Two write-only incremental magnetic tape recorders (Model 1610D-Kennedy) are provided for long term data storage aboard the buoy. They record on standard seven-track industry compatible format of 556 BPI. Tape recorder control electronics interfaces with the computer through a tape recorder interface in each recorder.

4.5.1.1.2 LMSC

The data processor is similar to the EDD system. The major differences are the incorporation of a ROLM 1601/00 digital computer and computer time reference instead of an independent hardware clocking reference. The ROLM uses architecture identical to that of the commercial NOVA machine, including multiple accumulators, auto-indexing from low core locations, and a flexible instruction set allowing very efficient assembly language programming.

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## 4.5.1.2 SMALL BUOYS

### 4.5.1.2.1 MAGNAVOX

The primary functions of the data processor are to collect and store meteorological, oceanographic, position fixing and status data; then, format this data for report transmission. This buoy has two report modes; synoptic and interrogated. The data processor has an interval clock that is preset prior to deployment. A block diagram of the data processor is shown in Figure 4.5-2. The temperature-compensated stable oscillator is stable to better than 1 part per million. The oscillator, timer and memory are continually powered. The data processor electronics is encased in an aluminum module, 6-3/8 inches wide, 12-3/8 inches high, and 14 inches deep. The weight is 5 pounds. The overall data processor can be described in terms of a simple non-programmable special purpose computer. This is sometimes alluded to as a "hard-wired" computer.

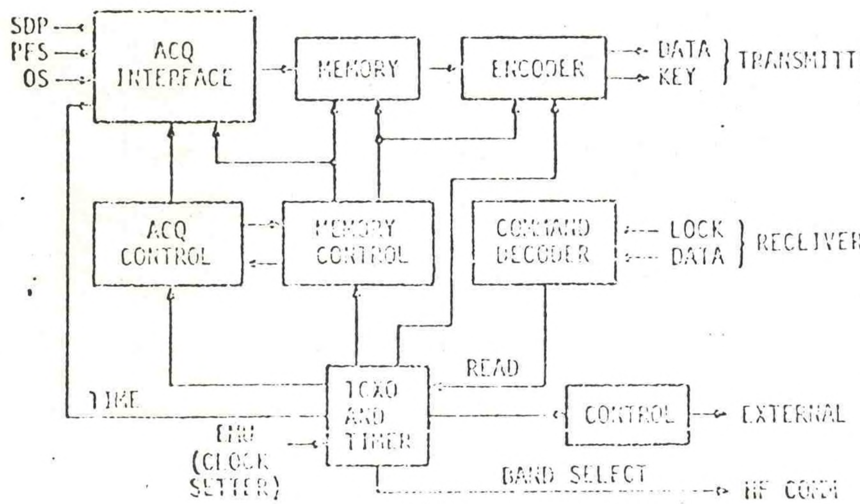



FIGURE 4.5-2 - MAGNAVOX SMALL BUOY DATA PROCESSOR

4.5.1.2.2 LMSC

The data processor performs signal conditioning, data acquisition, data storage, event timing, command decoding, telemetry formatting, and surge battery charger duration control. The data processor is housed in an aluminum box that is 20x10x8-in. and weighs 20 pounds. This buoy also has two report modes; synoptic and interrogated. A block diagram of the data processor is shown in Figure 4.5-3. The major elements comprising the data processor are: power converters, analog unit, data acquisition unit, averaging and storage unit, timing and controller, command decoder and output formatter. The generic description of the LMSC data processor also falls into the category of a simple non-programmable special purpose computer.

4.5.1.2.3 GE

The data processor provides timing, control and data processing and encoding functions for the buoy. These functions are contained in three major components; command decoder, timer programmer and data encoder. These components are bound in an overall single container 15-1/2x11 x17 in. and weighing 25 pounds. The generic description of the GE data processor also falls into the category of a simple non-programmable special purpose computer. Figure 4.5-4 reflects the GE configuration.

4.5.2 PERFORMANCE BASED ON EXPERIENCE

General data processors of the off-the-shelf variety used in the large buoys have not performed well. This has been due to the construction of these machines, and probably aggravated by the power

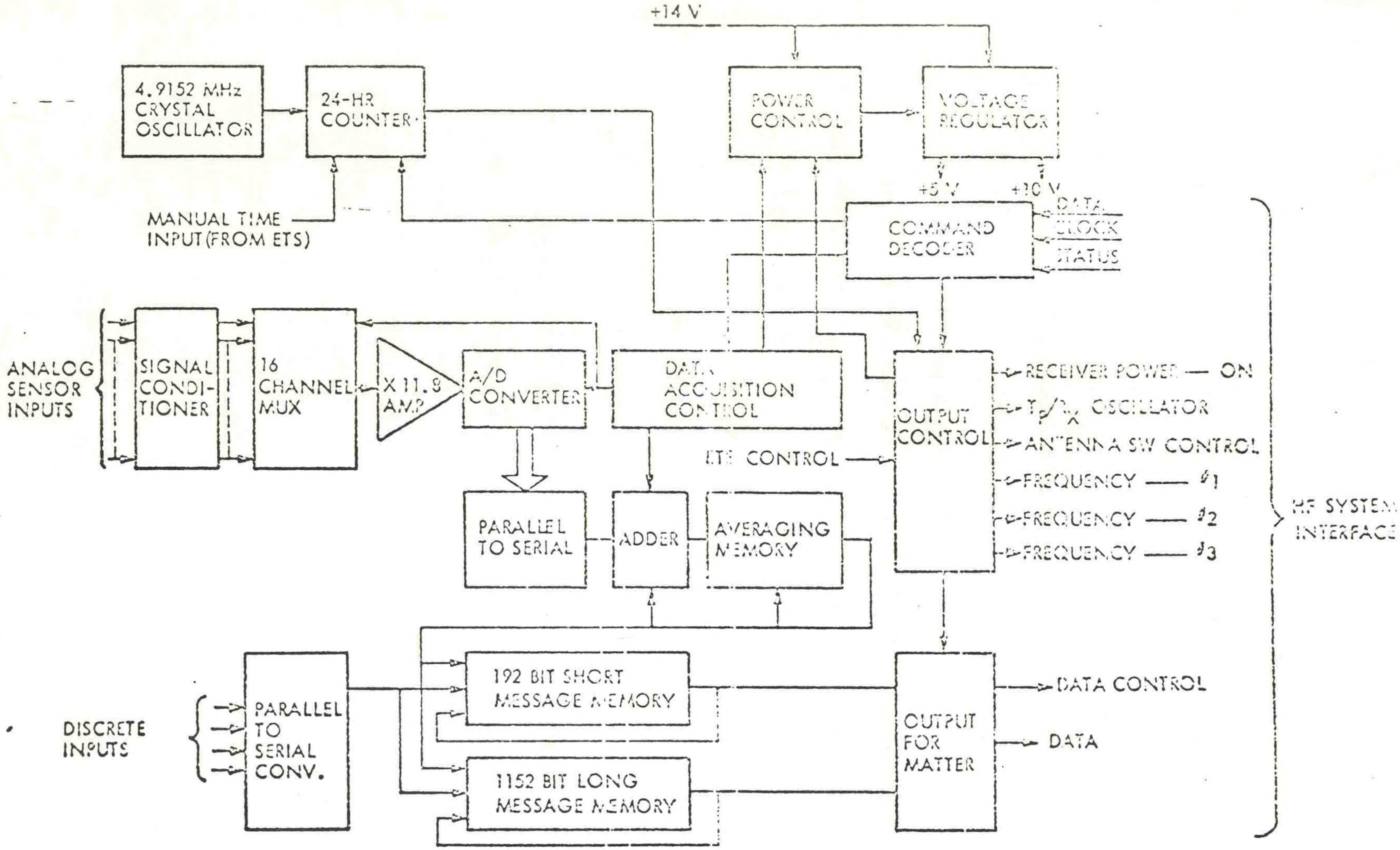



FIGURE 4.5-3 - LMSC DATA PROCESSOR SCHEMATIC

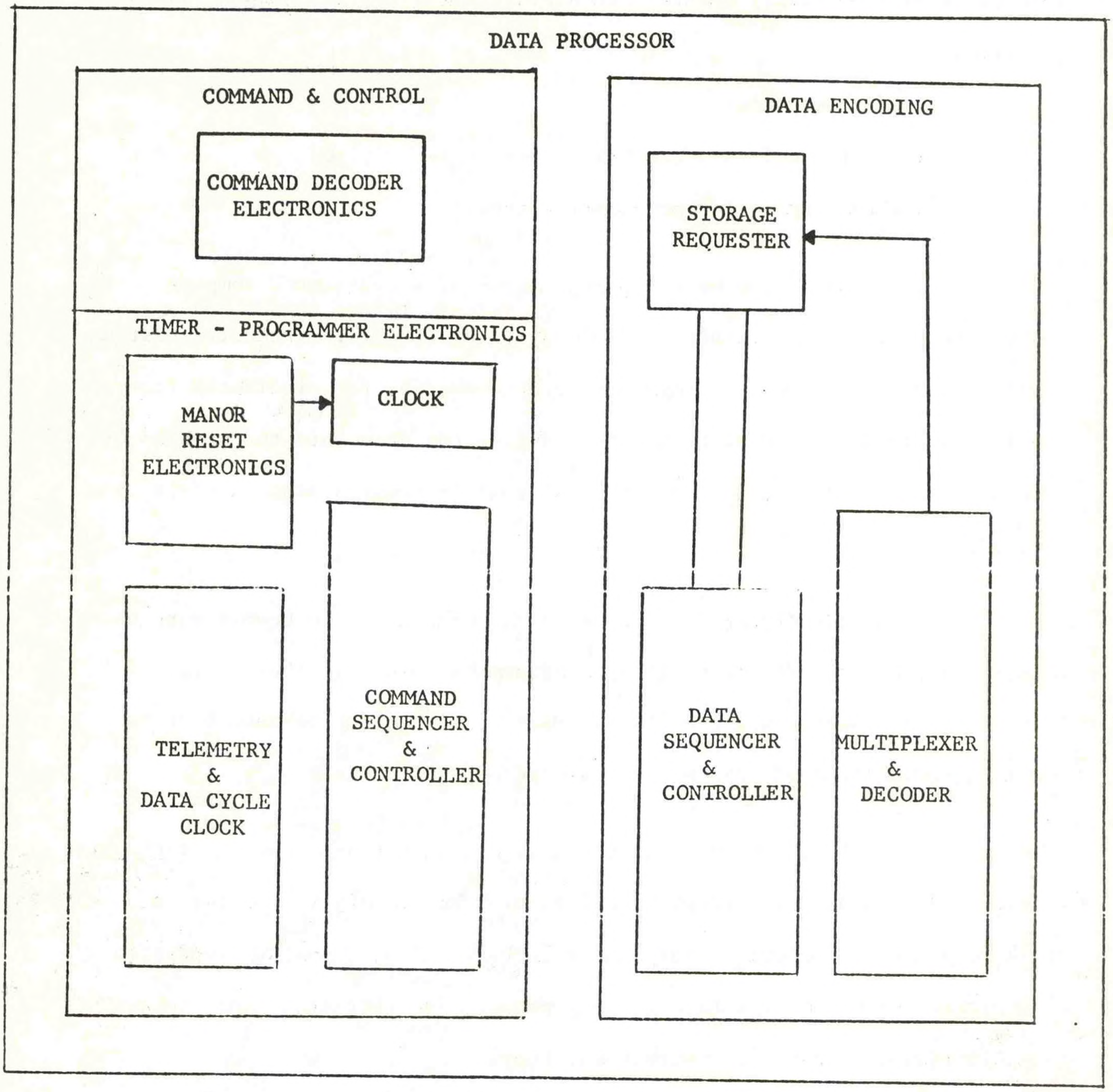



FIGURE 4.5-4 - GE DATA PROCESSOR

regulation achievable from available low-power diesels. Three types of failures have generally been experienced with the general purpose data processors:

- Power supply
- Pins and connection failures
- Memory and/or programming errors

To combat the power supply failures, a redesigned computer power supply has been incorporated into a buoy (EB-12). Extensive testing of EB-12 and subsequent deployment thereto have, so far, indicated favorable results. It appears that future buoy design can alleviate the problem of data power supply failures by use of a separate power system supplying the data processor.

Permanently programmed read-only memories have been incorporated in several buoys to correct either programming errors in the digital computer or memory failure or both. Memory failure can perhaps best be described in terms of "bombed" or "smoked" out core bits.

Finally, several failures have occurred because wire attachments to pins in the data processor have failed. The primary reason for failure has been due to motions of the buoy brought about by sea state conditions. An approach to the resolution of this problem is substitution of lighter weight wiring or harnesses within the buoys.

In contrast, buoy data processors specifically designed for buoys, seem to work. By simplifying and building data processors of the non-programmable "hard-wired" type, relatively fail-safe systems have been achieved for the small buoys.

## 4.5.3 APPROACHES

### 4.5.3.1 CRITERIA AND PROBLEM AREAS

The role of the data processor within the framework of Environmental Data Buoys is to make information acquired by a sensor(s) available to a user in a expeditious manner. Primarily, the user requirements determine the extent and complexity to which the data processor is configured. Intrinsically, the on-board data processor is responsible for on-board data processing and the interpretation of commands and reply of data to shore. Figure 4.5-5 provides a listing of data processor problem areas and associated design considerations for Environmental Data Buoys.

Many of these problem areas have fairly well known solutions and defined trade-off criteria. However, others do not and a prime example is the proper mix of hardware optimization and software optimization, which, in general, has yet to be adequately evaluated. Typically the final design goes to extremes one way or the other and ends up causing low system reliability and high risk.

### 4.5.3.2 STATE OF THE ART ALTERNATIVES

The present state of the art alternatives for the data processor encompass both data logging on magnetic tape for archival users and delivery of synoptic data to NWS (via data link) within one hour of acquisition. The implementation alternatives are presented in Figure 4.5-6.

| PROBLEM AREA | DESIGN CONSIDERATIONS |
|---|---|
| Flexibility | Control - Duplex Communication<br>Hardwire vs. Programmable |
| Power | Duty Cycle Data Rates |
| Communication | Bandwidth - Frequency - Rate |
| Complexity | Ashore - On-Board |
| Costs | Hardware - Software |
| Reliability | Redundancy |
| Quality Assurance | Hardware - Software |
| Modifications | Hardware vs. Software |
| Maintenance | Expendable vs. Refurbishable |
| Software | Machine Language vs. High Level Coding |

FIGURE 4.5-5 Problem Areas and considerations for Design of Data Processors for Environmental Buoys

| ALTERNATIVE | ADVANTAGES | LIMITATIONS |
| --- | --- | --- |
| 1. No On-Board Processing (Analog recording only) | Simplest and least expensive on-board system. | Buoy status indeterminate from shore. Periodic visits to buoy to gather data. |
| 2. A/D Conversion & Recording | Minimum cost very high reliability<br>Data filtering<br>Data interface with shore computer | |
| 3. Transfer to Communication Format | Modest cost, high reliability<br>Near real-time data available<br>Operational status of buoy determinable from shore | Subject to shore station operational priority |
| 4. Non-Programmable Special Purpose Computer | Data compression - low duty cycle data transmission.<br>Moderate flexibility - (a few mission changes may be incorporated after requirements are set).<br>Alternate operating modes<br>Moderate hardware changes required to reconfigure capability. | Moderate Cost Power Penalties |
| 5. Programmable General Purpose Computer | Maximum flexibility and operating modes (a number of mission changes may be incorporated after requirements are set).<br>Minimum hardware changes required to configure capability. | Highest cost & buoy payload penalty.<br>Least reliable. |

FIGURE 4.5-6 - Data Processor Implementation Alternatives

Five alternatives exist with regard to state-of-the-art capabilities for on-board data processors. These are:

- No on-board processing
- A/D conversions only
- Transfer to a format for communication
- Simple non-programmable special purpose computers
- Complex programmable general purpose computers

4.5.3.2.1 NO PROCESSING

The alternative of no processing (analog recording only) has the advantage of the simplest on-board system into which can be incorporated high reliability and lowest cost. Its limitations are that the status of the system cannot be determined remotely and periodic visits to the buoy must be made to retrieve the data. A direct implication of this approach is that all data processing will be done ashore requiring most likely A/D conversions, error detection and scaling. A direct outcome of this form of implementation is that usually most of the data either goes unprocessed, or is processed so long after its acquisition that its purpose is lost. Except for highly specialized short term operations this approach is not suitable.

4.5.3.2.2 ANALOG TO DIGITAL CONVERSION AND RECORDING

The alternative of analog to digital (A/D) conversion followed by logging on magnetic tape has most of the limitations of "no Processing". However, system noise can be filtered and data from the buoy can be inserted directly into a computer ashore for reduction and further processing. Again, similar to the alternative of "no processing," this implementation is suitable only under specialized circumstances.

4.5.3.2.3 TRANSFER TO A COMMUNICATIONS FORMAT

The alternative of transferring data into a communication format assumes a data link for data transmission. Complexity is increased as well as costs; however, the user is now capable of obtaining remote data. This has two distinct advantages: first the data can be used in near real-time and second, verification that the system is operating can be made in virtual real time. On the down side, data can easily be lost because of failure of non-buoy, system components such as shore communication stations and operational procedures which may not be under user or implementer cognizance. Again as with previously described alternatives, this form of implementation is usually suitable only for specialized conditions and short term operations because limited flexibility is achievable.

4.5.3.2.4 SIMPLE NON-PROGRAMMABLE SPECIAL PURPOSE COMPUTER

Inclusion of a special purpose non-programmable computer on-board the buoy brings about both major advantages and severe limitations. In terms of advantages it allows data compression and limited processing which increases data reliability, quality, and utility. These attributes decrease the demands on the data link duty cycle and processing ashore, thus preventing bottlenecks at these points in the overall chain of data handling. The system also begins to be capable of some degree of flexibility and alternative modes of operation. However, for the advantages gained by adding this functional element the penalty of increased complexity must be paid. This penalty brings about attended increased power requirements, albeit this penalty can be offset by use of Complementary Metal Oxide

Substrate (Cosmos) logic, and increased costs. In spite of these penalties this form of implementation does maintain some degree of simplicity, and high reliability can be fairly easily achieved. For operational buoy networks, this alternative appears to be the most viable.

4.5.3.2.5 PROGRAMMABLE GENERAL PURPOSE COMPUTERS

Inclusion of a progrommable general purpose computer on-board a buoy nears the ultimate in flexibility and complexity in on-board data processing. Virtually any form of processing can be accomplished, as well as alterations of the processing scheme without reconfiguration of hardware. Also, because general purpose computers are not tailor-made for each application, their costs are reasonable and they are available in proven forms as contrasted to special purpose hardwired computers. A penalty has been paid in power consumption, reliability and software development. In view of the on-board hardware failures associated with the general purpose NOVA computers, this approach has not been accepted favorably, however, the general purpose ROLM computer on the LMSC Large Buoy has not had a single catastrophic hardware or software failure.

# 4.6 COMMUNICATION EXPERIENCE

## 4.6.1 HARDWARE DESCRIPTION

### 4.6.1.1 GENERAL

All NDBO-developed buoys to date have utilized HF communications because of the maturity of the technology as related to buoy needs. Due to the great promise of UHF for buoy operations (which will be verified after the GOES-Satellite is launched and the reliability of the satellite-buoy UHF link has been established), NDBO has proceeded over the past few years along the developmental path toward attaining UHF subsystem hardware. The first of this UHF buoy hardware is scheduled for delivery by January, 1974. Documentation is available describing the expected performance and system interfaces. (Refer to Appendix 4.6-3)

The hardware designs described herein are all HF designs. The high frequency communication (HFC) system serves as the communication link between the shore communication station (SCS) and the on-board data processing system (DPS). The HFC data link provides for beyond-the-horizon ranges. The data link is a half-duplex operation at 75 BPS providing for interrogation-reply data transfer for meteorological, engineering and auxiliary environmental data.

a. International Framework

The overall framework by which environmental reporting is accomplished, is governed by international agreements, notably, the World Administration Radio Conference (WARC) 1967 and associated international panel of experts meeting, held in Geneva, Switzerland. The WARC channeling scheme is shown in Figure 4.6.1. Ten-300 Hz channels have been assigned on each of six HF bands. The spot frequency operation for NDBO buoys has been assigned to either 700 Hz or 2200 Hz above the lowest frequency in each assigned HF band.

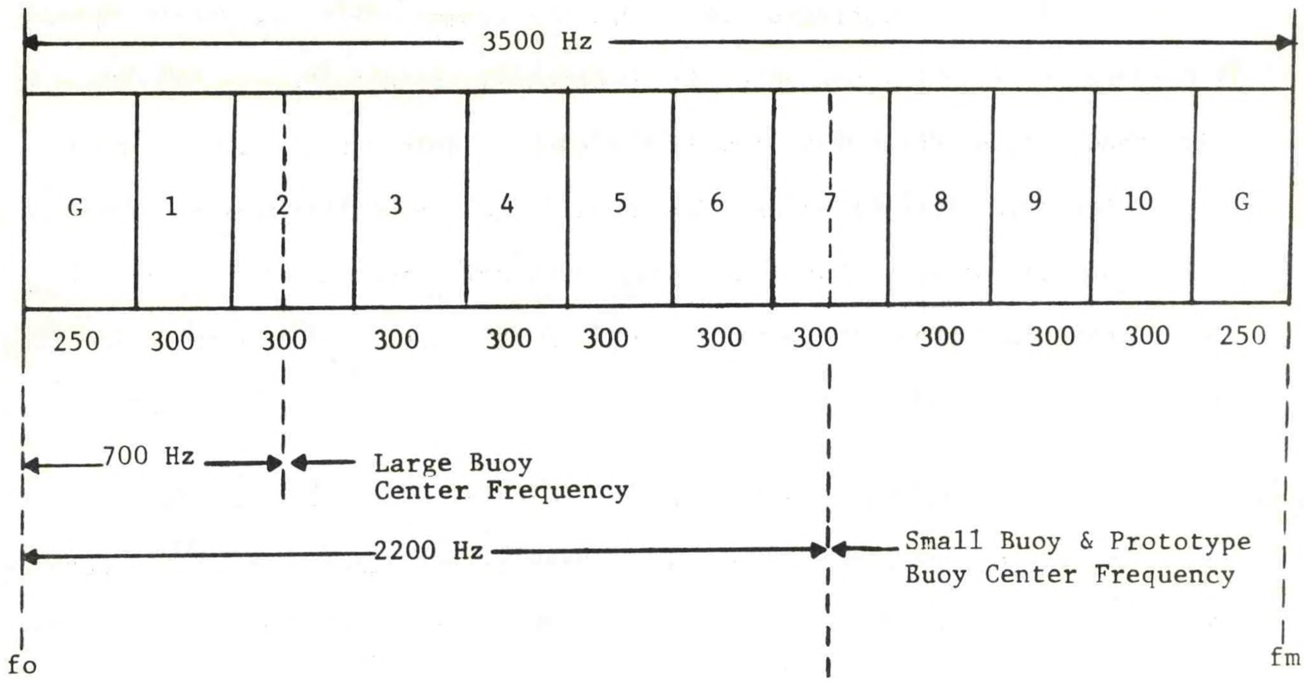
A table of recommended engineering characteristics is presented below indicating the adopted NDBO parameters and the International Telecommunications recommendations (ITEL):

| PARAMETERS | ITEL | NDBO |
|---|---|---|
| Modulation | FSK | FSK |
| Deviation | ± 42.5 Hz | ± 85 Hz |
| Channel Utilization | 170 Hz | 300 Hz |
| Modulation Rate | Less than 100 baud | 75 baud |
| Frequency Stability | Less than 2.5 Hz | Less than 5 Hz |

The frequency deviation and channel utilization by NDBO, for all buoys, are ± 85 Hz and 300 Hz rather than the ± 42.5 Hz and 170 Hz proposed by ITEL. The wider shift equipment is more resistant to noise and fading, which are the most significant contributors to error rate in HF data communication systems. The wide shift demodulators at the SCS use separate mark and space filters and variable threshold detectors to overcome the effects of selective fading of the mark and space tones.

b. Data Transmitted and Message Formats

The formats used for interrogating and transmitting the environmental data from buoy to shore for both high capability buoys (HCB's) and low capability buoys (LCB's) are shown in Figures 4.6-2 and 4.6-3. The processed message disseminated at the shore station is transmitted in Ship's Weather Format FM 21.D shown in Figure 4.6-4.




fo = 4.16250 MHz
6.24450 MHz
8.32800 MHz
12.47950 MHz
16.63650 MHz
22.16050 MHz

fm = 4.16600 MHz
6.24800 MHz
8.33150 MHz
12.48300 MHz
16.64000 MHz
22.16400 MHz

G = Guard Channel

fo = Lowest frequency in assigned HF band

fm = Upper frequency in assigned HF band

FIGURE 4.6.1 WARC Channeling Scheme Applied to NDBO Operations

4.6.1.2 LARGE BUOYS

A block diagram of the large buoy communication system is shown in Figure 4.6-5. This equipment is functionally able to receive and demodulate simultaneously on three separate HF bands and modulate and transmit on any one of the same three RF bands. The specific operating bands are selected from those allocated by WARC based on ionospheric predictions for reliable communications between the deployed buoys and the Shore Communication Station. All channel assignments for the large buoys are on the 700 Hz channels.

In the standby mode, the signals received by the buoy antenna are fed to three receiver channels where any usable incoming frequency is detected. Following detection, an FSK demodulator converts the incoming FSK tone to an NRZ-PCM digital signal suitable for entry into the buoy's data processing system. A special feature designed into this system is a decision threshold circuit. This device automatically determines the halfway or transition point between the mark and space signals. If one signal channel should fade during transmission, the output signal would still remain centered about the decision, level, bringing about operation in the event of complete loss of either the mark or space signal. The output signals from the decision threshold circuit are connected to the FSK bit synchronizer.

Each FSK demodulator and bit synchronizer channel is provided with a decision and control circuit. These devices detect a valid code and enable on-board computer turn on from data derived from the active HF channel.

The transmit portion of the system consists of three transmit channels, one of which is selected for transmission in response to a validated

The WARC recommended interrogation signal sequence is:

| SYNC SIGNAL | ADDRESS | INSTRUCTIONS |
|---|---|---|
| ←10 Secs→ | ←250 Bits→ | |

←less than 1 minute→

The NDBO Shore to HCB interrogation sequence is:

(12 to 53.4 sec. duration)

| BIT SYNC | BUOY ID | BIT SYNC | BUOY ID | FRAME SYNC | COMMAND MESSAGE | BIT SYNC | COMMAND MESSAGE |
|---|---|---|---|---|---|---|---|
| 336 | 16 | 112 | 16 | 16 | 32 (Min)<br>96 (Max) | | 32 (Min)<br>30816 (Max) |

←336→ (FRAME SYNC, COMMAND MESSAGE, BIT SYNC)

The NDBO Shore to LCB interrogation sequence is:

(5.1 sec. duration)

| BIT SYNC | FRAME SYNC | BUOY ID | COMMAND MESSAGE |
|---|---|---|---|
| 336 | 16 | 16 | 16 |

Figure 4.6-2 Interrogation Format

The WARC recommended buoy signal sequence is:

| SYNC SIGNAL | ADDRESS | TRANSMIT IDENTIFICATION | DATA |
|---|---|---|---|
| 10 SECS | 256 BITS | UNSPECIFIED | UNSPECIFIED |

Actual buoy signal sequencies:

HCB TO SHORE (6.2 TO 1311.8 SECONDS DURATION) -
58.3 SECONDS SYNOPTIC REPORT

| BIT SYNC | FRAME SYNC | COMMAND WORD | TIME OF YEAR | RF FWD POWER | RF REFL POWER | BUOY ID | DATA MESSAGE | POST SYNC |
|---|---|---|---|---|---|---|---|---|
| 336 | 16 | 16 | 32 | 16 | 16 | 16 | 0 (MINIMUM)<br>97920 (MAXIMUM) | 16 |

LCB TO SHORE

| BIT SYNC | FRAME SYNC | BUOY ID | DATA MESSAGE | POST SYNC |
|---|---|---|---|---|
| 336 | 16 | 16 | 32 (MINIMUM)<br>1616 (MAXIMUM) | 16 |

Figure 4.6-3 Reporting Format

| Symbol | Meaning | # of Teletype Characters | # of Levels | Total # of Teletype Characters |
|---|---|---|---|---|
| (OPSID) | OPS Identification | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| $99L_aL_aL_a$ | Position Group (Latitude) | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| $Q_cL_oL_oL_oL_o$ | Position Group (Longitude) | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| YYGGi | Date - Time Group | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| Nddff | Sky Cover - Wind Group (Reported as /ddff) | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| VVwwW | Visibility - Weather Group (Data not available - reported as /////) | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| PPPTT | Pressure - Temperature Group | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| $N_hC_lhC_mC_h$ | Cloud Group (Data not available - reported as /////) | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| $D_sV_sapp$ | Course-Speed Group for HCB and MLCB, reported as 00/// for DLCB, actual code values inserted | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| (7RRjj) | Precipitation Group (optional entry) | 5 | 1 | 5 |
| | Space | 1 | 1 | 1 |
| $(0T_sT_sT_dT_d)$ | Dew Point Temperature Group (optional entry) | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| $(1TwTwTwt_T)$ | Sea Surface Temperature Group (Optional entry) | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |
| (3PwPeHwHw) | Wave Group (optional entry for wind waves) | 5 | 1 | 5 |
| - | Space | 1 | 1 | 1 |

Figure 4.6-4 Synoptic Weather Report (Format FM 21.D)

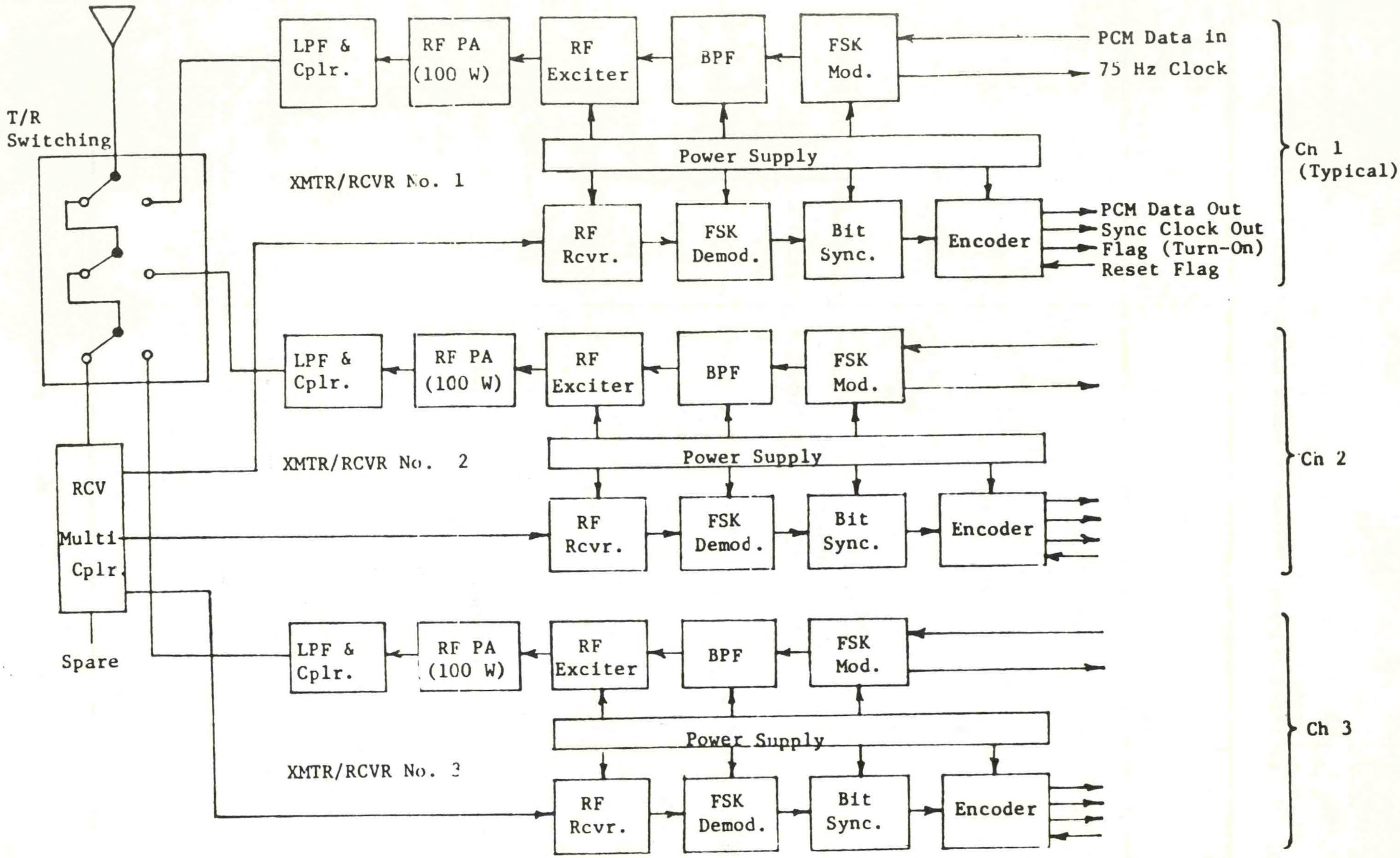



Figure 4.6-5 HFC Block Diagram

command. The selected transmit channel accepts digital data from the on-board data processor and converts it to an FSK carrier. This is accomplished by having the data processor feed a serial NRZ-PCM data stream to the FSK Modulator. The modulator output is then heterodyned up to the operating RF band by the appropriate RF exciter.

The RF exciter features a balanced mixer technique for carrier suppression on the order of 40 db below the desired sideband frequency. In addition, a band pass filter, employed in the design, suppresses the carrier by an additional 50 db providing a total RF suppression of the original carrier frequency of approximately 90 db. Finally, the 60 to 100 milliwatt output of the exciter is amplified to 100 watts by the RF power amplifier.

The large buoy antenna is pictured in Figure 4.6-6. The antenna is a disc-sleeve type utilizing the superstructure and antenna radials as the radiating elements. The antenna consists of 24 radial arms, each eight feet long, forming a disc in the horizontal plane approximately 24 feet above the deck. This disc causes the four foot diameter superstructure mast to radiate as the balance of the top-loaded disc-sleeve antenna. Detailed system characteristics are shown in Appendix 4.6-1.

4.6.1.3 SMALL BUOYS

In addition to the large buoy, NDBO has deployed three classes of smaller buoys. These buoys are the GE moored and drifting configurations, the Lockheed Missile and Space Division (LMSC) moored configuration and the Magnavox drifting configuration.

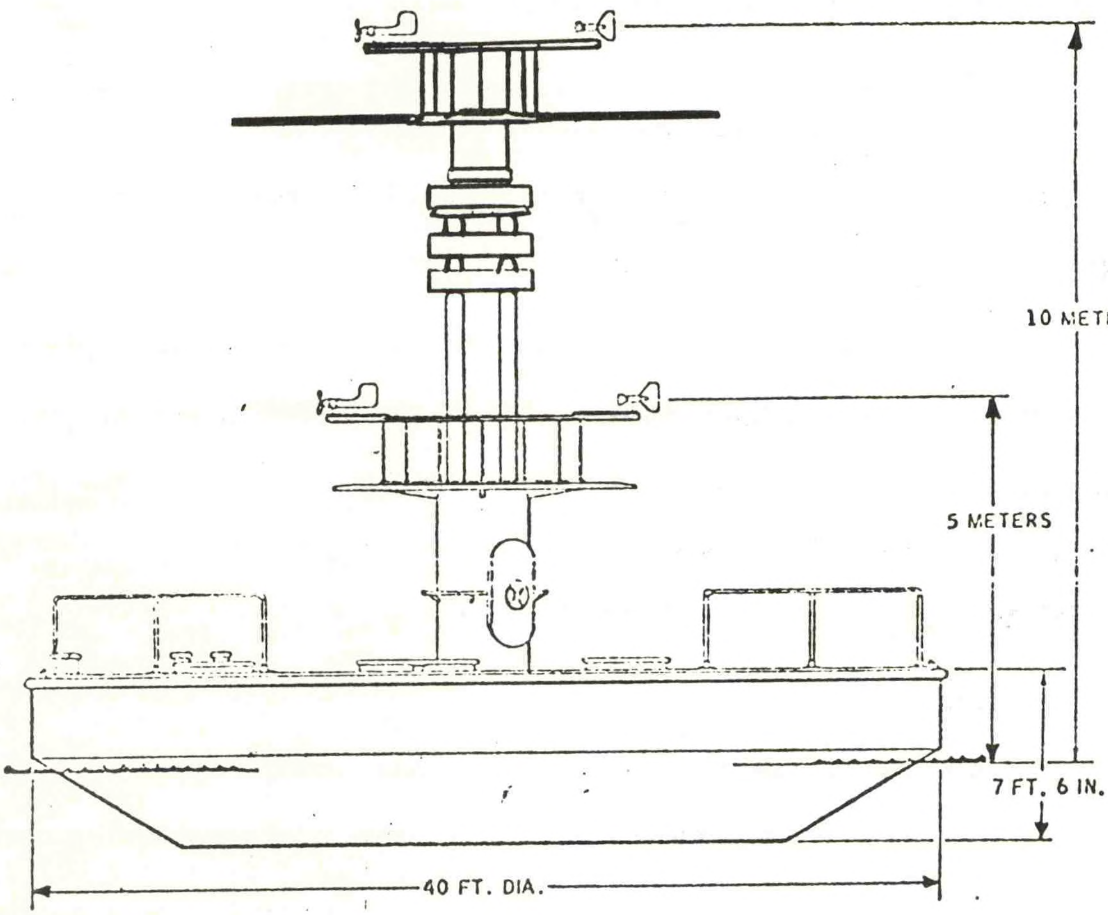



Figure 4.6-6 HCB Disc-Sleeve Antenna

The antennas for all small buoys are whips with associated tuning units. In addition to the description below, the detailed system characteristics are summarized in Appendix 4.6-1.

4.6.1.3.1 LMSC BUOYS

A block diagram of the LMSC communication system is shown in Figure 4.6-7. The LMSC interrogation approach is based upon a simultaneous receive capability on three separate channels on a 24 hour a day basis. When the bit sync is recognized on one of the incoming three channels, the on-board processor is activated and locks out the other two channels.

Normal synoptic transmission is accomplished by repetition of the message on each of the three RF bands. This transmission is self-initiated and required no interrogation command from the shore station. Transmissions in response to commands are performed on either all three frequencies or only the one frequency commanded, depending upon the interrogation command.

4.6.1.3.2 MAGNAVOX BUOYS

A block diagram of the Magnavox communication system is shown in Figure 4.6-8. The Magnavox approach for the reception of interrogation commands is based upon a frequency hopping scheme. The rate of frequency hopping is such that the dwell for each frequency is on the order of a few hundred milliseconds. This rate is sufficiently high to enable two complete frequency scans on each frequency band for every bit synchronization interval. For transmission a command frequency is employed for interrogated transmissions and a programmed frequency is employed for self-initiated transmissions.

4.6.1.3.3 GENERAL ELECTRIC BUOYS

The General Electric approach for reception and transmission of synoptic data is essentially a "static" one. In the interrogation mode, one

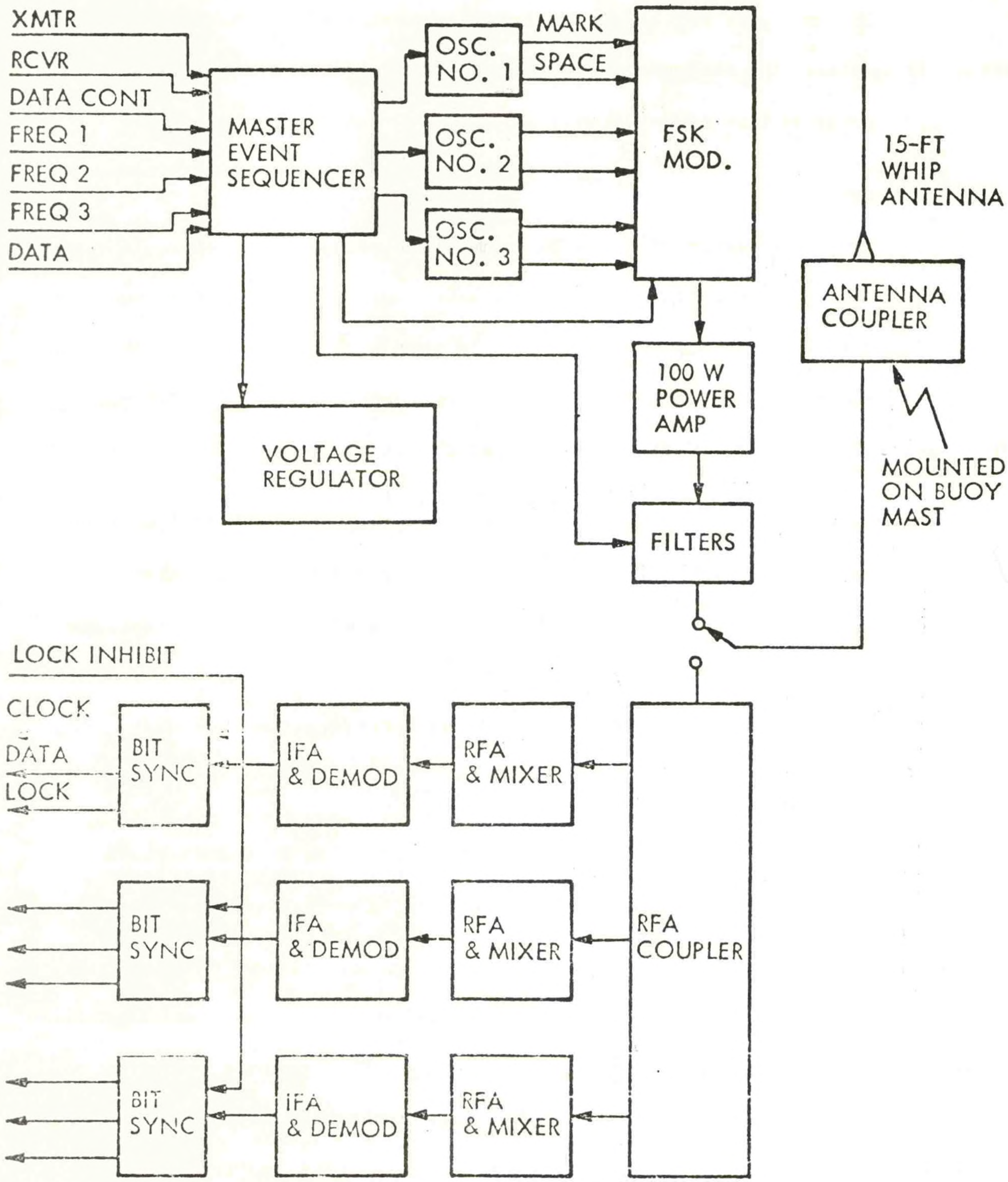



Figure 4.6-7 LMSC HF Communications System - Block Schematic

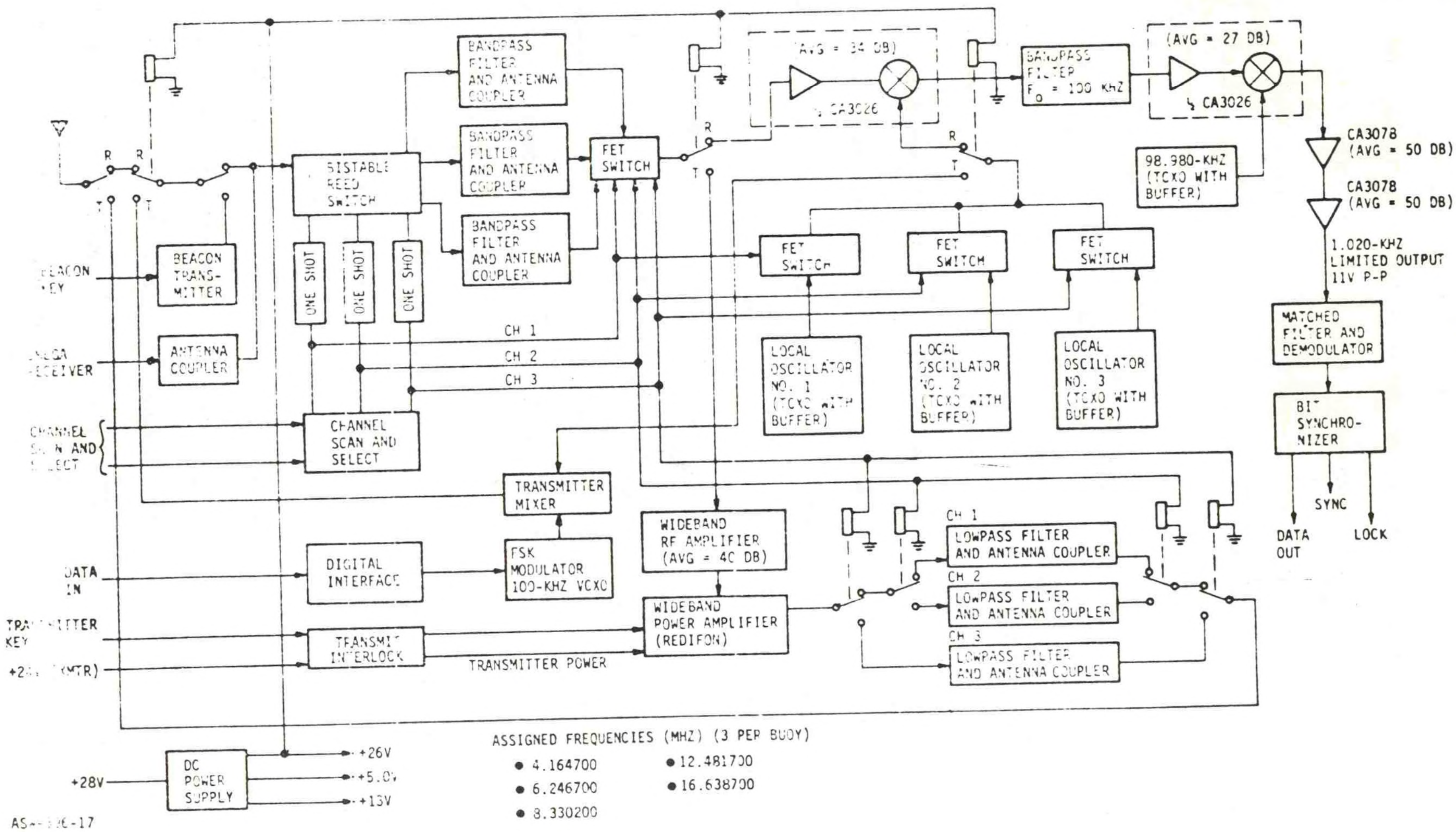



Figure 4.6-8 Magnavox HF Communication System - Block Diagram

of two frequencies are open for monitoring the shore station transmissions on a continuous basis. The command from the shore station includes a frequency select capability for interrogated transmissions. In the synoptic, self-initiated mode, one frequency is pre-designated as a function of the time of day.

## 4.6.2 PERFORMANCE BASED ON EXPERIENCE

### 4.6.2.1 LARGE BUOYS

The overall performance of the first three deployed large (forty foot discus) buoys from the period between October 7, 1972 and March 31, 1973 is shown in Figure 4.6-9. Figure 4.6-10 shows the performance of these same buoys for the period between April 1, 1973 and September 7, 1973 combined with the next two deployed large buoys (one forty foot discus and one boat shaped hull). The measure of performance indicated in these figures is the percent synoptic data forwarded to the National Weather Service (NWS). This data is scheduled for dissemination to NWS every three hours within one hour following the reporting of data from the buoys to the shore station. Because the large buoys can be readily programmed to use the best ionospheric frequency, overall performance should hover about the theoretical maximum achievable with HF for three frequency capability (approximately 90%). There are several reasons why performance is considerably below these figures for different times.

The primary reason for performance below the predicted rate was due to on-board equipment failures which directly affected the environmental data required for NWS data. The largest contributing factor has been the On-Board Data Processing Systems (See Section 4.5). The HF communications hardware has been virtually failure free. What the performance of the buoys has borne out is that equipment specifically designed for buoy application seems

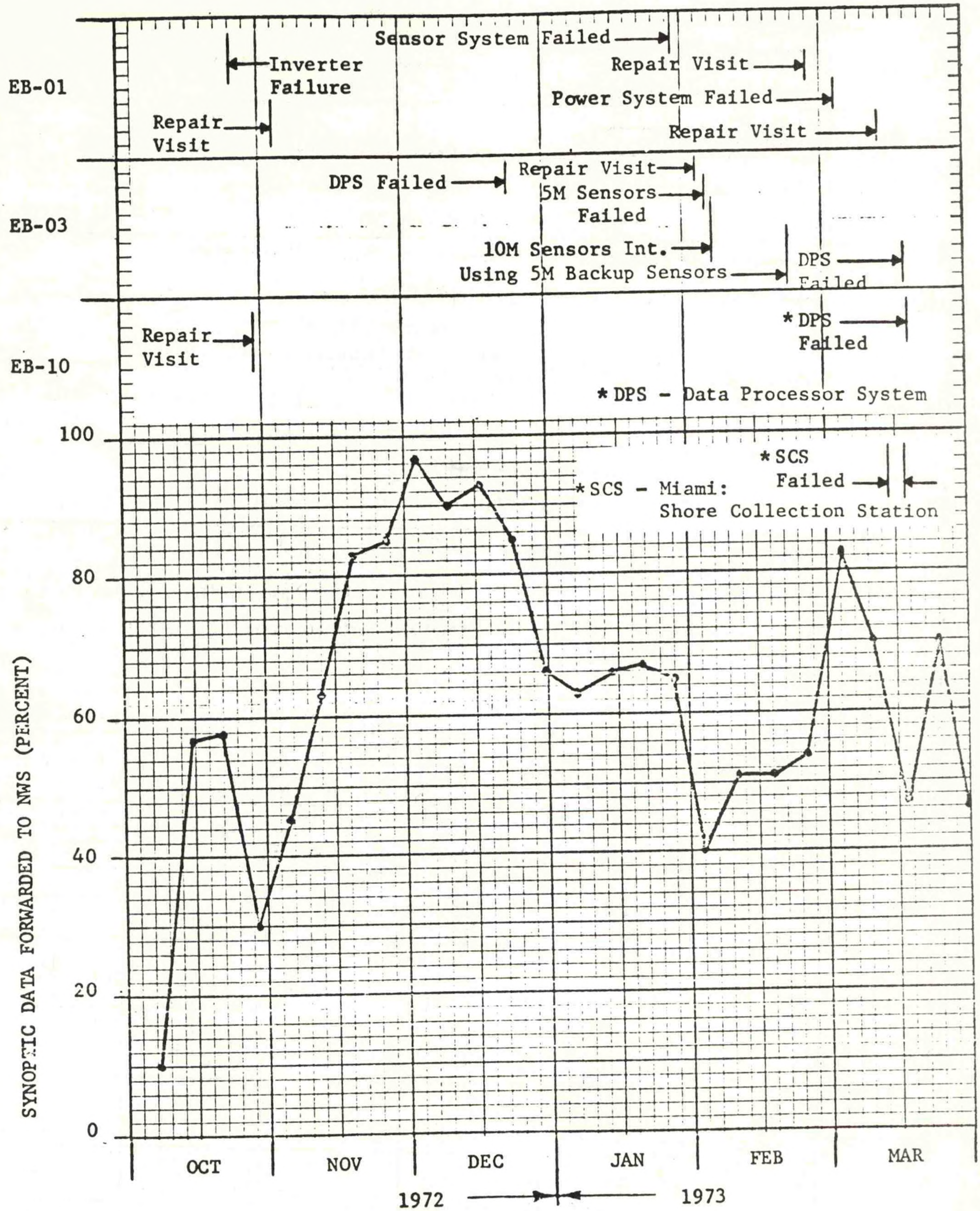



Figure 4.6-9 Large Buoy Performance

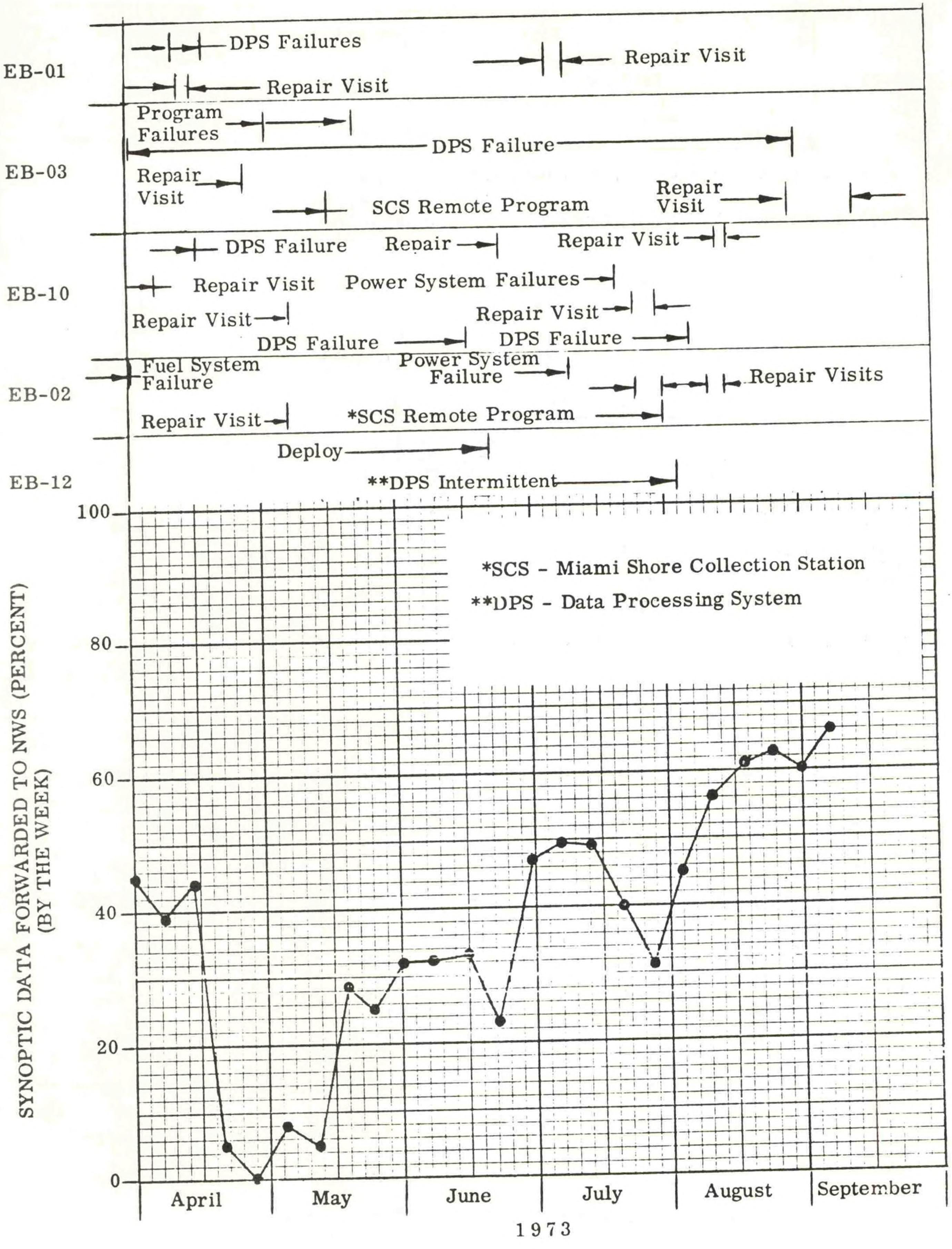



Figure 4.6 - 10. Large Buoy Performance - April through September

to work. Equipments that were essentially selected from off-the-shelf inventory has not measured up to the level of performance delivered by the custom design equipments.

4.6.2.2 SMALL BUOYS

The overall performance of the individual small buoys is shown in Table 4.6-1 and covers the period December 1972 - April 1973.

The small buoys are functionally similar and, to some extent, equipped similar to the 40 foot discus buoys. The major differences are the limitations on the number of sensors used and the elimination of a programmable general purpose computer on the small buoy. Instead, the small buoy uses hard-wired logic blocks comprising essentially electronic programmer, processor and encoder-decoder elements.

Two of the small buoys were damaged during initial launch. In one case, a support ship handling fitting failed, and the buoy was dropped. Another suffered a broken antenna by hitting the crane boom in the launch operations. Appendix 4.6-2 covers the small buoy whip antenna failures in more detail.

While operational anomalies have been experienced, performance of these buoys has been reasonably good. However, deployment experiences have been too short for a rigorous evaluation.

During the recent accelerated testing of the small buoys, each of the three small buoy systems have experienced one or two electronic failures in their HF communication systems. Although these failures might be seemingly minor, they result in a catastrophic failure of the buoy system.

| BUOY ID | MANUFACTURER | TYPE | PROGRAMMED RESPONSES | ACTUAL RESPONSES | RELATIVE SUCCESS (%) |
|---|---|---|---|---|---|
| EB-31 | GE | Moored | 331 | 239 | 72% |
| EB-32 | GE | Moored | 346 | 191 | 55% |
| EB-36 | LMSC | Moored | 243 | 174 | 72% |
| EB-37 | LMSC | Moored | 212 | 141 | 67% |
| EB-38 | LMSC | Moored | 50 | 36 | 72% |
| EB-51 | Magnavox | Drifter | 481 | 409 | 85% |
| EB-52 | Magnavox | Drifter | 431 | 382 | 89% |
| EB-53 | Magnavox | Drifter | 298 | 235 | 79% |
| EB-61 | GE | Drifter | 214 | 174 | 81% |
| EB-62 | GE | Drifter | 181 | 132 | 73% |

Table 4.6-1 Small Buoy Relative Success (December 1972 - April 1973)

### 4.6.3 APPROACHES

Since the buoy-to-shore data communication ranges will, in general, exceed line-of-sight ranges, the use of high frequency (HF) and satellite communications quickly becomes evident. The approaches applicable to the environmental prototype buoy mission must be considered in light of remote data acquisition, range requirements, timing requirements, buoy size and power limitations and the overall international framework by which environmental reporting is recommended. Finally, both the availability of satellites and performance reliability of buoy to satellite communications must be in hand to establish the extent of commitment afforded to satellite communications.

The communication mechanism designated for implementation of the environmental prototype buoy is HF, due to the unavilability of a suitable satellite until early 1974 and the lack of corresponding buoy-to-satellite experience to provide a realistic measure of performance. Considerable data is available to lend credence to the fact that HF can provide a good measure of performance until UHF can be confidently utilized. The first NDBO buoys were deployed in the summer of 1972, thereby giving rise to the initial buoy HF communication implementation.

As pointed out earlier, in particular in Figure 4.6-1, the large buoys are presently using Channel 2 for HF communication and the small buoys are using Channel 7. As a result of recent international agreements the use of Channel 2 by NDBO will be phased out. We will continue to use Channel 7 and we are authorized to use Channel 9 for future use. Since the Miami Shore Collection Station (SCS) is currently configured for Channel 7, this is the acceptable channel for use with the prototype buoy.

From the test program results to date, it has become clear that it is highly desirable to be able to interrogate a buoy on all of its available frequencies in order to maintain control of the buoy under adverse communication conditions. It is also desirable to be able to select the synoptic reporting frequencies remotely to compensate for changes in ionospheric conditions and maintain the best communications link.

In the design of the HF Communication System, consideration should be given to allow the anticipated future conversion to a UHF Communication System in an expeditious manner. Appendix 4.6-3 discusses the various aspects of UHF satellite-buoy communications, particularly relevant features of current activity.

APPENDIX 3.3.-1

OPERATION OF A SHORE COLLECTION CENTER

FOR

ACQUISITION OF MARINE DATA

# OPERATION OF A SHORE COLLECTION CENTER FOR ACQUISITION OF MARINE DATA

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NATIONAL DATA BUOY CENTER

ABSTRACT

A method of acquiring, processing and disseminating oceanographic and meteorological data from ocean platforms is described. The application of well known and mature technology is utilized in performing the data acquisition and telemetry functions. Following a brief introduction dealing with National Data Buoy System communication approaches, the shore communication station is described in terms of equipment capability and system operation. Finally, a brief discussion on initial system performance is presented.

## INTRODUCTION

The mission of the National Data Buoy Center (NDBC) is to gather and report oceanographic and meteorological data from marine areas on an accurate, reliable and synoptic basis. The goals of the National Data Buoy System (NDBS) are to provide the oceanographic and meteorological data upon which improved weather forecasts, warnings of impending catastrophies and knowledge of our natural environment is based.

The basic concept of the National Data Buoy Systems involves the use of a number of buoys moored in gulfs and oceans in a systematic array. These buoys are equipped with various sensors to measure oceanographic and meteorological parameters, and utilize radio frequency data links to transmit the onboard derived data to a Shore Collection Center. At the Shore Collection Center, the data is processed, validated and disseminated to users.

## NDBC PLANS AND PROGRAMS

In order to accomplish the NDBS goals, several major programs and numerous projects are under way. An Experimental Environmental Reporting Buoy (XERB-1), is on station 125 miles east of Norfolk, Virginia, and transmits eight synoptic weather and four bathy reports per day. Five 40 foot discus high capability buoys (HCB's) will be deployed in the summer of 1972 in the Gulf of Mexico. One additional HCB is scheduled for deployment in the Gulf of Alaska in the fall of 1972. A deep keel hull buoy similarly instrumented to the HCB is to be deployed in the Gulf of Mexico. In addition to the HCB's, ten limited capability buoys (LCB's), buoys considerably smaller in size than the HCB's, are scheduled for deployment in the Gulf of Mexico for late 1972. Two types of LCB configurations are in current development: Drifting and Moored. Table 1 reflects the HCB/LCB Data Acquisition and Dissemination Requirements.

In addition to the major buoy developments, a Shore Communication Station (SCS) is being established in Miami, Florida, to serve as the shore collection center for all classes of buoys. The SCS will be capable of providing both communication and data processing functions to enable the acquisition of data from buoys and dissemination of processed data to users.

## COMMUNICATION APPROACHES

The approaches applicable to the NDBC communication requirements must be considered in view of link range requirements, buoy size and power limitations, available frequencies and satellites. The buoy-to-shore link ranges are, in general, beyond line-of-sight. Conventional beyond line-of-sight links quickly reduce to High Frequency (HF) and satellite communications.

The near term mechanism for meeting the NDBC requirements is via HF ionospheric support propagation. This is due to the current and near term unavailability of satellites capable of serving the NDBC mission requirements.

It is well known that HF ionospheric propagation is limited, by nature, to a 90%, long term, communication reliability and at times, considerably less. However, the associated technology is mature and, with the exception of the ocean platform HF antenna and the task of operating with the best predicted frequency, overall implementation is straightforward. The NDBC approach has included ocean platform antenna impedance and radiation model measurements in addition to utilization of an ionospheric model to obtain the best frequencies for high reliability operation.

Paralleling the implementation with HF, considerable effort is being directed towards the utilization of UHF satellite communications. This effort is manifest in the NDBC procurements of LCB platform configurations optimized for satellite communications and various procurements for satellite communication elements. The satellite effort is directed at having a buoy-to-satellite mode in hand when a suitable satellite, serving the NDBC mission, is made available. NDBC has identified the Synchronous Meteorological

Satellite/Geostationary Operational Environmental Satellite (SMS/GOES), under current development, to satisfy the NDBC mission requirements. SMS/GOES operation is scheduled for early 1974.

National Data Buoy Center planning and experience in HF telemetry systems was developed utilizing the six HF bands allocated for ocean data collection by the 1967 World Administrative Radio Conference (WARC). In addition, a series of studies have been conducted by the Institute for Telecommunication Sciences (ITS), of the U. S. Department of Commerce, under the direction and support of the NDBC.

The studies have dealt with the following shore and ocean platform communication subjects:

- HF Antenna Systems for Buoys
- Modulation Systems
- Synchronization Techniques
- Error Control Techniques (Coding)
- Network Simulation Models
- Overall System Design

The network simulation model, a specialized adaptation of the HF circuit performance prediction computer is used in trade-off studies for the design of the HF telemetry system and serves as a United States contribution toward an international plan required by the 1967 WARC.

SHORE COMMUNICATION STATION DESCRIPTION

A block diagram of the Shore Communication Station (SCS) at Miami is shown in Figure 1. The major elements of the system are:

Antennas - Two horizontally polarized log periodic antennas (Hy-Gain LP-5002) are used primarily for reception of ocean platform systems. Antenna beam widths are in the order of 70°, with a 10-13 db gain capability. Both antennas will be used simultaneously for space diversity reception. An inverted discone (Granger 794-1) is normally available for the SCS transmit function.

Receivers - Two SSB units (Collins 651Gl) are used to enable space diversity reception. The receivers translate the incoming frequencies to the audio spectrum. The receiver audio output consists of either FSK or PSK tones. The output tones are fed to the FSK or PSK data modems for data demodulation and are also recorded on a predetection analog tape recorder. The two receivers are digitally tunable in 100 Hz increments, in the 2-30 MHz range and possess frequency stability characteristics better than one part in $10^8$ long term.

Transmitter - One (Gates FRT-79) HF transmitter is normally assigned for SCS operation with the buoy network. This transmitter is capable of 10 KW PEP output.

Computer - At present, one PDP-8 (DEC) computer is used at the SCS. The PDP-8 is a general purpose digital computer with 12K core memory. External serial devices working with the computer read in and out through interface units that convert serial to parallel and vice versa. Computer programming is accomplished through use of a teleprinter keyboard (KSR-35) and punch paper tape. The PDP-8 feeds PCM output to the modem (modulator) and receives PCM input from the modem (demodulator). Through software control, it acts as a frame synchronizer, buoy ID recognizer, error detector, data sorter and digital comparator. The computer scales, offsets, linearizes and combines data and formats it for line printout, digital tape storage and dataphone teletype scanout. It formats interrogation commands and programs for transmission to the buoy by means of stored programs and operator control.

FSK Modems - The FSK modems consist of two modulators (Frederick 1215) and four demodulators (Frederick 1200). The FSK modulator accepts 75 BPS - NRZ data and provides ± 85 Hz FSK signal to the HF transmitter. One modulator operates at 700 Hz and the other at 2200 Hz. The FSK demodulator accepts a FSK signal from the HF receiver and generates an NRZ-PCM 75 BPS digital signal at its output. Two demodulators operate at 700 Hz and two operate at 2200 Hz. The demodulators are so connected that either space or frequency diversity can be switched into the overall receiving system.

PSK Modems - One modulator and demodulator (Collins TE 216D-2D) is used in the system. The modulator converts 75 BPS-NRZ data into three tones, two of which are PSK data (1375 and 2200 Hz) and one the AFC tone (496 Hz). The demodulator accepts a PSK signal from the HF receiver and generates an NRZ-PCM 75 BPS digital signal at its output. The AFC tone is used to maintain all tones exactly on frequency and correct for ionospheric doppler shifts.

Accessory Equipment - Figure 2 is a block diagram of the data processing system at the SCS. The DEC tape system and the speed paper tape punch/reader are used for loading existing programs into the computer. The teleprinter is used to permit the operator to communicate with the computer. The DEC tape system (TU 55) consists of three tape transports for input/output storage devices for programs and data.

SYSTEM OPERATION

Functional Requirements

The SCS system is designed to interrogate and receive environmental data and engineering housekeeping data from a reporting buoy network for analysis. The SCS system is capable of three basic functions: buoy commands, data recovery, and data dissemination. The buoy's basic functions are: gathering the various environmental data through sensors, per Table 1, provide engineering test data, and making all of this data available for transmission, upon command from the SCS, via the radio link. The combined functions, or mission, of the SCS and buoy are as follows:

a. Obtain environmental data to depict weather abnormalities that directly affect the U.S. Mainland.

b. Establish environmental data trends that will provide a sound basis for the design of future environmental systems.

c. Collect engineering data to support subsystem performance analysis and to gain knowledge that will permit future hardware improvements.

Interrogation

The shore station interrogates the buoy by sending typically a 496 bit command. The buoy stores the command temporarily and then by retransmitting the command message confirms that the message was received. The PDP-8 in the shore station checks the retransmitted command for errors on a bit-by-bit basis, and if errors exist, the shore station retransmits the command. After the command has been validated, the buoy then transfers the command from the core memory to command storage from which it is interpreted and acted upon.

Each of these messages starts with Bit Sync, which is used by the modem to synchronize its bit clock with the incoming PCM bit stream. Frame Sync identifies the start of the message and ID identifies the buoy being interogated.

DATA TRANSMISSIONS

Two basic modes of operation exist: Synoptic and On-Line. In the synoptic mode, oceanographic and meteorological data are taken at scheduled hourly intervals in accordance with an on-board program. This data is stored in the on-board memory and transmitted to shore upon a synoptic interrogation command. The synoptic data contains, essentially, the parameters listed in Table 1. The prime purpose of the synoptic data is to make the environmental data available to users within one hour of its acquisition. This will enable generation of meaningful meteorological prediction data required for weather forecasting.

On-Line data includes a variety of on-board acquisition programs for the observance of intensely sampled oceanographic and/or meteorological environmental data over varying periods of time. In addition, the quality of the HF circuit and operational status of the buoy systems can be obtained via online reporting.

Data Processing

In general, the data processing operation of the SCS involves recognition of valid buoy reports, conversion of raw data into engineering, screening the data for data validity, and reformatting the data for dissemination. Typically, a one (1) hour synoptic report obtained from HCB's comprises 273 16-bit words. On-Line reports are variable in length, but range between 30 and 2,000 16-bit words. Both the synoptic and on-line reports obtained from LCB's comprise approximately 50 16-bit words.

Data Dissemination

Two modes of data dissemination are utilized at the SCS. The validated processed environmental data (meteorological and oceanographic parameters), in a format acceptable to synoptic users, are transmitted via a dedicated teletype circuit to the National Weather Service. In normal operations, this transmission is accomplished within one hour of its acquisition. In addition, all data in both raw binary and processed form, are transmitted via hardline communication circuits to engineering user facilities such as San Diego, and to a central data processing center at the Mississippi Test Facility, for further engineering data analyses and for generation of archival records. This dissemination mode is accomplished on a daily basis.

Performance

To date, with the exception of XERB-1, no performance data has been obtained, since the EEP/LCB network is not yet in service. However, deployment is scheduled for the second half of 1972 and performance results will become available during that period.

Performance data with regard to XERB-1 can perhaps be best described in the following table:

| Function | Nov. 1971 | Dec. 1971 |
|---|---|---|
| Reports Desired | 240 | 176 |
| Reports Delivered | 225 | 171 |
| Reports Late | 28 | 4 |
| Percentage Success | 93% | 97.5% |

| Function | Jan. 1972 | Feb. 1972 |
|---|---|---|
| Reports Desired | 176 | 232 |
| Reports Delivered | 162 | 191 |
| Reports Late | 9 | 7 |
| Percentage Success | 92.0% | 82.3% |

| Function | 4 Month Totals |
|---|---|
| Reports Desired | 824 |
| Reports Delivered | 749 |
| Reports Late | 48 |
| Percentage Success | 90.9% |

These figures do not include periods when XERB-1 was unable to report due to a known malfunction. Therefore, the table reflects the true communications link reliability achieved over the four month period.

## HCB MEASUREMENT SPECIFICATIONS

| Parameter | Range of Measurement | Maximum Allowable Error (RMS) (See Note 1) | Levels (Meters) (See Note 3) |
|---|---|---|---|
| METEOROLOGICAL | | | |
| Global Radiation | 0 to 2 Langleys/Min; .25 to 4.0 Microns | 0.05 Langleys/Min | 10 Meters |
| | 0 to 1 Langleys/Min, 4.0 to 50 Microns | 0.05 Langleys/Min | 10 Meters |
| Precipitation Rate | 0 to 20 CM/HR | 0.02 CM/HR or 1% | 10 Meters |
| Air Temperature | -10 to 40°C | 0.5°C | 5-10 Meters |
| Air Pressure | 900 to 1100 MB | 1.0 MB | 5-10 Meters |
| Dew Point | -10 to 40°C | 0.5°C | 5-10 Meters |
| Wind Velocity-N/S | 0 to 80 Mtrs/Sec | 0.5 Mtrs/Sec or 5% of value (see Note 2) | 5-10 Meters |
| Wind Velocity-E/W | 0 to 80 Mtrs/Sec | 3 Degrees (see Note 2) | 5-10 Meters |
| OCEANOGRAPHIC | | | |
| Water Temperature | 0 to 40°C | 0.06°C | 13 Lvls DWN to 500 Mtrs |
| Salinity | 20 to 40 Parts per Thousand (0/00) | 0.03/0/00 | 13 Lvls DWN to 500 Mtrs |
| Current Velocity-N/S | 0 to 3.0 Mtrs/Sec | 0.02 or 3% Mtrs/sec (See Note 2) | 13 Lvls DWN to 500 Mtrs |
| Current Velocity-E/W | 0 to 3.0 Mtrs/Sec | 10 Degrees (See Note 2) | 13 Lvls DWN to 500 Mtrs |
| Water Pressure | 0 to 55 $KG/CM^2$ | 0.5 $KG/CM^2$ | 13 Lvls DWN to 500 Mtrs |
| Sound Speed | 1410 to 1580 Mtrs/Sec | 0.3 Mtrs/Sec | 1 Lvl Between 0 and 500 Mtrs |

1. Maximum allowable system errors shown include sensor, ocean platform system, HF radio link and shore communication station errors.
2. Errors are given for magnitude and direction.
3. The 13 levels for all oceanographic parameters except sound speed will be 1, 10, 20, 30, 50, 75, 100, 150, 200, 250, 300, 400 and 500 meters.

Table 1. HCB/LCB Data Acquisition and Dissemination Requirements

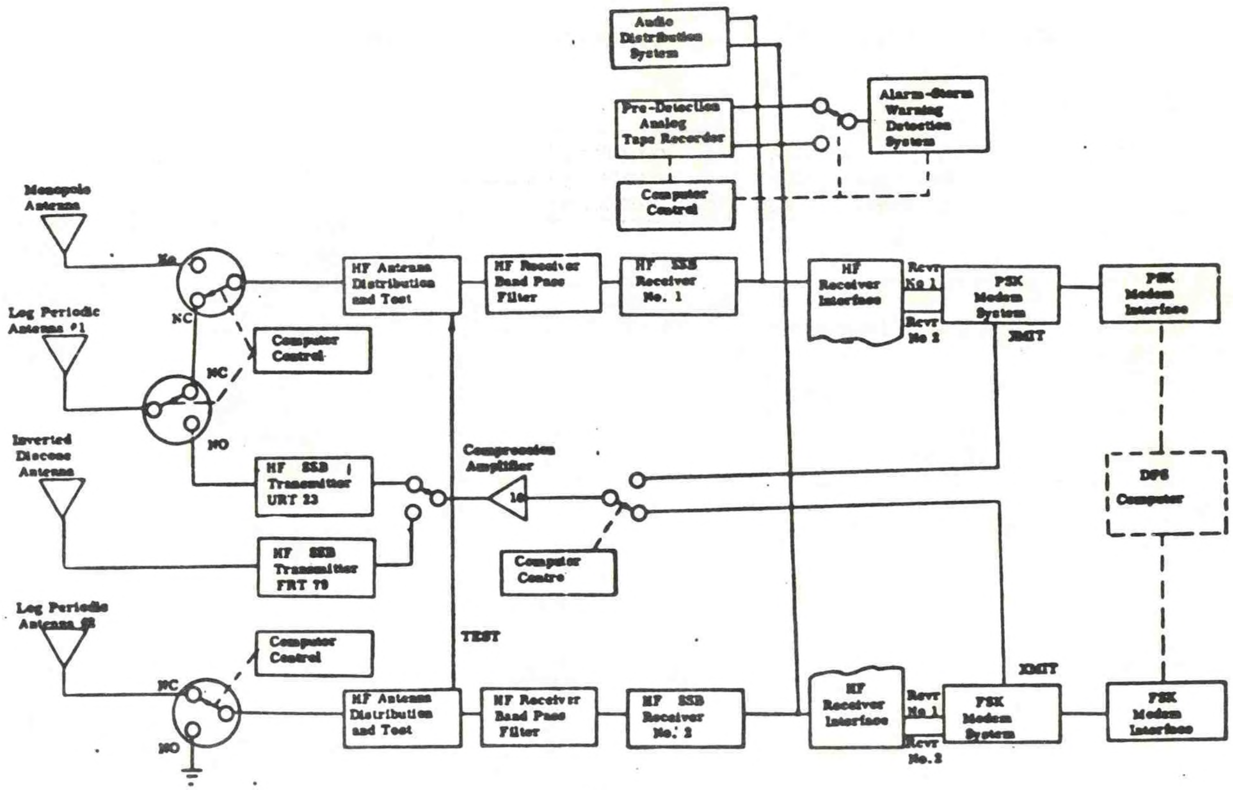
## LCB MEASUREMENT SPECIFICATIONS

| Parameter | Range of Measurement | Maximum Allowable Errors (RMS) (See Note 2) | Levels (Meters) (See Note 3) |
|---|---|---|---|
| METEOROLOGICAL | | | |
| Air Pressure | 900 to 1100 MB | 1.0 MB | 2 (Minimum) |
| Air Temperature | $-10^{\circ}$ to $40^{\circ}C$ | $0.5^{\circ}C$ | 2 (Minimum) |
| Wind Velocity-N/S | 1 to 50 (1) Mtrs/Sec | 1.0 or 5% whichever is greater | 2 (Minimum) |
| Wind Velocity-E/W | 1 to 50 (1) Mtrs/Sec | 1.0 or 5% whichever is greater | 2 (Minimum) |
| OCEANOGRAPHIC | | | |
| Water Temperature | $-2^{\circ}$ to $40^{\circ}C$ | $0.2^{\circ}C$ | 0 to 2 |
| Water Temperature | $-2^{\circ}$ to $40^{\circ}C$ | $0.1^{\circ}C$ | 10 to 200 5 Levels (Moored LCB Only) |
| Water Pressure | 15 to 23 $KG/CM^2$ | 0.5 $KG/CM^2$ | 200 (Moored LCB Only) |

1. 0.5 to 80 Meters/Second is a Design Goal

2. Includes Buoy Motion

Table 1. HCB/LCB Data Acquisition and Dissemination Requirements (Continued)




NOTE: PSK, FSK Modem Receivers are permanently connected to the SSB Receivers.

Figure 1. Existing Communication System, Miami Coast Guard Communication Station, block diagram.

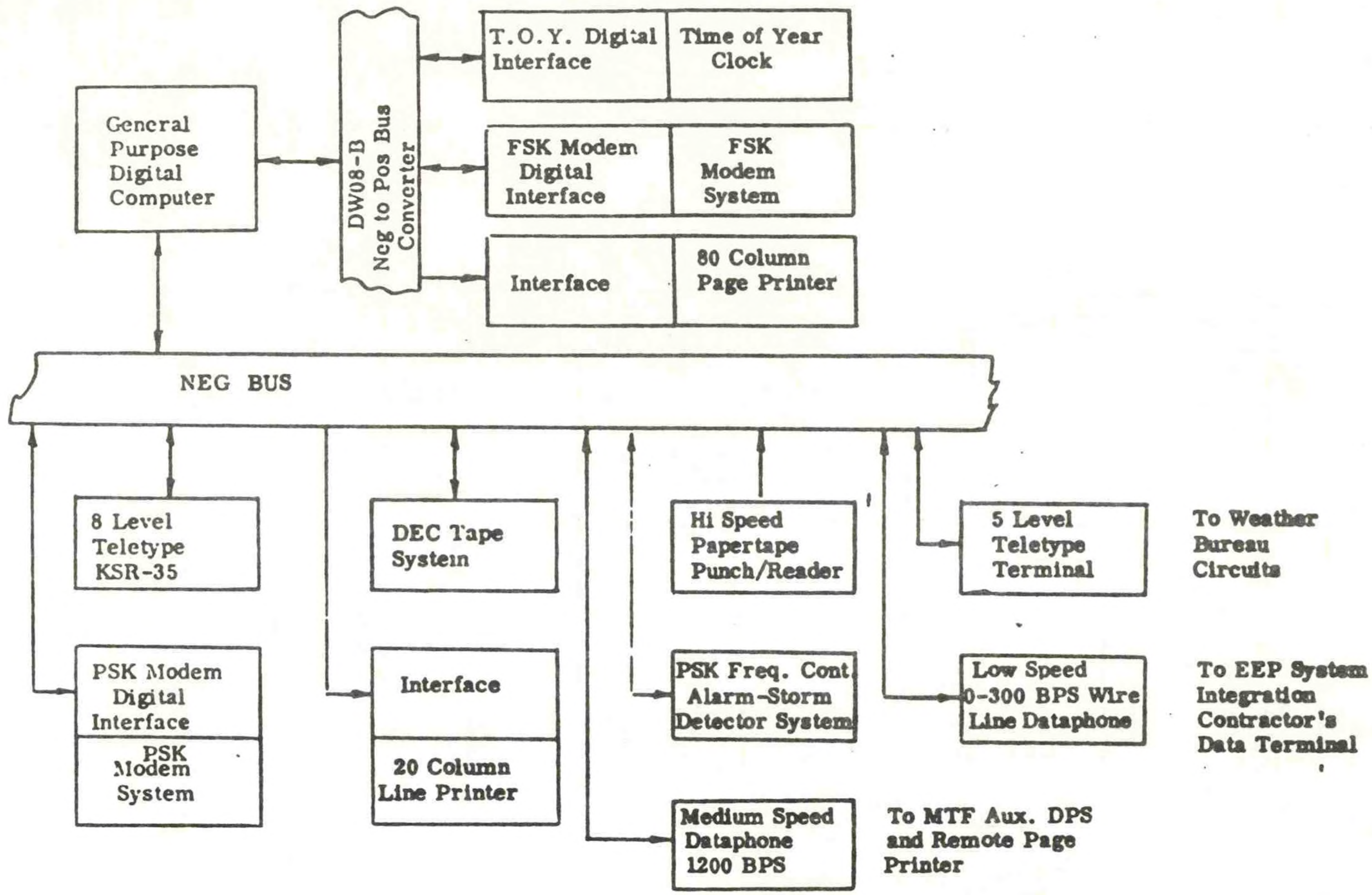



Figure 2. EEP Shore Communication Station Existing Primary Data Processing System Block Diagram

APPENDIX 3.3-2

ALASKAN BUOY COMMUNICATIONS METHODOLOGY

## ALASKAN BUOY COMMUNICATIONS METHODOLOGY

Communications between the Miami Shore Collection Station (SCS) Alaskan Buoys utilize three frequency bands of the 1967 WARC spectrum allocation. The optimum frequencies, based on ITS predictions are presented in Table 1. However, these frequencies are subject to change based upon operational data.

| Time (GMT) | Optimum Frequency (MHz) | Secondary Frequency (MHz) |
|---|---|---|
| 0300 | 12 | 8 |
| 0600 | 8 | 12 |
| 0900 | 8 | 12 |
| 1200 | 8 | 12 |
| 1500 | 12 | 8 |
| 1800 | 12 | 16 |
| 2100 | 16 | 12 |
| 2400 | 12 | 16 |

Table 1. Alaskan Buoy Operating Frequencies

A self-initiated synoptic reporting mode will be utilized to increase the communications reliability over the long transmission paths (1500 miles, nominally, from buoys to San Francisco, 3400 miles from buoys to Miami). The interrogated mode of reporting will provide a secondary or backup mode of operation. In order to achieve a useable reliability in the shore to buoy communications link, a 10 [illegible] transmitter will be utilized at the Miami SCS.

Shore to buoy data messages will be received simultaneously at both the Miami and San Francisco shore stations. The data received at Miami will be recorded and processed in real time in the same manner as data from buoys deployed in the Gulf of Mexico (FM predetection recording). The data received at San Francisco will be relayed to Miami over a dedicated hardline (telephone) link using multichannel FSK modem terminal equipment. Initially, the modulated subcarrier signal will be recorded on the predetection tape (direct record mode), and subsequently demodulated and the data processed by the PDP-8 data processor. When revised software incorporates multichannel data reception, the data relayed from San Francisco will be read into the computer simultaneously with the data received at Miami, on an interrupt basis, and both sets of data will be combined to maximize communication reliability. The operational sequence for simultaneous read in of data will be accomplished as follows:

a) The carrier detected signal output from the hardline FSK modem channel automatically connects the demodulator input to the pre D tape recorder input. In addition, the signal is routed to the PDP-8 for recognition purposes.

b) When the PDP-8 recognizes the carrier detected signal, it commands a relay closure to route the PCM data output of the modem channel to a bit synchronizer.

c) The bit synchronizer develops a 75 bps clock, synchronized with the data and outputs the clock and data stream to the computer through appropriate interface circuitry.

A functional block diagram of the data reception mode is presented in Figure 1.

The receiving systems at Miami and San Francisco will utilize log periodic directional antennas to increase the communications link reliability. The antenna pointing angles are calculated to be 322° at Miami and 324° at San Francisco, based upon great circle paths between the shore stations and the buoy.

Shore to buoy messages will be transmitted from the Miami SCS in the same manner as command messages are transmitted to buoys deployed in the Gulf of Mexico. At some later date, command messages may be relayed to San Francisco over the previously described hardline communications link for transmittal to the buoy using San Francisco transmitters. The operational sequence for accomplishing this command message transmission may be as follows:

a) Using a voice channel and the dedicated telephone line, Miami SCS operator will advise San Francisco operator of the message requirement, transmission frequency, and antenna pointing angle (if applicable).

b) Upon verification of proper equipment configuration, Miami operator will initiate the computer controlled transmission sequence.

    1) Transmitter keying signal is sent over the hardline using one of the FSK modulated channels.

    2) The complete command message is transmitted over the hardline, using one of the FSK modulated channels where it is used to modulate the transmitter at San Francisco.

    3) When the complete message has been transmitted, the computer removes the keying signal.

    4) With removal of the keying signal, the Miami and San Francisco stations are returned to a receive mode.

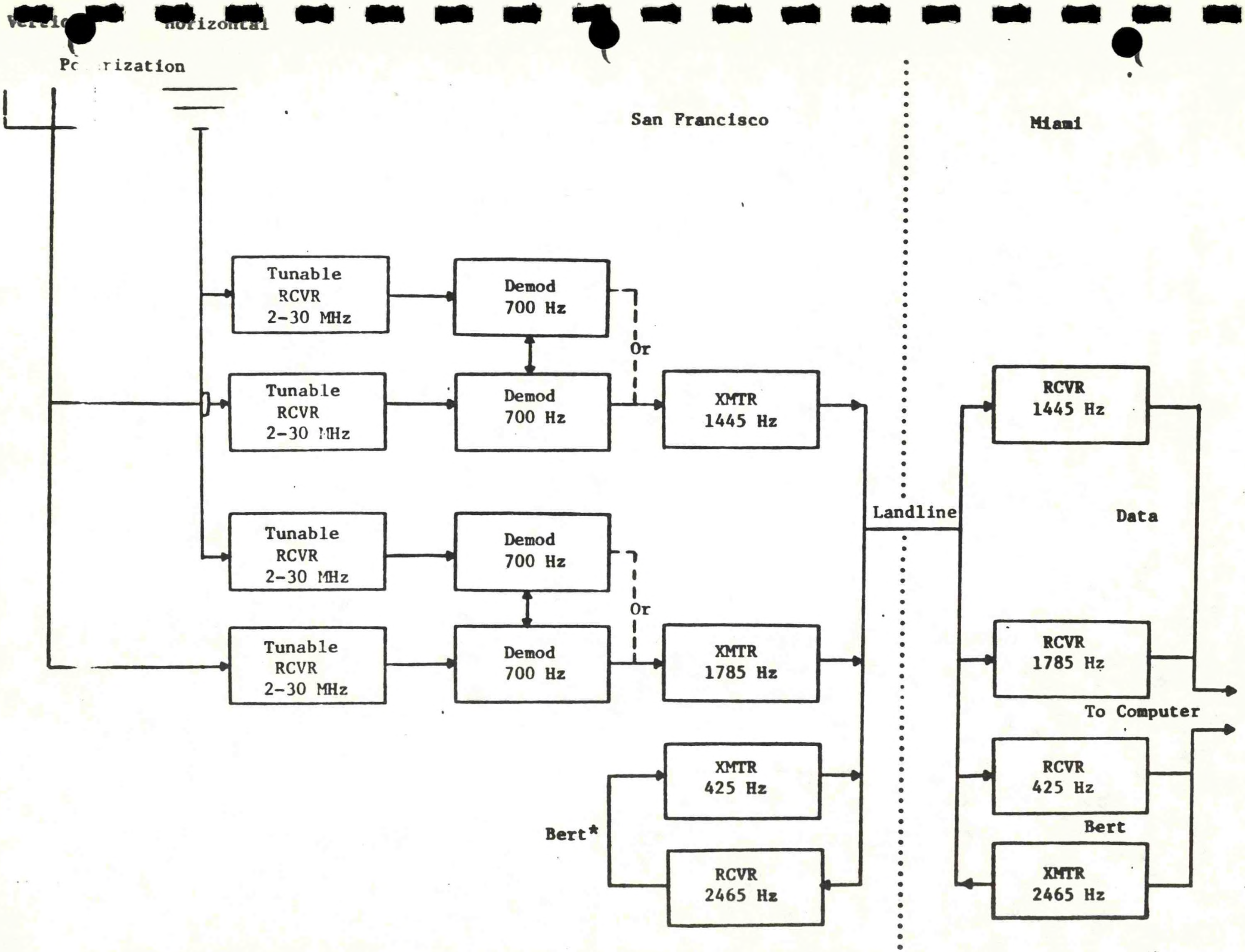



Figure 1. **Present Configuration San Francisco Shore Station Bit Error Rate Test**

APPENDIX 4.3-1

REPORT ON

CONNECTOR FAILURES/RELIABILITY

SPACE SUPPORT DIVISION | INFORMAL ENGINEERING REPORT

| CONTRACT NO. | A.O. NO. | DATE | FILE |
|---|---|---|---|
| NAS8-28165 | 23-45 | July 25, 1973 | |

Prepared By: J. F. Holmes

Reference (Requirement initiated by:) J. Greer

Distribution: CDR Charles S. Niederman, Joseph H. Greer, LCDR Robert H. Cassis, J. K. Sharp, L. S. Trest

Title and Purpose:

CONNECTOR FAILURES/RELIABILITY

Summary: (If Applicable)

SUBJECT - CONNECTOR FAILURES/RELIABILITY

To determine the magnitude of the connector problem six most recent Debriefing reports were used and all references to connectors were cut out and compiled.

A publication by Amphenol Co. on the reliability of connectors on 707/727 aircraft was the most useful document, as it had evaluation of a sufficient number of failures to derive reliability numbers by connector type and use.

The connector reliability for the 707 can be summarised as three failures per million connector hours. Obviously this is a simplification but the breakdown by type and location varies from 1 to 8 failures/per $10^6$ hours.

To put this in perspective with respect to the EFF buoys, it can be stated as follows, the buoy has approximately 240 connectors, and in a year (8000) hours would have 2 million connector hours which would result in 6 failures per year!



Report Prepared By: Title Date

Report Approved By:

| CONTRACT NO. | A.O. NO. | DATE | FILE |
|---|---|---|---|
| | 23-45 | July 25, 1973 | |

Detailed Comments:

The Debriefing reports are for 5 buoys over a 4 months period or 20 buoy months (it is obvious that this is not rigorous but it is used to obtain a number) which would amount to 3.6 million connector hours and predict 11 failures based on the Amphenol data.

By a weighted count I see 13 failures in these debriefing reports, which would indicate the ocean environment is harder on connectors than the aircraft environment.

Two of these connector failures resulted in total buoy failures as they shut the buoy down completely by: 1. taking the computer out, and 2. keeping the 8 MHZ transmitter keyed on.

It has been suggested that Mil spec connector would prevent the failures. The Amphenol data indicates the highest failure rate is $8/10^6$ hours and the lowest is $1/10^6$ hours. These two extremes are for Mil spec connectors, with the Mil average about $4/10^6$ hours. Mil spec connectors are not the answer to higher reliability.

CONCLUSIONS:

It would seem from the data that the only method of eliminating connector failures would be to eliminate all connectors. This is impossible, but with the total number of connectors on the buoy reduced to 20 we could expect only 1 connector failure in 2 years.

## CABLE CONNECTOR FAILURES

The following statements of connector problems have been edited from debriefing reports made after field trips to deploy or repair the buoys. The reports used were:

| | |
|---|---|
| EB-12 | 7/3/73 |
| EB-03 | 5/11/73 |
| EB-02 | 4/19/73 |
| EB-10 | 4/6/73 |
| EB-02 | 3/24/73 |
| EB-01 | 5/14/73 |

Investigation showed that pin "A" (+28 VDC) gave low resistance to pin "G" (grounded shield). The grounded shield was floated by removing connector at TB-10-5 in the Signal "J" Box. The cable rechecked good and the NS 13-0101-1 compass was installed (2030Z).

BSU cable investigation showed dead short between pins H and P. Checkout of the 5 M comparitor cable showed no discrepancies.

During change out of compass cable connector at 5 M level, discovered whole cable assembly full of water.

Compass cable problem still not corrected by floating ground in Signal "J" Box. Found 42 ohms between pins D and A today. Problem appears to be dampness in compass assembly cable and/or connector.

A problem had been experienced with the 4MH cannel from Miami. Investigation revealed a broken solder pin on connector A5P6 at the chassis. The pin was re-soldered, and the intermitent power problem was corrected.

Miami reported 10V reference voltage to be 4.05 to 4.08 volts. The shorted tensiometer "B" was suspect. Reboarded buoy at 1700Z and disabled same by lifting wire between TB10-19 and J12E in the Instrumentation "j" Box. Miami reported the 10V reference to be normal, 9.99 volts.

The tensiometer signal conditioning was found shorted in the input line, someplace between the tensiometer and the signal conditioning. A safe assumption can be made that the short is due to wate in the tensiometer connector which was physically damaged during deployment.

The connectors on the Engine Instrument Panel in Compt 3 were inspected, cleaned, and DC-4 applied.

The 250M and 500M installations were swapped, the decision was made to deploy, considering that the MLDL connector was proven by the test with the two good sensors.

Investigation revealed the power cable connector on back of computer to be intermittent. Computer could be turned on and off by wiggling the connector. Disassembled connector, could find no problem, re-assembled, installed, but could not repeat problem. Program displayed some fault during local interrogation.

Inspected flux gate compass at 10 M level found both male and female connectors corrorded. The wind and sea required the total assembly to be removed and the replacement compass was installed into the assembly on the deck of the buoy. The cable connectors were cleaned as best possible under the conditions and DC-4 was applied. With wind and seas building, the cable ring out was deleted and the installation completed.

All HFC, DPS, and Auxiliary circuit breakers were set to OFF. After approximately 10 minutes, the DC voltage was up to 27 volts. Investigations disclosed that corrosion in plug J7 on the HFC enclosure had kept the 8 MHz transmitter keyed ON. The connector was cleaned and a DC-4 applied to the mating surface. All connectors on the Signal J-Box, the HFC and the DPS enclosures were inspected, cleaned and DC-4 applied.

The connectors on the Engine Instrument Panel in Compt. 1 were inspected, cleaned and DC-4 applied. The connectors to the accelerometer in Compartment 2 were cleaned and protected with DC-4.

Completed potting of new compass cable connector.

| | | |
|---|---|---|
| 22 | 1520Z/2120Z | MLDL connector shall not properly seated - Adding shims |
| 22 | 1700Z/2300Z | MLDL connector seated - 2" shim added HMOS deployed. |

APPENDIX 4.3-2

TABLE OF PRIMARY

BATTERY CHARACTERISTICS

| PRIMARY BATTERIES - COMPARATIVE DATA | | | |
|---|---|---|---|
| | ZINC-AIR | CARBON-ZINC | ALKALINE-MANGANESE |
| TYPICAL DATA PER BATTERY OR CELL | | | |
| MANUFACTURER | EDISON BATTERY | UNION CARBIDE | UNION CARBIDE |
| Part No. | ST-2 | 1461 | 565 |
| Type or Size | | 4 #6 Cells | |
| Volts | 2.5 VDC | 6 VDC | 6 VDC |
| A. H. | 1000 AH | 45 AH | 20 AH (As a primary) |
| W. H. | 2500 WH | 270 WH | 120 WH |
| Price | $25.00 | $3.50 | $4.00 |
| Volume | 1170 Cu. in. | 199 Cu. in. | 40.5 cu. in. |
| Weight | 33.5 # | 9.3 # | 2.5 # |
| Max. Current | 1.25 A | | 1.25 A |
| TYPICAL DATA FOR 10 KWH | | | |
| Cost | $100 | $130 | $336 |
| Volume | 2.7 Cu. ft. | 4.3 Cu. ft. | 2.0 Cu. ft. |
| Weight | 134 # | 344 # | 210 # |
| No. of Batteries or Cells | 4 | 37 | 84 |

APPENDIX 4.3.3

REPORT ON

POWER REQUIREMENTS AND

POWER PROFILE FOR SMALL BUOY

# POWER PROFILE FOR MAGNAVOX LCB BUOY

## I. GENERAL

The Magnavox LCB power system consists of four sets of batteries, a voltage regulator, and a battery charger as shown in Figure 1. The four sets of batteries consist of two sets for the primary power (high voltage and low voltage), one set for emergency power, and one set of rechargeable batteries for the peak load power (HF transmitter).

Since the peak load batteries are rechargeable from the primary high voltage supply, and since the emergency batteries are used only for the navigation light, the power required to perform the buoy's primary mission is obtained from the two primary battery supplies.

The following paragraphs present the power requirements for the various subsystems and then presents a summary of the requirements in tables and in power profiles.

## II. ASSUMPTIONS

The assumptions used in establishing the power profile for the Magnavox LCB are:

A. Use of HF Communications

B. Use of Omega PFS

C. 8 Data transmissions per day (4 synoptic and 4 interrogate commands)

D. Average efficiency of Regulator and charger is 75%.

## III. HIGH VOLTAGE PRIMARY POWER SUPPLY

The following power requirements are summarized in Table I and are shown in a power profile in Figure 2. The loads given reflect the losses of the regulator and battery charger.

A. Loads on 28 Volt Regulator

1. HF Comms Exciter:

On full time; draws 0.80 watts constant with surges of 1.06 watts during operation of relays. Peak power is 1.06 W; avg. power is 0.80 W. With regulator efficiency of 75%; peak power is 1.42 W; avg. power is 1.07 W.

2. Sensor Data Processor (SDP):

On for 10 minutes each hour starting 10 minutes before the hour. Draws 2.8 watts during the 10 minutes after an 11.2 watt transient at turn-on for ½ millisecond. Power increases to 3.78 watts for 300 milliseconds every 4 seconds for 9.5 minutes due to the air pressure sensor. With regulator efficiency of 75% the turn-on transient is 14.95 watts; the peak power is 5.04 watts; the 10 minute quiescent power is 3.74 watts, and the avg. power is .64 watts.

$$P \text{ avg.} = 3.74\left(\frac{10}{60}\right) + (5.04-3.74)\left(\frac{.3}{4}\right)\left(\frac{9.5}{60}\right) =$$

$$= .623 + .015 = .64 \text{ watts}$$

3. Position Fixing System (PFS), Omega:

On for 6 minutes each hour starting 10 minutes before the hour. Draws 8.4 watts during the 6 minutes after a 23.8 watt transient at turn-on for 10 milliseconds. With regulator efficiency of 75% the turn-on transient is 31.7 watts; the peak power is 11.2 watts; and the avg. power is 1.12 watts.

$$P\ avg. = 11.2 \left(\frac{6}{60}\right) + (31.7-11.2)\left(\frac{.010}{60 \times 60}\right)$$
$$= 1.12 + .000057 = 1.12\ watts$$

B. Loads on 28 Volt Peak Load Battery Charger

1. Charge Mode

Power is replaced in the ni-cad batteries at a rate of 0.1 amp. until the replaced power is 1.5 times that removed. Power removed is 10 amps. at 28 volts for 10 seconds or 2800 watt-seconds. Power during charge is .1x28 or 2.8 watts. The charge time is $\frac{4200\ ws}{2.8\ Wx60}$ = 25 minutes Therefore, the charge mode is on for 25 minutes every three hours starting immediately after a data transmission. With charger efficiency of 75% the peak power is 3.74 watts, and the avg. power is 0.52 watts.

$$P\ avg. = 3.74 \times \frac{25}{60} \times \frac{1}{3} = .52\ watts$$

2. Trickle Mode

The ni-cad batteries are trickle charged at a rate of 30 milliamps whenever the normal charge mode is completed. Therefore, the trickle charge mode is on for 2 hours and 35 minutes every 3 hours and its load is 0.84 watts. With charger efficiency of 75% the peak power is 1.12 watts, and the avg. power is 0.965 watts.

$$P\ avg. = \frac{1.12 \times 2\frac{35}{60}}{3} = .965\ watts$$

IV. <u>LOW VOLTAGE PRIMARY POWER SUPPLY</u>

The following power requirements are summarized in Table II and are shown in a power profile in Figure 3.

A. Data Processing System (DPS):

The only load on these batteries is the DPS which draws 125 milliwatts constantly. The peak and avg. power is 0.125 watts.

V. <u>EMERGENCY POWER SUPPLY</u>

The following power requirements are summarized in Table III and are shown in a power profile in Figure 4.

A. Navigation Light:

The only load on these batteries is the Navigation Light which is on only at night. When on, it flashes on with .36 watt seconds of energy with a peak power of 2.0 watts for approximately .18 seconds. The flash repeats once a second for 3 flashes, then is off. The cycle is repeated every 20 seconds. Peak power is 2.0 watts and avg. power at night is 0.054 watts.

$$P \text{ avg. (night)} = \frac{2.0 \times .18 \times 3}{20} = 0.054 \text{ watts}$$

Avg. Power per day is 0.027 watts.

VI. PEAK LOAD POWER SUPPLY (Ni-Cad Rechargeable Batteries)

The following power requirements are summarized in Table IV and are shown in a power profile in Figure 5.

A. HF Comm. Transmitter (Power Amplifier):

On for 10 seconds approximately 30 minutes after the hour every 3 hours. Draws 10 amps or 280 watts during this time. Peak power is 280 watts; avg. power is 0.259 watts.

$$P \text{ avg.} = \frac{280 \times 10}{3 \times 60 \times 60} = .259 \text{ watts}$$

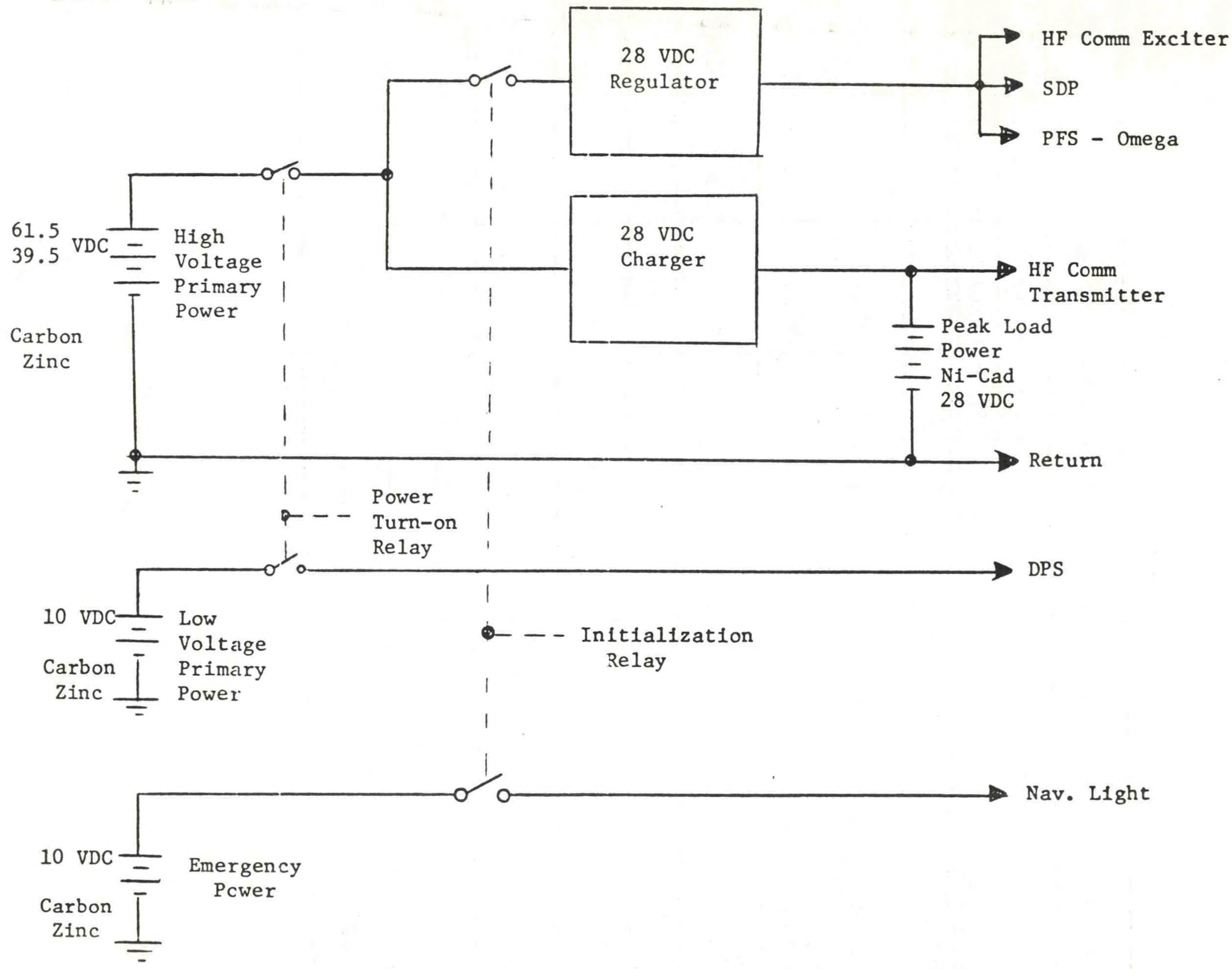



Figure 1. Power System - Simplified Schematic - Magnavox LCB

TABLE I

| HIGH VOLTAGE PRIMARY POWER REQUIREMENTS -- SUMMARY | | | | | | | |
|---|---|---|---|---|---|---|---|
| SUBSYSTEM | VOLTAGE NOMINAL (VDC) | PEAK * POWER (WATTS) | AVG POWER (WATTS) | ENERGY -- WATT -- HOURS ** | | | |
| | | | | 1 DAY | 1 MONTH | 6 MONTHS | 1 YEAR |
| LOADS ON REGULATOR @75% EFFICIENCY | | | | | | | |
| HF COMM EXCITER | 28 | 1.42 | 1.07 | 25.70 | 781. | 4,686 | 9,372 |
| SENSOR DATA PROC. | 28 | 5.04 | 0.64 | 15.35 | 466. | 2,796 | 5,592 |
| PFS OMEGA | 28 | 11.20 | 1.12 | 26.88 | 817. | 4,902 | 9,804 |
| LOADS ON CHARGER @75% EFFICIENCY | | | | | | | |
| CHARGE MODE | 28 | 3.74 | 0.52 | 12.48 | 380. | 2,280 | 4,560 |
| TRICKLE MODE | 28 | 1.12 | 0.97 | 23.16 | 704. | 4,224 | 8,448 |
| TOTAL | | | 4.32 | 103.6 | 3,148 | 18,888 | 37,776 |

* DOES NOT INCLUDE TURN-ON TRANSIENTS
**DOES NOT INCLUDE SELF DISCHARGE POWER OF BATTERIES

TABLE II

| LOW VOLTAGE PRIMARY POWER REQUIREMENTS -- SUMMARY | | | | | | | |
|---|---|---|---|---|---|---|---|
| SUBSYSTEM | VOLTAGE NOMINAL (VDC) | PEAK POWER (WATTS) | AVG POWER (WATTS) | ENERGY -- WATT -- HOURS ** | | | |
| | | | | 1 DAY | 1 MONTH | 6 MONTHS | 1 YEAR |
| DPS | 10 | 0.125 | 0.125 | 3.0 | 91.2 | 548. | 1,095. |

** DOES NOT INCLUDE SELF DISCHARGE POWER OF BATTERIES

TABLE III

| EMERGENCY POWER REQUIREMENTS -- SUMMARY | | | | | | | |
|---|---|---|---|---|---|---|---|
| SUBSYSTEM | VOLTAGE NOMINAL (VDC) | PEAK POWER (WATTS) | AVG POWER (WATTS) | ENERGY -- WATT -- HOURS ** | | | |
| | | | | 1 DAY | 1 MONTH | 6 MONTHS | 1 YEAR |
| NAV LIGHT | 10 | 2.0 | 0.027 | 0.648 | 19.7 | 119. | 237. |

** DOES NOT INCLUDE SELF DISCHARGE POWER OF BATTERIES

TABLE IV

| PEAK LOAD POWER REQUIREMENTS -- SUMMARY | | | | | | | |
|---|---|---|---|---|---|---|---|
| SUBSYSTEM | VOLTAGE NOMINAL (VDC) | PEAK POWER (WATTS) | AVG POWER (WATTS) | ENERGY -- WATT -- HOURS ** | | | |
| | | | | 1 DAY | 1 MONTH | 6 MONTHS | 1 YEAR |
| HF COMM TRANSMITTER | 28 | 280. | 0.259 | 5.97 | 181.4 | 1,089. | 2,178. |

** DOES NOT INCLUDE SELF DISCHARGE POWER OF BATTERIES

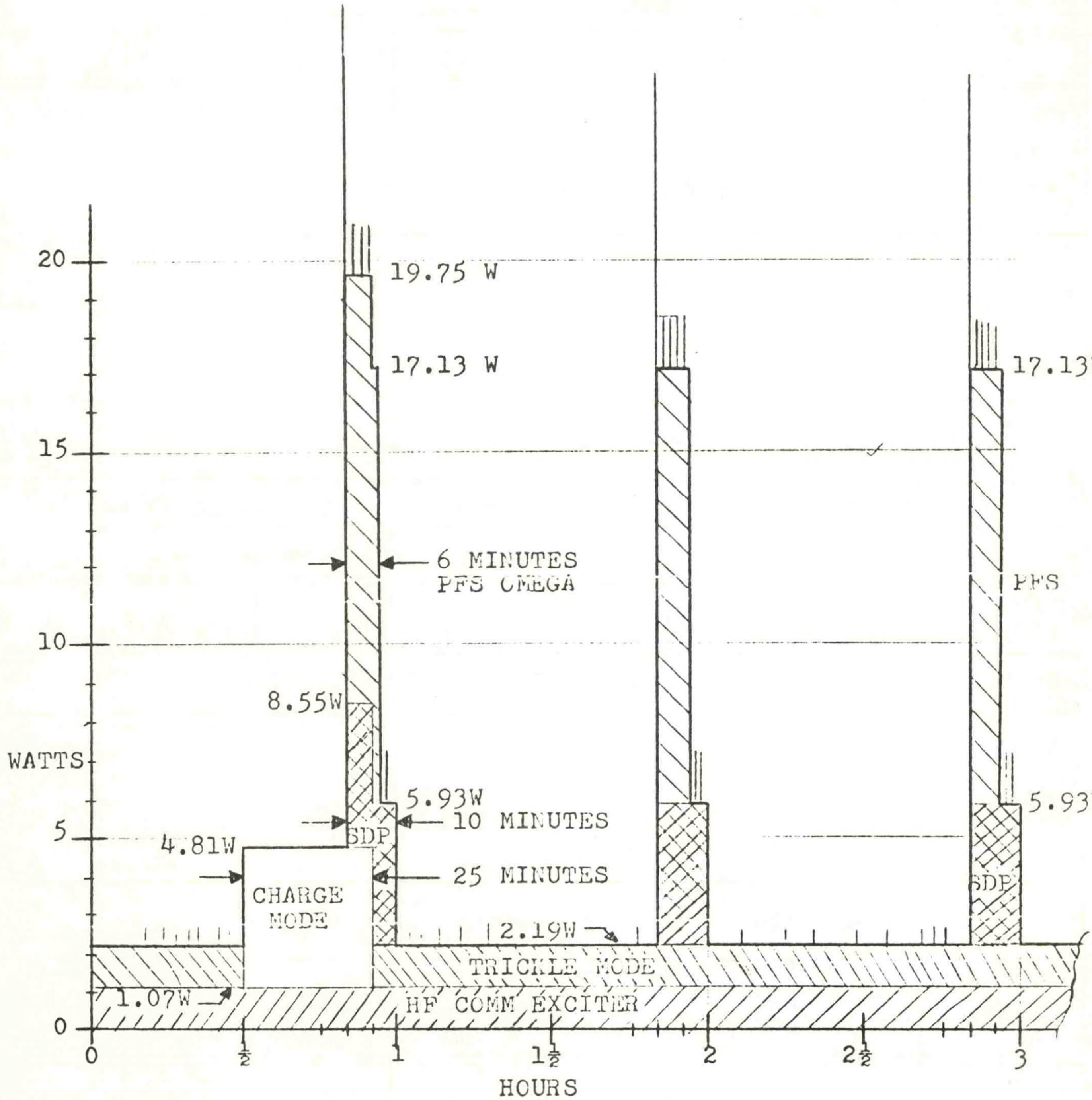



FIGURE 2. POWER PROFILE -- HIGH VOLTAGE PRIMARY POWER

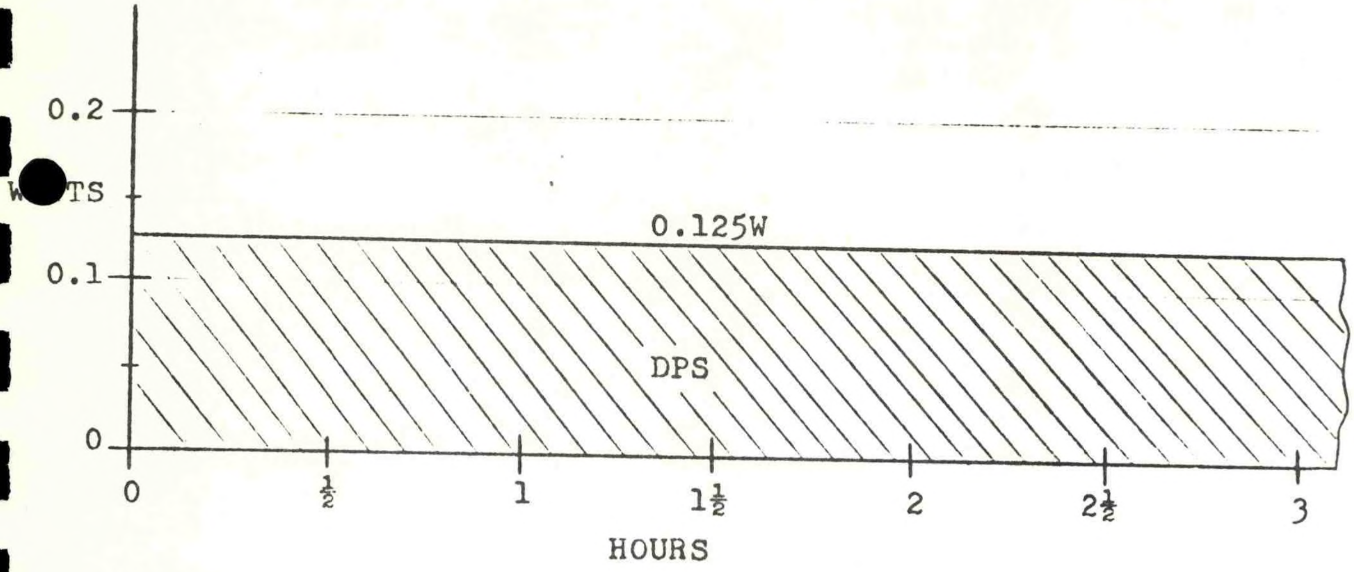



FIGURE 3. POWER PROFILE -- LOW VOLTAGE PRIMARY POWER

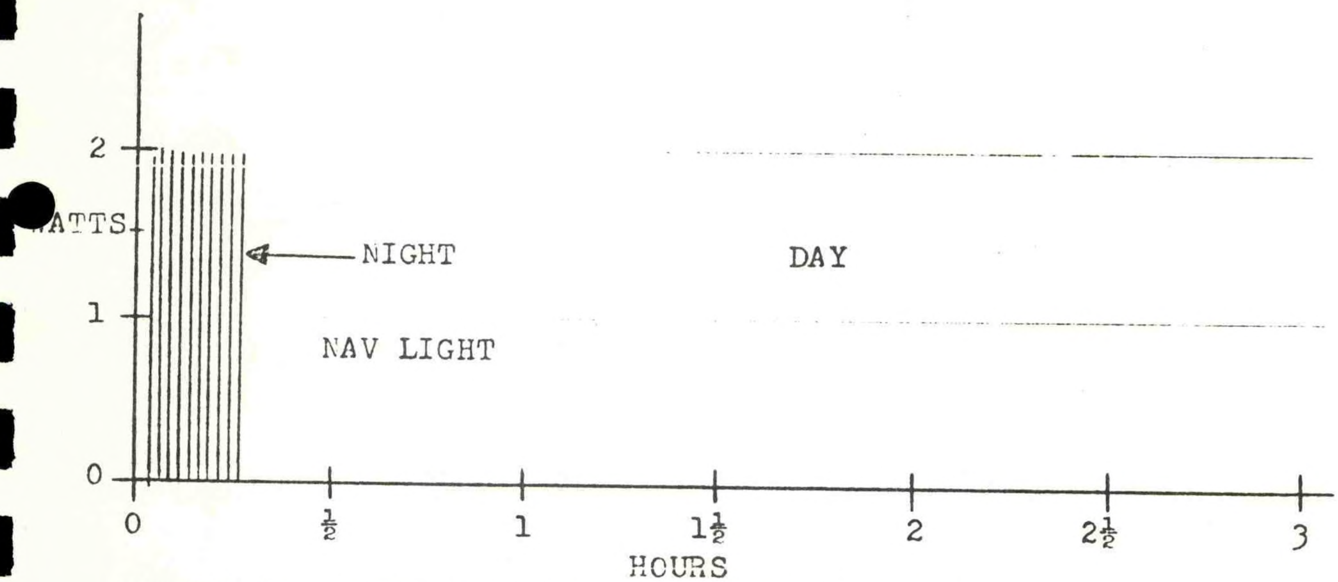



FIGURE 4. POWER PROFILE -- EMERGENCY POWER

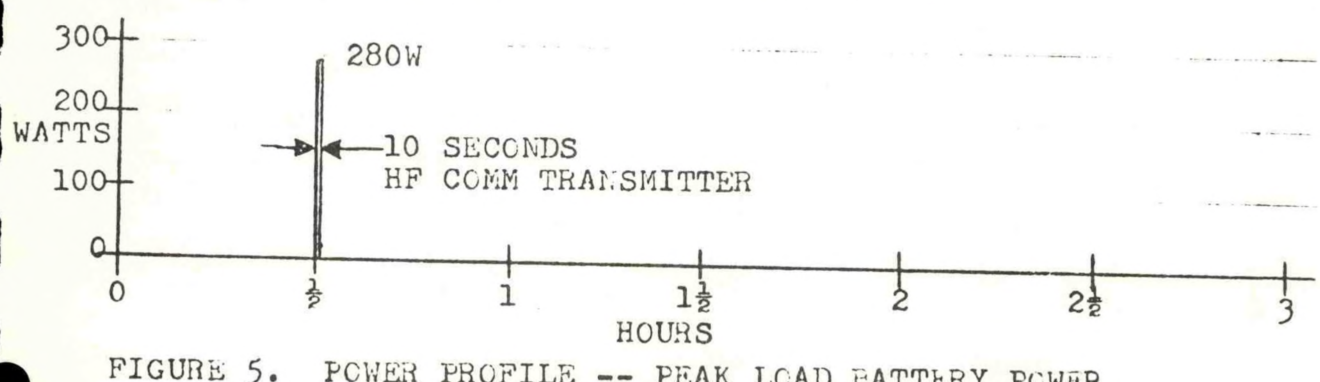



FIGURE 5. POWER PROFILE -- PEAK LOAD BATTERY POWER

# APPENDIX 4.6-1

## DETAILED SYSTEM CHARACTERISTICS

## HCB HF COMMUNICATIONS SYSTEM

NAME: HF Communications System

MFG: General Dynamics

DESCRIPTION:

The HF Communications System is a three channel HF transceiver system especially designed for High Capability Buoy Applications. The equipment has the capability to receive and demodulate on all three frequencies simultaneously, and to modulate and transmit on any one of the same three frequencies. The operating frequencies are one channel frequency in each of three RF bands, allocated by the World Administrative Radio Conference, for ocean data transmission. The data transmission technique used is single-sideband-suppressed carrier employing frequency-shift-keyed (FSK) subcarrier tones. These tones are keyed by pulse code modulation at 75 bps.

SPECIFICATIONS:

INPUT POWER: + 28 + 2, -5 VDC

Receive Mode: 28 Watts

Transmit Mode: 310 Watts

RF POWER OUTPUT: 100 Watts

MODULATION CHARACTERISTICS: FSK

Frequency Shift: 170 Hz

Modulation Rate: 75 bps

OPERATING FREQUENCIES: (Any 3 of the listed frequencies)

4,163.2 KHz

6,245.2 KHz

Operating Frequencies (Continued)

8,328.7 KHz

12,480.2 KHz

16,637.2 KHz

22,161.2 KHz

FREQUENCY STABILITY: ± 2.5 Hz

MECHANICAL CHARACTERISTICS:

Size: 62 In x 27 In x 32 In

RECEIVER SENSITIVITY: Provide 20 db Signal-to-Noise Ratio at -107 dbm Input Power

## DETAILED SYSTEM CHARACTERISTICS

| | GE | LMSC | MAGNAVOX |
|---|---|---|---|
| RECEIVER(S) | 2 | 1 | 1 |
| Frequency | 2 | 3 | 5 available, 3 auto-sel |
| 1st IF Freq. | 600 Hz @ 455 KHz | 25 MHz | 300 Hz @ 100 KHz |
| 2nd IF Freq. | ——— | 3.5 KHz @ 455 KHz | ± 85 Hz 1.020 KHz |
| 3rd IF Freq. | ——— | ± 85 KHz @ 2.2 KHz | ——— |
| Auto Gain Control | Yes | Yes | No |
| Limiting | Yes | (SQUELCH) | 11 Volt p-p |
| Demodulator | Phase Lock Loop (455 KHz) | Phase Lock Loop (Baseband) | Match Filter Disc. (1.020 KHz) |
| Sensitivity | -122 dBm | -161 dBm | ——— |
| Standby Power | .5 W | 4.0 W | 0.8 W |
| Lightning Protection | Yes | Yes | No |
| TRANSMITTER(S) | 2 | 1 | 1 |
| Modulator Freq. | 100 KHz | 2.2 KHz | 100 KHz |
| Modulator Type | Filter | Phase Shifting | Filter |
| Power Amplifier | 100 W HERMES | 100 W CONIC | 100 W REDIFON |
| P.A. Efficiency | 37% | 36% | 36% |
| ANTENNA TYPE | Vertical Whip | Vertical Whip | Vertical Whip |
| Length | 23' | 15' | 20' |
| Material | Braid-Fiberglass 2-piece | Stainless Telescoping | Fiberglass 2- piece |
| {Loading Coil} | {off-center switched} | {automatic} | {base switched "L"} |
| POSITION LOCATION | Radar Reflector<br>"X" Band BEACON | Radar Reflector<br>——— | Radar Reflector<br>3 MHz Beacon |

## INTERCHANGEABILITY

## PHYSICAL COMPARISON HFC SYSTEM

| | MAGNAVOX | GE | LOCKHEED |
|---|---|---|---|
| Height | 5.3 | 5" | 6" |
| Width | 15 | 14" | 14" |
| Length | 28 | 16" | 15" |
| Volume | 2135 cu. in. | 1120 cu. in. | 1260 cu. in. |
| Weight | 30 lb. | 16 lb. | 35 lb. |
| Voltage | 12V, 24V | 12V, -28 ±4V | ±14V ±0.3V, 24-29V |
| Power required | 280 W | 270 W | 280 W |

APPENDIX 4.6-2

HF ANTENNA FAILURES ON

SMALL BUOYS

SPERRY SPACE SUPPORT

INTER-OFFICE

FILE 320/22-91

FROM P. Wright

TO L. Livingston, C6223

DATE April 30, 1973

cc: E. Kerut, C6222

SUBJECT HF Antenna Failures on LCB's

Reference: Speed letter of 4-12-73 re: Subject Failures

The reference letter requested a review of the existing LCB HF antenna success/failure and appropriate corrective actions. This is an initial report presenting the current status of antenna failures on LCB's and appropriate recommendations.

There have been 4 failures of antennas or their associated parts during the deployment of LCB's in the Gulf of Mexico. Two Failures are associated with the Magnavox LCB and a single failure occurred with each of the Lockheed and General Electric buoys.

Magnavox Buoys EB-51 and EB-53

The Magnavox antenna is a 2 section fiberglass antenna manufactured by Carolina Dielectrics Company. The lower section is 1 1/2 inch diameter, 11 feet long and is mounted into a 6 feet long aluminum tube. The upper section is a reduced diameter (less than 1/2 inch) section, 9 feet long which attaches to the lower section with a threaded coupler. The antenna failure on EB-53 was in the upper 9 foot section. The antenna broke off just above the threaded coupling. This section was returned to the antenna contractor by Magnavox for review. The second failure occurred on EB-51 and was also just above the coupling in the upper 9 foot section. However, this failure was a vertical (longitudinal) crack just above the coupler, approximately half a foot long.

GE Buoy EB-31

The General Electric antenna is similar to the Magnavox antenna. It is a 2 section fiberglass antenna manufactured by Shakespeare. The bottom section is essentially the same as Magnavox except it has 6 conductors instead of 3 and it is 14 feet long mounted into a short (about 1 foot long) base. The upper section appears to be identical to the Magnavox upper section. The single GE antenna saw the entire loss of the upper 9 foot section at the coupling (the coupling apparently unscrewed due to vibration).

LMSC Buoy EB-36

The Lockheed antenna is a stainless steel telescoping antenna. It consists of 6 sections 6 feet long; the largest being 1 1/2 diameter with the smallest 1/4 diameter. When mounted, the antenna is 15 feet long and weighs 19 pounds. It is mounted directly to the antenna coupler. The failure of the antenna system on EB-36

LMSC Buoy EB-36 (Continued)

was that the insulating material holding the coupler stub and the coupler case together cracked. Lockheed has modified the antenna to delete the lower 1 1/2 O.D. section and a portion of the second section. The length remains at 15 feet overall but the weight has been reduced to 7 pounds.

It has been reported that during the launch of each LCB buoy the antenna hit the crane and/or the ship. In the case of Lockheed's EB-36 it was reported that the antenna coupler was damaged during launch.

Recommendations

There is no reason to believe that any of the three antenna types are inherently failure prone since it was not intended that they be made impervious to manhandling while being deployed. The following action is recommended:

a. GE and Magnavox should review their requirements for staking or securing the top 9 foot section to the lower section. If the top section is not secured at this time it is suggested that the use of an appropriate grade of loctite be used.

b. Deployment procedures should be reviewed to minimize damage of buoy appendages.

Paul W. Wright
P. Wright

PW:rd

APPENDIX 4.6-3

SATELLITE COMMUNICATIONS

BACKGROUND

The conversion to satellite communications has been a major effort at NDBO. The realization that virtually 100% communication could be attainable by use of a buoy-to-satellite communications mode prompted the NDBO quest for satellite and associate satellite element resources.

Since the late 1960's, maritime satellite communications tests, indicated that communications between a ship (ocean platform) at sea and a shore station employing a VHF satellite was readily achievable. Among the results derived from these tests were the noted variations in received signal levels during any one test period.

Experimental satellite communication activities were conducted in late 1969 by NDBO. The purpose of these experiments was to evaluate long-range communication between large, moored, unmanned ocean platforms and a shore station via satellite. Overall, these experiments demonstrated the feasibility of two-way satellite relay communications from and to an unattended ocean platform. However, reliability performance in terms of the successful number of interrogations responded to, was just under 50%. It was reasoned that the major cause for the number of unsuccessful communication attempts, as well as many of the bit errors, was frequent deep fading. The emphasis then was to include some additional margin to counteract the effects of fades noted on both the maritime and buoy satellite tests.

CURRENT ACTIVITY (GOES-RELATED)

Early NDBO satellite feasibility studies have indicated that a buoy data communication system using either geostationary or orbiting satellites is technically feasible for operational use. The most economical approach is one based on sharing a suitable satellite. The Synchronous Meteorological

Satellite/Geostationary Operational Environmental Satellite (SMS/GOES) is currently in the final stages of development, and it will include a UHF data collection capability for buoy platforms. The GOES is scheduled for launch by January, 1974.

In preparation for UHF-Satellite communication, NDBO contracted for five DCPRS systems (Data Collection Platform Radio Set) from Magnavox. These systems will be delivered around January, 1974.

UHF antennas have been developed by Geotronics and ECI (Electronics Communication, Inc.). A total quantity of ten (five from each contractor) have been delivered to NDBO.

The UHF system as developed will make up the first generation UHF Communication System for testing on various buoy platforms and possible retro-fit on the environmental prototype buoy.