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DEVELOPMENT OF OPERATIONAL AIDS FOR IMPROVED DRAGLINE UTILIZATION

FINAL TECHNICAL REPORT
AS OF
30 MAY 1981

This report represents work on a program that was originated by the Interior Department's Bureau of Mines and was transferred to the Department of Energy in January 1978

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ASSISTANT SECRETARY OF FOSSIL ENERGY
OFFICE OF COAL MINING

ABSTRACT

The Dragline Data Link Prototype System, developed under DOE Contract Number DE-AC22-76ET12201, Modification M007, provides for direct data transfer between the Display and Information Gathering System (DIGS) located on board a dragline and a computer system located in the mine office. Reports of dragline activity available from the DIGS on the dragline can also be accessed from the mine office. This report describes the Data Link System design, installation, application and evaluation in a working mine environment.

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FOREWORD

This report was prepared by McDonnell Douglas Electronics Company (MDEC) under the Department of Energy Contract DE-AC22-76ET12201 (formerly ET-76-C-01-8922) titled Development of Operational Aids for Improved Dragline Utilization. Modification M007, dated September 14, 1979, specifically authorizes the development of the Dragline Data Link System. This modification was administered under the direction of Mr. J. C. Riggs and Mr. H. E. Parkinson of the Carbondale Mining Technology Center. Mr. C. H. Curtis was the contract administrator for the Department of Energy.

A special note of appreciation is directed to the personnel of the Old Ben Coal Company of Oakland City, Indiana who assisted in the installation and evaluation of the Data Link System.

MDEC personnel contributing to this report include C. W. Eschman, J. S. Thorn, and M. A. Trelz. Mr. G. D. Dalton and W. J. Lally coordinated contractual matters.

1.0 EXECUTIVE SUMMARY

Productivity of draglines and other large mining equipment is dependent upon several factors. These include the operators skill in using the equipment and managements skill in analyzing mine operation and providing direction, training and procedures to mining personnel. Operational aids such as the dragline Display and Information Gathering System (DIGS) were developed to assist equipment operators and mine management personnel in the pursuit of better productivity. In addition to aiding the operators with pertinent performance displays the DIGS gathers, processes, records and prepares reports of the mine production activities of the dragline. These reports were available only on-board the dragline. To further increase the usage of these management reports a data link system has been added which transmits dragline activity data directly to the mine office where reports are immediately available. The feasibility of applying a radio data link between a dragline operating in a typical mining environment and a remote receiving station (mine office) for the purpose of digital data transmission has been demonstrated during the course of this program.

Background. As part of a program to develop techniques and equipment to increase coal productivity, McDonnell Douglas Electronics Company (MDEC) was awarded Contract No. H0262056 by the U.S. Bureau of Mines in September of 1976. This program was transferred to the Department of Energy in January of 1978 and continued under Contract No. ET-76-C-01-8922. The contract number was later changed to DE-AC22-76ET12201. This program, titled Operational Aids for Improved Dragline Utilization, continued the development of an on-board display and information gathering system and dragline computer simulation model begun under a prior U.S. Bureau of Mines Contract Number J0255014, Concept Feasibility Study for Training Equipment to Improve

Coal Productivity. The dragline Display and Information Gathering System (DIGS) was developed to the prototype state and the system was installed at the Jim Bridger Mine in Wyoming to collect and record data pertinent to the evaluation of the system. During this validation exercise, the introspective training value and the productivity reporting capability of DIGS was confirmed. The DIGS was consequently developed for production and offered on the commercial market. In addition to the initial prototype, three production systems have been installed and are operational and a fourth will soon be activated.

In September of 1979 DOE modified Contract No. DE-AC22-76ET12201 (Modification M007) to incorporate the Dragline Data Link. The objective of this modification was to "modify an existing on-board dragline display system and demonstrate/ evaluate the benefits of a data link connecting a computer located in a remote office, with the data recording system located on board the dragline." The dragline data link system was completed and installed at Old Ben Coal Co. Old Ben Number 2 Mine near Oakland City, Indiana in November 1980. The system is interfaced to a DIGS installed on a Bucyrus-Erie Model 1370 dragline. The remote installation is in the engineers office at the mine office. The system performed flawlessly during the two month evaluation period.

Display and Information Gathering System (DIGS). The prime objective of the base contract, that includes the development of the Dragline Data Link, is to increase dragline utilization and, therefore, mine productivity. Data Link can aid productivity improvement only as a vehicle to speed the flow of data to those whose decisions affect production. This data is the important factor and its usefullness is dependent upon its accuracy, completeness and timeliness. Since this data is automatically gathered and processed by DIGS, it is necessary to understand this process such that the Data Link can be evaluated in qualitative productivity terms.

DIGS is a system marketed by MDEC for installation on-board a dragline to provide and record feedback of the draglines activities. It has two separate but related functions both of which are directed toward productivity improvement. Ths most visible is its display capability. From a console located in the cab the operator can obtain a variety of feedback data relative to his performance in operating the dragline. This data is additionally processed and stored for future use by the report preparation capability.

System Operation. The components of the DIGS are shown in Figure 1-1. The control and display console (Figures 1-1, center) is installed in the cab within reach of the operator. The teletypewriter, computer console, and input/out box are installed on-board the dragline at environmentally suitable and convenient locations. In addition, sensors for hoist, drag and swing positions and power data are installed at the source of this data. Typical position sensor installations are shown in Figures 1-2 and 1-3. Figure 1-4 block diagram describes the data flow. Feedback from the sensors and the control panel are input into the computer. Operator inputs include his code, the job code and down time codes. This data is processed in the computer to drive the displays shown in Figure 1-5. Bucket position is shown in the "Height", "Reach" and "Swing Angle" displays.

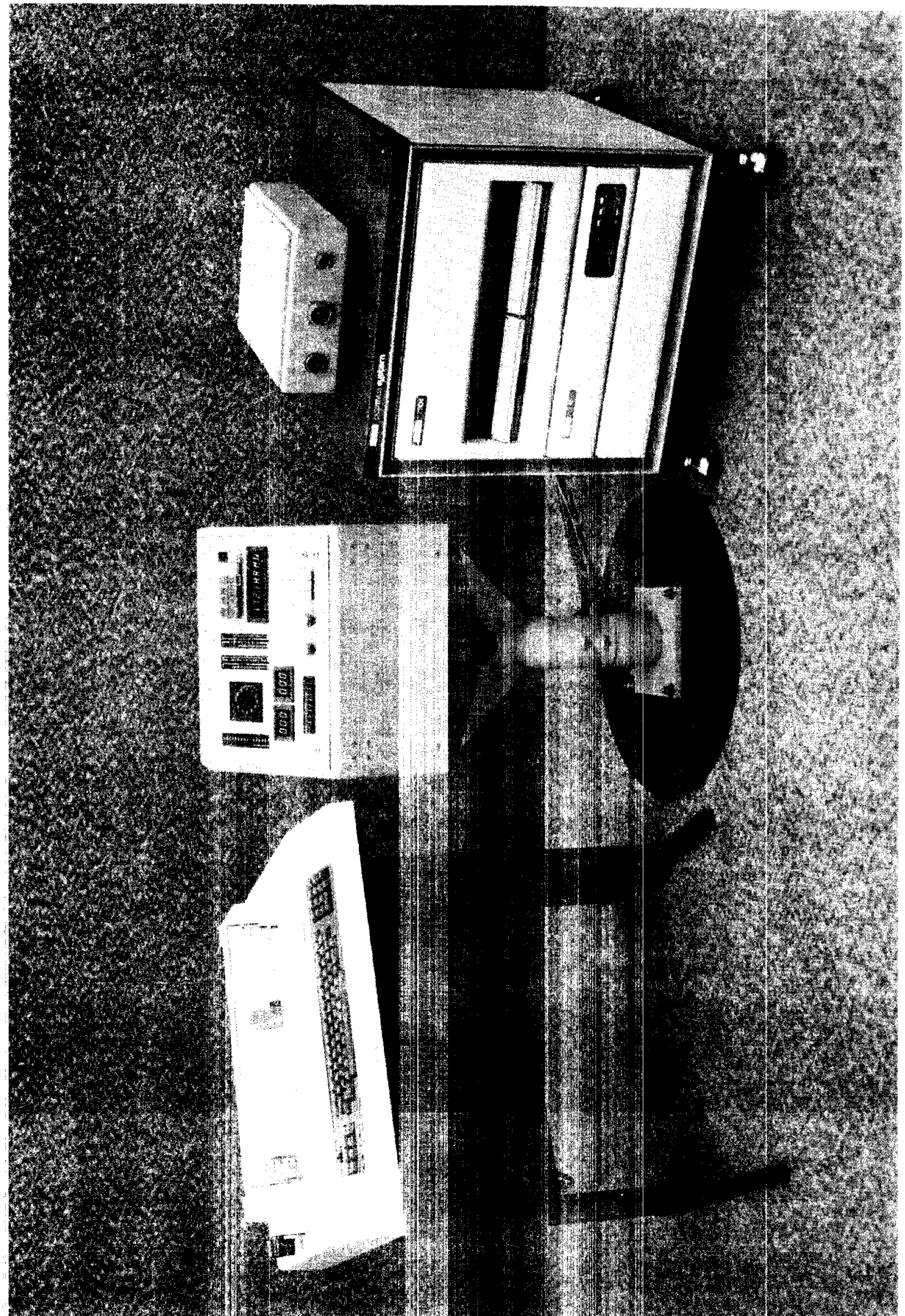

Figure 1-1

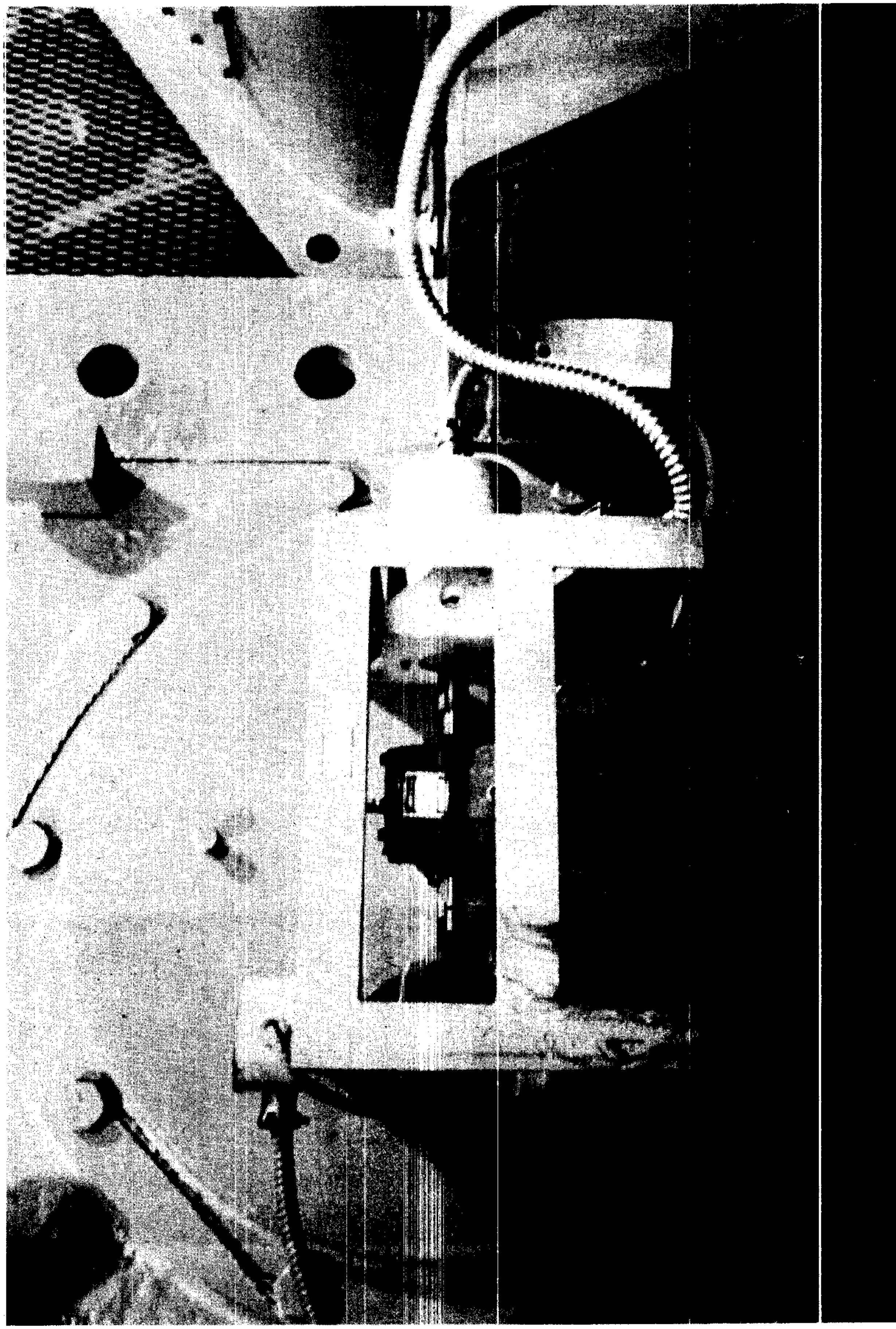

Figure 1-2

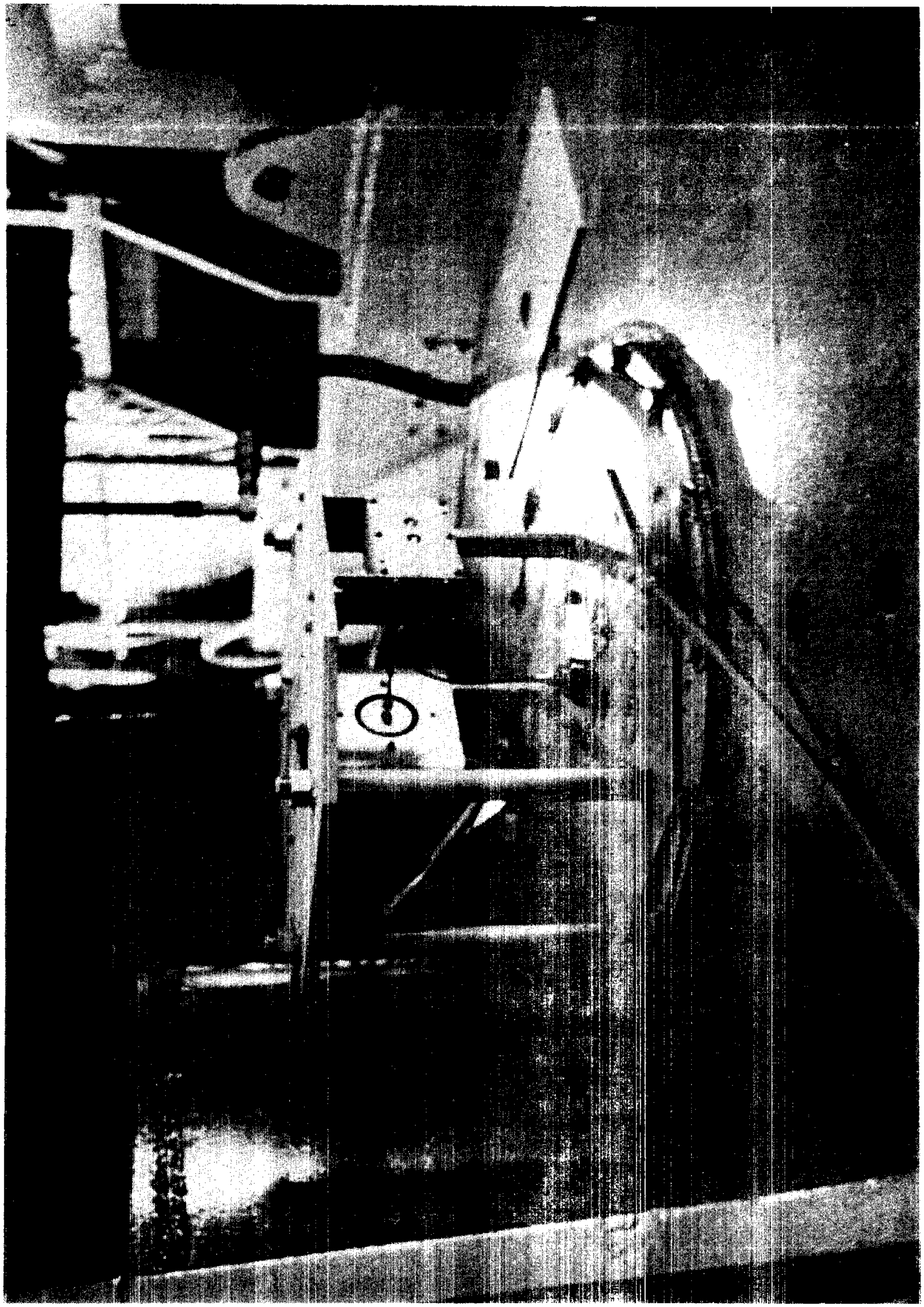

Figure 1-3

DIGS BLOCK DIAGRAM

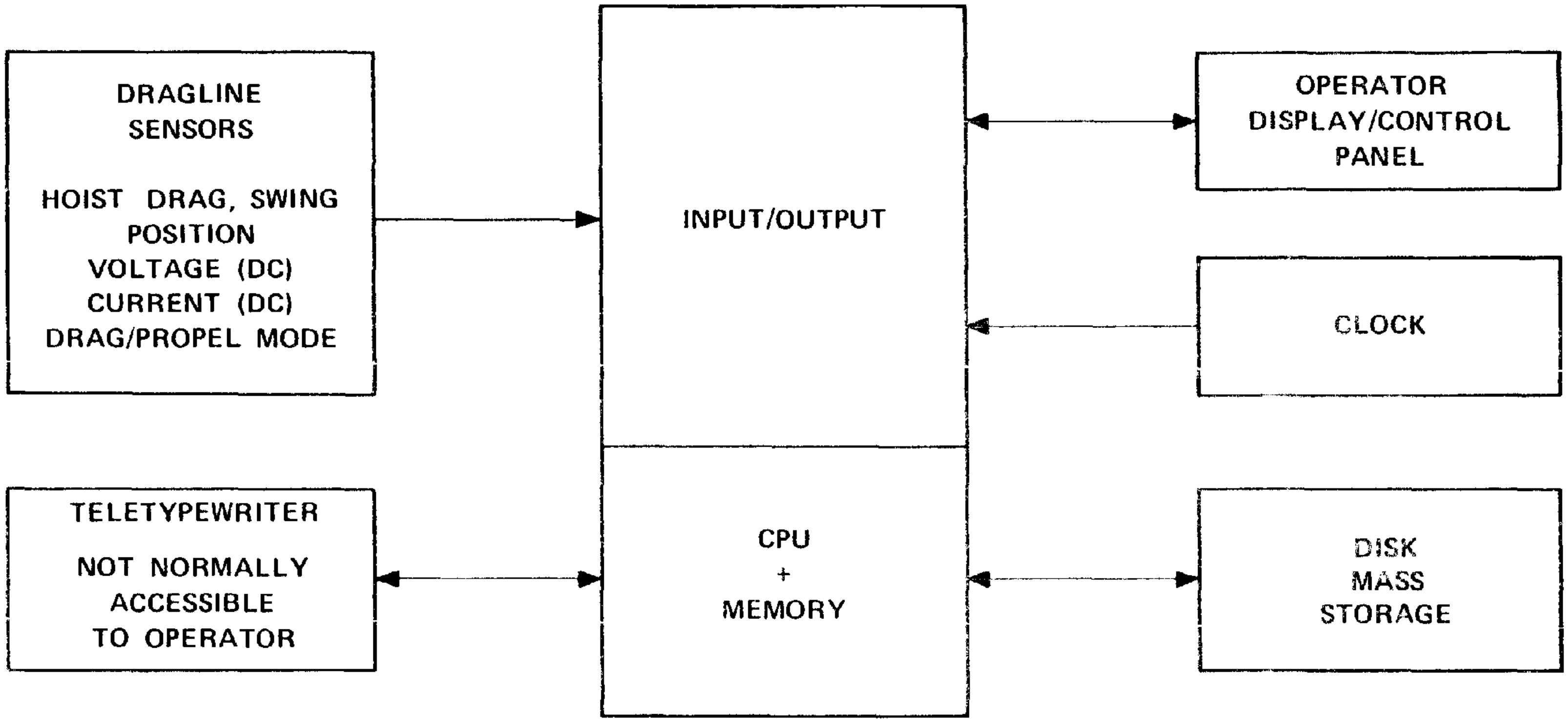

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Figure 1-4. Block Diagram

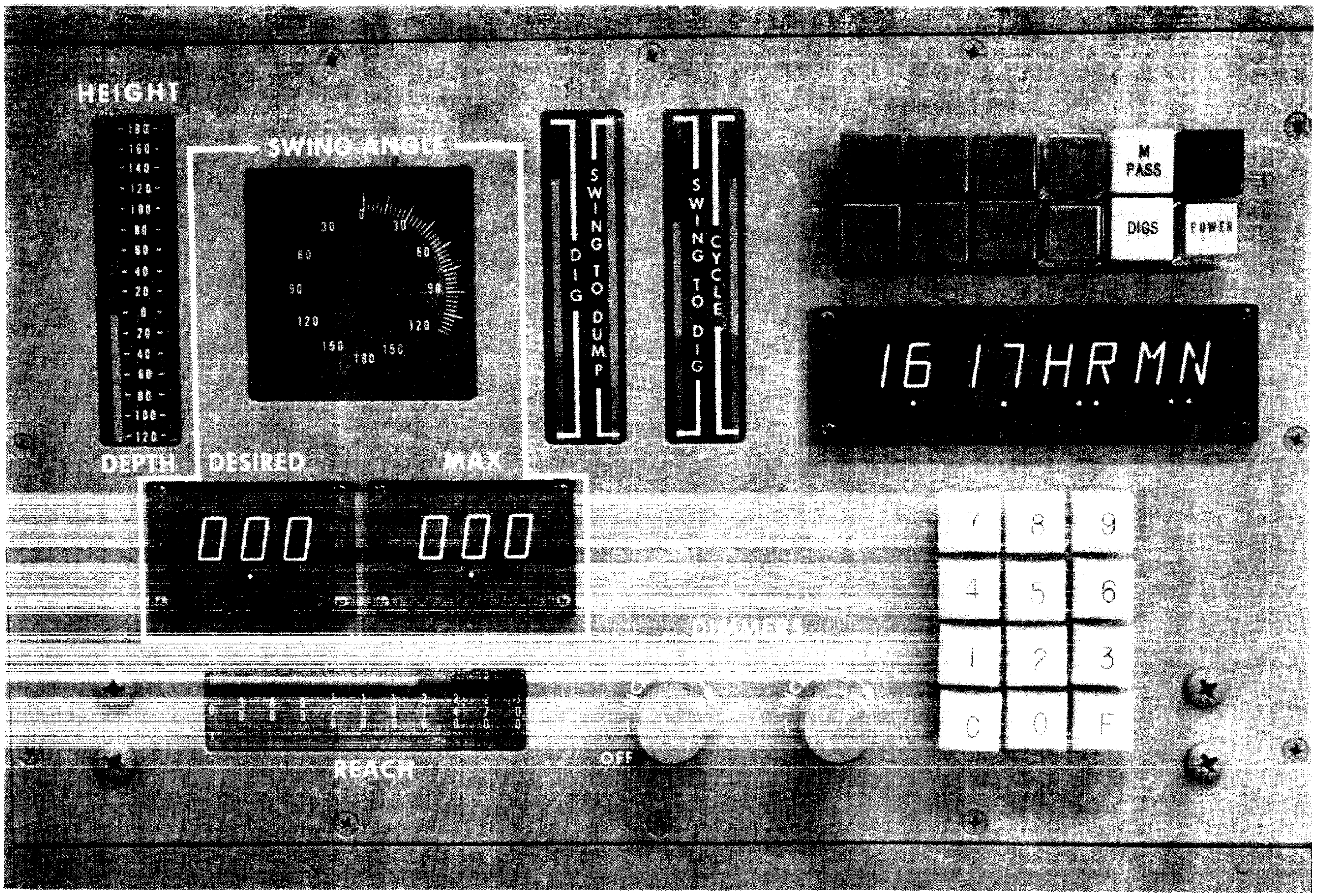
HEIGHT
DEPTH
SWING ANGLE
DESIRED
MAX
SWING TO DUMP
DIG
SWING TO DIG
CYCLE
M PASS
DIGS
POWER
16 17HRMN
DIMMERS
OFF
REACH

Figure 1-5

A figure of merit for last cycle performance is shown in the bar graphs labeled "DIG", "SWING TO DUMP", "SWING TO DIG" and total "CYCLE". Lighted push-button switches allow the operator to enter down time, operator code, job code, perform self diagnostic (DIGS) and select display codes. In addition, alert indicators for multipass operation, tightlining and excessive power usage are included in this cluster. The keyboard is used to enter appropriate codes for that function selected by the pushbutton switches or to call up specific displays when the display pushbutton is depressed. These groups of information are available:

(1) Totals, such as number of cycles, yardages, and strip rates.

(2) Averages, such as yardage, load distance, load time, cycle time and energy usage.

(3) Last cycle information, such as yardage, load time, cycle time and energy.

Report Generation: The feedback data collected from the dragline sensors and the operators control panel are additionally processed and stored in a disk mass storage device. Approximately two weeks of data may be stored on a dual density flexible disk and retained in that form as a permanent record. This data can also be accessed at any time and for any period of operating time within the two week period by specified (usually management) personnel. This is accomplished by requesting the type of report desired on the tele-typewriter. Figures 1-6, 1-7 and 1-8 are examples of a Chronological Report, Operator Summary Report and Total Summary Report. Other optimal reports include Dragline Operating Summary, Current Rope and Chain, Post Rope and Chain and Power Use Reports.

PORTION OF CHRONOLOGICAL REPORT

OPERATOR # 32 FROM WED 15 MAR-1978 0: 6 TO WED 15-MAR-1978 5:26

	OVRBDN REMOVAL	KEYCUT	BENCH REMOVAL	BENCH FILL	CLEAN COAL	RE-HANDLE
MINUTES	55.	0.	0.	0.	0.	172.
CYCLES	44.	0.	0.	0.	0.	142.
YARDS	5169.	0.	0.	0.	0.	12802.
KWH	1125.	0.	0.	0.	0.	3435.
AV SW ANG	94.	0.	0.	0.	0.	118.
XTRA PASS	0.	0.	0.	0.	0.	13.
TL STAT	0.	0.	0.	0.	0.	1.
TL DYN	0.	0.	0.	0.	0.	0.
CB YARDS	603.	0.	0.	0.	0.	199.
STRIP RATE	5642.	0.	0.	0.	0.	4461.

```
   LONG CYCLE                                0:10 -  0:13    3 MIN   73 KWH
   LONG CYCLE                                0:15 -  0:19    4 MIN   71 KWH
14 MOVE UP AND LEVELING                      1: 4 -  1: 5    1 MIN    0 KWH
14 MOVE UP AND LEVELING                      1: 5 -  1: 9    4 MIN    2 KWH
MOVED     3 STEPS, AT    217 DEGREES, IN     3 MIN
         MOVE COMPLETED AT   1:11
MOVED     3 STEPS, AT    219 DEGREES, IN     3 MIN
         MOVE COMPLETED AT   2: 8
 6 OIL AND GREASE MACHINE                    2:58 -  3:11   13 MIN    3 KWH
14 MOVE UP AND LEVELING                      3:16 -  3:19    3 MIN    1 KWH
14 MOVE UP AND LEVELING                      3:21 -  3:22    1 MIN    0 KWH
14 MOVE UP AND LEVELING                      3:23 -  3:26    3 MIN    0 KWH
14 MOVE UP AND LEVELING                      3:28 -  3:33    5 MIN    5 KWH
MOVED     5 STEPS, AT    280 DEGREES, IN     4 MIN
MOVED    20 STEPS, AT    290 DEGREES, IN    17 MIN
         MOVE COMPLETED AT   3:55
14 MOVE UP AND LEVELING                      3:57 -  3:59    2 MIN    0 KWH
   LONG CYCLE                                4: 2 -  4: 6    4 MIN   75 KWH
14 MOVE UP AND LEVELING                      4: 6 -  4: 8    2 MIN   17 KWH
14 MOVE UP AND LEVELING                      4:11 -  4:19    8 MIN    2 KWH
MOVED     8 STEPS, AT    268 DEGREES, IN     7 MIN
         MOVE COMPLETED AT   4:26
```

OPERATOR # 55 FROM WED 15-MAR-1978 5:26 TO WED 15-MAR-1978 6:30

	OVRBDN REMOVAL	KEYCUT	BENCH REMOVAL	BENCH FILL	CLEAN COAL	RE-HANDLE
MINUTES	65.	0.	0.	0.	0.	0.
CYCLES	45.	0.	0.	0.	0.	0.
YARDS	5383.	0.	0.	0.	0.	0.
KWH	1208.	0.	0.	0.	0.	0.
AV SW ANG	131.	0.	0.	0.	0.	0.
XTRA PASS	0.	0.	0.	0.	0.	0.
TL STAT	3.	0.	0.	0.	0.	0.
TL DYN	0.	0.	0.	0.	0.	0.
CB YARDS	529.	0.	0.	0.	0.	0.
STRIP RATE	4770.	0.	0.	0.	0.	0.

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Figure 1-6. Chronological Report

PORTION OF OPERATOR SUMMARY REPORT

	OVRBRDN REMOVAL	KEYCUT	BENCH REMOVAL	BENCH FILL	CLEAN COAL	RE-HANDLE
OPERATOR # 55 FROM MON 13-MAR-1978 3:11 TO THU 16-MAR-1978 4:54						
MINUTES	114.	0.	0.	0.	0.	60.
CYCLES	75.	0.	0.	0.	0.	49.
YARDS	8824.	0.	0.	0.	0.	5430.
KWH	2016.	0.	0.	0.	0.	1005.
AV SW ANG	118.	0.	0.	0.	0.	60.
XTRA PASS	3.	0.	0.	0.	0.	1.
TL STAT	4.	0.	0.	0.	0.	2.
TL DYN	0.	0.	0.	0.	0.	0.
CB YARDS	615.	0.	0.	0.	0.	0.
STRIP RATE	4625.	0.	0.	0.	0.	5450.

```
MON 13-MAR-1978
 6 OIL AND GREASE MACHINE          3:11 -  3:12    1 MIN    2 KWH
 6 OIL AND GREASE MACHINE          3:37 -  3:40    3 MIN    2 KWH
14 MOVE UP AND LEVELING            3:43 -  4:11   28 MIN    9 KWH
         MOVE COMPLETED AT  4:13
         MOVE COMPLETED AT  4:15
MOVED    4 STEPS, AT   131 DEGREES, IN   15 MIN
MOVED   11 STEPS, AT   121 DEGREES, IN   11 MIN
         MOVE COMPLETED AT  4:41

TUE 14-MAR-1978

WED 15-MAR-1978

THU 16-MAR-1978
 6 OIL AND GREASE MACHINE          3:12 -  3:14    2 MIN    7 KWH
   LONG CYCLE                      3:56 -  4: 0    4 MIN   32 KWH
   LONG CYCLE                      4: 0 -  4: 3    3 MIN   57 KWH
   LONG CYCLE                      4: 5 -  4: 9    4 MIN   49 KWH
   LONG CYCLE                      4: 9 -  4:12    3 MIN   53 KWH
   LONG CYCLE                      4:12 -  4:15    3 MIN   54 KWH
   LONG CYCLE                      4:15 -  4:19    4 MIN   59 KWH
14 MOVE UP AND LEVELING            4:25 -  4:29    4 MIN    0 KWH
14 MOVE UP AND LEVELING            4:40 -  4:42    2 MIN    0 KWH
   LONG CYCLE                      4:43 -  4:46    3 MIN   31 KWH
MOVED    6 STEPS, AT   277 DEGREES, IN    5 MIN
         MOVE COMPLETED AT  4:51
         MOVE COMPLETED AT  4:51
```

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Figure 1-7. Operator's Summary Report

TOTAL SUMMARY REPORT

	OVRBRDN REMOVAL	KEYCUT	BENCH REMOVAL	BENCH FILL	CLEAN COAL	RE-HANDLE

DRAGLINE OPERATIONS FROM MON 13-MAR-1978 3:11 TO MON 20-MAR-1978 7:21

	OVRBRDN REMOVAL	KEYCUT	BENCH REMOVAL	BENCH FILL	CLEAN COAL	RE-HANDLE
MINUTES	3643.	34.	467.	0.	113.	2621.
CYCLES	3380.	27.	521.	0.	96.	2764.
YARDS	323919.	2225.	43853.	0.	8511.	223681.
KWH	84712.	696.	11109.	0.	2592.	55741.
AV SW ANG	99.	97.	85.	0.	95.	80.
XTRA PASS	89.	0.	6.	0.	3.	115.
TL STAT	8.	0.	4.	0.	0.	7.
TL DYN	0.	0.	0.	0.	0.	0.
CB YARDS	41595.	202.	698.	0.	705.	0.
STRIP RATE	5334.	3946.	5633.	0.	4518.	5121.

--OPERATIONAL DELAYS--		
CHANGE POWER CABLE	17. MIN	12. KWH
OIL AND GREASE MACHINE	654. MIN	279. KWH
TRAFFIC PASSING MACHINE	2. MIN	4. KWH
MOVE UP AND LEVELING	1697. MIN	132. KWH
SHOOTING HIGHWALL	2. MIN	8. KWH
LOADING SUPPLIES	21. MIN	83. KWH
NOT REQUIRED	1. MIN	7. KWH
--BREAKDOWN REPAIRS--		
HOIST	10. MIN	4. KWH
SWING	15. MIN	-5. KWH
BUCKET, CHAINS, PINS, TEETH	26. MIN	21. KWH
ALL OTHER ELECTRICAL	121. MIN	56. KWH
--UNCONTROLLABLE DELAYS--		
POWER OUTAGE	6. MIN	43. KWH
PREVENTIVE MAINTENANCE	573. MIN	1. KWH
--OTHER DELAYS--		
INVALID CODE	21. MIN	1. KWH
LONG CYCLES	331. MIN	2235. KWH
PROPEL MODE	653. MIN	616. STEPS

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Figure 1-8. Total Summary Report

Most DIGS users agree that reports summarizing production are desirable at least on a daily basis and that other reports such as maintenance activity reports should be available on demand. This would require daily visits to the dragline to acquire the desired routine data and occasional additional visits to obtain specific data as its need arises. Aside from the inconvenience to the authorized system operator, his travel time and the time spent waiting for generation and printout of the reports could be better applied to his primary function. Although the data collection means provided by the DIGS is significantly more efficient than that by conventional means the printing of the DIGS reports is often postponed and sometimes ignored due to other pressing matters of mine operation. The role of the data link system, as applied to DIGS, is to provide the means to collect current dragline performance and maintenance data when it is desired with minimum inconvenience and time loss.

Installation Site. The choice of an installation and evaluation site for the Dragline Data Link System was limited to users of DIGS. This criteria, in itself, lends credence to the site selection since it implies an active mine operation with progressive management interested in improving productivity through better data communication. Old Ben Coal Co. through their Regional Office at Oakland City, Indiana agreed to participate in this program. A DIGS was in use on a Bucyrus Erie Model 1370 dragline at their Old Ben No. 2 Mine approximately ten miles north of Oakland City. Their personnel participated in the installation of the system on the dragline and in the engineering area at the mine office and were the prime equipment operators during the evaluation phase.

Old Ben Mine No. 2 Mine provided most of the objectives used in the system design of the data link system. They operate under a variety of weather conditions and provide a transmission path over irregular terrain with the line of sight broken by spoil peaks. The antenna to antenna distance varied from about 1 to 1.3 miles, however, and did not allow verification of longer distance transmission.

A radio operation license was applied for and received from the Federal Communications Commission through the Special Industrial Radio Service Association Inc. in the name of the Old Ben Coal Company Inc. A frequency in the high band VHF range was assigned.

2.0 SYSTEM APPROACH

The design of the Data Link System was predicated upon a universal application for data exchange in a mining environment. The model system shown in Figure 2-1 and 2-2 consists of a central base installation at the mine office capable of supporting many remote or mobile data collection sources. Data transfer is initiated from the base installation by entering the remote system address, the data category and the period of time for which the data is desired. The addressed remote system will respond and transmit the required data to the base station. All record print-out routines are resident in the base system such that print-out can be immediately obtained following completion of the data transfer. The system evaluated uses a radio frequency (RF) data link, however, the data format and protocol is compatible with a conventional telephone link. Both half and full duplex transmission modes can be accommodated although a single frequency system was used for the evaluation. Terrain and topography considerations for the RF link are based upon irregular terrain with the line of sight transmission path blocked by "spoil" piles located near the remote system. A figure of 99% probability of reception at any location within a five mile sector radius was made a design goal. Wherever practical, readily available commercial quality equipment consistent with the environmental conditions were utilized.

2.1 Site Selection. Old Ben Coal Company agreed to allow MDEC to install the Data Link at their Old Ben Number 2 Mine near Oakland City, Indiana. They also assisted in its installation and evaluation. Their selection was almost mandatory since they were the sole established user of a production EIGS at the time that site selection was made.

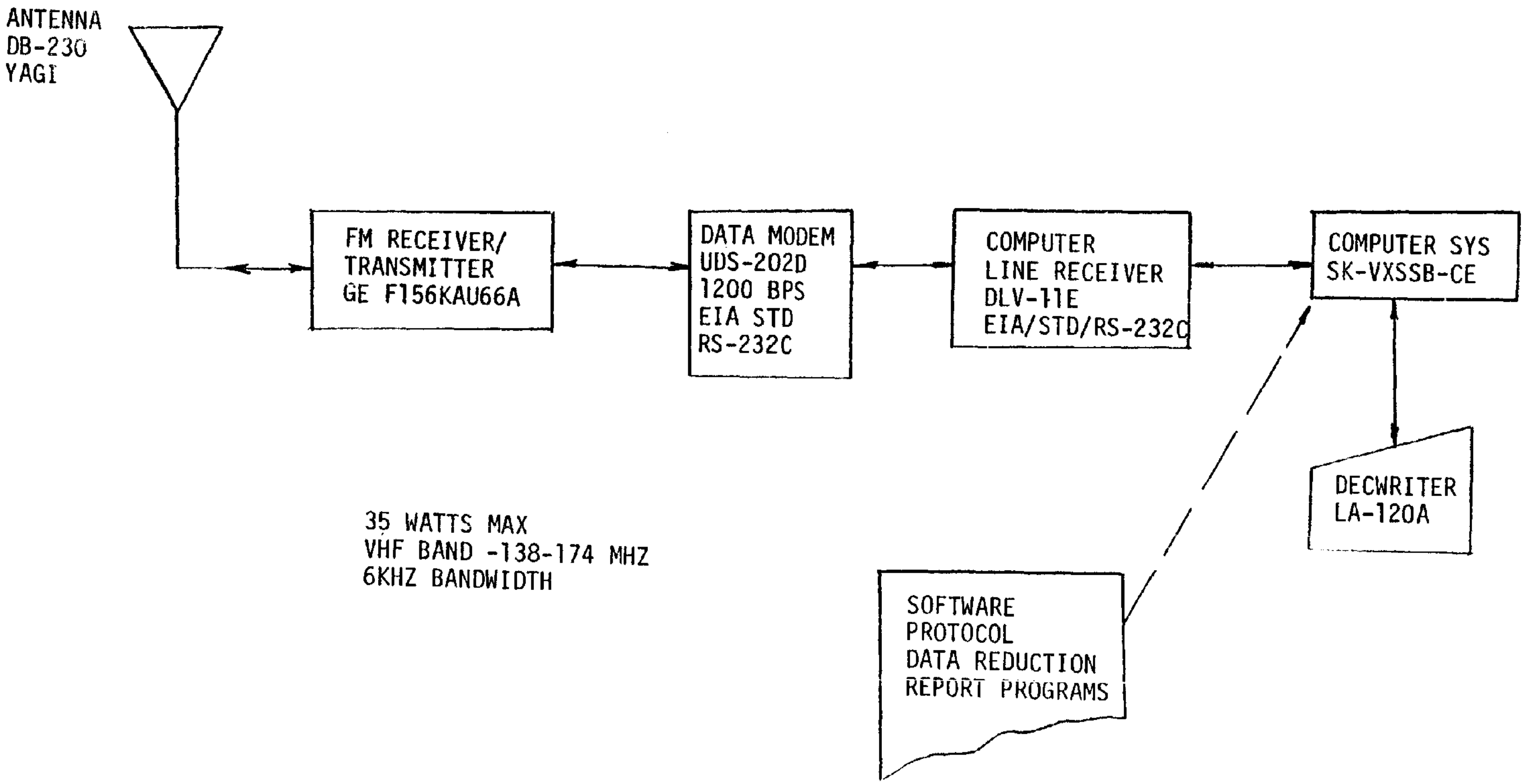


Figure 2-1. Block Diagram, Mine Office Data Link

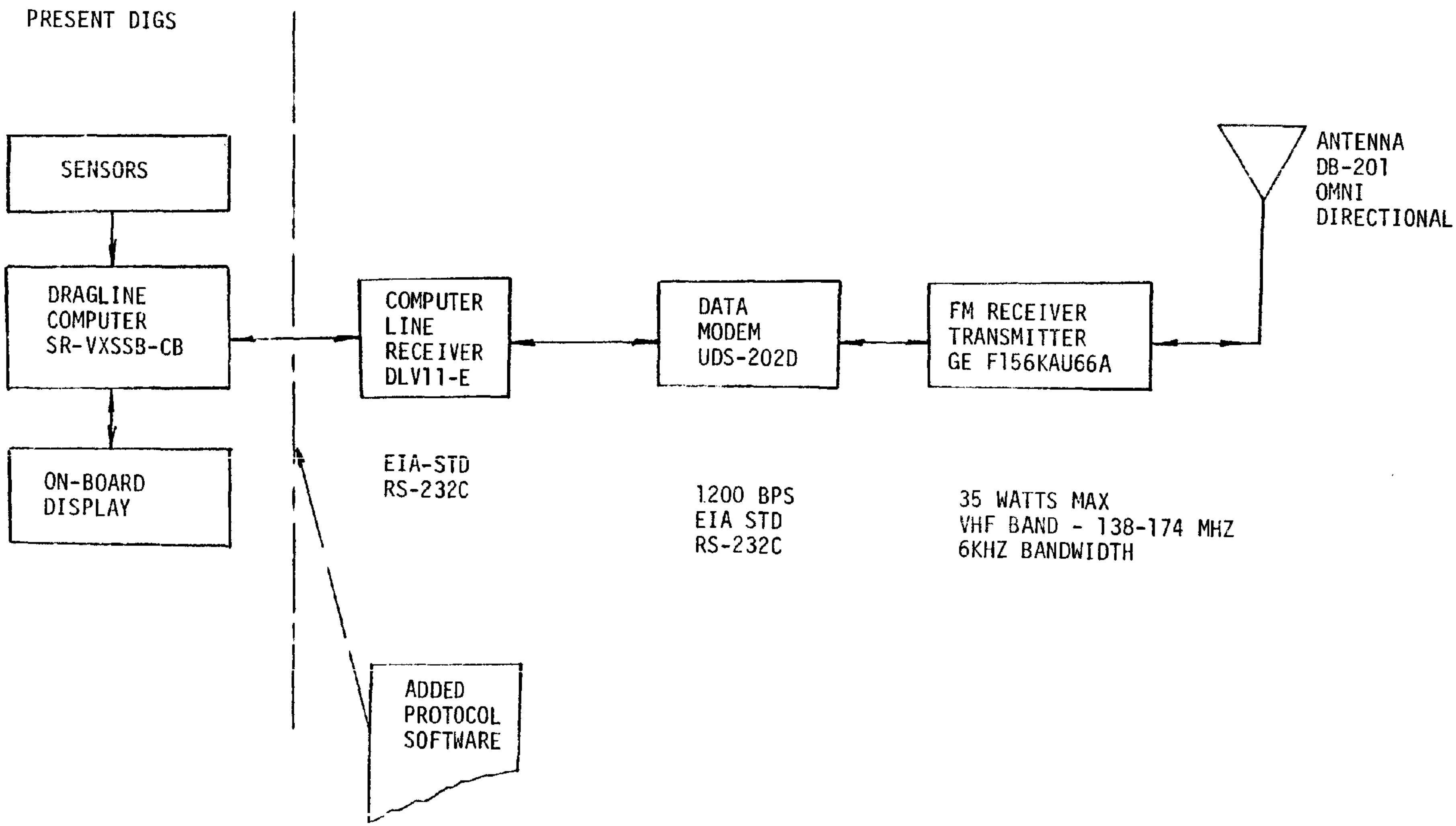


Figure 2-2. Block Diagram, Dragline Data Link

Old Ben Coal Company provided space in their engineering office for installation of the mine office data link and computer system. A 20a 115V service outlet was available to power this equipment. Approximately six square feet of floor space is required for this installation. The equipment is free standing with the radio and modem stacked on the computer. The teletypewriter is positioned adjacent to the computer. Figure 2-3 shows this installation.

The dragline data link system was installed in the DIGS room located in the tub of the BE Model 1370 dragline. This room was previously constructed for and contains the computer and teletypewriter supplied with DIGS. The room is sealed to dust, insulated and temperature controlled between 12°C to 24°C. Vibration/shock levels recorded on two models of draglines indicate levels of less than .5 grms. Although the model 1370 was not specifically tested, its similarity of construction and operation, tends to support similar results.

Installation of the radio and modem is identical to that of the base station, i.e., free standing on the DIGS computer. Power is supplied by conventional 20 amp 115V service outlets. Figures 2-4 and 2-5 depict the dragline data link installation.

The topography at Old Ben Mine Number 2 is typical of midwestern strip mines. The terrain is irregular due to past mining activity. Conventional benching and spoiling techniques are employed. At various dragline positions the antenna to antenna line of sight is interrupted by spoil peaks. Figure 2-6 shows the approximate line of sight path. The base station antenna is located about midway on the mast adjacent to the mine office. The dragline's antenna is located on the "A" frame.

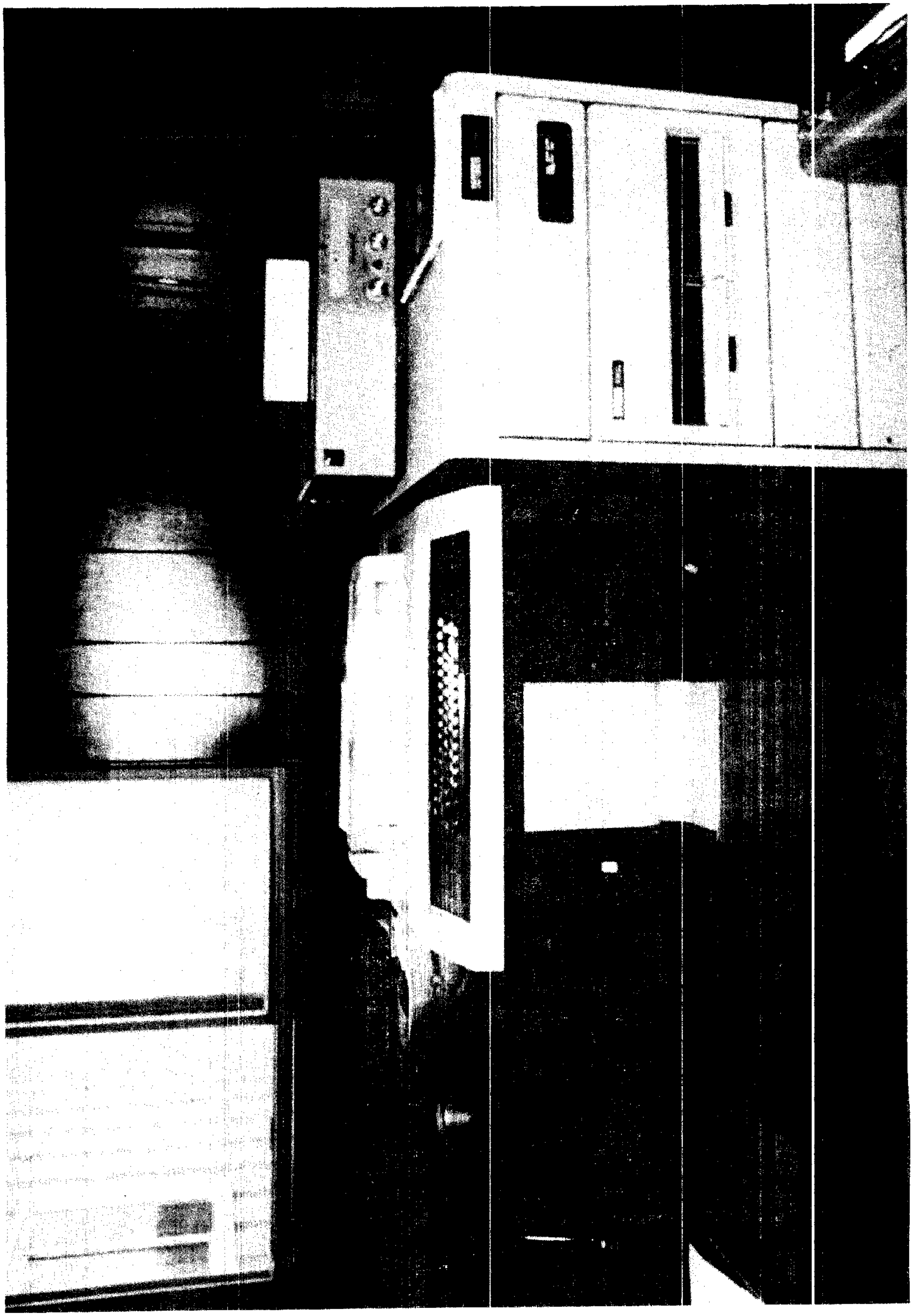


Figure 2-3

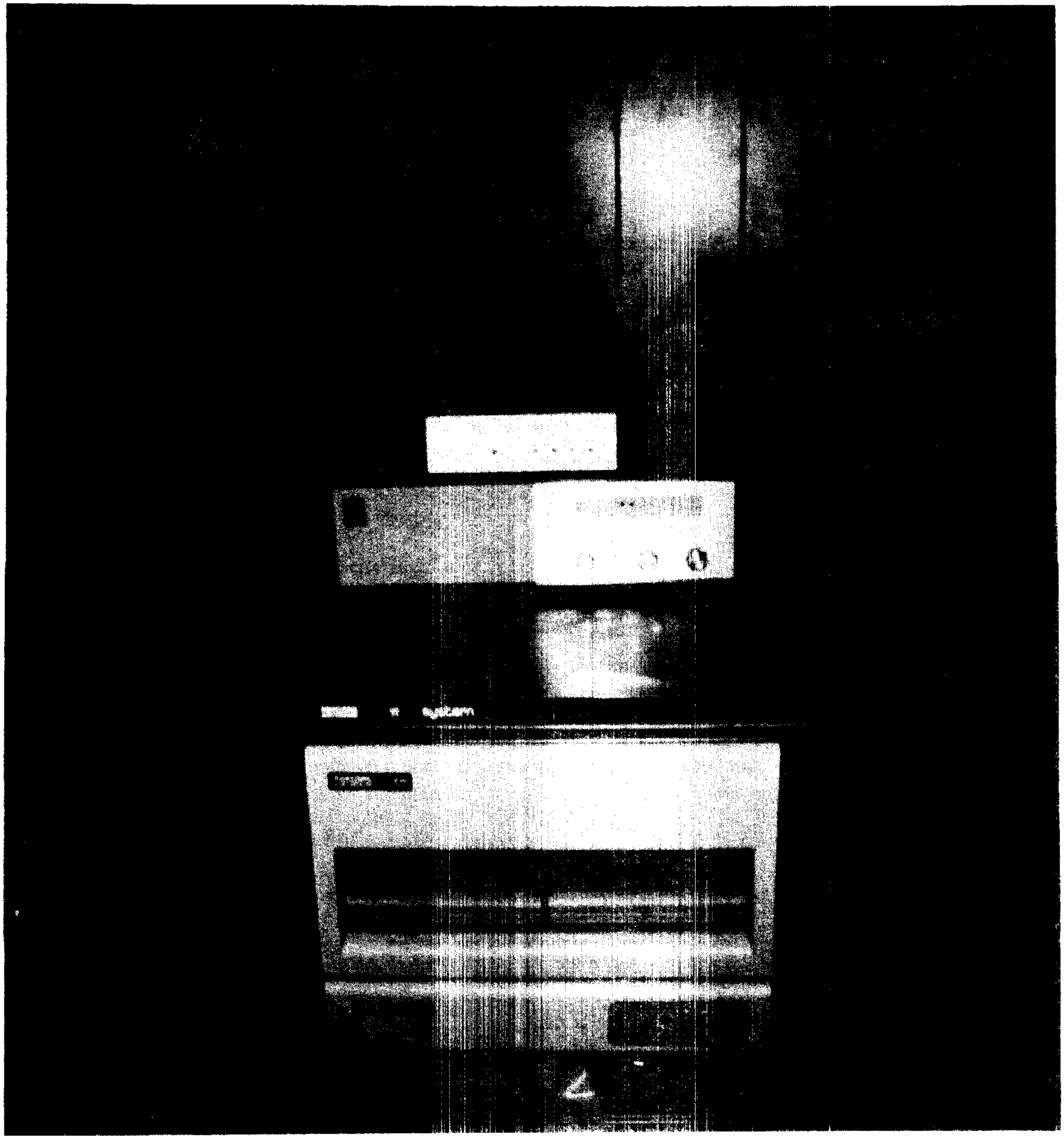


Figure 2-4

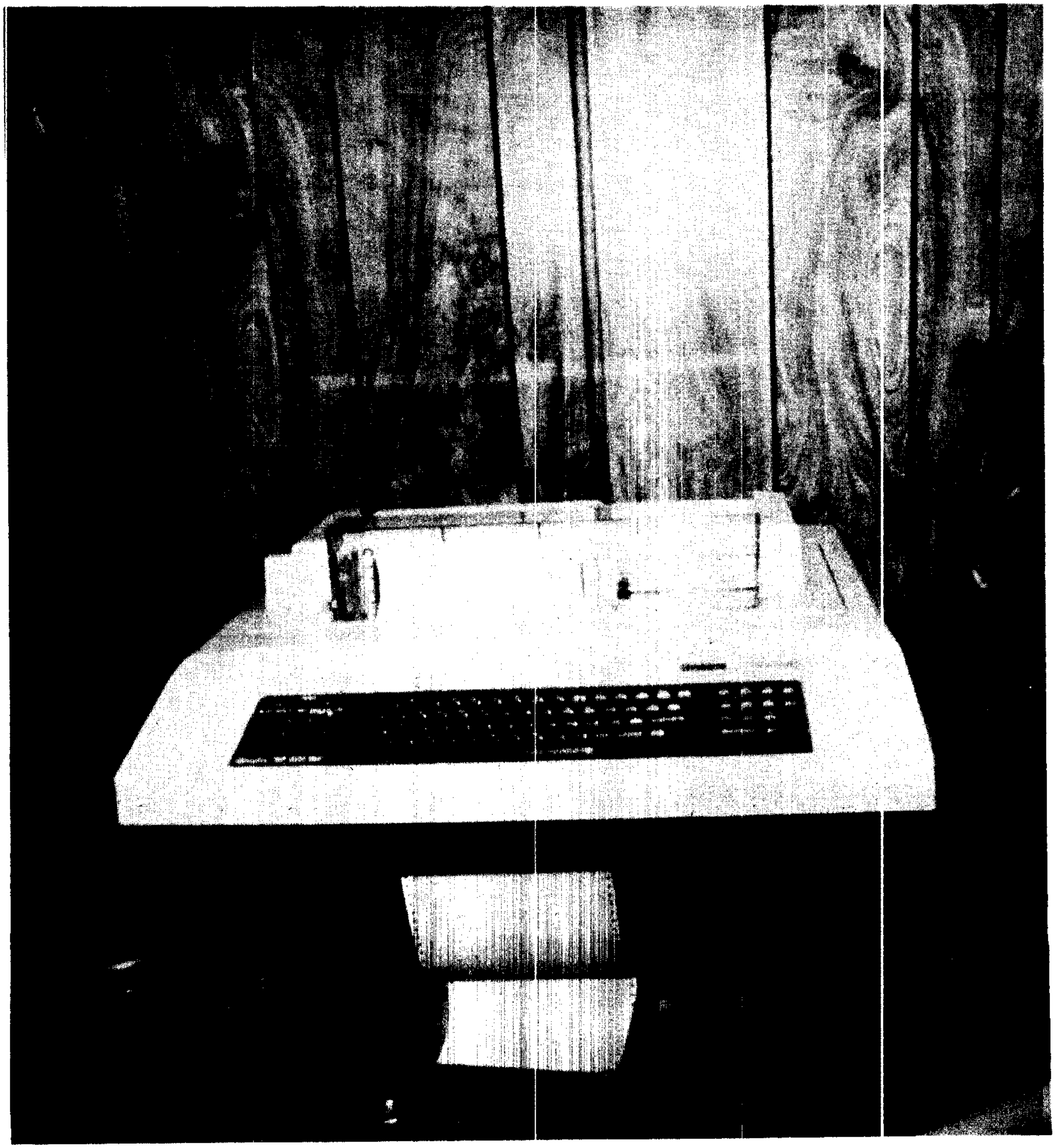


Figure 2-5

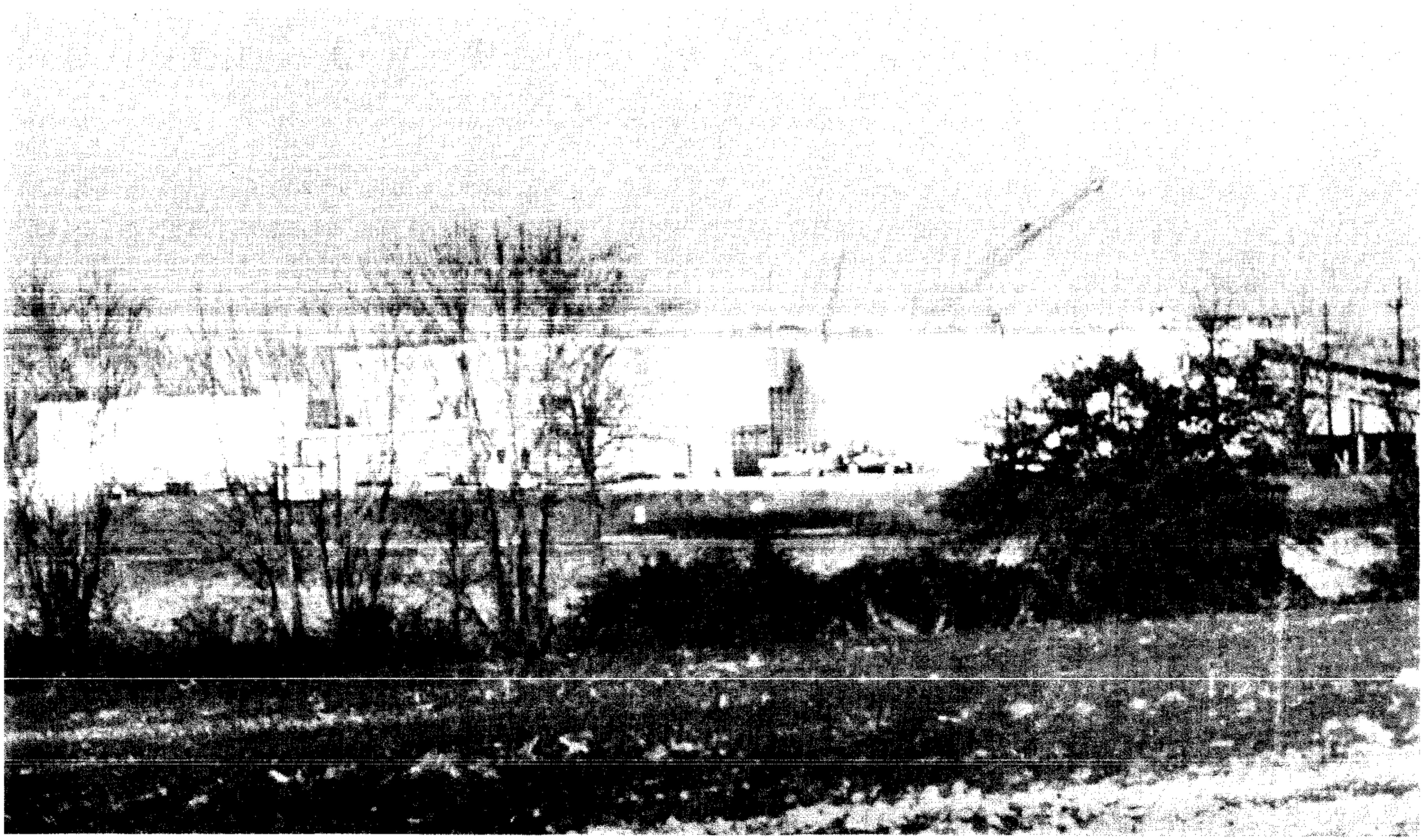


Figure 2-6

2.2 Frequency Selection. In reviewing the Federal Communications Commission rules for frequency assignment it was determined that the mine data link application resides with the Special Industrial Radio Service Group. Reasonable selections available were in bands about 150 MHZ, 170 MHZ and 450 MHZ. Due to path loss considerations the lower frequency groups were desired. Application for frequency recommendation was made to the Special Industrial Radio Service (SIRSA). After coordination with radio users in the Oakland City locale they recommended that 154.46375 MHZ be used. Application was made and a radio license received from the FCC in Nov. 1980, in the name of Old Ben Coal Co. The license provides for 35 watt output, type 6F9 emmission, and 203.5 HZ tone controlled squelch frequency. The base station (mine office) is classed as Operational Fixed and utilizes a directional antenna having 10db gain. Its location is 38°26'10" lattitude and 87°14'42" longitude. The remote station (dragline) is classed as Temporary Operational Fixed. It also provides for 35 watts output, type 6F9 emmission but uses a unity gain omnidirectional antenna.

2.3 Design Considerations.

2.3.1 Transmission Path Loss: The Data Link model used for the loss calculation is as follows:

Receiver Sensitivity (20db quieting)	- 0.5 uv
Base Antenna, Directional 3 element Yaggi gain over dipole	- 7dB
Base Antenna Height	- 50 Ft.
Dragline Antenna, Dipole Gain	- Unity
Dragline Antenna Height (Ground Level)	- 40 Ft.
Distance Between Antennas	- 5 Miles

Total Length Coaxial Cable - 500 Ft.

Frequency - 154.46375 MHZ

The theoretical plane earth received power between dipoles, empirically modified for irregular terrain at above 40 MHZ is given by

$$P_r = 0.345 \left(\frac{h_t h_r}{d^2}\right)^2 \left(\frac{40}{f}\right)^2 P_t \times 10^{-14} \qquad (1)$$

where P_r = Received power - watts

h_t = Transmitting antenna height - feet

h_r = Receiving antenna height - feet

d = Distance between antennas - miles

f = Frequency - MHZ

P_t = Transmitted power - watts

For the model specified and P_t = 1Watt

$P_r = 1.48 \times 10^{-12}$ watts

p_r = 118.3 dBw

The path loss calculation methods per foot note(1) were statistically and empirically derived for 50 percentile locations. The results are adjusted statistically to achieve better coverage by applying the power terrain factor for fixed to vehicular service. From footnote (1)

for 90 percentile locations add -24dB

for 99 percentile locations add -33dB

(1) Radio Propagation Above 40 MHZ Over Irregular Terrain, John J. Egli, Proceedings of IRE Oct 1957, Page 1383.

The received power figure for the 99 percentile location is

P_R = -151.3

Additional loss for coaxial cable at 0.027 db per foot	13.5db
Total Path loss then is	-164.8db
System gain for receiver sensitivity specified at 0.5 microvolts into a 50 ohm load is	-143db
Antenna gain over dipole is	7db
Total system gain	-150db
Total gain deficit	14.8db

The transmitter power required to achieve the required level of reception for the given model is:

$P_r = 10^{1.48} = 30.2$ watts

The antenna separation at evaluation site, however, was a maximum of 1.5 miles giving a net gain for transmitter power of one watt equal to 7.9 dBw.

2.3.2 Bandwidth. The dragline data link system was designed for compatability with conventional unconditioned telephone line transmission. Transmission bit rate established at 1200 bits per second. The data modem provided Frequency Shift Keyed (FSK) modulation with a 1200 HZ mark and 2200 HZ space. For FSK telegraphy, the required bandwidth is given by

Bw = BK + 2D (2)

where Bw = bandwidth lw HZ

B = Band rate - bits per sec.

K = Distortion factor (for nonfading signals = 3)

D = Half the difference between maximum and minimum modulation frequencies.

Bw = 4600 HZ

(2) Reference Data for Radio Engineers, International Telephone and Telegraph Corp. Fourth Edition.

Conventional FM modulation techniques were used for the RF link. The frequency deviation was established at 3.6 KHz giving a modulation index of 3 and 1.7 for the mark and space respectively. Reviewing the side band distribution in conjunction with the Bessel Function of the first kind and using a frequency deviation of 3.6 KHZ, better than 70% of the modulation power is contained within a 5 KHZ bandwidth.

2.3.3 Information Transfer/Modem. The modem and interface used in the Data Link system was chosen to be compatible with EIA Standard RS-232C. The modem is also compatible with Bell WE-202D. This system was selected based upon applicability, availability and relative cost of equipment. Frequency shift keyed modulation is used at a rate of 1200 bits per second. Data is transmitted in groups of 256 bytes. Four additional bytes are used for addressing and transfer validity. The transmission duty cycle is approximately 50%. Data processing and timing delays make up the other 50% of the time. A complete transmission cycle requires about 2 sec. At that rate a full disk of data (480 blocks of 512 bytes each) can be transmitted in about 30 minutes. Reports used at Old Ben Coal Co. range from 80,000 bytes for power to 110 bytes for current rope and chain reports. These reports require about 22 and less than 1 minute of transmission time respectively.

2.4 Equipment Specification. The major equipment items making up the data link system are the computer, line interface, data modem, radio and antenna. Both the mine office and dragline installations are functionally the same. The functional schematic of the system is shown in Figure 2-7. The parts list is shown in Table 2-1.

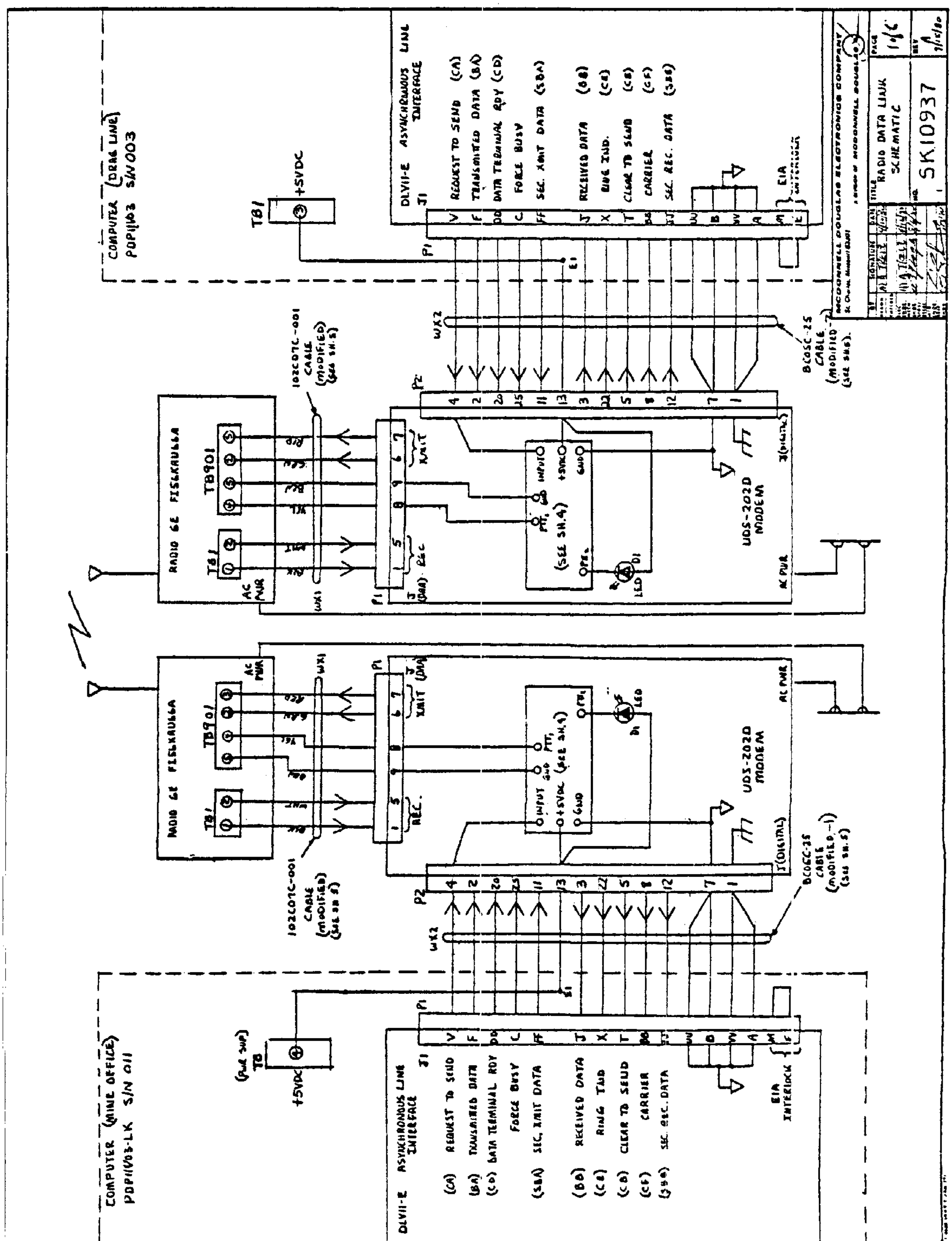


Figure 2-7. Functional Schematic

Qty	Part No.	Name	Manufacturer
2	DLV11-E	Asynchronous Line Interface	Digital Equipment Corp. (DEC)
1	PDP1103-L	Computer W/LA120 DecWriter Fortran/RJ-11/RX02 Disk/ Cables and Installation	Digital Equipment Corp. (DEC)
2	UDS-202D	Data modem and cable	Universal Data Systems (UDS)
2	BCOSC-25	Model Cable	DEC
2	F15GKAUGGA	Transmitter/Receiver	GE
1	DB-230	Antenna, 1/AGI	Decibel Products
1	DB-201	Antenna, Dipole	Decibel Products
500	RG-80	Cable, Coaxial	
2	SK10937	Transmitter Keying Circuit Assy	MDEC

TABLE 2-1. PARTS LIST, RADIO DATA LINK

2.4.1 Computer. The Digital Equipment Corporation Model PDP1103-L Computer System was selected for the data link system. This is the same computer as used on DIGS. It has 56 kilo bytes of memory and utilizes the RX02 dual flexible disk and LA120 DecWriter. FORTRAN/RJ-11 system software is provided. The computer system, shown in Figure 2-4, is packaged in a short cabinet configuration suitable for office environment. Its operating temperature range is 5 to 40°C. The internal configuration of the mine office and dragline computers is shown in Figure 2.8.

2.4.2 Data Modem Interface. The DLV11-B is an asynchronous line interface module that interfaces the PDP 1103L bus to any of several types of serial communications lines. The module receives serial data from a peripheral device, assembles it into parallel data and transfers it to the bus. It accepts data from the bus, converts it into serial data and transmits it to the peripheral device. The DLV11-E offers full modem control and is compatible with EIA Standard RS-232C, Bell WE-202D and other devices. The DLV11-E is a circuit card that is installed directly into the PDP1103-L computer system. Various functional configurations are implemented by jumper on the card. Figure 2-9 shows the configuration used with the data link.

2.4.3 Data Modem. The Universal Data Systems Model 202D is a phase coherent, frequency shift keyed (FSK) data modem designed for asynchronous operation up to 1800 bps. The modem, packaged as a desk top unit, complies with EIA Standard RS-232C and is compatible with existing Bell WE-202D modems. The UDS-202D processes up to 1200 bits per second serial, asynchronous, digital, input data for transmission over unconditioned lines and up to 1800 bits per

MINE OFFICE COMPUTER
PDP-11V03-LK S/N 011

M7270 (KD11-HA) LSI PROCESSOR	
M8044 (MSV11-D) MOS MEMORY	
M8029 (RXV21) RX02 CONTROLLER	
M8043 (DLV11-J) LA120 CONTROLLER	
M8017 (DLV11-E) MODEM CONTROLLER	
M8012 (BDV11) BOOT BOARD	

COMPUTER CARD SLOT ASSIGNMENT

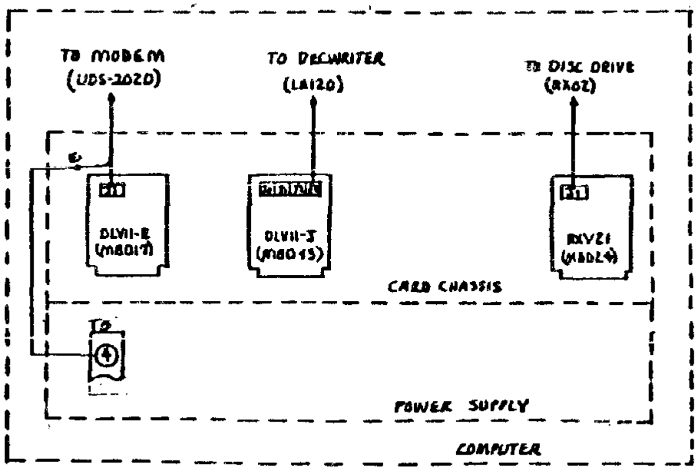
DRAGLINE COMPUTER
PDP-11V03 S/N 003

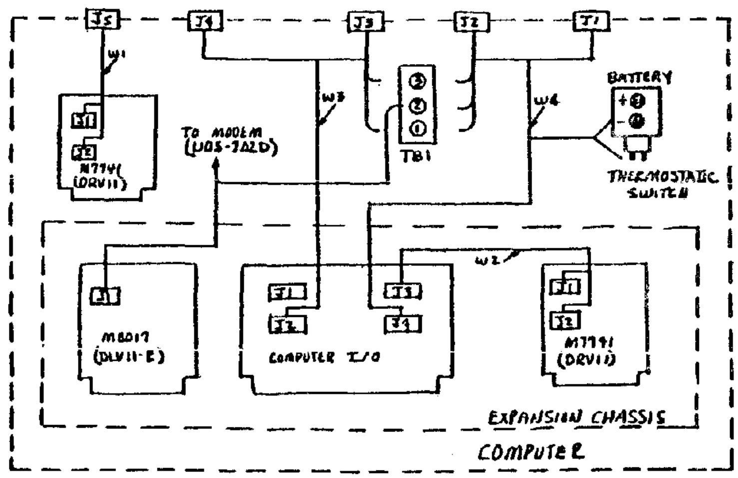
M7264TA LSI-11 COMPUTER	
M7955 YJ 16K MEMORY	
M8044 16K MEMORY	M7940 DLV11 (DECWRITER)
M7400YE EXPANSION CARD	M7941 DRV11

EXPANSION BOX

M9401 EXPANSION CARD	M7941 DRV11
M9400VA BUS TERMINATOR	M7946 FLOPPY DISC INTERFACE
M8017 DLV11-E MODEM CONTROLLER	EMPTY
MDEC COMPUTER INTERFACE BOARD	

COMPUTER CARD SLOT ASSIGNMENT





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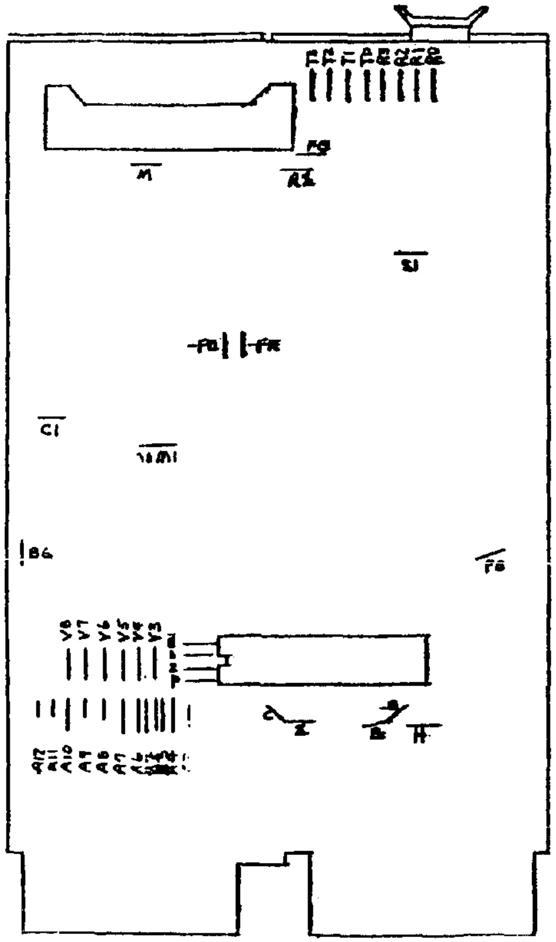
TITLE	RADIO DATA LINK COMPUTER CONFIGURATION
PAGE	6/6
NO.	SK10937
REV	A

Figure 2-8 Computer Configuration



DLV11-E JUMPER LOCATIONS

JUMPER DESIGNATION	JUMPER STATE	FUNCTION IMPLEMENTED
A3	I	JUMPERS A3 THRU A12 IMPLEMENT DEVICE ADDRESS 17661X UNIT #1.
A4	R	
A5	R	
A6	R	
A7	I	
A8	I	
A9	I	
A10	R	
A11	I	
A12	I	
V3	I	JUMPERS V3 THRU V8 IMPLEMENT INTERRUPT VECTOR ADDRESS 170_8
V4	I	
V5	I	
V6	I	
V7	R	
V8	R	
R0	R	MODULE CONFIGURED TO RECEIVE 1200 BAUD. (COMMON SPEED)
R1	R	
R2	R	
R3	I	
T0	R	MODULE CONFIGURED TO TRANSMIT 1200 BAUD. (COMMON SPEED)
T1	R	
T2	R	
T3	I	
B6	I	BREAK GENERATION IS ENABLED
P	R	PARITY BIT IS DISABLED
E	R	PARITY TYPE NOT APPLICABLE WHEN P IS REMOVED
1	R	OPERATION WITH 8 DATA BITS PER CHARACTER
2	R	
PB	R	PROGRAMMABLE BAUD RATE FUNCTION DISABLED.
C	I	COMMON SPEED ENABLED
C1	I	
S	R	SPLIT SPEED DISABLED
S1	R	
H	R	HALT ON FRAMING ERROR DISABLED.
B	R	BOOT ON FRAMING ERROR DISABLED.
-B	I	
-FD	I	"DATA TERMINAL RDY" (CD) SIGNAL NOT FORCED TRUE.
-FR	I	"REQUEST TO SEND" (CA) SIGNAL NOT FORCED TRUE.
RS	I	"REQUEST TO SEND" (CA) SIGNAL IS ENABLED.
FB	R	"FORCE BUSY" SIGNAL IS DISABLED.
M	R	FACTORY USE ONLY.
M1	R	FACTORY USE ONLY.

R = JUMPER REMOVED

I = JUMPER INSTALLED

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BY	SIGNATURE	DATE	TITLE	PAGE
DRAWN	M.A. TRELE	[illegible]	RADIO DATA LINK — DLV11-E P.C. BOARD MOD.	3 of 6
CHECKED	M.A. TRELE	[illegible]	NO. SK10937	REV A 9/15/86

Figure 2-9. Data Modem Interface Configuration

second over conditioned lines. In the dragline data link application the FSK modulating frequencies are level controlled and input directly to the audio input terminals of the transmitter. The modems were modified at MDEC by the addition of a transmitter keying circuit as shown in Figure 2-10. The circuit provides a relay closure in lieu of the microphone press to talk switch upon receipt of a request to send signal from the computer. The data modem cable is modified to add the keying feature as shown in Figure 2-11. Specifications are as follows:

Dimensions - 9 x 2.6 x 10 inches

Weight - 5 lbs.

Operating Temperature -0 to 65°C

Storage Temperature -40 to 70°C

Humidity -95% relative (no condensation)

Power - 115VAC = 10% single phase

47 to 63 HZ, 5 watts maximum

Data Rate 0 - 1200 bps, unconditioned line

0 - 1800 bps, C2 conditioned line

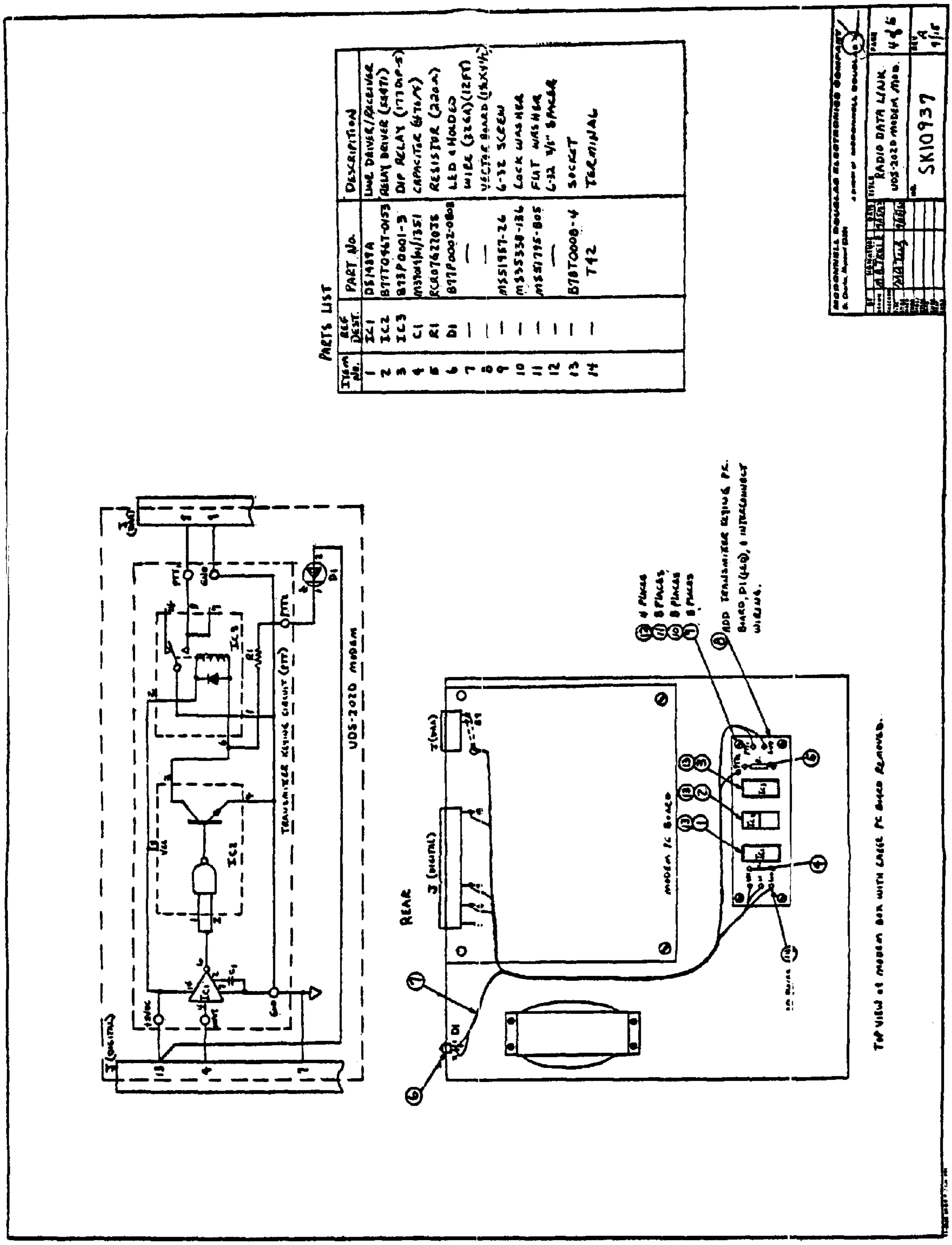
Modulation - Frequency Shift Keyed

Audio frequencies - Mark - 1200Hz

Space - 2200Hz

Soft carrier turn-off - 900 Hz

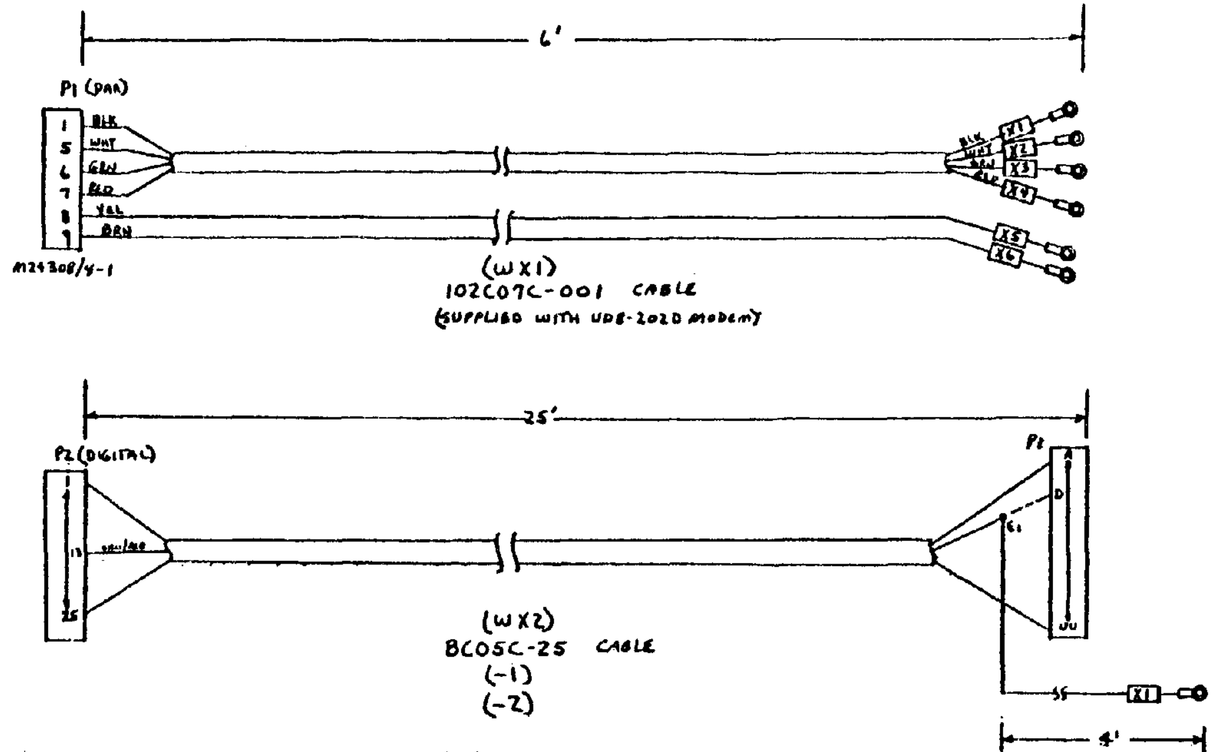
Frequency Stability ± 1%



PARTS LIST

ITEM NO.	REF DEST.	PART NO.	DESCRIPTION
1	IC1	DS1489A	LINE DRIVER/RECEIVER
2	IC2	B77T0947-0153	RELAY DRIVER (SS471)
3	IC3	B73P0001-3	DIP RELAY (17 DIP-5)
4	C1	M39014/01/1351	CAPACITOR (.47 uF)
5	R1	RCR07G220JS	RESISTOR (220 Ω)
6	D1	B77P0002-0808	LED & HOLDER
7	—	—	WIRE (32GA)(12FT)
8	—	—	VECTOR BOARD (1½X4½)
9	—	MS51957-26	6-32 SCREW
10	—	MS35338-136	LOCK WASHER
11	—	MS51795-805	FLAT WASHER
12	—	—	6-32 1/8" SPACER
13	—	B78T0008-4	SOCKET
14	—	T42	TERMINAL

Figure Z-10. Modification to Data Modem



WX1 CABLE MOD

1. REMOVE PRESENT P1 (DAR) CONNECTOR DEC-9P & REPLACE WITH M24308/4-1 CONNECTOR, WIRE TO THE ABOVE DWG.

2. MARKER BAND TABLE I

MARKER BAND	CABLE
X1	TB1-1
X2	TB1-2
X3	TB901-2
X4	TB901-3
X5	TB901-4
X6	TB901-5

3. TIE WRAP THE TWO ADDED WIRES TO THE OUTSIDE OF CABLE.

WX2 CABLE MOD.

1. REMOVE WIRE FROM P1-D. AND CUT OFF THE EXISTING PIN.

2. SPLICE 4' OF WIRE TO E1 AND INSTALL A TERMINAL AT THE OTHER END PER TABLE II.

3. MARKER BAND TABLE II

MARKER BAND	MINE STRIKE COMPUTER PDP11/04 (-1)	ORACLIVE COMPUTER PDP11/03 (-2)
X1	(POWER SUPPLY) TB -4	TB1-3

TRANSMITTER / RECEIVER MODIFICATION.

MODIFY DC REMOTE CONTROL BOARD PER TABLE III

JUMPER	RESULTS
H32 TO H33	REMOVE
H34 TO H35	REMOVE
H33 TO H35	ADD

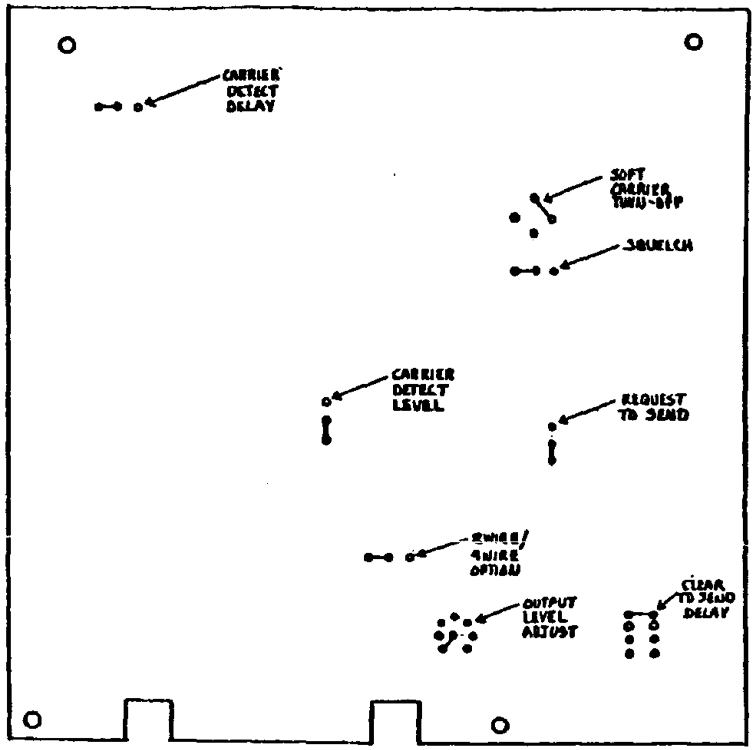
TABLE III

MCDONNELL DOUGLAS ELECTRONICS COMPANY, St. Charles, Missouri 63301, A DIVISION OF MCDONNELL DOUGLAS			
BY / SIGNATURE / DATE: DRAWN M A TRELE; M A TRUB	TITLE: RADIO DATA LINK MODEM CABLE MOD.	PAGE: 5 of 6	
	NO. SK10937	REV A 9/15	

Figure 2-11. Data Modem Cable

Transmitter Output Level (Strap Selectable)	0, -2, -4, -6, -8, -10, -12 dbm
Receiver Input Level	0 to -48 dbm
Carrier Detect Level (Strap Selectable)	0 to -30dbm -12 to -48dbm
Carrier Detect Delay	
Operate	6 ± 1 ms or 23 ± 3 ms
Release	6 ± 1 ms
Line Impedance	600 ohm, balanced
Operating Modes	Half Duplex (2 wire) Full Duplex (4 wire)
Test	Remove and local
Digital Interface	EIA STD RS-232C
Clear to Send Delay (Strap Selectable)	8.5 ± 1 ms, 30 ± 3 ms 60 ± 6 ms, 200 ± 20ms
Receiver and Call Turn Around Squelch	Squelch Receiver during local transmission and for 110 ms after end of transmission
Soft Carrier Turn off	900 HZ tone for 25 ms
Front Panel Switchs	Local/Operate/Remote select Power On

The UDS-202D data modem can be configured for various applications by shorting strap placement. The strap or jumper configuration as used with the data link are shown in Figure 2-12. The data modems are used in the four wire full duplex mode even though the data link system is half duplex. This allows use of convenient local and remote loop back from the computer terminal. Test selection is switchable from the modem front panel as shown in Figure 2-13. The modem timing is setup as follows: The local modem receives a request to send (RTS) commands from the computer. The transmitter is keyed and a mark frequency of 1200 HZ applied. After a 200 millisecond delay the clear to send (CTS) is enabled and data is transmitted. When data transmission is completed the RTS is removed by the computer. The transmitter maintains transmission of a 900HZ signal for an additional 25 milliseconds under modem control. This soft carrier turn-off prevents erratic reception by the receiving modem at the end of transmission. The remote modem receives the mark frequency and after 25 milliseconds sets the carrier detect (CD). Data can now be received. The carrier detect signal is maintained for an additional 23 milliseconds after the data transmission is completed to avoid early termination of data reception. The modem is returned to its neutral state awaiting another request to send from the computer or a carrier detect from the receiver. The receiver input level is set at zero dBm. The carrier detect level is set at -30dBm.



UDS-202D MODEM PC BOARD
(INSTALL JUMPERS AS SHOWN)

JUMPER	FUNCTION IMPLEMENTED
CARRIER DETECT DELAY	CD WIRED FOR 25mSEC DELAY
SOFT CARRIER TURN-OFF	SCTO WIRED FOR 25mSEC DELAY
SQUELCH	SQUELCH WIRED OUT
CARRIER DETECT LEVEL	CDL WIRED FOR -30db LEVEL.
REQUEST TO SEND	RTS WIRED FOR COMPUTER CONTROL.
2WIRE/4WIRE OPTION	MODEM WIRED FOR 4 WIRE (FULL-DUPLEX) OPERATION.
OUTPUT LEVEL ADJUST	OL. WIRED FOR 0 dBm
CLEAR TO SEND DELAY	CTS WIRED FOR 200 mSEC DELAY

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St. Charles, Missouri 63301
A DIVISION OF MCDONNELL DOUGLAS

TITLE: RADIO DATA LINK — UDS-202D MODEM P.C. BOARD MODIFICATION
NO. SK10937
PAGE 2 of 6
REV A

Figure 2-12. Data Modem Strap Configuration

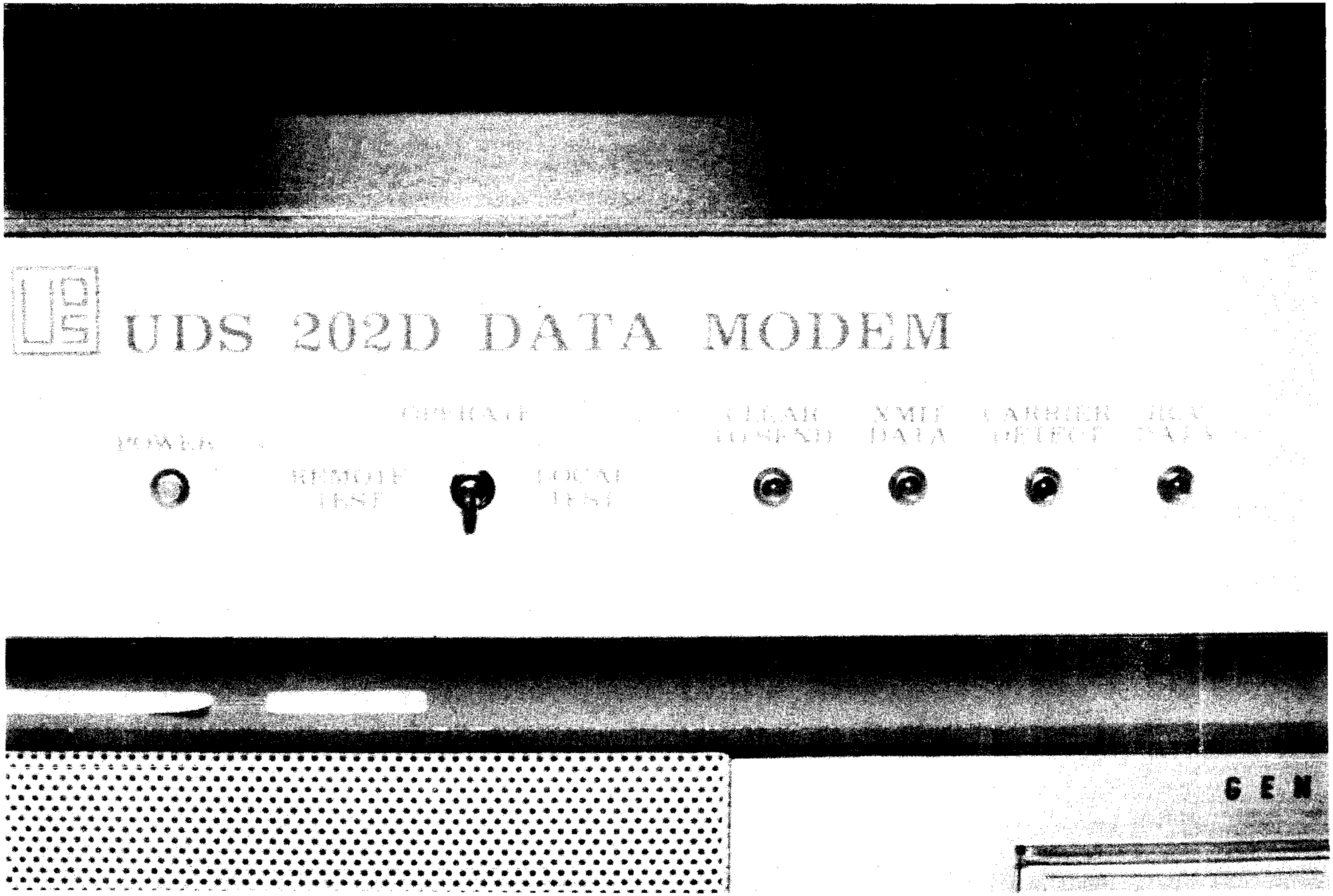


Figure 2-13

2.4.4 Radio. The MASTR Executive II transmitter-receiver manufactured by General Electric was chosen for the dragline data link. Although larger than its mobile radio counterpart it has the advantage of a built-in power supply for 115VAC operation and the proper interface for direct connection to the data modem. The radio, part number F156KAULLA, is a desk top station. Its dimensions are 6 x 20.25 x 13.75 inches and weigh 46 lbs. Power requirements are 121/242 volts, 50/60 HZ at 260 watts transmit, 45 watts receive and 20 watts standby. The operating temperature range is -30 to 60°C. The transmitter specifications are:

RF Power Output	35 Watts (Adjustable from 10 to 35 watts)
Crystal Multiplication Factor	12
Frequency Stability	± .0005%
Spurious and Harmonic Emission at 150.8 to 174 MHt	At least 80 dB below maximum rated power output.
Modulation	Adjustable from 0 to ±5 KHZ Swing
Modulation Sensitivity	75 to 120 millivolts
Audio Frequency Characteristics	Within +1 to -3dB of a 6-dB/octave preemphasis from 300 to 3000 HZ per EIA STD.
Distortion	Less than 5%
Deviation Symmetry	0.5 KHZ maximum
Maximum Freq Spread	
Full Specification	2 MHZ
1 dB Degradation	2.5 MHZ
Duty Cycle	EIA 20 Intermittent
RF Output Impedance	50 Ohms.

Control	Local or Remote
Frequency Transmit	154.46375 MHZ
Option	Channel Guard at 203 HZ
Receiver Specifications	
Sensitivity (-20 dB Quieting)	.50 Microvolts
Selectivity (EIA Two Signal Method)	-90 dB
Spurious Response	-100dB
Intermodulation (EIA)	-85dB
Frequency Stability	± .0005%
Modulation Acceptance	± 7KHZ
Squelch Sensitivity	4 dB SINAD
Maximum Frequency Separation	
Full Specification	1.0 MHZ
3dB Degradation	1.8 MHZ
Frequency Response	Within ± and -8dB of a standard 6 -dB per octave deemphasis curve from 300 to 3000 HZ
RF Input Impedance	50 Ohm
RF Frequency	154.46375 MHZ

The radio panel contains a volume and squelch control and a channel guard defeat switch. The band select switch is disabled since only a single frequency is used. Figure 2-7 shows the radio interconnection to the modem. The microphone usually connected to TB901 is removed and the transmit function of the modem tied in to this interconnect. The press to talk switch is also interconnected to TP901.

The General Electric MASTR Executive II stations contain DC control boards for direct application of remote control. On the data link system this feature has been configured for a four wire telephone line hook-up. Specifications for the remote control board are:

Line Terminating Impedance	600 Ohms
Line Loop Impedance	11000 Ohms maximum
Audio Line Output	-20 to +11 dBm
Frequency Response	±3dB from 300 to 3000 HZ
Distortion	Less than 3%

The radios installed at Old Ben Coal Company were adjusted for 15 watt output. Frequency deviation was set at 3.6KHZ. Audio output to the modem is 5V peak to peak.

2.4.5 Antenna: The antenna installed at the mine office shown in Figure 2-14 is a Model DB-230 Broad Directional Antenna manufactured by Decibel Products Inc. The DB-203 is a three element Yagi having a forward gain of 7db over half wave dipole. Gain is provided over a relatively broad horizontal pattern so that mounting is not critical. It can be mounted to the top or side of the tower. Pertinent specifications are:

Frequency Range	148 to 174 MHZ (Tuned to transmit frequency at installation)
VSWR	1.5 to or less at .7 MHZ Bandwidth
Nominal Impedance	500 Ohms
Maximum Midband Gain (over half wave dipole)	7dB
Maximum Power Input	500 Watts
Horizontal Pattern Beamwidth (half power points)	76°
Front to Back Ratio	22dB
Lighting Protection	Direct Ground

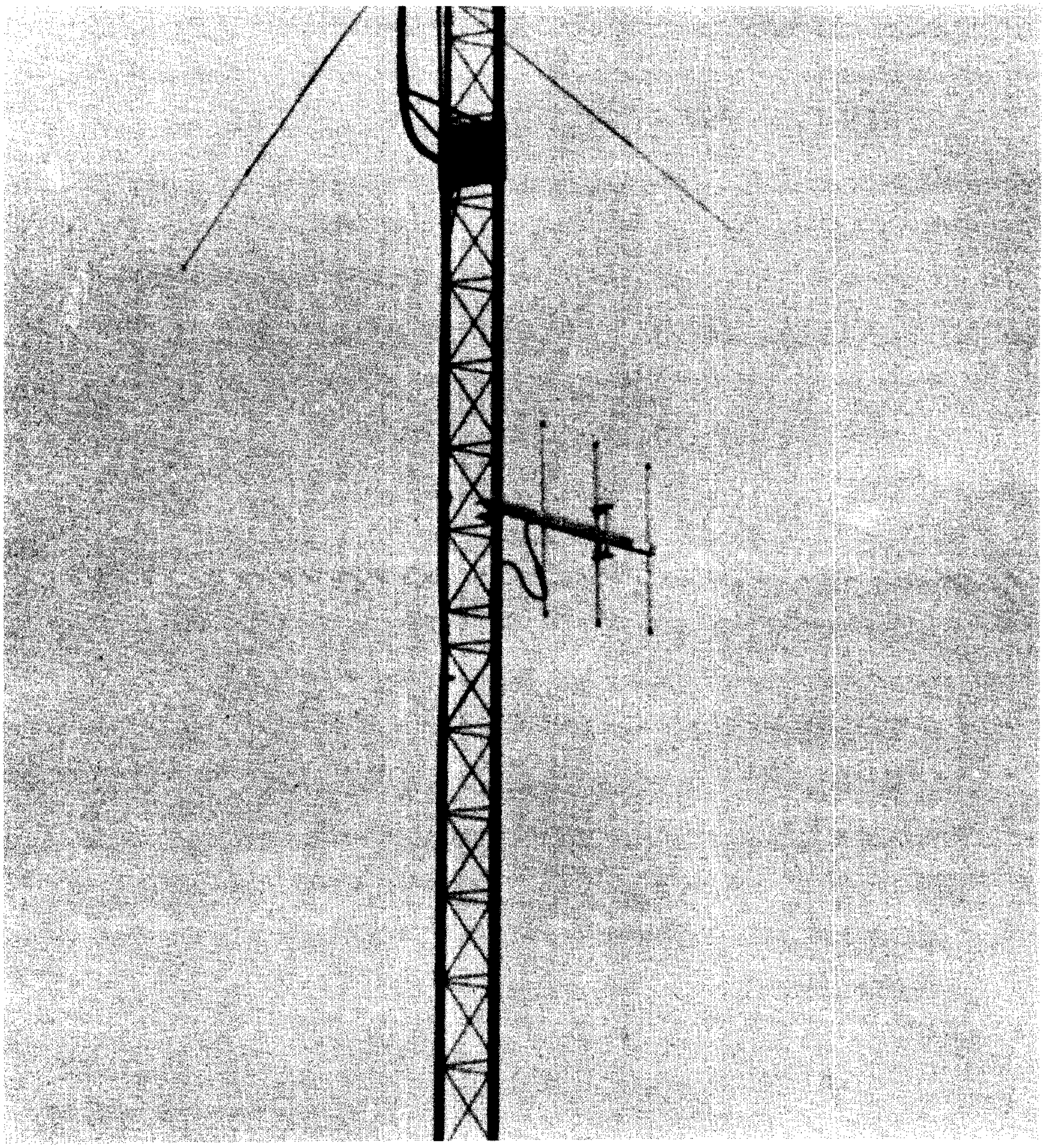


Figure 2-14

Height	6.6 Ft.
Length	6.5 Ft.
Weight W/Clamps, Brackets	27 Lbs.
Wind Rating	
Survival W/O Ice	110 MPH
Survival With 0.5 In. Ice	75 MPH

The dragline mounted antenna is a Decibel Products Inc. Model DB-201. This ground plane antenna is omnidirectional with a unity gain with respect to a half wave dipole. It is designed to mount on top of a tower or pole. Its installation of Old Ben Coal Co. is shown in Figure 2-15 and 2-16. Its specifications are:

Frequency Range	144-174 MHZ
Bandwidth	2% of Frequency
VSWR	1.5 to 1 or less
Nominal Impedance	50 ohms
Gain (over half wave dipole)	Unity
Maximum Power Input	500 Watts
Vertical Pattern Beamwidth	78°
Lighting Protection	Direct Ground
Height (above base plate)	18 Inches
Overall Length	30 Inches
Maximum Width	49 Inches
Net Weight (with Clamps)	10 Lbs.
Wind Rating	
Survival/Without Ice	Over 125 MPH
Survival (1/2 Inch Radial Ice)	Over 125 MPH

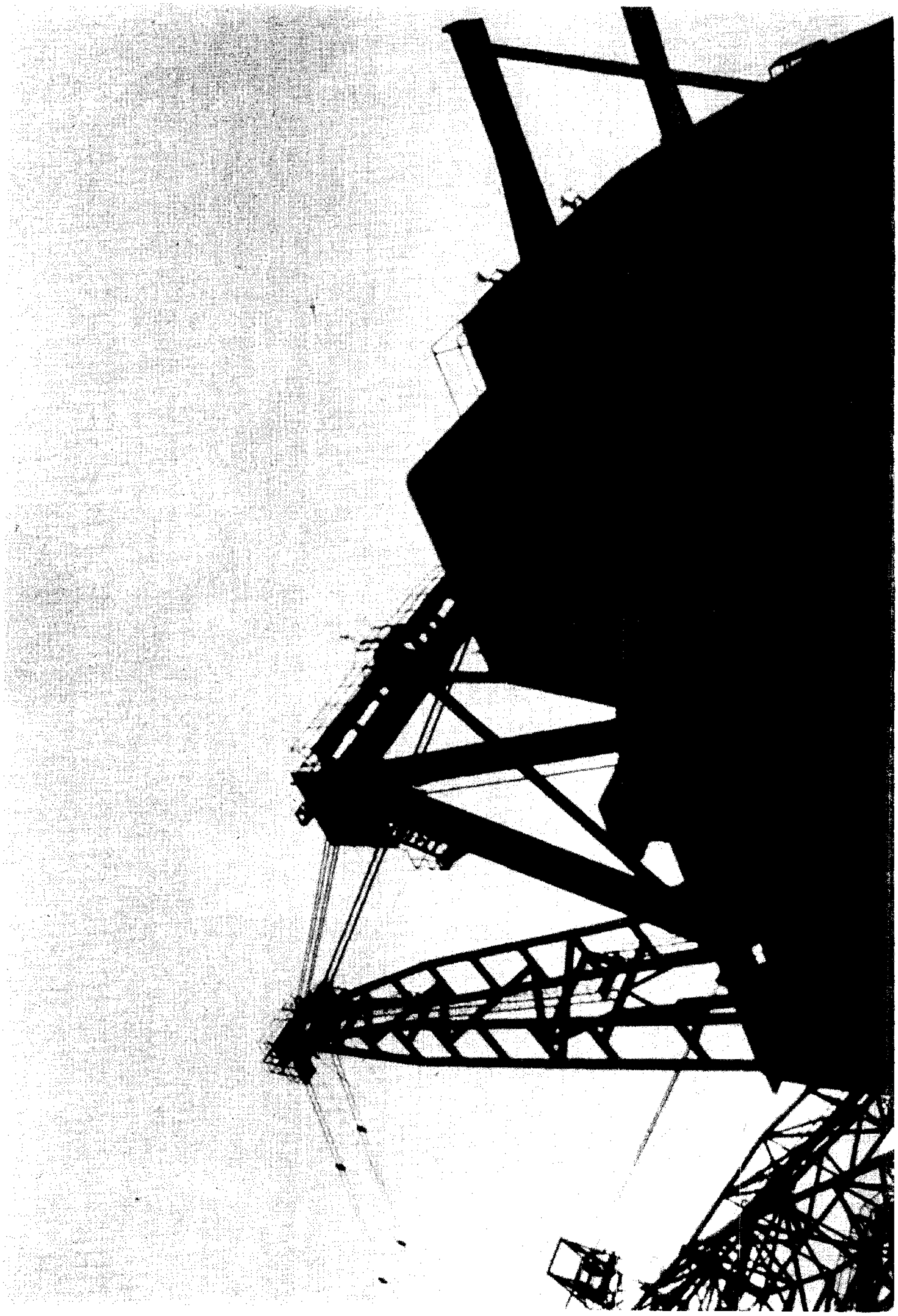


Figure 2-15

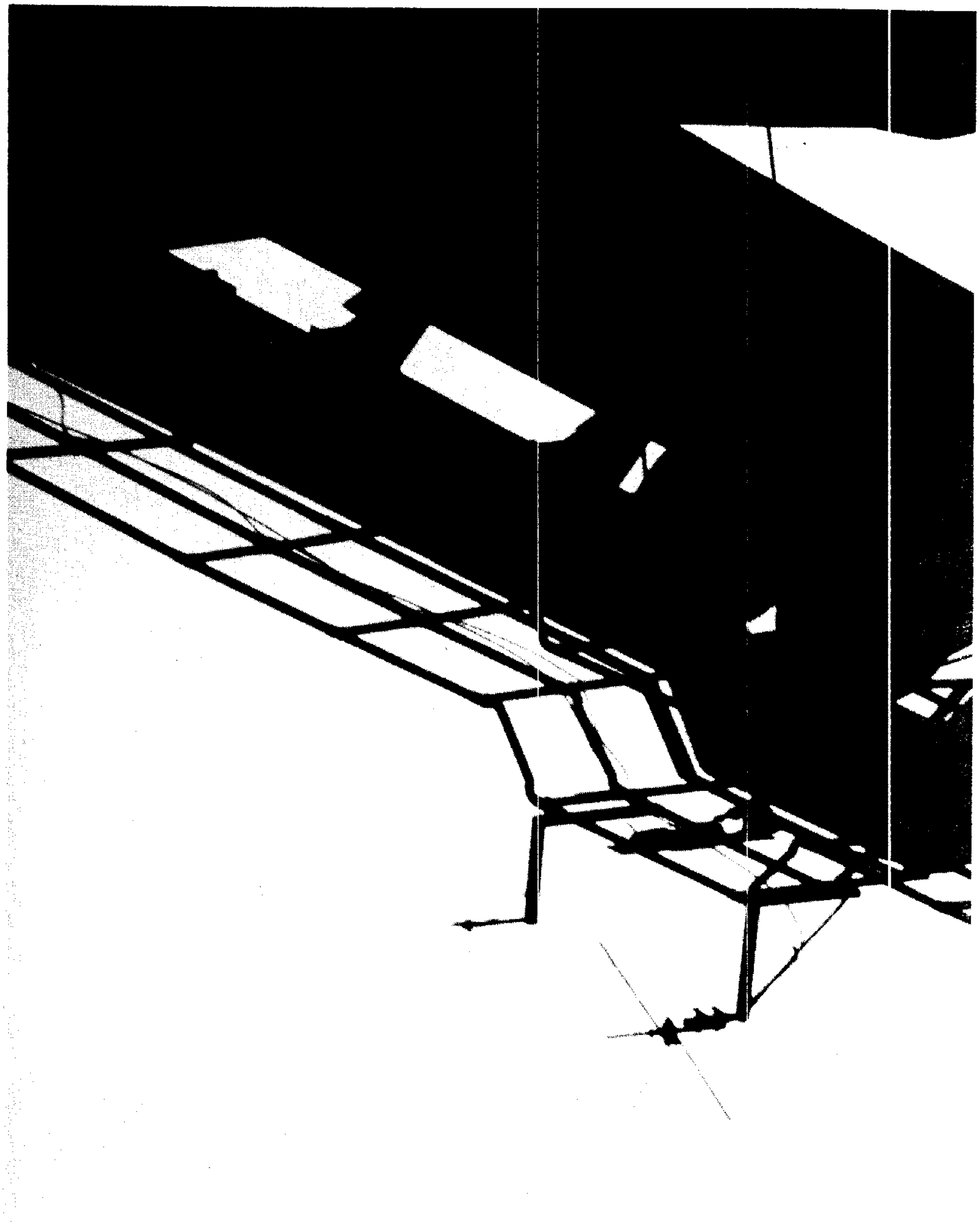


Figure 2-16

The base antenna is mounted to the existing tower at Old Ben Coal Co. Mine No. 2 Mine approximately 50 feet above ground level. It is positioned with its forward lobe pointing north. The dragline antenna is mounted on the "A" frame approximately 90 feet above bench level.

2.5 Computer Program. The data link computer programs, like the DIGS programs, run on the Digital Equipment Corporation Model PDP 11V03 Computer under the RT-11 operating system. File and device names in the following discussion follow the RT-11 convention.

The computer program, BSRPRT, runs in the mine office computer and operates one end of the radio link. It will, on command, initiate transfers of data files from the dragline to the office. BSRPRT also contains the report writing subroutines necessary to produce all the DIGS printouts.

2.5.1 Operating Instructions: To obtain data from the dragline via radio, the radio transceivers and modems must be powered. A diskette containing the file BSRPRT.SAV, plus space for the files which will be obtained from the dragline: CMPRS.DAT, CANDR.DAT, and CRACCU.DAT must be loaded in the disk drive which is assigned to be DK:. One disk in the system should be assigned to be CYC: and should have 125 free blocks to receive KWH.DAT.

Run BSRPRT. The computer will explain the responses needed. It will type:

TO OBTAIN DATA FROM THE DRAGLINE VIA RADIO

TYPE "DIGGING", "ROPES", OR "POWER".

TO PRINT A REPORT, TYPE "RPRT".

TYPE "SEND" FOR TWX MODE.

Before a report can be printed, the appropriate data file will need to be transfered. Type "DIGGING" to transfer CMPRS.DAT, type "ROPES" to transfer CANDR.DAT and CRACCU.DAT, or type "POWER" to transfer KWH.DAT. The computer will send the appropriate signal to the dragline to initiate the transfer. The requested data file will be sent in packets of 256 bytes each. After each packet of data, the office computer will check its validity and either acknowledge its receipt or request retransmission. If all data is received correctly, a message for the file transferred will be printed and the program will be restarted. If no response is received from the dragline within a fixed time interval, the message "TIME OUT. THE DRAGLINE DOESNT ANSWER." will be printed and the program will print the original message.

The procedure for printing a report is the same as used on the dragline DIGS.

If you type "SEND" and a one line message, the message will be printed on the other end of the radio link. Messages can be sent from the office to the dragline or from the dragline to the office. When a message is received, the bell on the typewriter rings 3 times and the message is preceded by the character ">".

2.5.2 Description of Data Link Programs

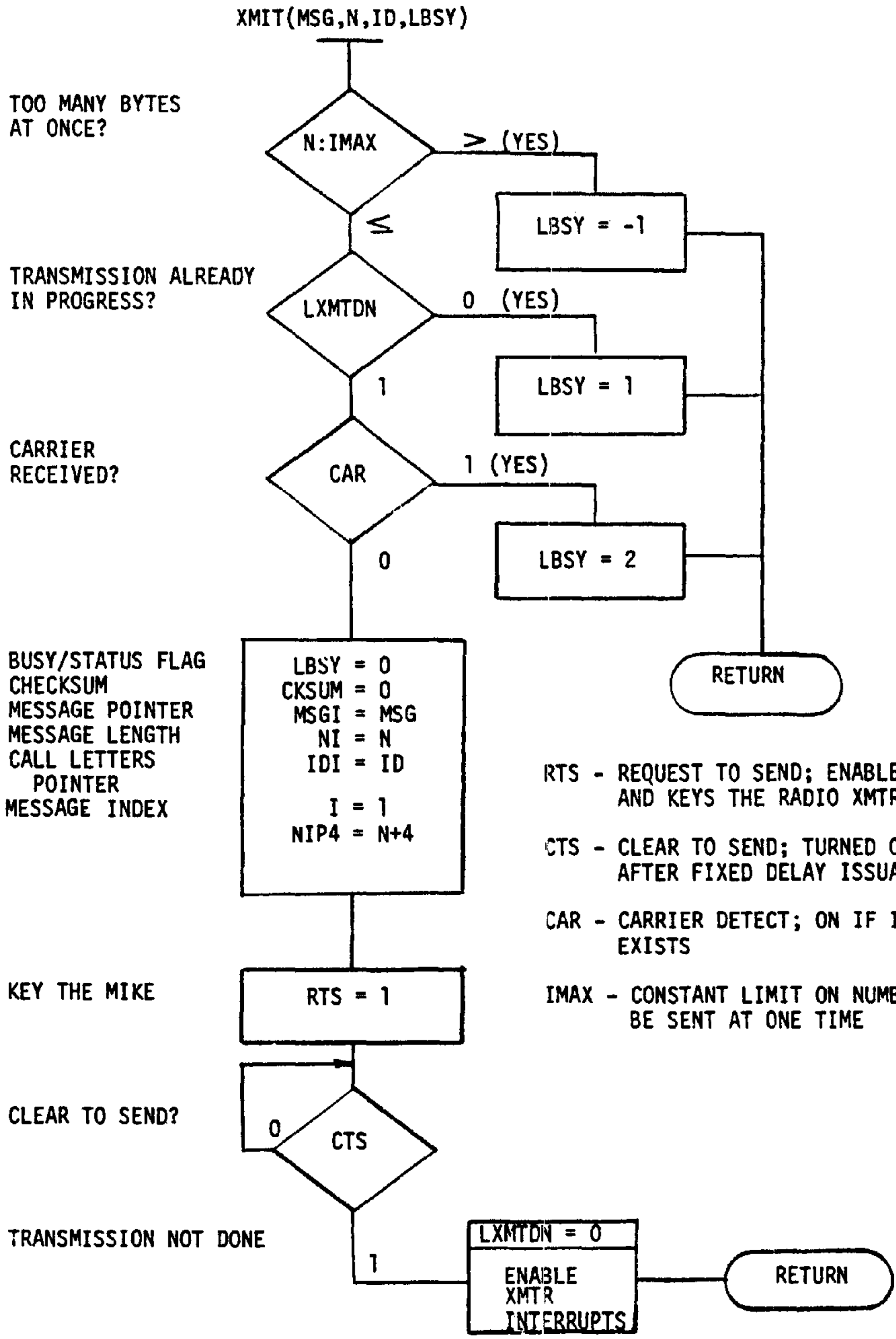
DLINK--Radio Interface Handlers

Data is transmitted and received over the radio by means of special assembly language interface handler routines contained in the module DLINK. There are three independent subroutines in DLINK: XMIT, Figure 2-17, is called from a FORTRAN program to initiate a transmission. XISR, Figure 2-18, executes upon a transmitter interrupt and outputs one byte of data to the radio, and RISR, Figures 2-19 and 2-20, inputs one byte of data from the radio when a receiver interrupt occurs.

XMIT sets up the transmission of a message with length of up to 256 bytes. The starting address of the message, the number of bytes in it, the call letters of the station to which the message is directed and a status flag are passed as arguments to XMIT by the calling program. The call letters are two bytes which are unique for each station in the communication system. The status flag indicates to the calling program if it was impossible to transmit the message because of traffic on the air or if the message length exceeded the limit of 256 bytes.

The interface between the computer and the radio complies to the RS-232 standard. Besides turning on the carrier in the modem, the RS-232 "request to send" signal also keys the radio transmitter. When XMIT is invoked to send a message, it first checks the length of the message. Then it checks to see if a transmission is already in progress. When these checks pass, the message pointer, byte count and call letters are stored for the interrupt service routine and the

XMIT IS CALLED BY A FORTRAN PROGRAM TO INITIATE TRANSMISSION
OF MESSAGE NAMED MSG WITH LENGTH N BYTES, USING CALL LETTERS, ID



RTS - REQUEST TO SEND; ENABLES MODEM XMTR AND KEYS THE RADIO XMTR

CTS - CLEAR TO SEND; TURNED ON BY THE MODEM AFTER FIXED DELAY ISSUANCE OF RTS

CAR - CARRIER DETECT; ON IF INCOMING CARRIER EXISTS

IMAX - CONSTANT LIMIT ON NUMBER OF BYTES TO BE SENT AT ONE TIME

Figure 2-17. Program Diagram - XMIT

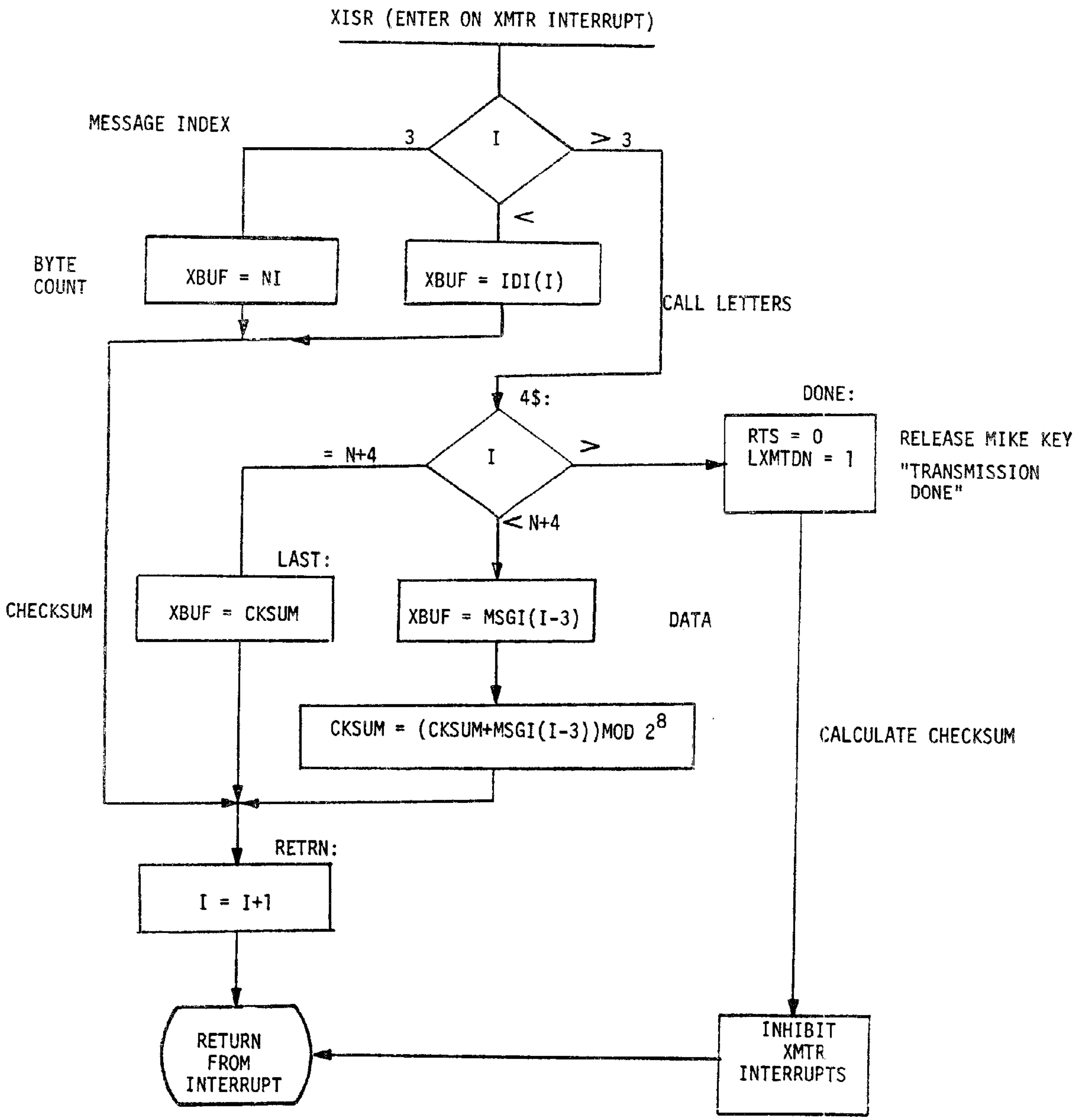


Figure 2-18. Program Diagram - XISR

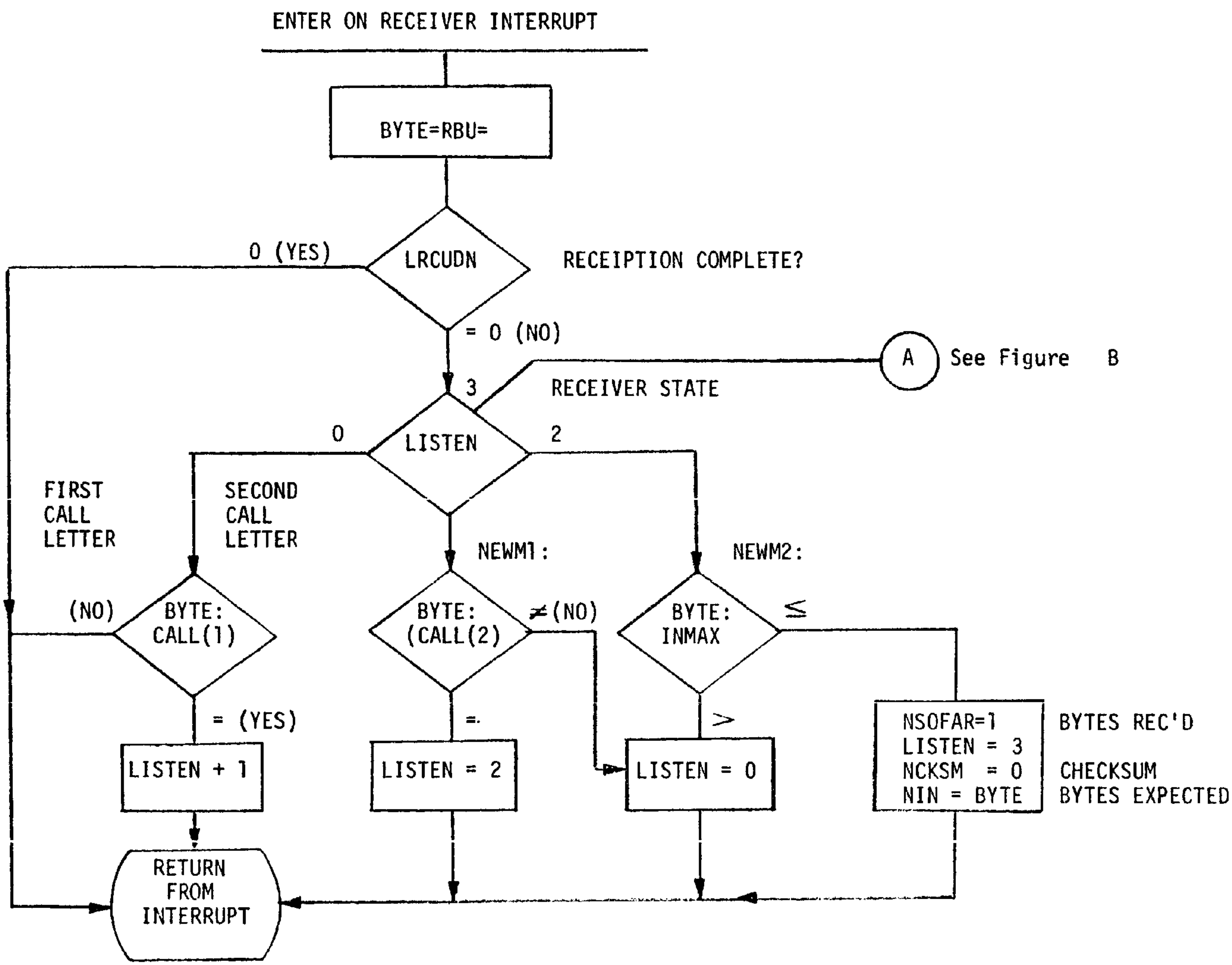


Figure 2-19. Program Diagram - RISR

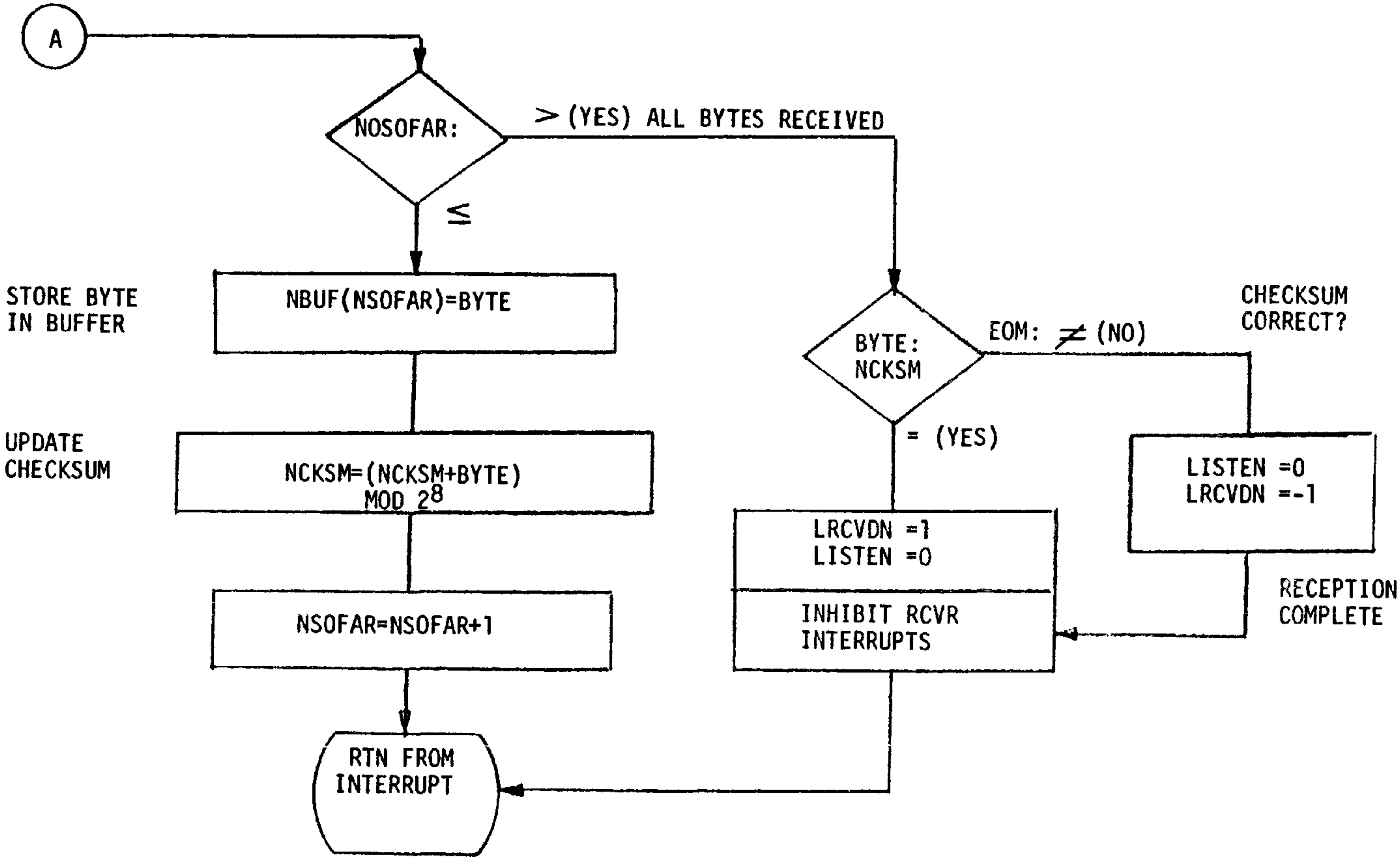


Figure 2-20. Program Diagram - RISR (Continued)

"request to send" signal is issued. The routine loops while waiting for the "clear to send" signal from the modem to become true and then enables the transmitter interface interrupts. When a message is transmitted, it is preceded by the two call letter bytes and a byte which contains the number of bytes in the message. The message is followed by a check sum which is formed by adding all the bytes of the message and allowing the sum to overflow. The least significant byte of the sum is the checksum byte.

XISR is the transmitter interrupt service routine. It is executed when the transmitter interface is ready to transmit the next byte and performs an interrupt. The checksum is computed from each byte as it is transmitted. After the call letters, byte count, message and checksum have been transmitted, XISR turns off the transmitter by clearing "request to send" and inhibits further transmitter interface interrupts.

RISR is the receiver interrupt service routine. It is executed each time a new byte is passed by the modem to the receiver interface. Bytes are ignored by RISR until the two bytes of its station's call letters are received in order. The next byte received is then regarded as the count of bytes to follow. (A count of 0 is interpreted as 256--no zero length messages should be sent.) That many bytes are then stored (one for each receiver interrupt) in the array NBUF. The checksum is computed as each byte is received. The byte after the message is then compared to the computed checksum. The flag LRCVDN is set to +1 if they are equal. LRCVDN is set to -1 if the checksums do not agree.

BSRPRT--Base Station file transfer programs. BSRPT program heirarchy is shown in Figure 2-21. When a command is given to the BSRPRT program to obtain a data file from the dragline, it executes one of the subroutines DIGGING, ROPES, or POWER.

DIGGING obtains the primary DIGS data file, 'CMPRS.DAT', from the dragline. That file contains the dragline's digging performance information. Rather than having the entire file sent each time, the routine requests the "earliest date of interest" to be entered at the keyboard, and then sends that date to the dragline. The dragline then returns only those data sections of 'CMPRS.DAT' with dates following the entered date. DIGGING builds a base station copy of 'CMPRS.DAT' from the received packets of data. After receipt of each packet, the routine ACKNOG is called to acknowledge it. Receipt of a message with length equal 1 byte signals the end of transmission. Receipt of a message with length equal to 2 bytes signals that a bad block exists in the 'CMPRS.DAT' file on board the dragline and the transmission is aborted. When the end of data message is received, the number of 'CMPRS.DAT' records transmitted is printed on the typewriter.

POWER obtains the 'KWH.DAT' data file, Old Ben's special power monitor data file, from the dragline. Complete transmission of the file takes about one half hour under normal conditions. When the file has been transmitted 'KWH.DAT RECEIVED' is printed at the typewriter.

ROPES obtains Old Ben's special rope and chain report files, CANDR.DAT' and 'CRACCU.DAT'. Each packet of data is received by the subroutine 'LISTEN' and is acknowledged by the routine ACKNOG. The message 'CANDR.DAT and CRACCU.DAT RECEIVED' follows receipt of both files.

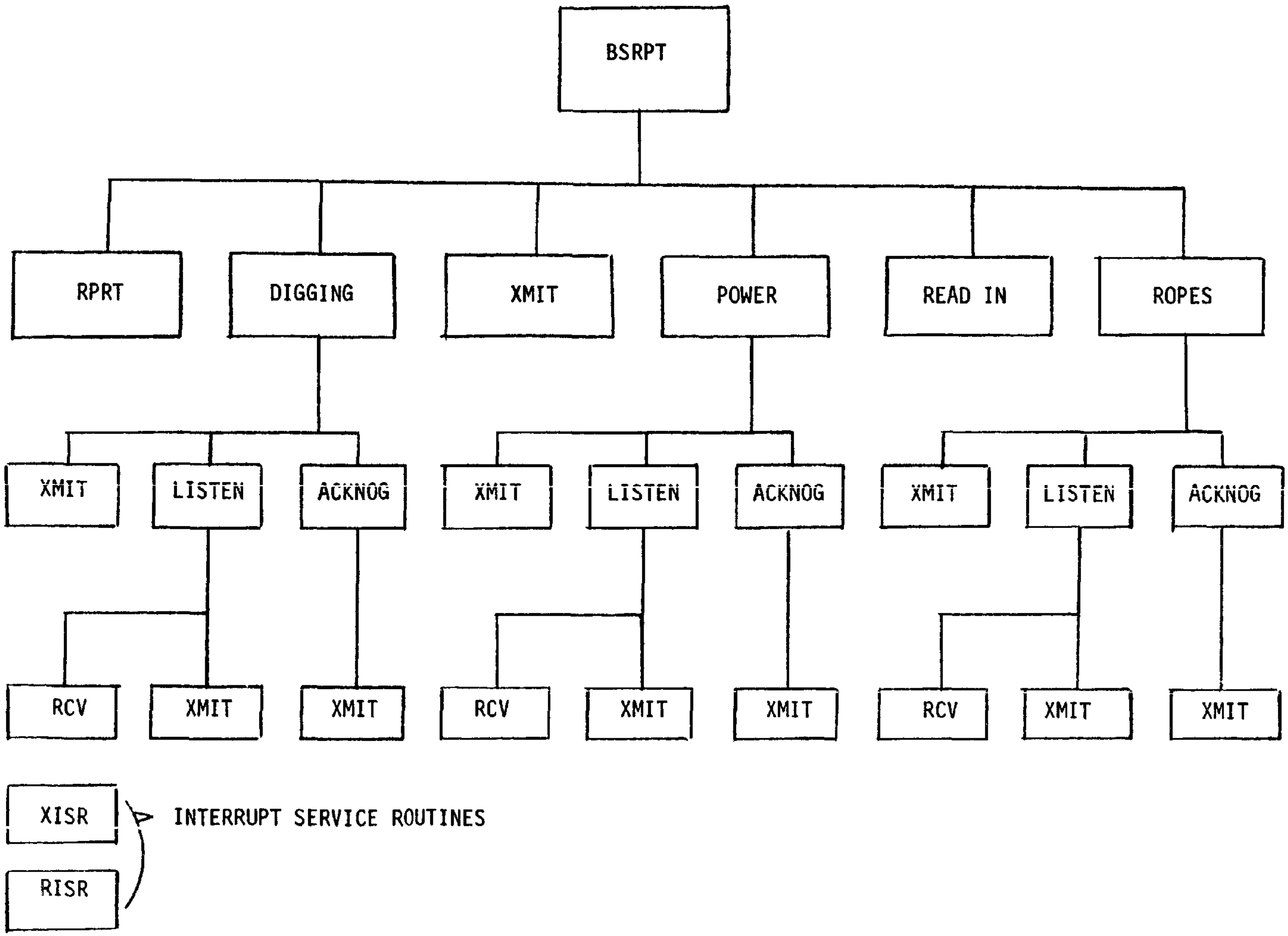


Figure 2-21. Program Heirarchy, Base Station

LISTEN, an integer function, monitors the receipt of a packet of data from the dragline. It requests retransmission of the packet if a checksum error occurred in its original transmission, or if no packet is received within 30 seconds. After 3 requests for retransmissions due to time out, it prints 'TIME OUT. THE DRAGLINE DOESN'T ANSWER.' at the typewriter.

RADIO--Dragline Half of Data Link

The main loop of the DIGS program, HIMAIN, Figure 2-22, receives messages from the DIGS typewriter or from the radio data link via the routine READIN. If the first four characters of a message are "RDIO", the subroutine RADIO is called to transmit a data file.

The second group of 4 characters following "RDIO" determine which data file is to be transmitted. "CMPR" causes the normal digging data file, "CMPRS.DAT" to be sent. RADIO sends the power data file, KWH.DAT, if it sees "POWR", and the rope data files, CANDR.DAT and CRACCU.DAT when "ROPE" is received.

If "CMPR" is the message, the two bytes following the message comprise an integer date. Only that data in CMPRS.DAT following that date are transmitted. The other data files are always transmitted in their entirety.

RADIO calls the subroutine ITALK to transmit blocks of 256 bytes. ITALK invokes XMIT and then monitors the receive done flag, LRCVDN. If the acknowledgement message is received from the base station, ITALK returns to the caller. If the base station sends anything other than the acknowledgement, then the data block is retransmitted. If nothing is heard from the base station within 100

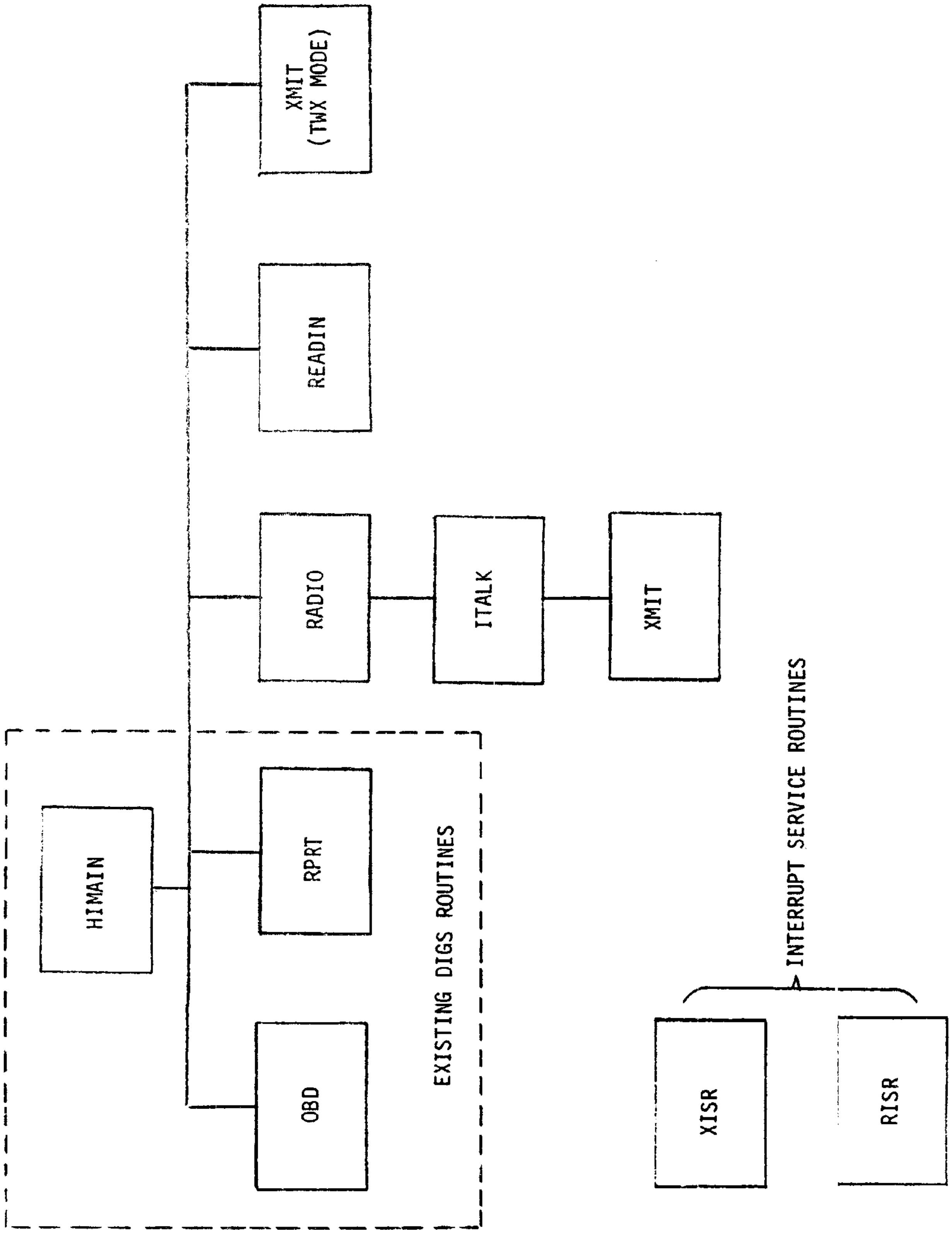


Figure 2-22. Program Heirarchy - Dragline Data Link With CIGS

seconds, RADIO sets a time out flag, rings the typewriter bell and returns.

RCV prepares the system to receive a new message by resetting the reception complete flag and the receiver buffer index.

The DIGS Radio Data Link Program and Handlers are listed in the Appendix.

3.0 DEVELOPMENT AND LABORATORY TESTING

The Dragline Data Link System component less antennas were received and functionally tested by MDEC prior to delivery to the mine site. Each component was operationally checked against its specifications and assembled in the functional configuration for system developmental tests. Two test set-ups were used. The first set-up used the data link computer, a similar computer, to simulate the DIGS computer, and the data modems interconnecting the computers directly. This test configuration was used mainly during the software development phase. The second test configuration simulated the field installation except radio were coupled through attenuators. Antennas were not used nor were any radiation tests made. The system configuration was used to verify operation of the system at predetermined timing and signal level.

3.1 Radio: The transmitters were operated into a dummy loads and power output levels checked. Power adjustments range from less than 1 watt to about 43 watts. Power levels were set at 15 watts for bench tests. Figure 3-1 shows the opened power chassis and power adjustment potentiometer.

Receiver sensitivities were checked using a Hewlett Packard HP 8640B signal generator, with the frequency set at 154.46375 MHZ, modulation frequencies at 900,1200 and 2200 HZ, and peak deviation at 3.6 KHZ usable signals were obtained with inputs varied from 20 to -130 dBm.

Figure

Peak deviation was checked using the procedure above to determine a reference output. The HP8640B signal generator was set at the licensed frequency with the modulation frequency at 2200 HZ, peak deviation at 3600 HZ and input level at -60 dBm. The receiver output was measured at 8V peak to peak. The transmitter to be checked was substituted for the RF signal generator and coupled to the reference receiver through attenuators. A Wave Tek Model 114 audio signal generator provided 2200HZ modulation to the transmitter. The receiver output with the transmitter keyed was measured at 8V peak to peak. The roles of the two radios were interchanged in this test with duplicate results. Tests were performed at 5 and 15 watt RF output levels of the transmitters.

3.2 Modem: The data modems were configured as described in paragraph 2.4.3. Carrier detect level was set by selectable strap at -30 dBm. Transmitter output level of Zero dBm was selected. Modem tests were conducted in a system test configuration. The pair of modems were used to interconnect two computer systems. The capability of the modems to transmit data and to satisfactorily pass local and remote loop back tests were criteria for acceptance.

3.3 Computer: The PDP 1103 computer system used with data link is basically identical to the DIGS computer. These devices are tested upon receipt by a Digital Equipment Corp. representative using established diagnostic programs. The test is witnessed by a MDEC representative. The device is then operated for a minimum of 100 hours and retested using diagnostic routines.

3.4 System Tests: The data link system and a computer simulating the DIGS were configured as shown in Figure 3-2. The functional interconnection is identical to that shown in Figure 2-7 except the radio interconnection was accomplished using attenuators providing 70dB attenuation. Power levels are set at 5 and 15 watts. End to end tests using both the teletype and data transfer modes were repeated over a period of two weeks. During this period only minor changes were required to the software. The receiver outputs of both radios were adjusted to 5V peak to peak and the soft carrier delay was increased to 25 milliseconds from 8 milliseconds.

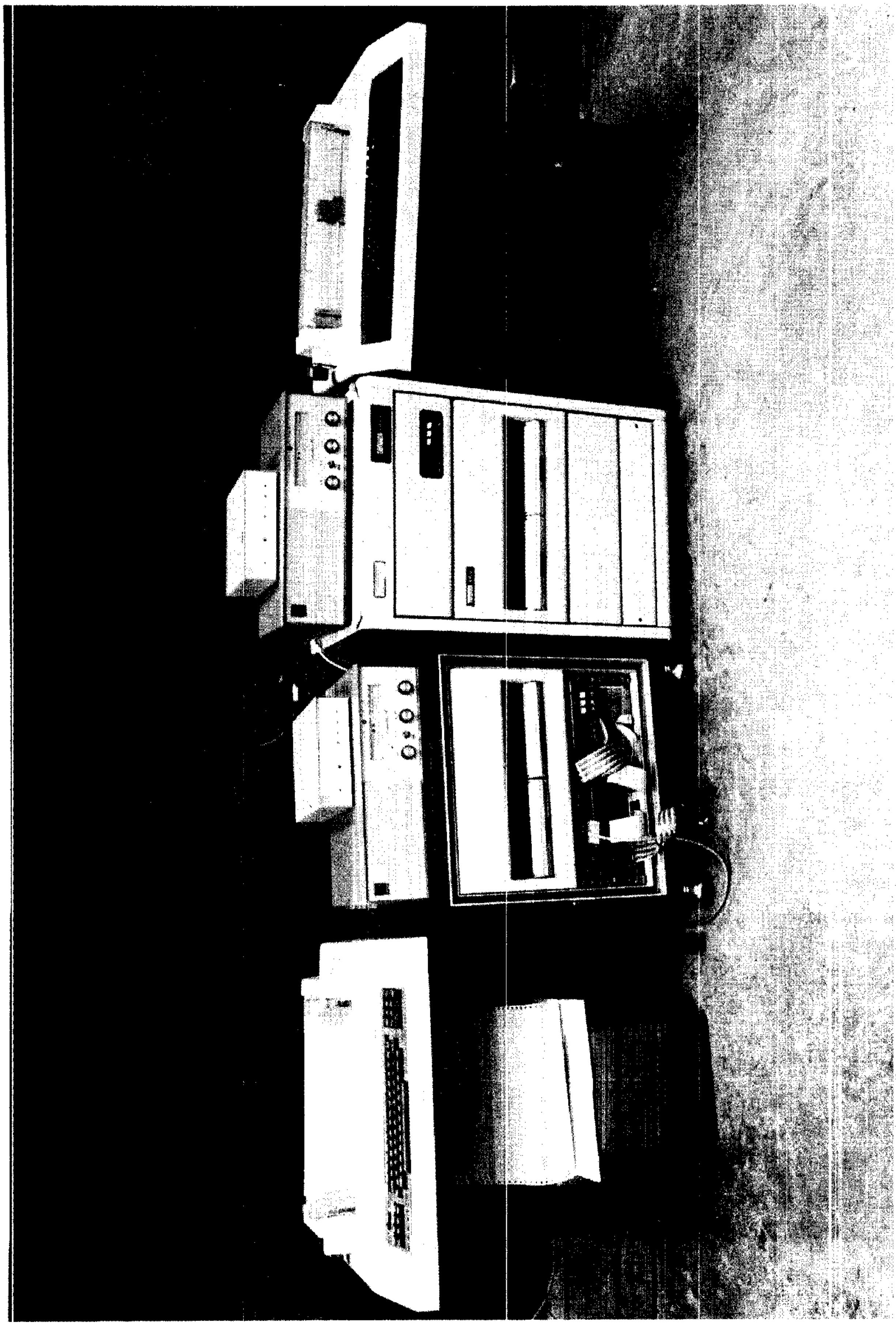


Figure 3-2

4.0 FIELD INSTALLATION AND TEST

DIGS Data Link System was installed and went on the air at Old Ben Coal Co. Mine No. 2 on 25 November 1980. The radio communication of data files worked without problem from the start. The first transmission used the teletype mode. These results are shown in Figure 4-1. A minor software problem in the base station was corrected. A more serious problem with the DIGS as modified by Data Link was discovered. When a report was being printed with the drag-line was in operation, the computer memory was insufficient for all the input/output buffers. An additional disk overlay was created to reduce the main memory requirement to an acceptable level.

4.1 Dragline System. Installation of the dragline system amounted to stacking the radio and modem on the DIGS computer and installing two modem interconnecting cables. The antenna had previously been installed by a subcontractor, Tri-State Communications, Inc. of Evansville, Indiana. The antenna was trimmed to the assigned frequency and secured to the "A" frame of the dragline. Figure 2-18 shows the antenna installation. RG-8U coaxial cable was routed through cable ways to the DIGS computer room. The DIGS and Dragline Data Link installation are shown in Figures 2-4 and 2-5.

4.2 Mine Office Installation. The mine office data link installation is shown in Figure 2-3. The computer and teletypewriter were placed in the mine engineering office. The radio and modem were stacked on top of the computer. The mine office antenna was secured to an existing mast adjacent to the mine office by Tri State Communications, Inc. Figure 4-2 is a view of the Old Ben No. 2 mine office showing the radio mast.

```
.BOOT DY:^U
BOOT DX:

RT-11SJ    V03-02

.ASSIGN DX1: CYC

.R OBD
SEND HELLO
> HELLO
SEND HEY DAVE ^G^G^G^G^G^G^G  ARE YOU THERE?
SEND WAKE UP YOU GUYS!
                      > YES I AM
^U
SEND WE'RE HERE TOO!
SEND I GUESS IT WORKS.
SEND TYPE SOMETHING ELSE DAVE.

> I GUESS WE ARE IN BUSINSEND I AM A SLOW TYPEST


SEND HOORAY.
SEND
    > I AM ASLO A BAD SPELLER
HOW ABOUTY \ Y\ TYPING 'DIGGING'

> DID YOU GETSEND DIGGING
SEND DON'T TYPE 'SEND DIGGING', JUST TYPE 'DIGGING'.
SEND SEE IF YOU CAN PRINT A RPEORT NOW.

> I ALREADY HAVE
SEND GREAT
SEND DO YOU HAVE ANY CHAMPAGNE?

> NO, BUTT I HAVE SOME RIPPLE
SEND IF YOU LEAVE BEFORE WE GET BACK... WE'LL BE BACK TOMORROW
SEND WE'LL KEEP THE COMPUTER ROOM KEY

> SEND THAT WILL BE FINE
SEND GOOD \ \BYE.\.\ FOR NOW.
```

Figure 4-1. The First Data Link Transmission

4.3 System Tests. Test of the data link system at the system level included transmission and comparison of reports from data generated by the operational dragline. Various RF power level settings from less than 1.0 to 15 watts were used during transmission tests. Figure 4-2 is a typical "ROPES" report as used by Old Ben Coal Co. This report was transmitted to the mine office via the data link with the transmitters adjusted to 5 watts RF power. Identical reports were transmitted at 2 and 15 watts RF power. The "rope and chains" report consist of 5730 bytes of data. This requires approximately 26 transmissions to transfer this report by data link. The total time required to transfer this report was measured at one minute and forty nine seconds. At two seconds per transmission and a 50% duty cycle the theoretical transmission time is one minute and forty four seconds. The "power" report consists of 80,000 bytes or 303 transmissions. This report required 23 minutes to transmit. Two extra transmissions were noted during this run. Transmissions are repeated (up to three times) if a transmission of 256 bytes fails the parity or checksum tests. The "digging" report can vary, depending upon the length of time data is acquired, up to 64000 bytes. A full record would require 250 transmissions and require 16 minutes and 40 seconds. The "digging" report requested contained 13,200 bytes and required 5 minutes and 24 seconds to complete. The average transmission time as measured over these timed runs is 1.91 seconds. Repeated transmissions were made without loss of data with RF power settings at less than 1 watt, 5 watts, 7.5 watts, 10 watts and 15 watts. Some distortion was noted at the lower power settings (less than 5 watt) but not to the extent to cause loss of data. The transmitter has a specified power range of 10 to 35 watts. On several occasions during early tests some interference was noted. Since it was infrequent and random, no analysis was possible. It appeared on the audio as heard through the speaker as data, not voice. It did not abort report transmission, but since it did not occur during timed runs its effect on byte retransmission was not determined. The system has been in operation from

```
ROPES

CANDR.DAT AND CRACCU.DAT RECIEVED

TO GET DATA FROM THE DRAGLINE VIA  RADIO
TYPE 'DIGGING', 'POWER', OR 'ROPES';
TYPE 'RPRT' TO PRINT A REPORT
TYPE 'SEND' FOR TWX MODE

SEND REPORT HAS BEEN TRANSMITTED AS HAS BEEN RECIEVED.....
SEND WILL NOW RUN
RPRT

IF YOU WANT...
A CHRONOLOGICAL REPORT,  ENTER 1;
TOTALS BY OPERATOR, ENTER 2;
TOTALS, ENTER 3;
A DRAGLINE OPERATING SUMMARY, ENTER 4;
A CURRENT ROPE AND CHAIN REPORT, ENTER 5;
A PAST ROPE AND CHAIN REPORT, ENTER 6.
POWER USE, ENTER 7.
5

FIND THE TOP OF THE PAGE AND HIT RETURN
```

Figure 4.2. Typical Old Ben Ropes Report (Sheet 1 of 7)

5 WATT

	WIRE ROPES		CHAINS		
	DRAG	HOIST	DRAG	UPPER HOIST	LOWER HOIST
ACTIVITY	40	55	60	70	80
DATE OF ACTIVITY	18-DEC-1980	11-DEC-1980	18-SEP-1980	11-OCT-1979	7-JUN-1979
DATE INSTALLED	18-DEC-1980	31-JUL-1980	18-SEP-1980	11-OCT-1979	7-JUN-1979
YARDS SINCE INSTALLED	690883.	3357825.	1437936.	9622451.	11907172.
YARDS SINCE ACTIVITY	690883.	955199.	1437936.	9622451.	11907172.
CYCLES SINCE ACTIVITY	11692.	16633.	25395.	165301.	205586.
HOURS OF DIGGING SINCE ACTIVITY	223.	321.	510.	3450.	4306.

END OF REPORT

TO GET DATA FROM THE DRAGLINE VIA RADIO
TYPE 'DIGGING', 'POWER', OR 'ROPES';
TYPE 'RPRT' TO PRINT A REPORT
TYPE 'SEND' FOR TWX MODE

RPRT

IF YOU WANT...
A CHRONOLOGICAL REPORT, ENTER 1;
TOTALS BY OPERATOR, ENTER 2;
TOTALS, ENTER 3;
A DRAGLINE OPERATING SUMMARY, ENTER 4;
A CURRENT ROPE AND CHAIN REPORT, ENTER 5;
A PAST ROPE AND CHAIN REPORT, ENTER 6.
POWER USE, ENTER 7.
6

FIND THE TOP OF THE PAGE AND HIT RETURN

Figure 4-2. Typical Old Ben Ropes Report (Sheet 2 of 7)

	WIRE ROPES		CHAINS		
	DRAG	HOIST	DRAG	UPPER HOIST	LOWER HOIST
ACTIVITY	43	52	60	70	80
DATE OF ACTIVITY	14-MAY-1979	24-MAY-1979	7-JUN-1979	7-JUN-1979	7-JUN-1979
YARDS SINCE ACTIVITY	208632.	1005011.	250311.	1988602.	11907172.
CYCLES SINCE ACTIVITY	3055.	17356.	3645.	35203.	205586.
HOURS OF DIGGING SINCE ACTIVITY	63.	368.	75.	744.	4306.
ACTIVITY	44	53	61	70	
DATE OF ACTIVITY	11-JUN-1979	29-JUN-1979	12-JUN-1979	4-OCT-1979	
YARDS SINCE ACTIVITY	232064.	0.	23745.	0.	
CYCLES SINCE ACTIVITY	3508.	0.	323.	0.	
HOURS OF DIGGING SINCE ACTIVITY	76.	0.	7.	0.	
ACTIVITY	44	53	62	70	
DATE OF ACTIVITY	15-JUN-1979	29-JUN-1979	12-JUN-1979	4-OCT-1979	
YARDS SINCE ACTIVITY	509975.	308555.	310351.	296011.	
CYCLES SINCE ACTIVITY	9697.	5493.	5175.	5082.	
HOURS OF DIGGING SINCE ACTIVITY	207.	119.	113.	112.	
ACTIVITY	46	50	63	70	
DATE OF ACTIVITY	27-JUN-1979	12-JUL-1979	18-JUN-1979	11-OCT-1979	
YARDS SINCE ACTIVITY	0.	675035.	73787.	9622451.	
CYCLES SINCE ACTIVITY	0.	12354.	1390.	165301.	
HOURS OF DIGGING SINCE ACTIVITY	0.	258.	29.	3450.	
ACTIVITY	40	50	64		
DATE OF ACTIVITY	27-JUN-1979	4-OCT-1979	19-JUN-1979		
YARDS SINCE ACTIVITY	0.	253765.	824740.		
CYCLES SINCE ACTIVITY	0.	4372.	16102.		
HOURS OF DIGGING SINCE ACTIVITY	0.	98.	335.		
ACTIVITY	40	50	65		
DATE OF ACTIVITY	27-JUN-1979	10-OCT-1979	24-JUL-1979		
YARDS SINCE ACTIVITY	679247.	5882.	473727.		
CYCLES SINCE ACTIVITY	13145.	101.	7996.		
HOURS OF DIGGING SINCE ACTIVITY	275.	2.	174.		
ACTIVITY	43	50	60		
DATE OF ACTIVITY	7-AUG-1979	10-OCT-1979	3-OCT-1979		
YARDS SINCE ACTIVITY	0.	0.	31944.		
CYCLES SINCE ACTIVITY	0.	0.	572.		
HOURS OF DIGGING SINCE ACTIVITY	0.	0.	11.		

Figure 4.2. Typical Old Ben Ropes Report (Sheet 3 of 7)

	WIRE ROPES		CHAINS		
	DRAG	HOIST	DRAG	UPPER HOIST	LOWER HOIST
ACTIVITY	43	50	60		
DATE OF ACTIVITY	7-AUG-1979	10-OCT-1979	4-OCT-1979		
YARDS SINCE ACTIVITY	0.	0.	8480444.		
CYCLES SINCE ACTIVITY	0.	0.	144988.		
HOURS OF DIGGING SINCE ACTIVITY	0.	0.	3051.		
ACTIVITY	43	50	60		
DATE OF ACTIVITY	7-AUG-1979	10-OCT-1979	18-SEP-1980		
YARDS SINCE ACTIVITY	3310.	0.	1437936.		
CYCLES SINCE ACTIVITY	57.	0.	25395.		
HOURS OF DIGGING SINCE ACTIVITY	1.	0.	510.		
ACTIVITY	43	56			
DATE OF ACTIVITY	7-AUG-1979	10-OCT-1979			
YARDS SINCE ACTIVITY	0.	0.			
CYCLES SINCE ACTIVITY	0.	0.			
HOURS OF DIGGING SINCE ACTIVITY	0.	0.			
ACTIVITY	43	50			
DATE OF ACTIVITY	7-AUG-1979	10-OCT-1979			
YARDS SINCE ACTIVITY	500.	59490.			
CYCLES SINCE ACTIVITY	10.	1048.			
HOURS OF DIGGING SINCE ACTIVITY	0.	21.			
ACTIVITY	43	50			
DATE OF ACTIVITY	7-AUG-1979	11-OCT-1979			
YARDS SINCE ACTIVITY	322933.	6241449.			
CYCLES SINCE ACTIVITY	5159.	106624.			
HOURS OF DIGGING SINCE ACTIVITY	111.	2252.			
ACTIVITY	40	50			
DATE OF ACTIVITY	3-OCT-1979	31-JUL-1980			
YARDS SINCE ACTIVITY	31944.	1520931.			
CYCLES SINCE ACTIVITY	572.	26767.			
HOURS OF DIGGING SINCE ACTIVITY	11.	552.			
ACTIVITY	40	51			
DATE OF ACTIVITY	4-OCT-1979	11-SEP-1980			
YARDS SINCE ACTIVITY	0.	881686.			
CYCLES SINCE ACTIVITY	0.	14838.			
HOURS OF DIGGING SINCE ACTIVITY	0.	316.			

Figure 4.2. Typical Old Ben Ropes Report (Sheet 4 of 7)

	WIRE ROPES		CHAINS		
	DRAG	HOIST	DRAG	UPPER HOIST	LOWER HOIST
ACTIVITY	40	55			
DATE OF ACTIVITY	4-OCT-1979	11-DEC-1980			
YARDS SINCE ACTIVITY	0.	955199.			
CYCLES SINCE ACTIVITY	0.	16633.			
HOURS OF DIGGING SINCE ACTIVITY	0.	321.			
ACTIVITY	40				
DATE OF ACTIVITY	4-OCT-1979				
YARDS SINCE ACTIVITY	259647.				
CYCLES SINCE ACTIVITY	4473.				
HOURS OF DIGGING SINCE ACTIVITY	100.				
ACTIVITY	43				
DATE OF ACTIVITY	10-OCT-1979				
YARDS SINCE ACTIVITY	59446.				
CYCLES SINCE ACTIVITY	1047.				
HOURS OF DIGGING SINCE ACTIVITY	21.				
ACTIVITY	43				
DATE OF ACTIVITY	11-OCT-1979				
YARDS SINCE ACTIVITY	572380.				
CYCLES SINCE ACTIVITY	9794.				
HOURS OF DIGGING SINCE ACTIVITY	204.				
ACTIVITY	41				
DATE OF ACTIVITY	26-OCT-1979				
YARDS SINCE ACTIVITY	2374422.				
CYCLES SINCE ACTIVITY	40393.				
HOURS OF DIGGING SINCE ACTIVITY	845.				
ACTIVITY	41				
DATE OF ACTIVITY	1-MAY-1980				
YARDS SINCE ACTIVITY	0.				
CYCLES SINCE ACTIVITY	0.				
HOURS OF DIGGING SINCE ACTIVITY	0.				
ACTIVITY	41				
DATE OF ACTIVITY	1-MAY-1980				
YARDS SINCE ACTIVITY	1636493.				
CYCLES SINCE ACTIVITY	23516.				
HOURS OF DIGGING SINCE ACTIVITY	532.				

Figure 4.2. Typical Old Ben Ropes Report (Sheet 5 of 7)

	WIRE ROPES		CHAINS		
	DRAG	HOIST	DRAG	UPPER HOIST	LOWER HOIST
ACTIVITY	43				
DATE OF ACTIVITY	4-JUN-1980				
YARDS SINCE ACTIVITY	173641.				
CYCLES SINCE ACTIVITY	3045.				
HOURS OF DIGGING SINCE ACTIVITY	63.				
ACTIVITY	44				
DATE OF ACTIVITY	7-JUN-1980				
YARDS SINCE ACTIVITY	590309.				
CYCLES SINCE ACTIVITY	11013.				
HOURS OF DIGGING SINCE ACTIVITY	226.				
ACTIVITY	44				
DATE OF ACTIVITY	21-JUN-1980				
YARDS SINCE ACTIVITY	0.				
CYCLES SINCE ACTIVITY	0.				
HOURS OF DIGGING SINCE ACTIVITY	0.				
ACTIVITY	43				
DATE OF ACTIVITY	21-JUN-1980				
YARDS SINCE ACTIVITY	840395.				
CYCLES SINCE ACTIVITY	16699.				
HOURS OF DIGGING SINCE ACTIVITY	340.				
ACTIVITY	41				
DATE OF ACTIVITY	28-JUL-1980				
YARDS SINCE ACTIVITY	875400.				
CYCLES SINCE ACTIVITY	18187.				
HOURS OF DIGGING SINCE ACTIVITY	374.				
ACTIVITY	41				
DATE OF ACTIVITY	18-AUG-1980				
YARDS SINCE ACTIVITY	397651.				
CYCLES SINCE ACTIVITY	6238.				
HOURS OF DIGGING SINCE ACTIVITY	124.				
ACTIVITY	43				
DATE OF ACTIVITY	5-SEP-1980				
YARDS SINCE ACTIVITY	1183532.				
CYCLES SINCE ACTIVITY	19345.				
HOURS OF DIGGING SINCE ACTIVITY	413.				

Figure 4.2. Typical Old Ben Ropes Report (Sheet 6 of 7)

	WIRE ROPES		CHAINS		
	DRAG	HOIST	DRAG	UPPER HOIST	LOWER HOIST
ACTIVITY	41				
DATE OF ACTIVITY	11-DEC-1980				
YARDS SINCE ACTIVITY	264313.				
CYCLES SINCE ACTIVITY	4941.				
HOURS OF DIGGING SINCE ACTIVITY	98.				
ACTIVITY	40				
DATE OF ACTIVITY	18-DEC-1980				
YARDS SINCE ACTIVITY	690883.				
CYCLES SINCE ACTIVITY	11692.				
HOURS OF DIGGING SINCE ACTIVITY	223.				

THE FOLLOWING AMOUNTS 119 59 35 15 3
HAVE BEEN USED FROM THE ROPE AND CHAIN RECORDS OUT OF 281 POSSIBLE FOR EACH ONE

END OF REPORT

Figure 4.2. Typical Old Ben Ropes Report (Sheet 7 of 7)

25 November 1980 through the completion without problem. Data transmitted and reports obtained through the data link system have been consistently reliable when compared with reports generated on the prime DIGS.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Design Goals. Goals of the Dragline Data Link program have been fully achieved with respect to operation and data transfer fidelity. Test performed at the evaluation site demonstrated that the data link system can be applied to the surface mining environment. The evaluation site provided a test range that met the criteria of the design model with the exception of range. The design model established a conservative five mile range as a typical maximum distance between the base and remote station. An equally conservative path loss analysis established a RF power requirement at 30 watts. Old Ben Coal Co. provided a 1.3 mile range. Transmission tests using as low as one watt of RF power demonstrated the feasibility of longer range operation and the validity of the path loss analysis.

5.2 Operational Goals: The ultimate goal of DIGS as enhanced by the data link system is to increase mining productivity. As determined from proprietary data obtained from DIGS users, a minimum of 3% increase in productivity is noted. The added effects attributable to data link are not yet as clearly determined. The DIGS statistics required years of data gathering to assure adequate normalization. The short evaluation time could not provide the cause and effect relationships and the necessary response by the mine operator to an over abundance of data to achieve measurable productivity improvement. The benefits noted by the mine operator are superficial at this time. The data link system provides convenient access to the data already available at the dragline DIGS. It eliminates time spent in travel to the dragline and the time spent awaiting report printouts. It encourages frequent collection of this data and more responsive use of available reports.

A more subtle but interesting benefit is being considered. The ready availability of data from the dragline provides for new and innovative uses for DIGS. More detailed reports such as cycle by cycle reports or real time reporting of detailed dragline activities could provide for more realistic and accurate time and productivity studies. The expansion of similar data acquisition and reporting systems to other draglines, shovels and material handling equipment of many types, serviced by a single data link system (some 676 system can presently be individually addressed) can lead to composite production reports and offer even greater mine management potential.

5.3 Recommendations: The value of a data link system as applied to DIGS and related data systems could not be verified in full during a two month evaluation period. It will require the innovative application by a progressive and dedicated mining operation over a long period of time to develop the methods and confidence to effect productivity improvements. To this end it is suggested that the evaluation of the dragline data link system be continued by a mine operator and that they be encouraged to try new and innovative techniques in data gathering, reporting and management for productivity.

The design of the data link system was predicated upon use of available equipment containing built-in options for direct integration into a data transmission system. The radio for example is a desk top unit with built-in power supply and DC remote interface board. The data modem is of a commercial design and provides for selectable interface options. This equipment is acceptable for the dragline where space and the environment are not critical factors. This equipment, however, would not be suitable for the more restraining space requirements and harsh environment of equipment such as a front end loader.

It is suggested that the data link design be evolved into a more rugged and smaller system utilizing a mobile radio and developing a dedicated interface and data modem peculiar to its restricted application. Size, power requirement and its ability to survive the harsh temperature, dust, humidity, vibration and shock environments should be considered. Interface with mine and microcomputer systems should also be addressed.

Additional system developments including full duplex operation and low power remote systems using repeater stations are recommended.

APPENDIX A

TABLE OF CONTENTS

```
                                              .TITLE DIGS RADIO DATA LINK HANDLERS
           175610                             RCSR=175610
           175612                             RBUF=175612
           175614                             XCSR=175614
           175616                             XBUF=175616
    000000                                    .PSECT  RADIO,RW,D,GBL,REL,OVR
    000000                          NBUF:     .BLKB   256.
    000400 000001                             LRCVDN: .WORD   1
    000402 000000                   NIN:      .WORD   0
                                              .SBTTL  RCV
    000000                                    .PSECT  RCV
                                              .GLOBL  RCV
    000000 005067  000400'          RCV:      CLR     LRCVDN
    000004 005067  000244'                    CLR     LISTEN
    000010 000207                             RTS     PC
                                              .SBTTL RISR
```

```
000000                              .PSECT RISR
                            ;
                                    .GLOBL  RISR
000000  000240              RISR:   NOP
000002  005767  000400'             TST     LRCVDN          ;HAS THE PREVIOUS MESSAGE BEEN CONSIDERED?
000006  001404                      BEQ     1$              ;YES,  START LISTENING
000010  116767  175612  000236      MOVB    RBUF,BYTE
000016  000002                      RTI                     ;NO.  IGNORE THIS STUFF
                            ;
000020  116767  175612  000226 1$:  MOVB    RBUF,BYTE       ;INPUT BYTE FROM RADIO
000026  026727  000212  000001      CMP     LISTEN,#1       ;WHAT PART OF MESSAGE?
000034  002425                      BLT     NEW             ;FIRST BYTE
000036  001433                      BEQ     NEWM1           ;SECOND BYTE
000040  026727  000200  000002      CMP     LISTEN,#2       ;NO., THEN IS THIS 3RD BYTE?
000046  001440                      BEQ     NEWM2           ;YES.  = NUMBER OF BYTES TO FOLLOW.
                            ;
                            ; HEADER RECEIVED, MESSAGE IN PROGRESS
000050  026767  000174  000402'     CMP     NSOFAR,NIN      ;BYTE COUNT EXCEEDED?
000056  002056                      BGE     EOM             ;YES. STOP LISTENING
000060  012746  000000'             MOV     #NBUF,-(SP)     ;BUFFER ADDRESS ON STACK
000064  066716  000160              ADD     NSOFAR,(SP)     ;ADD BUFFER INDEX
000070  116736  000160              MOVB    BYTE,@(SP)+     ;STORE BYTE, RESTORE STACK
000074  005267  000150              INC     NSOFAR          ;INCREMENT BUFFER INDEX
000100  066767  000150  000140      ADD     BYTE,NCKSM      ;UPDATE  CHECKSUM
000106  000002                      RTI
                            ;
                            ;
                            ; FIRST BYTE OF A NEW MESSAGE
                            ;
000110  126767  000140  000134 NEW: CMPB    BYTE,ID1        ;FIRST CALL LETTER?
000116  001002                      BNE     1$              ;NO. IGNORE IT
000120  005267  000120              INC     LISTEN          ;YES!  LISTEN FOR SECOND CALL LETTER
000124  000002              1$:     RTI
                            ;
                            ;
                            ; SECOND BYTE OF A MESSAGE
                            ;
000126  005267  000112      NEWM1:  INC     LISTEN
000132  126767  000116  000113      CMPB    BYTE,ID2        ;SECOND CALL LETTER
000140  001402                      BEQ     1$              ;YES, GET BYTE COUNT
000142  005067  000076              CLR     LISTEN          ;WRONG. START OVER
000146  000002              1$:     RTI
                            ;
                            ;
                            ; BYTE COUNT
                            ;
000150  012767  000400  000402' NEWM2: MOV  #256.,NIN
000156  005767  000072              TST     BYTE
000162  001402                      BEQ     2$
000164  005067  000402'             CLR     NIN
000170  005067  000054      2$:     CLR     NSOFAR
000174  005267  000044              INC     LISTEN
000200  005067  000042              CLR     NCKSM
000204  116767  000044  000402'     MOVB    BYTE,NIN
000212  000002                      RTI
                            ;
                            ;
```

```
                                        ; LAST BYTE OF MESSAGE
                                        ;
   000214  005067  000024               EOM:    CLR     LISTEN
   000220  012767  000001  000400'              MOV     #1,LRCVDN
   000226  126767  000022  000012               CMPB    BYTE,NCXSM
   000234  001402                               BEQ     1$
   000236  005167  000400'                      COM     LRCVDN
   000242  000002                       1$:     RTI
   000244  000000                               LISTEN: .WORD   0
   000246  000000                       NCXSM:  .WORD   0
   000250  000000                       NSOFAR: .WORD   0
   000252     101                       ID1:    .BYTE   'A
   000253     102                       ID2:    .BYTE   'B
   000254  000000                       BYTE:   .WORD   0
                                        ;
                                        ;
                                        .SBTTL  XMIT
```

```
000000                          .PSECT  XMIT
                                .GLOBL  XMIT
                                ;
000000  012500                  XMIT:   MOV     (R5)+,R0        ;ARGUMENT COUNT
000002  012500                          MOV     (R5)+,R0        ;MSG
000004  012501                          MOV     (R5)+,R1        ;N
000006  012502                          MOV     (R5)+,R2        ;ID
000010  021127  000400                  CMP     (R1),#256.      ;TOO MANY BYTES AT ONCE?
000014  003403                          BLE     1$              ;NO
000016  012735  177777                  MOV     #-1,@(R5)+      ;LBSY=-1
000022  000207                          RTS     PC
000024  005767  000156          1$:     TST     LXMTDN          ;TRANSMISSION ALREADY IN PROGRESS?
000030  001003                          BNE     2$              ;NO
000032  012735  000001                  MOV     #1,@(R5)+       ;LBSY=1
000036  000207                          RTS     PC
000040  032767  010000  175610  2$:     BIT     #10000,RCSR     ;CARRIER DETECT?
000046  001403                          BEQ     3$              ;NO, GO AHEAD
000050  012735  000002                  MOV     #2,@(R5)+       ;LBSY=2
000054  000207                          RTS     PC
000056  005035                  3$:     CLR     @(R5)+
000060  005067  000144'                 CLR     CKSUM           ;RESET CHECKSUM
000064  010067  000146'                 MOV     R0,MSGI         ;MESSAGE POINTER
000070  011167  000150'                 MOV     @R1,NI          ;BYTE COUNT
000074  012767  000004  000152'         MOV     #4,NIP4
000102  061167  000152'                 ADD     @R1,NIP4
000106  011267  000154'                 MOV     @R2,IDI         ;CALL LETTERS
000112  012767  000001  000160'         MOV     #1,I
000120  052767  000004  175610          BIS     #4,RCSR         ;ISSUE REQUEST TO SEND
                                ; (THE FOLLOWING TEST IS 10/SEC, NOT FREE RUNNING, ON DRAGLINE)
000126  032767  020000  175610  4$:     BIT     #20000,RCSR     ;CLEAR TO SEND?
000134  001774                          BEQ     4$              ;NO, WAIT
000136  005067  000156'                 CLR     LXMTDN
000142  106427  000200                  MTPS    #200            ;INHIBIT INTERRUPTS
000146  052767  000100  175614          BIS     #100,XCSR       ;ENABLE XMIT INTERRUPTS
000154  106427  000000                  MTPS    #0              ;ENABLE INTERRUPTS
000160  000207                          RTS     PC
                                ;
                                ;
                                .SBTTL XISR
```

```
                                        ;
  000000                                .PSECT  XISR
                                        .GLOBL  XISR
                                        ;
  000000  000240                        XISR:   NOP                     ;THIS INSTRUCTION MIGHT NOT EXECUTE
  000002  010046                                MOV     R0,-(SP)        ;PUSH R0
  000004  016700  000150                        MOV     I,R0            ;BYTE NUMBER
  000010  020027  000003                        CMP     R0,#3           ;ID AND COUNT TRANSMITTED
  000014  003011                                BGT     4$              ;YES, SEND MESSAGE
  000016  001404                                BEQ     3$              ;SEND BYTE COUNT
  000020  116067  000153' 175616                MOVB    IDI-1(R0),XBUF  ;SEND ID
  000026  000424                                BR      RETRN
  000030  116767  000114  175616        3$:     MOVB    NI,XBUF         ;BYTE COUNT
  000036  000420                                BR      RETRN
  000040  020067  000106                4$:     CMP     R0,NIP4         ;MESSAGE, CHECKSUM, OR DONE?
  000044  001412                                BEQ     LAST            ;CHECKSUM
  000046  003020                                BGT     DONE            ;DONE
  000050  066700  000072                        ADD     MSGI,R0         ;OUTPUT
  000054  116000  177774                        MOVB    -4(R0),R0       ;MESSAGE BYTE
  000060  110067  175616                        MOVB    R0,XBUF         ;TRANSMIT IT
  000064  060067  000054                        ADD     R0,CKSUM        ;UPDATE CHECKSUM
  000070  000403                                BR      RETRN
  000072  116767  000046  175616        LAST:   MOVB    CKSUM,XBUF      ;XMIT CHECKSUM
  000100  005267  000054                RETRN:  INC     I               ;COUNT A BYTE
  000104  012600                                MOV     (SP)+,R0        ;POP R0
  000106  000002                                RTI
  000110  005300                        DONE:   DEC     R0              ;TRANSMIT
  000112  020067  000034                        CMP     R0,NIP4         ; CHECKSUM
  000116  001765                                BEQ     LAST            ;  TWICE
  000120  042767  000004  175610                BIC     #4,RCSR         ;RELEASE THE MIKE KEY
  000126  012767  000001  000022                MOV     #1,LXMTDN
  000134  042767  000100  175614                BIC     #100,XCSR       ;INHIBIT XMTR INTERRUPTS
  000142  000756                                BR      RETRN
  000144  000000                        CKSUM:  .WORD   0
  000146  000000                        MSGI:   .WORD   0
  000150  000000                        NI:     .WORD   0
  000152  000000                        NIP4:   .WORD   0
  000154  041101                        IDI:    .WORD   'AB
  000156  000001                        LXMTDN: .WORD   1
  000160  000000                        I:      .WORD   0
          000001                                .END
```

```
SYMBOL TABLE

BYTE    000254R    004 ID2     000253R    004 NBUF    000000R    002 NIN     000402R    002 RETRN   000100R    006
CKSUM   000144R    006 LAST    000072R    006 NCKSM   000246R    004 NIP4    000152R    006 RISR    000000RG   004
DONE    000110R    006 LISTEN  000244R    004 NEW     000110R    004 NSOFAR  000250R    004 XBUF  = 175616
EOM     000214R    004 LRCVDN  000400R    002 NEWM1   000126R    004 RBUF  = 175612        XCSR  = 175614
I       000160R    006 LXMTDN  000156R    006 NEWM2   000150R    004 RCSR  = 175610        XISR    000000RG   006
ID3     000154R    006 MSGI    000146R    006 NI      000150R    006 RCV     000000RG   003 XMIT    000000RG   005
ID1     000252R    004

. ABS.  000000     000
        000000     001
RADIO   000404     002
RCV     000012     003
RISR    000256     004
XMIT    000162     005
XISR    000162     006
ERRORS DETECTED:  0

VIRTUAL MEMORY USED:  323 WORDS  ( 2 PAGES)
DYNAMIC MEMORY AVAILABLE FOR  74 PAGES
,TT:DLINK=DK:DLINK

ERRORS DETECTED:  0
```

```
FOR/CODE:THR/LIST:TT:/NOOBJ BSRPRT
```

```
0001          PROGRAM BSRPRT
        C
        C  BSRPRT IS THE DIGS REPORT WRITING PROGRAM
        C    USED AT THE MINE OFFICE.  DATA IS RECEIVED
        C    FROM THE DRAGLINE VIA THE RADIO DATA LINK.
        C
0002          EXTERNAL RISR,XISR
0003          LOGICAL*1 LS(80),NBUF
0004          EQUIVALENCE (S,LS(1))
0005          COMMON /RADIO/NBUF(256),LRCVDN,NIN
0006          DATA ID/'AB'/
        C
0007          IR=IADDR(RISR)
0008          IT=IADDR(XISR)
0009          CALL IPOKE('172,'200)
0010          CALL IPOKE('170,IR)
0011          CALL IPOKE('176,'200)
0012          CALL IPOKE('174,IT)
0013          CALL IPOKE('175610,'100)
0014    1     WRITE(7,100)
0015    100   FORMAT(/' TO GET DATA FROM THE DRAGLINE VIA
             * RADIO'/' TYPE 'DIGGING', 'POWER', OR 'ROPES';'/
             *' TYPE 'RPRT' TO PRINT A REPORT'/
             *' TYPE 'SEND' FOR TWX MODE'//)
0016    2     CALL READIN(LS,N)
0017          IF(S.EQ.'DIGG') CALL DIGGING
0019          IF(S.EQ.'POWE') CALL POWER
0021          IF(S.EQ.'ROPE') CALL ROPES
0023          IF(S.EQ.'RPRT') CALL RPRT
0025          IF(S.EQ.'SEND') GO TO 3
0027          IF(S.EQ.'HARK') GO TO 4
0029          GO TO 1
        C
0030    3     S='HARK'
0031          CALL XMIT(LS,MIN0(256,N),'AB',LBSY)
0032          GO TO 2
0033    4     WRITE(7,200) 7,7,7,(LS(I),I=5,N),'12
0034    200   FORMAT(' >',75A1//)
0035          GO TO 2
0036          END
BSRPRT
?FORTRAN-I-[BSRPRT] Errors: 0, Warnings: 1
```

```
FORTRAN IV      Storage Map for Program Unit BSRPRT

Local Variables, .PSECT $DATA, Size = 000142 (   49. words)

Name    Type  Offset      Name    Type  Offset      Name    Type  Offset
I       I*2   000136      ID      I*2   000122      IR      I*2   000126
IT      I*2   000130      LBSY    I*2   000134      N       I*2   000132
S       R*4   000002 Eqv


COMMON Block /RADIO /, Size = 000404 (  130. words)

Name    Type  Offset      Name    Type  Offset      Name    Type  Offset
NBUF    L*1   000000      LRCVDN I*2    000400      NIN     I*2   000402

Local and COMMON Arrays:

Name      Type    Section Offset  ------Size----- Dimensions
LS      L*1       $DATA   000002  000120 (   40.) (80)
NBUF    L*1       RADIO   000000  000400 (  128.) (256)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name    Type    Name    Type    Name    Type    Name    Type    Name    Type
DIGGIN   R*4    IADDR    I*2    IPOKE    I*2    MINO     I*2    POWER    R*4
READIN   R*4    RISR     R*4    ROPES    R*4    RPRT     R*4    XISR     R*4
XMIT     R*4
```

```
0001          SUBROUTINE DIGGING
        C
        C  DIGGING OBTAINS CMPRS.DAT DATA FROM THE DRAGLINE
        C    VIA THE RADIO DATA LINK.  BSRPRT CALLS DIGGING.
        C
0002          LOGICAL*1 NBUF
0003          COMMON /RADIO/NBUF(256),LRCVDN,NIN
0004          REAL CMSG(3)
0005          EQUIVALENCE (CMSG(3),IDATE)
0006          DATA CMSG/'RDIO','CMPR',0./
        C
0007          CALL ASSIGN(3,'CMPRS.DAT',9)
0008          DEFINE FILE 3(8000,4,U,IAV)
0009          I=3
0010          WRITE(7,100)
0011    100   FORMAT('$ENTER EARLIEST DATE OF INTEREST (DDMMYY.)...')
0012          READ(5,200) DATE
0013    200   FORMAT(F20.0)
0014          CALL DAY(IDATE,DATE)
0015    5     CALL XMIT(CMSG,10,'AB',LBSY)
0016          IF(LBSY.NE.0) GO TO 5
        C
0018    1     K=LISTEN()
0019          IF(K.EQ.1) GO TO 9
0021          IF(K.EQ.0) GO TO 2
0023          CALL CLOSE(3)
0024          RETURN
0025    2     IF(NIN.EQ.2) GO TO 10
0027          DO 6 J=1,NIN/8
0028          WRITE(3'I) (NBUF(K),K=8*(J-1)+1,8*J)
0029          I=I+1
0030          IF(NBUF(8*(J-1)+1).EQ.-1) NDXOP=I
0032    6     NDXDT=I
0033          WRITE(3'1) NDXDT,NDXOP
0034          CALL ACKNOG
0035          GO TO 1
        C
        C
        C
0036    9     WRITE (3'I) 0
0037          WRITE(7,400) I-2
0038    400   FORMAT(X,I4,' RECORDS RECEIVED FROM "CMPRS.DAT"'/)
0039          CALL ACKNOG
0040          CALL CLOSE (3)
0041          RETURN
0042    10    WRITE(7,500)
0043    500   FORMAT(' A BAD BLOCK EXISTS IN THE DRAGLINES "CMPRS.DAT"'/
             *' TRANSMISSION ABORTED.'/)
0044          CALL CLOSE(3)
0045          CALL ACKNOG
0046          RETURN
0047          END
DIGSIN
```

FORTRAN IV Storage Map for Program Unit DIGGIN

Local Variables, .PSECT $DATA, Size = 000050 (20. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
DATE	R*4	000024	I	I*2	000022	IAV	I*2	000020 Eqv
IDATE	I*2	000012 Eqv	J	I*2	000034	K	I*2	000032
LBSY	I*2	000030	NDXDT	I*2	000040	NDXOP	I*2	000036

COMMON Block /RADIO /, Size = 000404 (130. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
NBUF	L*1	000000	LRCVDN	I*2	000400	NIN	I*2	000402

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----	Dimensions
CMSG	R*4	$DATA	000002	000014 (6.)	(3)
NBUF	L*1	RADIO	000000	000400 (128.)	(256)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
ACKNOG	R*4	ASSIGN	R*4	CLOSE	R*4	DAY	R*4	LISTEN	I*2
XMIT	R*4								

```
0001          SUBROUTINE POWER
      C
      C  POWER  OBTAINS KWH.DAT DATA FROM THE DRAGLINE
      C    VIA THE RADIO DATA LINK.  BSRPRT CALLS POWER.
      C
0002          LOGICAL*1 NBUF
0003          COMMON /RADIO/NBUF(256),LRCVDN,NIN
0004          REAL PMSG(2)
0005          DATA PMSG/'RDIO','POWR'/
      C
0006          CALL ASSIGN(16,'KWH.DAT',7)
0007          DEFINE FILE 16(10000,4,U,IAV)
      C
0008  1       CALL XMIT(PMSG,8,'AB',LBSY)
0009          IF(IBSY.NE.0) GO TO 1
      C
0011          I=1
      C
0012  3       K=LISTEN()
0013          IF(K.EQ.1) GO TO 9
0015          IF(K.EQ.0) GO TO 2
0017          CALL CLOSE(16)
0018          RETURN
0019  2       DO 5 J=1,NIN/8
0020          WRITE(16'I) (NBUF(K),K=8*(J-1)+1,8*J)
0021  5       I=I+1
0022          CALL ACKNOG
0023          GO TO 3
      C
0024  9       WRITE(7,400)
0025  400     FORMAT(' KWH.DAT RECIEVED')
0026          CALL ACKNOG
0027          CALL CLOSE(16)
0028          RETURN
0029          END
POWER
```

```
FORTRAN IV      Storage Map for Program Unit POWER

Local Variables, .PSECT $DATA, Size = 000032 (    13. words)

Name    Type  Offset      Name    Type  Offset      Name    Type  Offset
I       I*2   000020      IAV     I*2   000012 Eqv  IBSY    I*2   000016
J       I*2   000024      K       I*2   000022      LBSY    I*2   000014


COMMON Block /RADIO /, Size = 000404 (   130. words)

Name    Type  Offset      Name    Type  Offset      Name    Type  Offset
NBUF    L*1   000000      LRCVDN  I*2   000400      NIN     I*2   000402

Local and COMMON Arrays:

Name     Type    Section Offset  ------Size----- Dimensions
NBUF    L*1      RADIO   000000  000400 (   128.) (256)
PMSG    R*4      $DATA   000000  000010 (     4.) (2)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name    Type   Name    Type   Name    Type   Name    Type   Name    Type
ACKNOG  R*4    ASSIGN  R*4    CLOSE   R*4    LISTEN  I*2    XMIT    R*4
```

```
0001          FUNCTION LISTEN
      C  LISTEN FOR REPLY
0002          LOGICAL*1 NBUF
0003          COMMON /RADIO/NBUF(256),LRCVDN,NC
0004          INTEGER ITIME(2),IT1(2)
0005          DATA ITMOUT/1800/
0006          ITCNT=0
0007  1       CALL RCV
0008          CALL GTIM(ITIME)
0009  5       IF(LRCVDN.NE.0) GO TO 2
0011          CALL GTIM(IT1)
0012          IF(IABS(IT1(2)-ITIME(2)).GT.ITMOUT) GO TO 3
0014          GO TO 5
      C
0015  2       IF(LRCVDN.EQ.-1) GO TO 3
0017          IF(NC.EQ.1) GO TO 9
0019          LISTEN=0
0020          RETURN
0021  3       IF(ITCNT.GT.2)GO TO 4
0023          ITCNT=ITCNT+1
0024          CALL XMIT('?',1,'AB',LBSY)
0025          IF(LBSY.NE.0) GO TO 3
0027          GO TO 1
      C
      C
0028  4       WRITE(7,300)
0029  300     FORMAT(' TIME OUT.  THE DRAGLINE DOESNT ANSWER.')
0030          LISTEN=-1
0031          RETURN
      C
0032  9       LISTEN=1
0033          RETURN
0034          END
LISTEN
```

FORTRAN IV   Storage Map for Program Unit LISTEN

Local Variables, .PSECT $DATA, Size = 000022 (9. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
ITCNT	I*2	000014	ITMOUT	I*2	000012	LBSY	I*2	000016
LISTEN	I*2	000010 Eqv						

COMMON Block /RADIO /, Size = 000404 (130. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
NBUF	L*1	000000	LRCVDN	I*2	000400	NC	I*2	000402

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----	Dimensions
ITIME	I*2	$DATA	000000	000004 (2.)	(2)
IT1	I*2	$DATA	000004	000004 (2.)	(2)
NBUF	L*1	RADIO	000000	000400 (128.)	(256)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
GTIM	R*4	IABS	I*2	RCV	R*4	XMIT	R*4		

```
0001        SUBROUTINE ACKNOG
0002        INTEGER I(2),J(2)
0003        CALL GTIM(I)
0004  2     CALL GTIM(J)
0005        IF(IABS(J(2)-I(2)).LT.60) GO TO 2
0007  1     CALL XMIT('R',1,'AB',LBSY)
0008        IF(LBSY.NE.0) GO TO 1
0010        RETURN
0011        END
ACKNOG
```

```
FORTRAN IV      Storage Map for Program Unit ACKNOG

Local Variables, .PSECT $DATA, Size = 000014 (    6. words)

Name   Type  Offset      Name   Type  Offset      Name   Type  Offset
LBSY   I*2   000010

Local and COMMON Arrays:

Name     Type    Section Offset  ------Size----- Dimensions
I      I*2      $DATA   000000  000004 (     2.) (2)
J      I*2      $DATA   000004  000004 (     2.) (2)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name   Type   Name   Type   Name   Type   Name   Type   Name   Type
GTIM    R*4   IABS    I*2   XMIT    R*4
```

```
FPR/CODE:THR/LIST^U
FOR/CODE:THR/LIST:TT:/NOOBJ ROPES
```

```
        SUBROUTINE ROPES
C
C  ROPES OBTAINS CANDR.DAT AND CRACCU.DAT
C   FROM THE DRAGLINE VIA THE RADIO DATA LINK.
C   BSRPRT CALLS ROPES.
C
        LOGICAL *1 NBUF
        COMMON /RADIO/NBUF(256),LRCVDN
        REAL RMSG(2)
        DATA RMSG/'RDIO','ROPE'/
C
        CALL ASSIGN(10,'CANDR.DAT',9)
        DEFINE FILE 10(5,11,U,IAV)
C
1       CALL XMIT(RMSG,8,'AB',LBSY)
        IF(LBSY.NE.0) GO TO 1
C
        K=LISTEN()
        IF(K.EQ.0) GO TO 2
        CALL CLOSE(10)
        RETURN
C
2       DO 3 I=1,5
3       WRITE(10'I) (NBUF(J),J=22*(I-1)+1,22*I)
        CALL CLOSE(10)
        CALL ACKNOG
        IF(LISTEN().NE.1) RETURN
        CALL ACKNOG
10      CONTINUE
C
C
C  NOW GET CRACCU.DAT
C
11      CALL ASSIGN(11,'CRACCU.DAT',10)
        DEFINE FILE 11(281,10,U,IAV)
        J=1
13      K=LISTEN()
        IF(K.EQ.1) GO TO 19
        IF(K.EQ.0) GO TO 12
        CALL CLOSE(11)
        RETURN
C
12      DO 14 I=1,12
        IF(12*(J-1)+I.GT.281) GO TO 15
14      WRITE(11'12*(J-1)+I) (NBUF(K),K=20*(I-1)+1,20*I)
15      J=J+1
        CALL ACKNOG
        GO TO 13
C
19      CALL CLOSE(11)
        WRITE(7,100)
100     FORMAT(' CANDR.DAT AND CRACCU.DAT RECIEVED')
        CALL ACKNOG
        RETURN
```

```
0046        END
ROPES
?FORTRAN-I-[ROPES ] Errors: 0, Warnings: 1
```

FORTRAN IV   Storage Map for Program Unit ROPES

Local Variables, .PSECT $DATA, Size = 000034 (14. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
I	I*2	000022	IAV	I*2	000014 Eqv	J	I*2	000024
K	I*2	000020	LBSY	I*2	000016			

COMMON Block /RADIO /, Size = 000402 (129. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
NBUF	L*1	000000	LRCVDN	I*2	000400			

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----	Dimensions
NBUF	L*1	RADIO	000000	000400 (128.)	(256)
RMSG	R*4	$DATA	000000	000010 (4.)	(2)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
ACKNOG	R*4	ASSIGN	R*4	CLOSE	R*4	LISTEN	I*2	XMIT	R*4

FOR/CODE:THR/LIST:TT:/NOOBJ RADIO

```
0001          SUBROUTINE RADIO
        C  DATA LINK BACKGROUND ON BOARD DRAGLINE
        C   OCCUPIES A REPORT OVERLAY
        C
0002          LOGICAL*1 FILE,XBUF(256),NBUF
0003          COMMON /RADIO/FILE(256),LRCVDN
0004          EQUIVALENCE (X,FILE(5)),(NDATE,FILE(9))
0005          DATA NOGOOD/'NG'/NG/2/ID/'AB'/
        C
0006          IF(X.EQ.'CMPR') GO TO 1
0008          IF(X.EQ.'POWR') GO TO 1000
0010          IF(X.EQ.'ROPE') GO TO 2000
0012          RETURN
        C
        C
        C  TRANSMIT CMPRS.DAT SECTIONS SINCE REQUEST DATE
        C
0013    1     CALL ASSIGN(12,'CMPRS.DAT',9,'OLD')
0014          DEFINE FILE 12(8000,4,U,L)
0015          READ(12'1,ERR=999) NDXDT
0016          L=3
0017    2     READ(12'L,ERR=3) IDATE
0018          L=L-1
0019          IF(IDATE.GE.NDATE) GO TO 4
0021    3     IF(INCBLK(L,NDXDT).EQ.0) GO TO 2
0023          GO TO 10
        C
0024    4     DO 6 I=1,32
0025          READ(12'L,ERR=999) (XBUF(J),J=8*(I-1)+1,8*I)
0026          IF(L.GE.NDXDT) GO TO 9
0028    6     CONTINUE
0029          I=I-1
0030    9     IF(ITALK(XBUF,8*I,ID).NE.-1) GO TO 11
0032    10    CALL CLOSE (12)
0033          RETURN
        C
0034    11    IF(L.LT.NDXDT) GO TO 4
        C
        C
        C  SIGNAL END OF DATA
        C
0036          I=ITALK(0,1,ID)
0037          GO TO 10
        C
        C
        C  BAD BLOCK--GIVE IT UP
        C
0038    999   I=ITALK(NOGOOD,NG,ID)
0039          GO TO 10
        C
        C
        C  POWER FILE
        C
0040    1000  CALL ASSIGN(12,'CYC:KWH.DAT',11)
```

```
            DEFINE FILE 12(10000,4,U,IAV)
      C
            LP=1
            DO 1010 I=1,313
            DO 1009 J=1,32
            READ(12'LP)(XBUF(K),K=8*(J-1)+1,8*J)
            LP=LP+1
            IF(LP.GT.10000) GO TO 1007
      1009  CONTINUE
      C
            J=J-1
      1007  IF(ITALK(XBUF,8*J,ID).NE.-1) GO TO 1006
      1008  CALL CLOSE(12)
            RETURN
      C
      1006  IF(LP.LT.10000) GO TO 1010
            I=ITALK(0,1,ID)
            CALL CLOSE(12)
            RETURN
      1010  CONTINUE
            CALL CLOSE(12)
            RETURN
      C
      C
      C  CANDR/CRACCU -- OLD BEN'S ROPE FILES
      C
      2000  CALL ASSIGN(10,'CANDR.DAT',9,'OLD')
            DEFINE FILE 10(5,11,U,IAV)
            DO 2001 I=1,5
            READ(10'I) (XBUF(J),J=22*(I-1)+1,22*I)
      2001  CONTINUE
      C
            IF(ITALK(XBUF,110,ID).NE.-1) GO TO 2002
            CALL CLOSE(10)
            RETURN
      C
      2002  I=ITALK(0,1,ID)
            CALL CLOSE(10)
      C
      C
            CALL ASSIGN(11,'CRACCU.DAT',10,'OLD')
            DEFINE FILE 11(281,10,U,IAV)
            DO 2010 I=1,24
            DO 2009 J=1,12
            IF((12*(I-1)+J).GT.281) GO TO 2011
      2009  READ(11'12*(I-1)+J) (XBUF(K),K=20*(J-1)+1,20*J)
      2011  IF(ITALK(XBUF,240,ID).NE.-1) GO TO 2008
            CALL CLOSE(11)
            RETURN
      2008  CONTINUE
      2010  CONTINUE
      C
            I=ITALK(0,1,ID)
            CALL CLOSE(11)
```

```
0089        RETURN
0090        END
RADIO
?FORTRAN-I-[RADIO ] Errors: 0, Warnings: 2
```

FORTRAN IV   Storage Map for Program Unit RADIO

Local Variables, .PSECT $DATA, Size = 000456 (151. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
I	I*2	000426	IAV	I*2	000432 Eqv	ID	I*2	000404
IDATE	I*2	000424	J	I*2	000430	K	I*2	000436
L	I*2	000420 Eqv	LP	I*2	000434	NBUF	L*1	000416
NDXDT	I*2	000422	NG	I*2	000402	NOGOOD	I*2	000400

COMMON Block /RADIO /, Size = 000402 (129. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
FILE	L*1	000000 Eqv	LRCVON	I*2	000400	X	R*4	000004 Eqv
NDATE	I*2	000010 Eqv						

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----	Dimensions
FILE	L*1	RADIO	000000	000400 (128.)	(256)
XBUF	L*1	$DATA	000000	000400 (128.)	(256)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
ASSIGN	R*4	CLOSE	R*4	INCBLK	I*2	ITALK	I*2		

```
        FUNCTION ITALK(MSG,N,ID)
C
        INTEGER VECT,RING,DSPN,FAZE,FC,FNMP,STEP
        LOGICAL*1 DNTM,OPR,DSPY,DISF,DMPF,CYFLG,DIGF,DIGS
        LOGICAL*1 DOWN,WALKF,PRPLP,PULSE
        INTEGER DTR,DTS,DTF,TWALK
        COMMON RING(16,30),CYFLG,DIGF,REF(4),DC(3),A(3),V(3)
        COMMON DCMIN(3),DCMAX(3),VECT,DSPN,FAZE,FC,FNMP,NF,TF
        COMMON T,P,W,DISF,DMPF,SFZ,ZD,ZDP,NP,NMP
        COMMON DOWN,WALKF,DTR,DTS,DTF,TWALK,IANG,STEP,PRPLP,PULSE,SW
        LOGICAL*1 NBUF,IOK
        COMMON/RADIO/NBUF(256),LRCVDN
        DATA TIMOUT/1000./
        DATA IOK/'R'/
C
1       CALL XMIT(MSG,N,ID,LBSY)
        IF(LBSY.NE.0) GO TO 1
        TT=T
        LRCVDN=0
2       IF(LRCVDN.EQ.1) GO TO 3
        IF(ABS(T-TT).GE.TIMOUT) GO TO 4
        CALL  OBD
        GO TO 2
C
3       IF(NBUF(1).NE.IOK) GO TO 1
        ITALK=0
        RETURN
C
4       ITALK=-1
        I=ITTOUR(7)
        RETURN
        END
ITALK
```

FORTRAN IV   Storage Map for Program Unit ITALK

Local Variables, .PSECT $DATA, Size = 000036 (15. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
DIGS	L*1	000020	DNTM	L*1	000015	DSPY	L*1	000017
I	I*2	000030	ID	I*2 @	000004	IOK	L*1	000014
ITALK	I*2	000006 Eqv	LBSY	I*2	000022	MSG	I*2 @	000000
N	I*2 @	000002	OPR	L*1	000016	TIMOUT	R*4	000010
TT	R*4	000024						

COMMON Block /   /, Size = 002120 (552. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
RING	I*2	000000	CYFLG	L*1	001700	DIGF	L*1	001701
REF	R*4	001702	DC	R*4	001722	A	R*4	001736
V	R*4	001752	DCMIN	R*4	001766	DCMAX	R*4	002002
VECT	I*2	002016	DSPN	I*2	002020	FAZE	I*2	002022
FC	I*2	002024	FNMP	I*2	002026	NF	I*2	002030
TF	R*4	002032	T	R*4	002036	P	R*4	002042
W	R*4	002046	DISF	L*1	002052	DMPF	L*1	002053
SFZ	R*4	002054	ZD	R*4	002060	ZDP	R*4	002064
NP	I*2	002070	NMP	I*2	002072	DOWN	L*1	002074
WALKF	L*1	002075	DTR	I*2	002076	DTS	I*2	002100
DTF	I*2	002102	TWALK	I*2	002104	IANG	I*2	002106
STEP	I*2	002110	PRPLP	L*1	002112	PULSE	L*1	002113
SW	R*4	002114						

COMMON Block /RADIO /, Size = 000402 (129. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
NBUF	L*1	000000	LRCVDN	I*2	000400			

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----	Dimensions
A	R*4	.$$$$.	001736	000014 (6.)	(3)
DC	R*4	.$$$$.	001722	000014 (6.)	(3)
DCMAX	R*4	.$$$$.	002002	000014 (6.)	(3)
DCMIN	R*4	.$$$$.	001766	000014 (6.)	(3)
NBUF	L*1	RADIO	000000	000400 (128.)	(256)
REF	R*4	.$$$$.	001702	000020 (8.)	(4)
RING	I*2 Vec	.$$$$.	000000	001700 (480.)	(16,30)
V	R*4	.$$$$.	001752	000014 (6.)	(3)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
ABS	R*4	ITTOUR	I*2	OBD	R*4	XMIT	R*4		

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