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TECHNICAL REPORT

NORSAR PHASE 1

OPERATION AND MAINTENANCE

1 FEB TO 30 NOV 1968

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TECHNICAL REPORT

NORSAR (NORWEGIAN SEISMIC ARRAY)

PHASE 1 (Operation and maintenance)

NORWEGIAN DEFENCE
RESEARCH ESTABLISHMENT
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FOREWORD

This research installation project and the operation of it is sponsored and supported by the Advanced Research Project Agency of the Department of Defense. Technical guidance and direction for Contract No F61052-68-C-0009 has been provided by the Electronics System Division (AFSC). Contractual support was provided by the European Office of Aerospace Research, OAR. This report covers the period from 1 February through November 1968.

We wish to acknowledge the very considerable support and assistance provided during the course of this project by the Nuclear Test Detection Office (ARPA), the Seismic Array Program Office (ESD), the European Office of Aerospace Research (EOAR), the Lincoln Laboratory (MIT) and the Education and Technical Services Division of the Philco-Ford Corporation.

This technical report has been reviewed and is approved.

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CONTENTS

NORSAR PHASE 1 - OPERATION AND MAINTENANCE

SUMMARY

This report covers operation and maintenance (O&M) of the NORSAR Phase 1 Seismic System during the period 1 February - 30 November 1968.

The main purpose of the operation was acquisition of data on teleseismic signals transmission and noise characteristics within south-eastern Norway, essential information when decisions were to be made on geometrical parameters of the large array to be built in the same area. In addition, practical experiences from running the limited system would obviously help the planning of the O&M organization for the future, full-scale system.

The report presents a technical description of the system and the O&M organization with facilities and procedures, followed by a chronological narrative of the operation. Stress is laid on the extraction of experiences, partly in the form of statistics.

1 INTRODUCTION

The decision to divide the NORSAR installation into two phases was taken quite early during the introductory project negotiations. Several circumstances made such a decision appropriate:

a) Installation of a large seismic array represents an unusual undertaking in many ways, even if each element of the array may be rather conventional. Very little of the experience gathered from installation of the LASA in Montana could be transferred unchanged to NORSAR. Major modifications or even completely new solutions had to be introduced for the various array elements due to widely different conditions regarding climate, topography, surface geology, population densities, communications in the widest sense, etc. On the average these practical "environmental" parameters were less favourable in Norway than in Montana, and consequently called for more work-consuming methods and hardware.

It was generally agreed that the installation should be a Norwegian undertaking to the largest possible extent, and doubts could be raised as to the capacity and competence of the domestic resources. It was judged that installation of a limited phase 1 system as a separate task would probe the domestic potential effectively and give the experience necessary for handling a main installation phase in an efficient way.

The installation of the Phase 1 system, completed January 1968, is reported in Final Technical Report, NORSAR Phase 1 - Installation, later in the text referred to as INST PH 1 REP.

b) When the US - Norway negotiations were initiated in early summer 1967, the layout of the large array was still far from being settled. Major variables such as the aperture dimension and the geometrical configuration itself were open questions and obviously would remain so for some time.

Important parts of the decision-making were related to basic array theory in general, independent of site. Others were connected to the seismic conditions in the potential area, south-eastern Norway. Some knowledge of the latter was available, e g through the operation of a small array at Ringsaker near Lillehammer. However, further data on teleseismic signals transmission and noise characteristics within the area were evidently needed to lay a sound basis for deciding certain parameters of the large array configuration. It was felt that operation of a phase 1 system would contribute heavily towards this end. It was intended that the system be designed so that most of it eventually could be incorporated in the large array as vaguely conceived at that time.

This report covers the operation of the Phase 1 system in the period 1 February through 30 November 1968. It does not cover the results of the data-processing and the consequences of these.

1.1 The operation and maintenance (O&M) tasks

Generally defined these were to operate and maintain the system in such a way as to meet the requirements set down by ESD on behalf of the users of seismic data from the system, of which the more important ones were Lincoln Laboratory (LL), MIT; Seismic Array Analysis Center (SAAC), IBM; and the University of Bergen (U of B).

More specifically the operation consisted in continuous recording of seismometer signals and other pertinent data on magnetic tape and distribution of the tape according to the user's demands. Preventive and corrective maintenance was to be performed to an extent that kept system downtime within reasonable limits.

Most of the work was to follow specified routines valid for the whole operation period, but these routines could be interrupted at any time and be replaced by special investigations called for by a user.

An important by-product of the O&M tasks would be gathering of statistics on system and elements reliability.

1.2 Subcontracting of the O&M tasks

The Norwegian Defence Research Establishment (NDRE) could not provide an O&M group from its permanent staff, and it was very doubtful whether it would be in its interests to build up an organization of this type within the establishment.

It was therefore decided that the tasks should be subcontracted to a private firm chosen through bid competition. The O&M contract was awarded to Noratom-Norcontrol A/S, Oslo, the lowest bidder, and found acceptable by NDRE.

1.3 Guidance and assistance from US consultants

It was obvious that the O&M tasks could not be undertaken without introductory support from US consultants. This support had to cover staff training, setting-up of procedures for operation and calibrations, and to some extent also corrective maintenance during the first months of the period.

US consultants were personnel from Philco-Ford, an LL subcontractor.

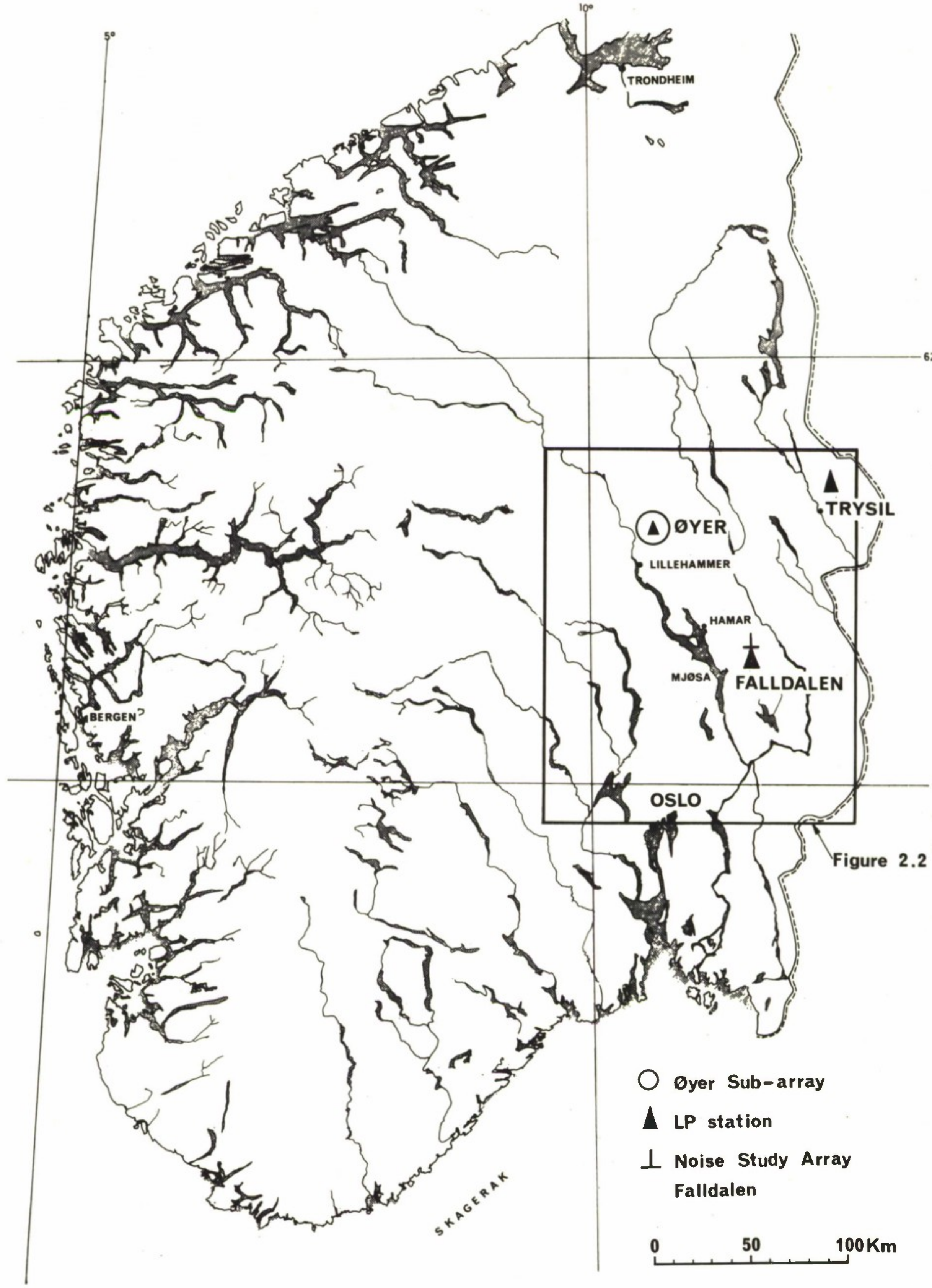


Figure 2.1 Southern Norway
Square indicates general area of interest, shown in detail in Figure 2.2.

0 5 10 20 30 Km

0 5 10 20 Miles

○ Øyer Sub-array

▲ LP station

⊥ Noise Study Array Falldalen

Figure 2.2 South-eastern Norway
Area of operation.

2 TECHNICAL DESCRIPTION OF THE NORSAR PHASE 1 SYSTEM

The Phase 1 system actually consisted of three individual seismic sub-systems, a Short Period (SP, 1 Hz) sub-array, and a Long Period (LP, 0.05 Hz) array, both of which could eventually be integrated in a final NORSAR large array, and finally an experimental SP array intended for special noise studies.

2.1 Geographical configuration of the system

The installations were located at three different sites in the south-eastern part of Norway, Figures 2.1 and 2.2.

2.1.1 The Øyer site

The Øyer SP sub-array, now integrated in the Phase 2 system, is located on a mountain plateau some 25 km north of Lillehammer at a height of 900 - 1000 meters above sea level (masl). Figure 2.3 shows typical terrain of the Øyer mountain plateau. The traveling distance from Oslo is 240 km.

As this array was meant to be part of the final NORSAR system, it was built permanently with buried cables and a Central Terminal Vault (CTV) for termination of all signal cables and accommodation for data handling equipment.

However, in Phase 1 recording was to be done on site, and for this purpose temporary housing for a Data Recording Center (DRC) was erected close to the CTV. All cables were looped at the CTV and brought into the DRC.

Besides the SP sub-array containing 12 SP seismometers, the site also has a three-component LP installation. The LP seismometers, which were part of the LP array and now incorporated in the Phase 2 system, are installed in a permanent Long Period Vault (LPV) located 50 m from the CTV, which in turn is located 50 m from the DRC. Situation map of the site is shown in Figure 2.4.

Figure 2.3 Øyer mountain plateau, typical terrain

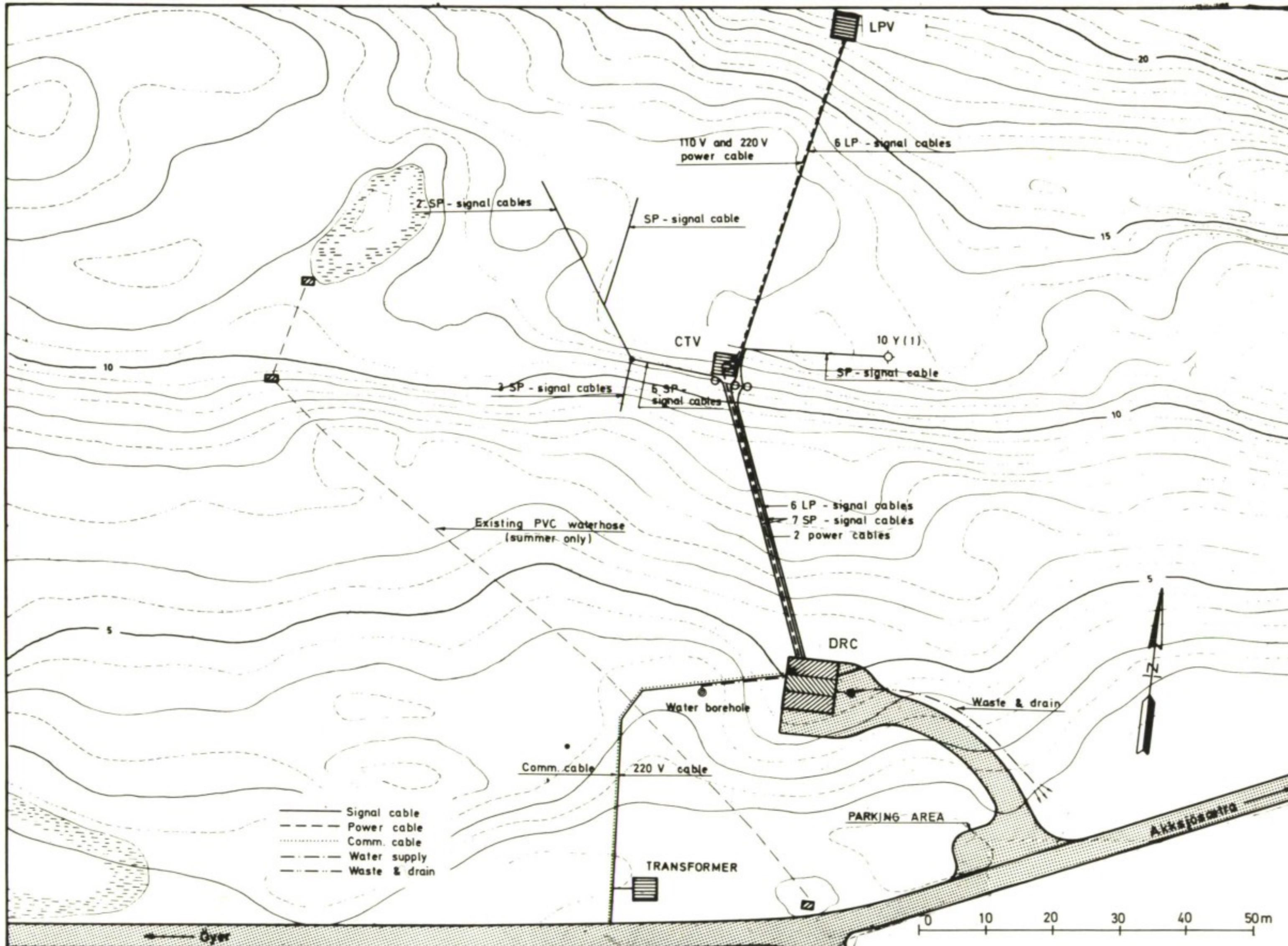


Figure 2.4 Øyer DRC area

The DRC (Figure 2.5) is built up of prefabricated units and arranged as shown in Figure 2.6. It has an instrument room for the recording equipment, where all cables are terminated, and it has an office with telephone and telex, and finally it contains fairly well equipped living quarters for two persons. An old farmhouse nearby was used as storage for spare seismometers.

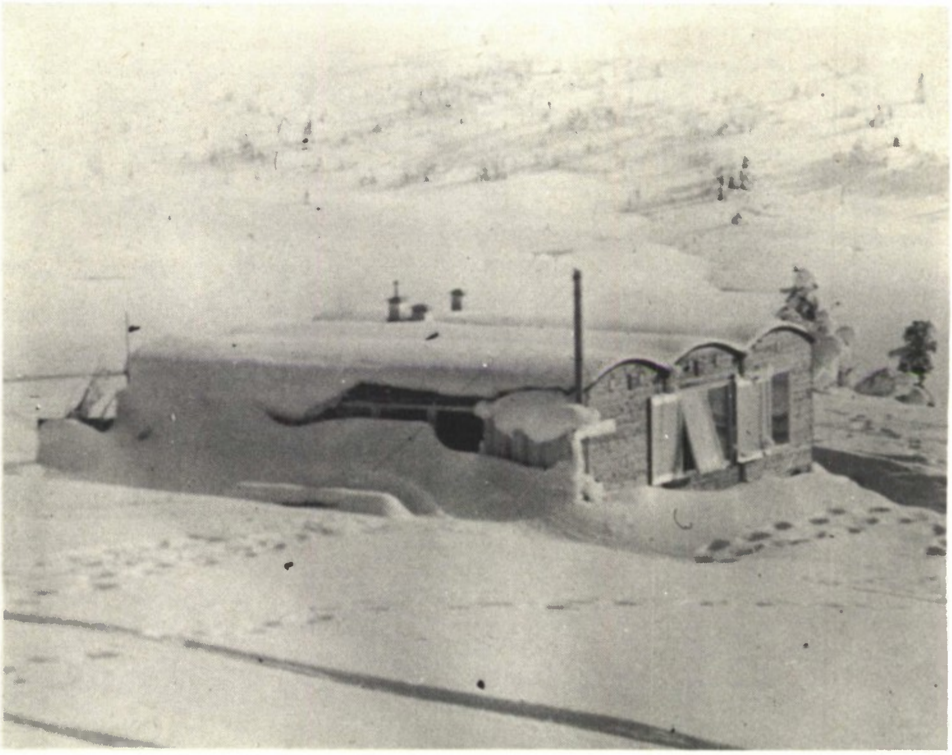
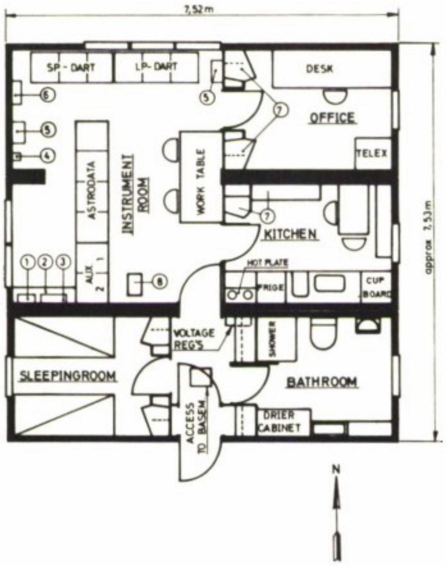


Figure 2.5 Øyer DRC



1 Battery charger
2 Batteries
3 SP junction box
4 Communication line terminal
5 Tape rack
(LP-amplifiers
6 (Junction box
(Calibration panel
7 Spare parts
8 Oscilloscope

Figure 2.6 Arrangement of Øyer DRC

The site can be reached by car during the summer months, June - October, but snow vehicles (Figure 2.7) are necessary for the last 12 km during the winter period.

Figure 2.7 Snow vehicles at Øyer site

2.1.2 The Falldalen site

The experimental noise study array was located at Falldalen, a small, open valley about 30 km SE of Hamar some 300 masl. Travelling distance from Oslo was 135 km.

Being a temporary installation, all signal cables were laid on the surface, and the recording equipment was placed in a temporary DRC.

Besides the noise study array this site also had a three-component LP installation, which constituted the second point of the LP array. The sensors were installed in a permanent vault (LPV) located 100 m from the DRC. Situation map of the site is shown in Figure 2.8.

The DRC (Figure 2.9) was housed in a prefabricated unit similar to the ones used at Øyer site. It provided a single room for the technical installations arranged as shown in Figure 2.10 and had no facilities as living quarters. An old farmhouse nearby was used as storage for spare parts such as seismometers, power supplies, etc.

The site was accessible by car throughout the year.

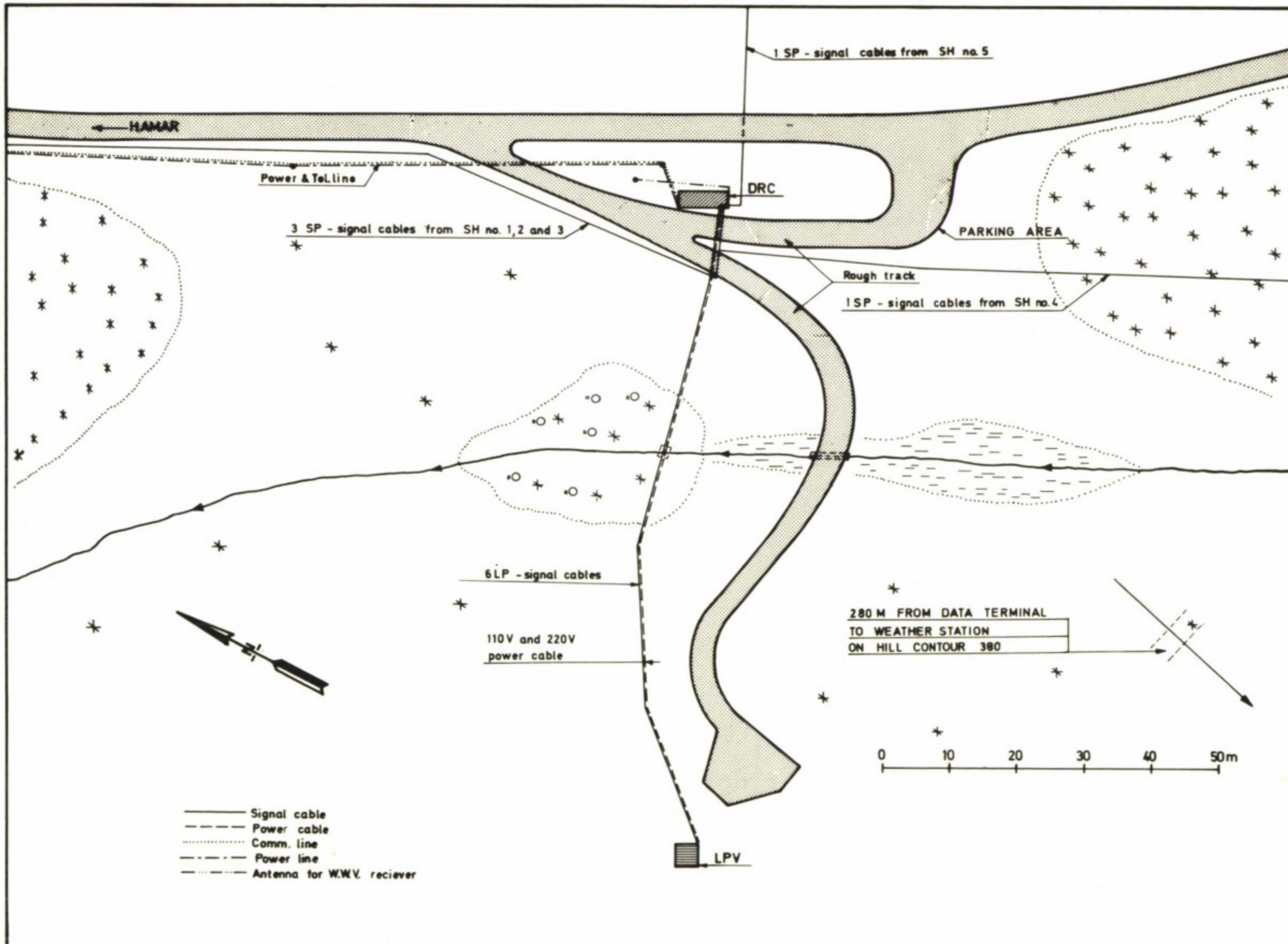


Figure 2.8 Falldalen DRC area

Figure 2.9 Falldalen DRC

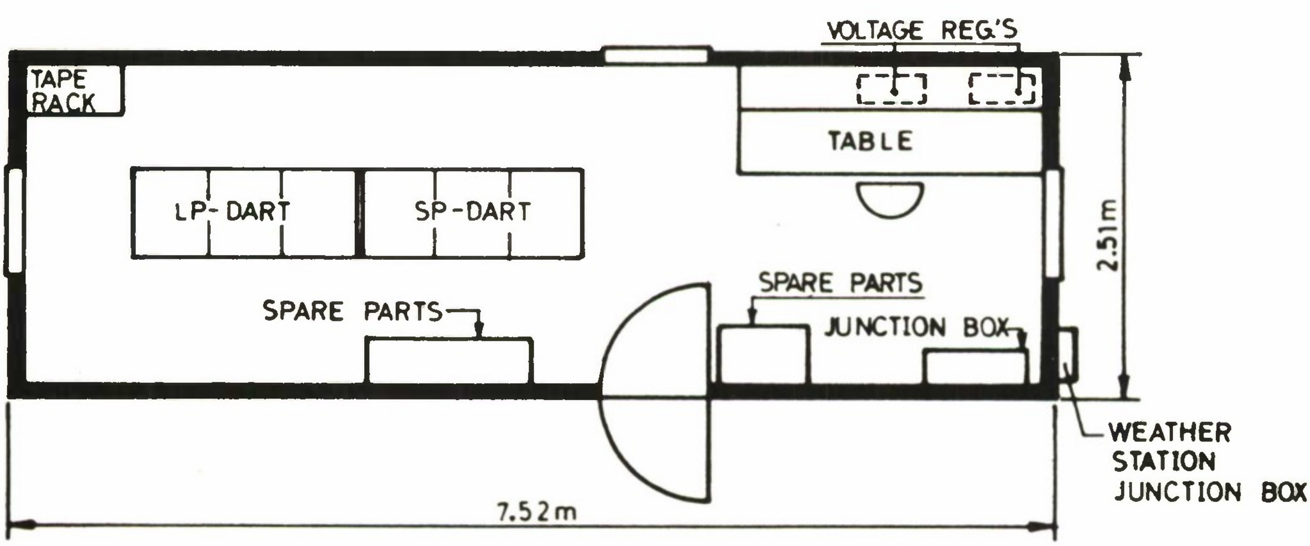


Figure 2.10 Arrangement of Falldalen DRC

2.1.3 The Trysil (Borgseter) site

This site contained the third station of the LP array. It was located at Borgseter about 13 km NE of the community of Trysil, some 800 masl. The traveling distance from Falldalen site was 135 km and from Oslo 270 km.

The LP sensors were, as for the two other sites, installed in a permanent vault (LPV) while the recording equipment was installed in a temporary DRC about 80 m away. Situation map of the site is shown in Figure 2.11.

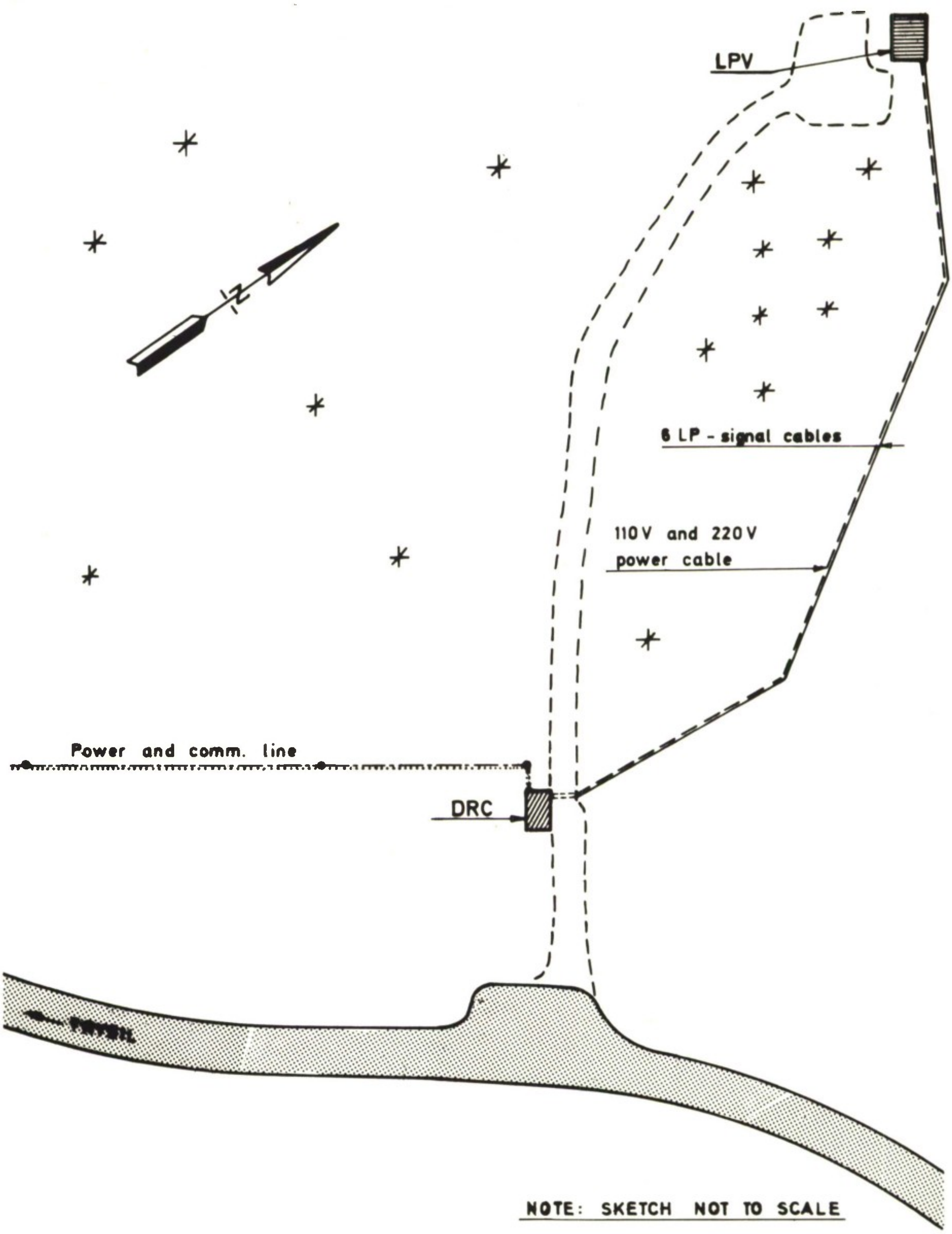
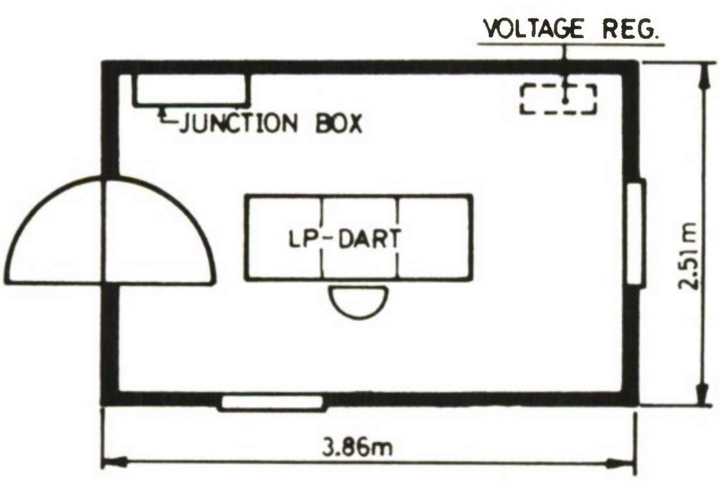


Figure 2.11 Trysil DRC area

Figure 2.12 Trysil DRC



A prefabricated unit somewhat smaller than the one at Falldalen site was used as DRC (Figure 2.12). It was arranged as shown in Figure 2.13.

The site was accessible by car throughout the year.

Figure 2.13 Arrangement of Trysil DRC

2.2 The SP sub-array

Figure 2.14 shows the layout of the array. It contains 12 vertical seismometers distributed along two diameters (combination of two radially opposite legs), legs A and D with 3 sensors each and legs C and F with 3 and 2 sensors, respectively. The twelfth seismometer is located at 10Y in the center of the array, close to the DRC. The distance between neighboring seismometers varies from approximately 3 to 5 km. 1F4 is an exception, being located only about 1 km from the center.

All signal cables from sensors to DRC as well as power and communication cables within the area are buried at a depth of 50 to 60 cm.

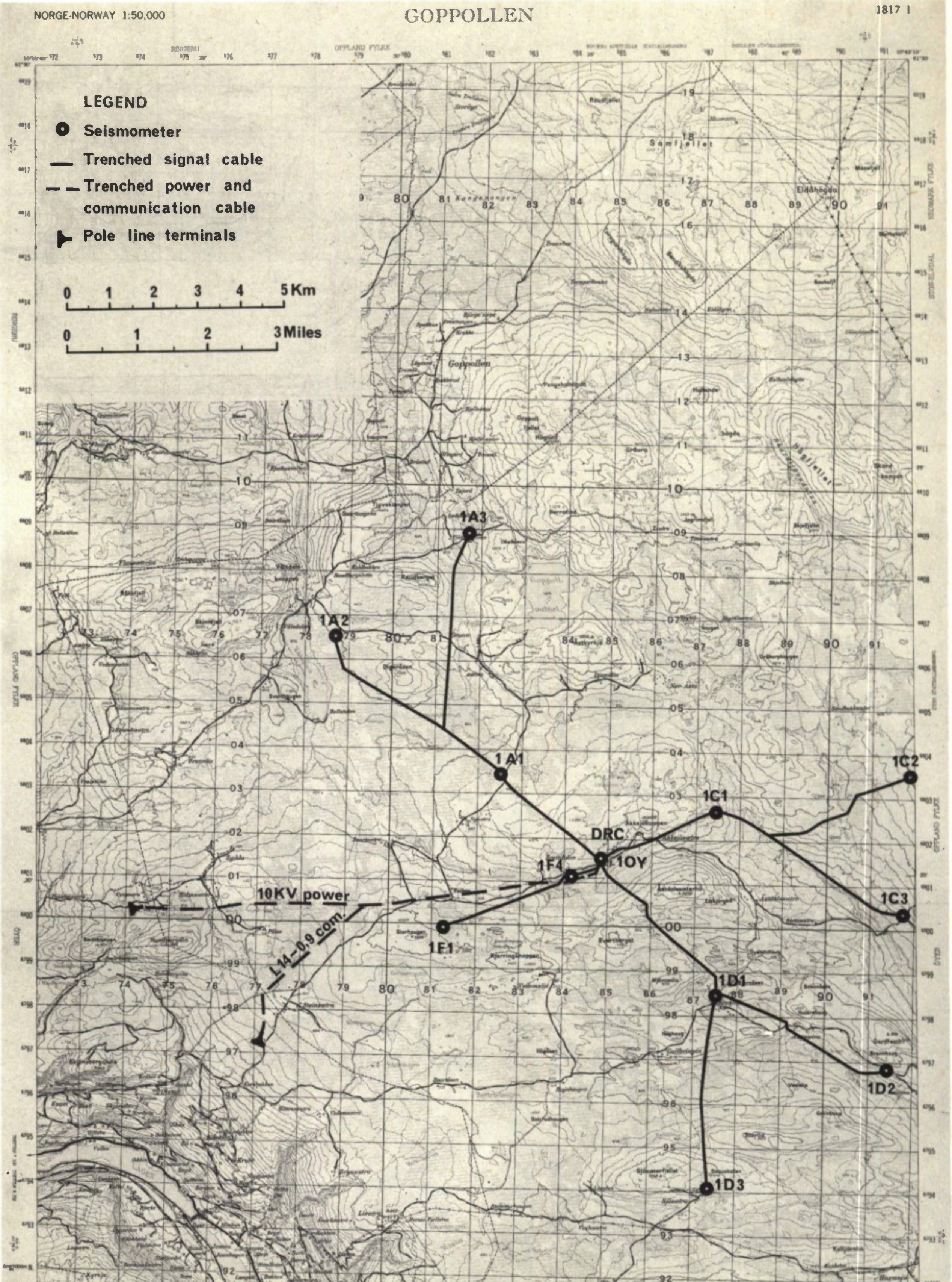


Figure 2.14 Øyer SP subarray, layout

2.2.1 Coordinates list

The coordinates of the seismic points are given in the list below:

Seismic point	Cartesian		UTM-system		Altitude in meters above sea level
	°N	°E	X	Y	
10Y	61°20'13.4546"	10°35' 8.2385"	6801524.999	584847.858	974.54
1A1	61°21'17.2450"	10°32'36.2904"	6803444.364	582542.923	922.22
1A2	61°22'59.9818"	10°28'25.5383"	6806536.715	578746.490	904.95
1A3	61°24'13.9576"	10°31'50.6081"	6808895.390	581736.124	1004.63
1C1	61°20'46.2759"	10°38' 4.0405"	6802604.810	587435.264	918.80
1C2	61°21'12.9977"	10°43' 4.9589"	6803546.275	591884.295	961.67
1C3	61°19'29.9726"	10°42'39.3073"	6800353.020	591735.483	799.45
1D1	61°18'32.0614"	10°38' 0.6381"	6798451.451	587488.536	931.81
1D2	61°17'38.2190"	10°42'20.3333"	6796884.583	591395.026	864.40
1D3	61°16' 9.3848"	10°37'45.4451"	6794031.946	587372.649	990.42
1F1	61°19'24.1201"	10°31' 5.7732"	6799913.060	581279.788	989.98
1F4	61°20' 2.2700"	10°34'17.3629"	6801160.699	584100.071	928.35

Table 2.1 Øyer SP array coordinates list

2.2.2 The SP front end (FE) system

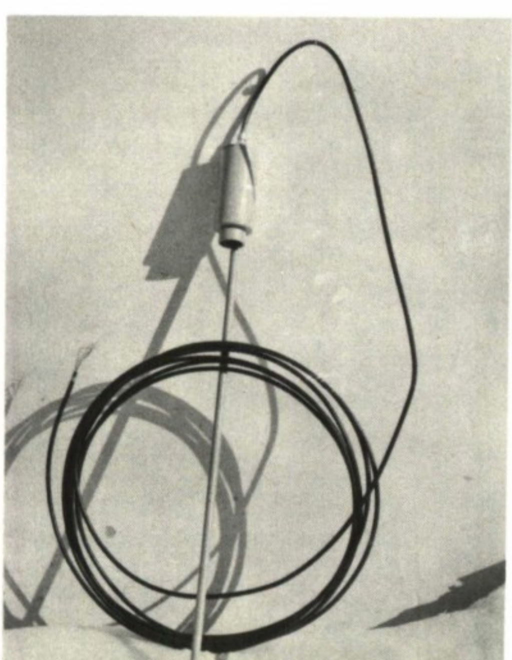


Figure 2.15 SP seismometer on stilt (Model Hall-Sears HS-10-1/ARPA)

The type of sensor used in the SP subarray is Hall-Sears HS-10-1/ARPA vertical seismometer (Figure 2.15, specifications in Appendix A1.1), a spring-mass, velocity type instrument with a natural frequency of 1 Hz, and a 0.2 to 5.0 Hz band. The seismometer is a modified version of the standard HS-10-1 and is fitted with a calibration coil to enable remote calibration from the DRC. The cylindrical instrument with OD 121 mm (4.75 in) and height 286 mm (11.25 in) is placed in a 15 m (48 ft) deep rock borehole lined with a sealed steel casing. It is fitted peripherally with an axially oriented steel rod so that the lower end of the seismometer in operation rests 152 cm (5 ft) above the bottom of the hole casing. The instrument is sealed.

Figure 2.16 Typical Well Head Vault (10Y)

Figure 2.17 Well Head Vault with hat and insulation removed

Buried in the ground, lid at ground level (Figures 2.16 and 2.17) and welded to the top of the seismometer hole casing, the Well Head Vault (WHV, a modified oil drum) serves as housing for the seismometer/cable interfacing electronics. This consists of the Amplifier Box (AB) and the Junction Box (JB). The WHV drum is fitted with one or three cable entrances, depending on the location in the array. Figure 2.18 shows a seismometer hole with WHV and complete installation.

The FE system comprises seismometers, ABs, JBs and signal cables from WHVs to DRC. Wiring diagrams of the FE system are found in Appendix A1.

The AB (Figure 2.19) contains a low frequency, low noise amplifier (Texas Instrument RA5, specifications in Appendix A1.4), an input card (Figure 2.20) and a protect card (Figure 2.21). The seismometer cable as well as the JB cable are plugged onto the AB for convenient maintenance (Figure 2.22).

The JB is equipped with taperpin blocks for cable interconnections, and with lightning protectors. There are two versions of the JB. One of them (Figure 2.23) is for the "end-of-leg" seismometers and the other (Figure 2.24) for the branching points. The JB is also fitted with telephone jacks, inside and on the cover (Figure 2.25) for intercommunication between the seismic points and the DRC.

The input card in AB (Appendix A1.3, Figure A1.1) is equipped with a relay which, operated from the DRC, switches the calibration signal directly to the input of the RA5 amplifier, bypassing the seismometer. It is thereby possible to check the input amplifier itself without the presence of seismic signals.

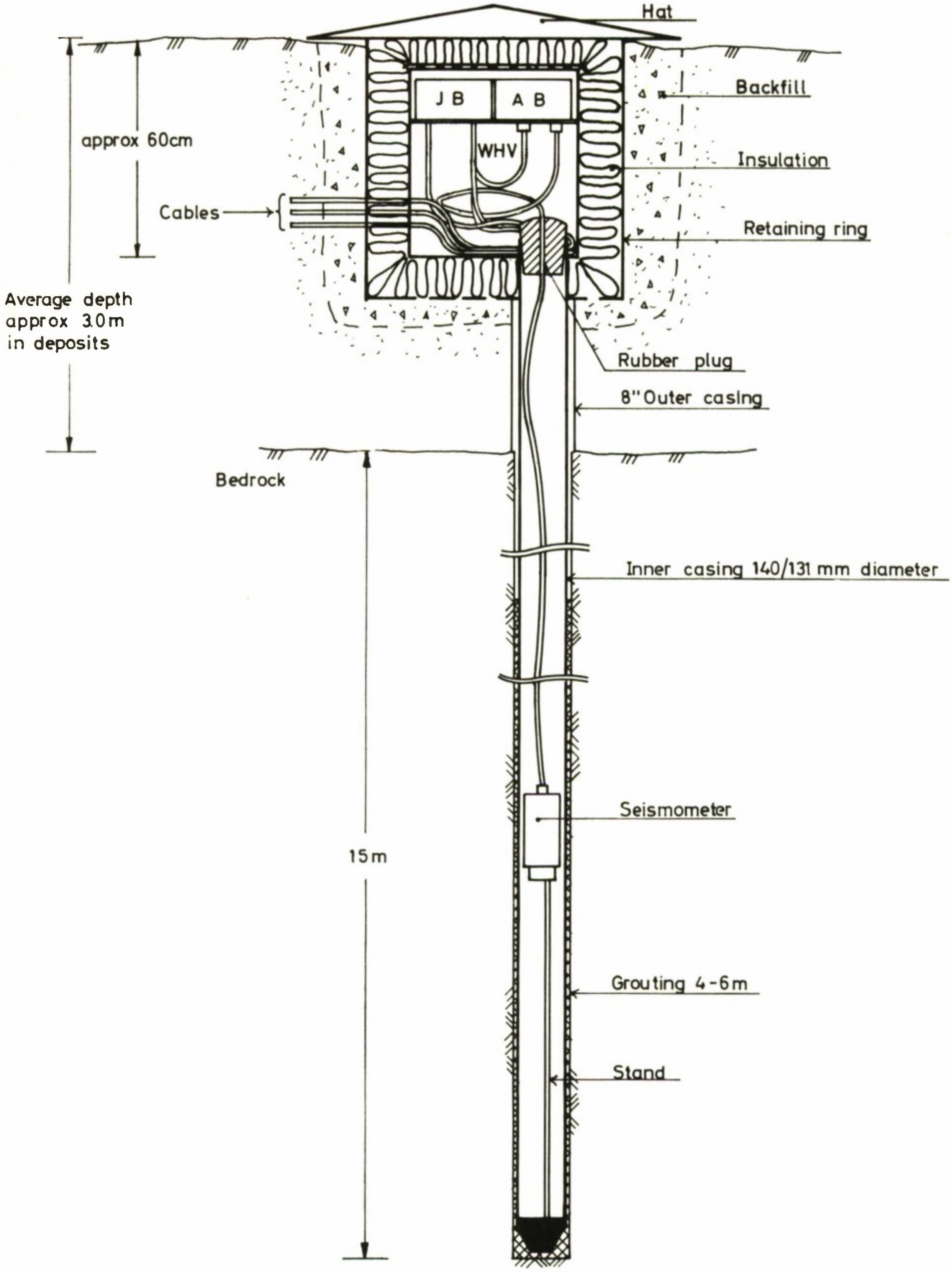


Figure 2.18 SP seismometer hole, with WHV and complete installation

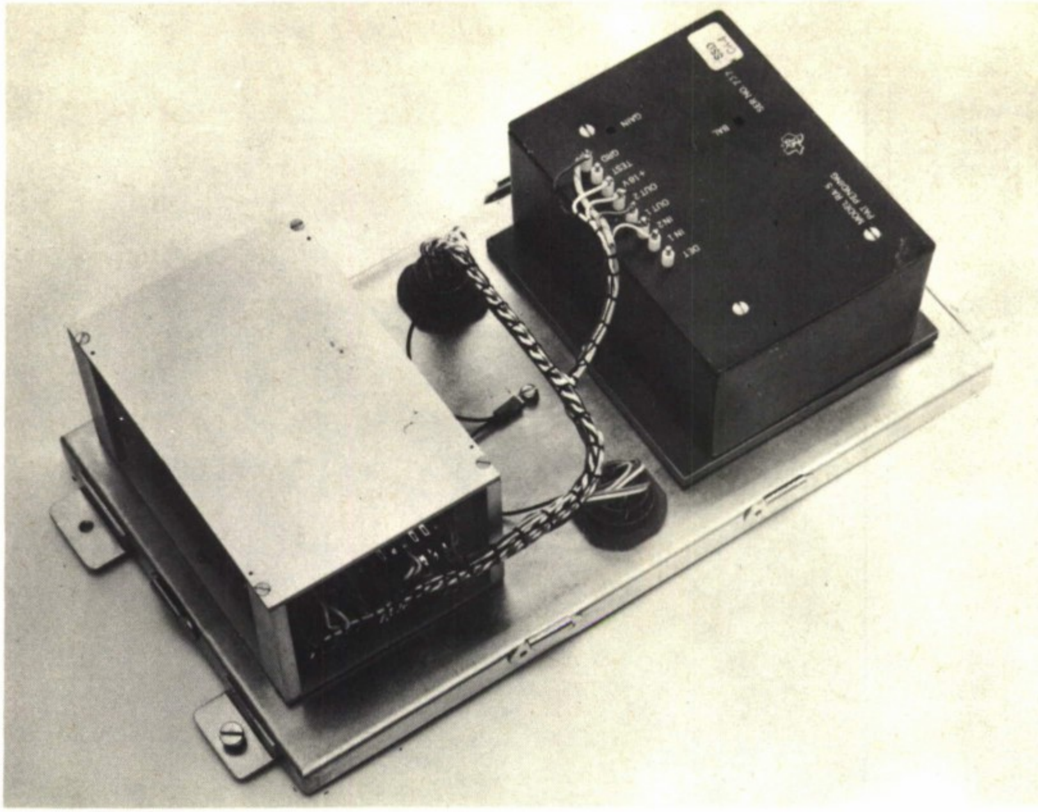


Figure 2.19 Amplifier Box, cover removed

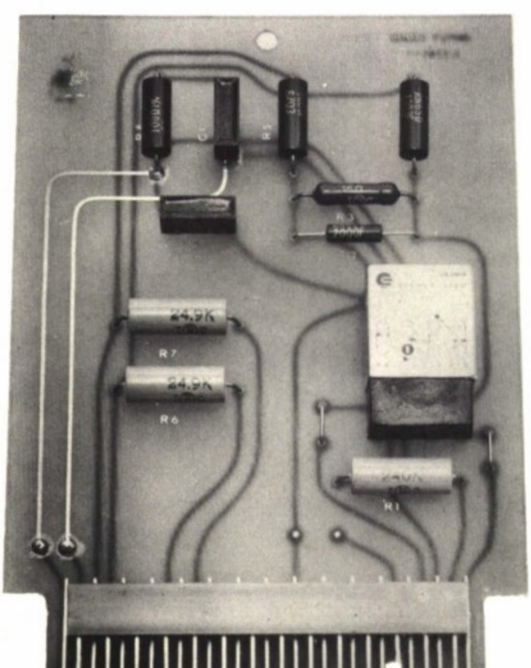


Figure 2.20 Input Card

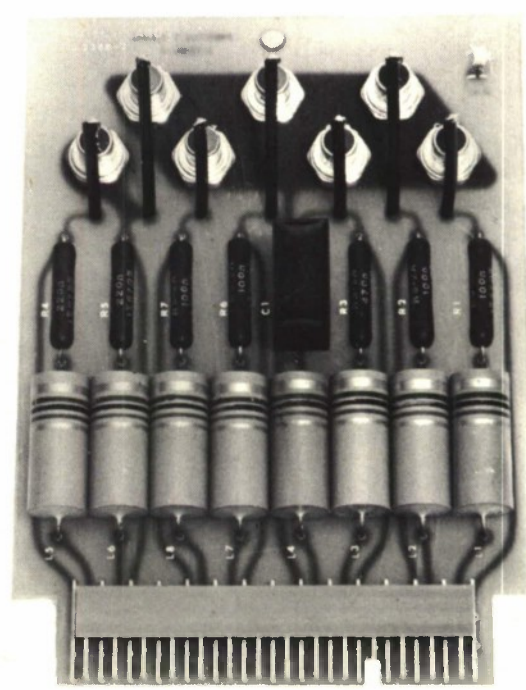


Figure 2.21 Protect Card

Figure 2.22 Amplifier Box, bottom view showing seismometer- and JB-connections

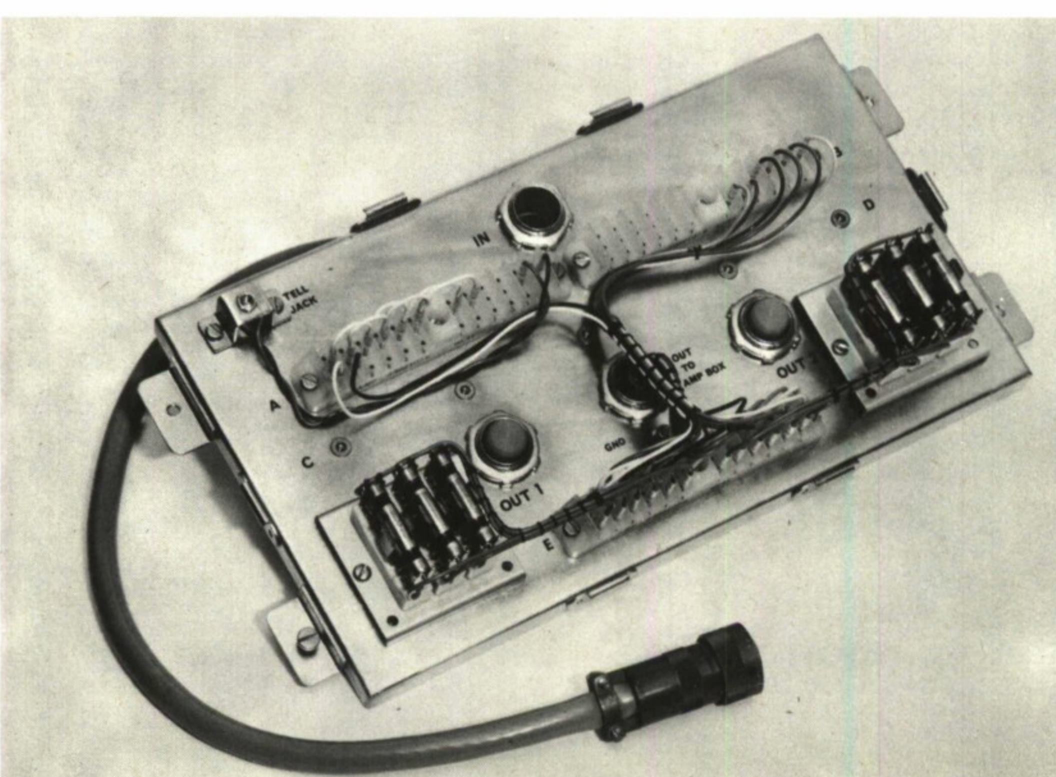


Figure 2.23 Junction Box, end-of-leg type

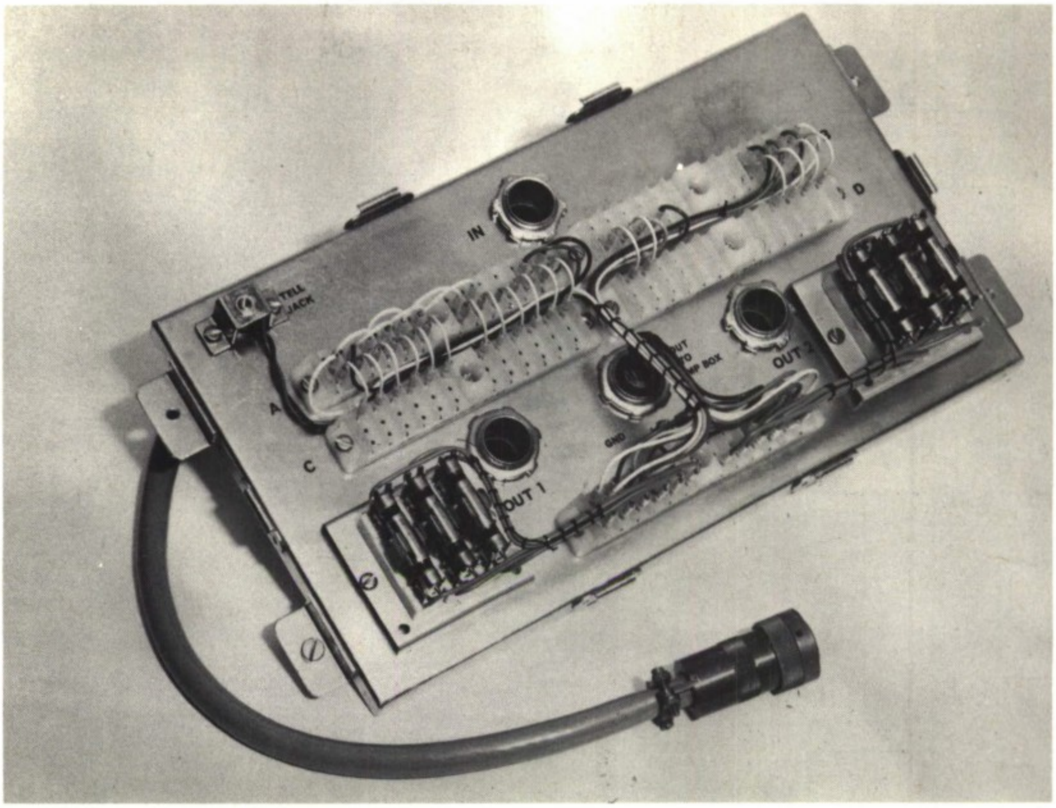


Figure 2. 24 Junction Box, branching type

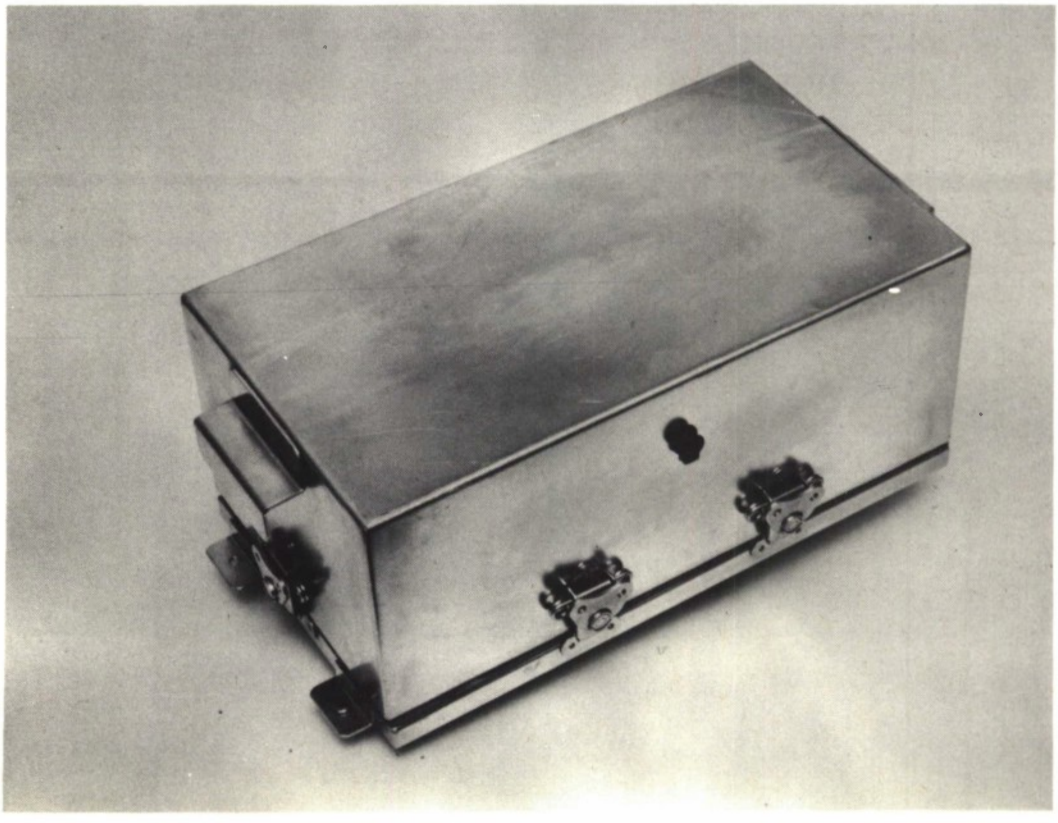


Figure 2. 25 Junction Box, telephone jack on side of cover

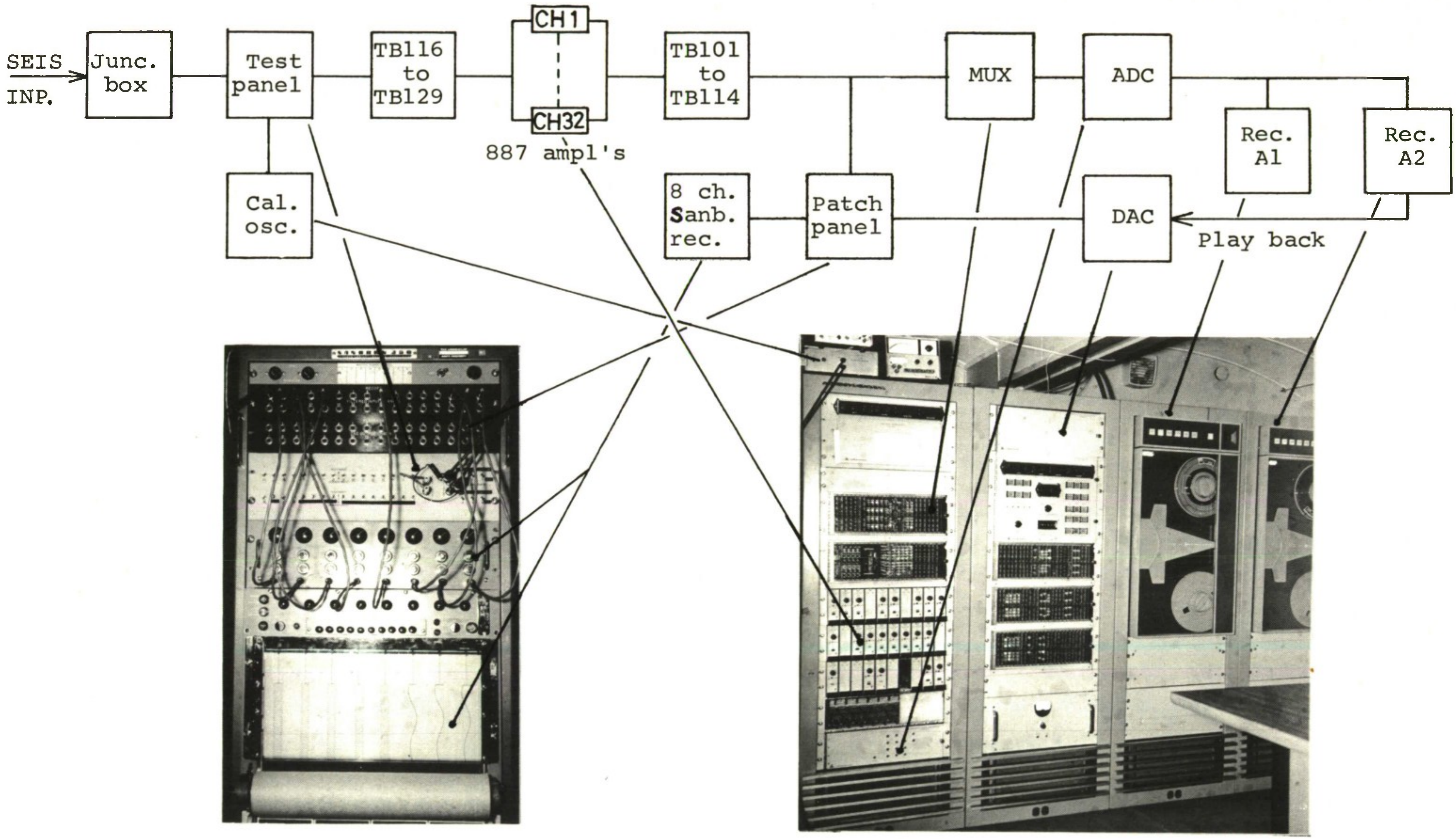


Figure 2.26 The Astrodata with auxiliary equipment

2.2.3 Recording and auxiliary equipment

Two mutually independent systems were available at Øyer for recording of SP seismometer signals.

a) An Astrodata with auxiliary equipment

b) A Data Recording Terminal (DART)

The Astrodata was used as the main system due to its larger input capacity (32 input channels) while the DART (6 input channels) was stand-by equipment to be used during Astrodata downtime or during FE-system check-out or in other cases when crew had to leave site for more than 5 hours.

a) The Astrodata with auxiliary equipment (Figure 2.26)

i) General description

The Astrodata is capable of sampling the analog input from 32 seismometers, converting these data to digital codes, and recording them on magnetic tape together with information giving identification of the site, time-of-day (TOD) as derived from the Astrodata clock, and other particulars about the recordings.

Two Datamec tape stations are included in the system to make possible continuous recording. One of these tape stations can be used for playback of recorded tape in connection with a digital-to-analog converter (DAC). The output of the DAC is made available for presentation on a chart recorder.

Auxiliary equipment used for test and calibration of the seismometers are a test and calibration panel with calibration oscillator, a patch panel for phonoplug connections to either input or playback channels and an 8-channel Sanborn chart recorder. An Event Detector (Figure 2.27) is also part of the auxiliary equipment. It punches out on teleprinter tape seismic events as sensed through any single SP seismometer.

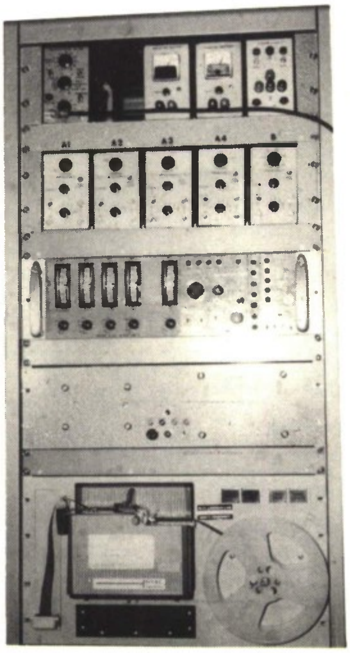


Figure 2.27 Event Detector

ii) Modes of operation (Figure 2.28)

Astrodata, normal run

The analog inputs from the seismometers are fed to the test panel which has provisions for substituting the signals from any individual channel with a test signal. This signal is provided by an external generator connected to the panel.

From the test panel the analog signals are fed through a set of dc-amplifiers to a multiplexer which samples the channels at a rate of 20 times/s and feeds them to an analog-to-digital converter (ADC). The ADC passes the signals on in series of 14 bit digital words (including the sign bit) and applies them to a data register where a parity bit is added and the sign bit is extended to 4 bits. A complete word consists of 18 bits as shown in Figure 2.29.

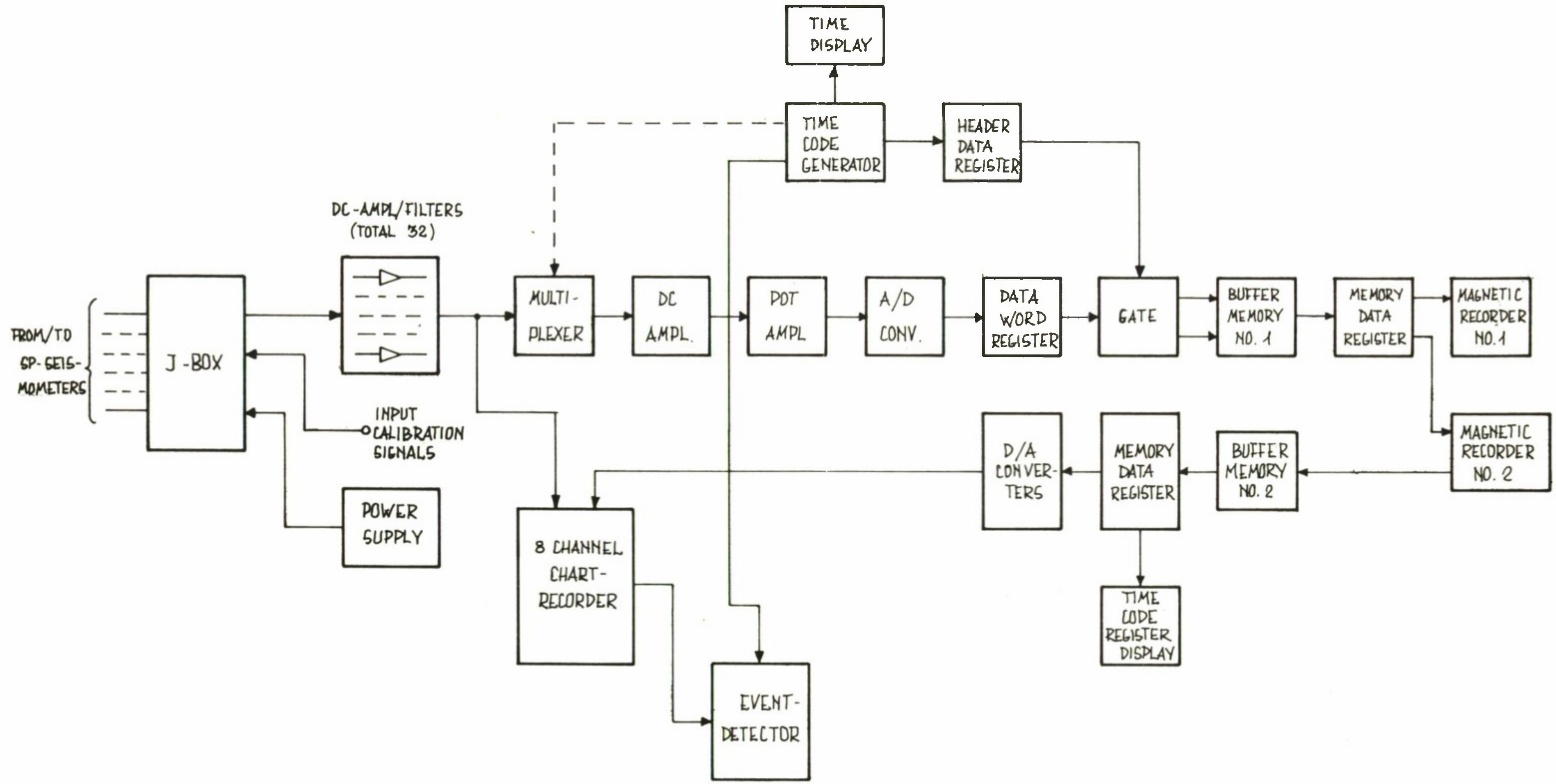


Figure 2. 28 Block diagram of SP recording equipment (Astrodata) at Øyer DRC

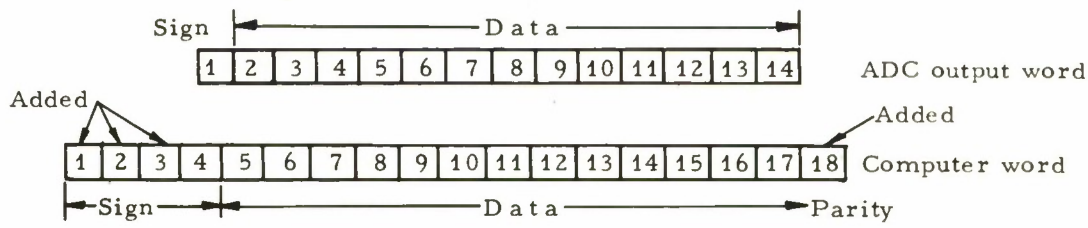


Figure 2.29 Astrodata word configuration

Every two seconds two header words (headers) presenting TOD information in BCD code are fed from the clock into a header register together with a third header presenting the parity error status of the previous record and a fourth header containing site information, sampling rate and number of sensors. These data are put on tape in the form of records, each containing four headers and 1280 data words. Every tape reel starts or ends with a number of records containing calibration data applied manually by the operator.

To fill the 7 track tape, the 18 bit words are broken down into three 6-bit characters when loaded into the data register, the seventh track being reserved for the parity bit. Since headers and record gaps are not written on tape synchronized with input sampling and digitizing timing, a memory (Ferroxcube type) is used as a buffer. The headers and data words are loaded into memory in 6-bit characters and later unloaded and recorded by one of the two tape stations. When an end-of-tape tab is sensed, recording is transferred to the other tape station automatically, while the first tape station is put into rewind.

The parity is checked immediately after it is written on the tape. The number of parity errors are counted continuously and the accumulated sum is displayed on a parity error counter on the control panel.

The control section synchronizes the different functions and operation modes, guided by the clock.

One reel holds 2400 feet of tape and provides approx 2.5 hours of recording time. The system can therefore record continuously for approx 5 hours without manual tape change.

Astrodata, playback

Tape station 2 and a second buffer memory can be used for playback of recorded tape. This mode is initiated manually from the control panel and effects unloading from tape into the memory. From the memory, playback data are loaded into the memory output register. The data is then converted to analog by a digital-to-analog converter (DAC) and loaded into the correct output channels as controlled by a DAC load sequencer. The analog output from the DAC is applied to phonojacks on the patch panel for connection to the Sanborn chart recorder. A Nixie tube display on the control panel gives the TOD information from the played back tape.

Chart recorder

The 8-channel Sanborn chart recorder is used for calibration and checking purposes and is mounted in auxiliary cabinet 1 (Figures 2.6 and 2.26) together with the patch panel and the test and calibration panel.

The input signals or the playback signals from the DAC are connected to the recorder over the patch panel.

A calibration signal from a built-in oscillator can be applied to each channel with the sensitivity switch in calibration position.

Event Detector (Figure 2.27)

The event detector is designed and built by Lincoln Laboratory. Its purpose is to detect and classify seismic events and to present data and time of signal reception from these events on paper tape. The event bulletins are in standard teleprinter code for inclusion in telex messages to the customer (LL).

The incoming signals are fed through a set of 4 filters, the frequency of which lies around 1 Hz. A fifth filter, the B filter, at 2.25 Hz is used to classify the event as teleseismic or not. The discrimination is based on the fact that the earth mantle acts as a filter for teleseismic signals and actually cuts off all frequencies above 2 Hz. Since other than teleseismic signals do not pass through the earth mantle filter, the frequencies above 2 Hz are not filtered out. The output of the B filter can therefore be used as a classifying parameter.

Time-of-day receivers

Two TOD receivers were available, a Hammarlund Radio model SP 600 and a WWV Radio Receiver model SR7R. The receivers have a phonojack for connection to oscilloscope and were used to synchronize the Astrodata and DART clocks with standard time signals from Rugby, UK.

b) The DART recording system (Figure 2.30)

i) General description

The DART is designed and built by LL, and is in principle similar to the Astrodata system. Facilities for direct or playback analog DART recording are not available.

The DART is available in two versions, viz the SP-6 for recording of SP seismometer signals and the LP-6 for LP seismometer signals. Øyer DRC was fitted with an LP-6 for recording of signals from the LP installation and an SP-6 as standby unit for the Astrodata.

The characteristics of the two systems differ mainly regarding sampling rate and record length.

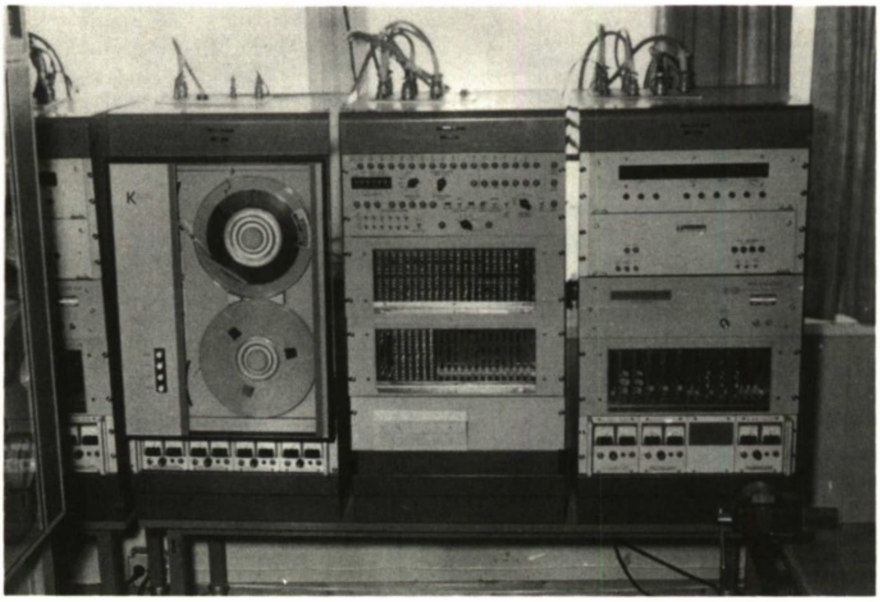


Figure 2.30 The DART recording system

ii) Mode of operation (Figure 2.31)

The multiverter senses the channels in turn and converts each sample to a digital word of 13 bits + sign bit. For each sample the multiverter generates a Conversion Complete signal which effects loading of the data in parallel into the first of 64 buffer registers together with a data indicator bit. The buffer register serves the purpose of storing the data while the recorder is doing a record gap and inserts a header, and also of matching the recording and sampling rates.

When all channels have been sampled, a 100 kHz signal is gated to the buffer registers to shift the data through the registers. The data indicator bit controls the packing and outputting modes, and prevents data from being loaded into a register unit until it is empty. It also prevents data from being shifted off the last stage.

When the last register contains data and the recorder is ready for data (record gap or header insert is not being performed), sensing of the data indicator bit in the last register effects recording of the word on tape in the form of three 6-bit characters. Next, a new data request pulse commands all data words to advance one step through the buffer register.

When the recorder, directed by the timing and control section, inserts a record gap with a step rate of 1000 steps/s on the tape, the buffer register is prevented from outputting, but sampling and loading into it continues at a normal rate. Immediately after the record gap the four header words from the header register are split into characters and recorded. The buffer register is now filled and readout switches from normal to peak rate (load and pack modes are kept at normal rate). Readout is continued at peak rate until the buffer register is empty, at which time the readout is continued at normal rate.

The pulses for control of the above sequences and time information for headers are derived from a time code generator. BCD output from the clock presents day of the year and time of the day in hours, minutes and seconds.

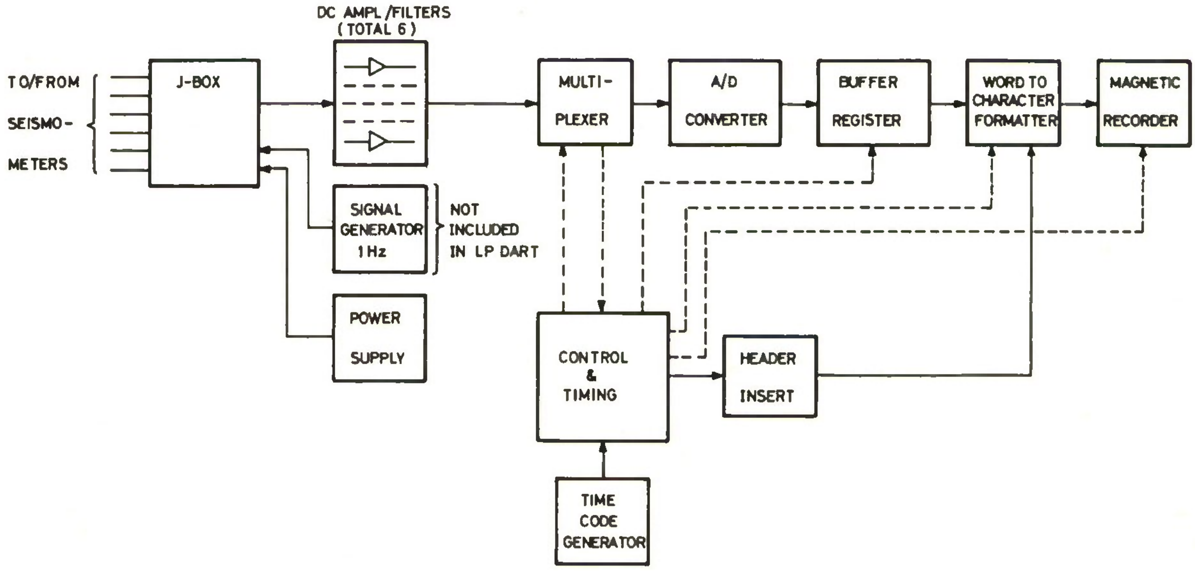


Figure 2.31 Block diagram of the DART system

2.2.4 Recorder outputs

The recording medium for data was Scotch Computer Tape No 777 (specifications in Appendix A3), supplied by Minnesota Mining and Manufacturing Co. Packing densities were 800 bits per inch (bpi) for the Astrodata and 556 bpi for the DART.

The specific recorder outputs were as follows:

a) Astrodata

Tape speed	2.8 inches/second
Record length	4.8 inches
Record gap	0.78 "

One record length with the following record gap thus occupies 5.58 inches. One record comprises 4 headers and 1280 data words which represent the value and signs of 40 samples of each of the 32 analog input signals. The structure and details of the record format are shown in Figure 2.32.

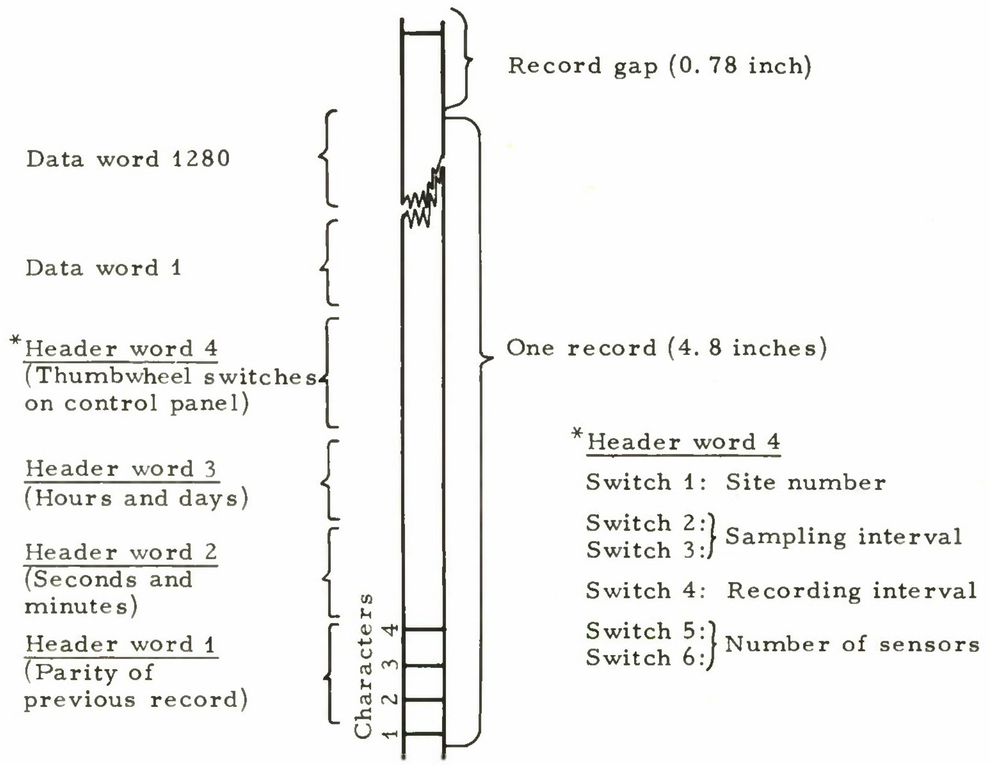


Figure 2.32 Astrodata tape format

b) DART

The main specifications of two basic DART systems are listed below:

	SP-6	LP-6
Number of input channels	6	6
Sampling rate	20/s	1/s
Tape capacity	2400 ft	2400 ft
Record length	20 s	10 min
Recorder stepping rates:		
Average	60 steps/s/input	3 steps/s/input
Peak (catch-up rates)		
1-4 inputs	300 steps/s	100 steps/s
5-6 inputs	500 steps/s	100 steps/s

18 bit computer words/ record	SP-6	LP-6
1 input	400 data words + 4 header words	600 data words + 4 header words
2 inputs	800 data words + 4 header words	1200 data words + 4 header words
3 inputs	1200 data words + 4 header words	1800 data words + 4 header words
4 inputs	1600 data words + 4 header words	2400 data words + 4 header words
5 inputs	2000 data words + 4 header words	3000 data words + 4 header words
6 inputs	2400 data words + 4 header words	3600 data words + 4 header words

DART tapes begin with a file gap called the "beginning of tape gap" immediately after a start-of-tape tab. This is followed by a series of test records. With the probable exception of the initial test record, all records will begin with a header of four 18-bit words, i e 12 tape characters. The initial record will normally lack header information due to randomness in the start of recording. Figure 2. 33 details the information contained in the header words. Immediately after the four header words, data are recorded for the remainder of each record. For test records the duration of each record is subject to manual control and may therefore vary according to tests conducted.

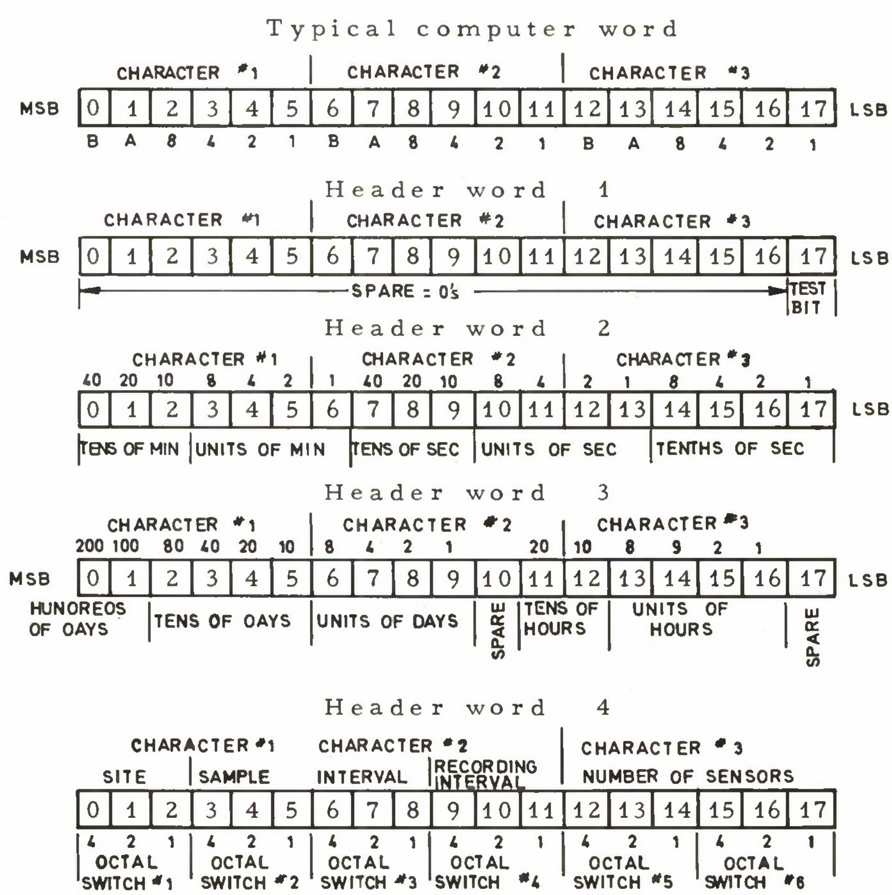


Figure 2.33 DART data and header words

Header word number one of test records will contain a "1" in the bit 17 position to indicate test mode recording. The remaining bits in word one will always be "0". There will be an arbitrary number of test records made while the system is being checked by the maintenance team. After the system has been checked out, the test bit in header word number one will be set to zero to indicate normal system recording.

c) Sanborn chart recorder

The 8 channel chart recorder, used for calibration and check purposes, uses Permapaper with 4 cm wide channels, each with 50 divisions.

The paper speed is adjustable on the recorder in steps from 0.25 to 100 mm/s and the recorder sensitivity may be adjusted from 0.1 to 5 volts/division.

d) Event detector

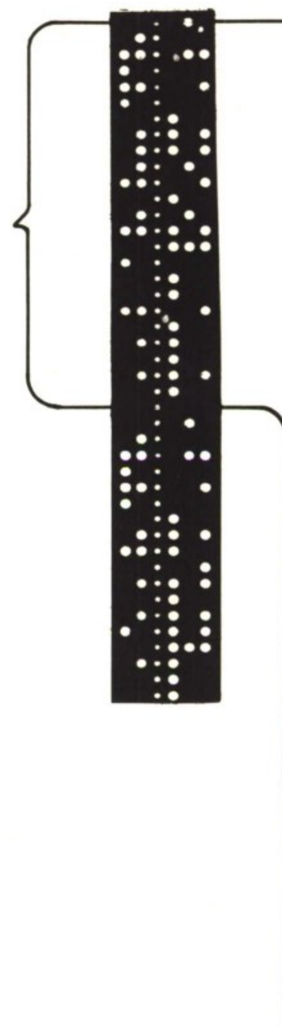
Event data is punched on paper tape in 5 bit standard teletype code in the following sequence:

		Code
1	Carriage return	00010
2	Line feed	01000
3	Figures	11011
4	Hundreds of days	x
5	Tens of days	x
6	Units of days	x
7	Space	00100
8	Tens of hours	x
9	Units of hours	x
10	Tens of minutes	x
11	Units of minutes	x
12	Space	00100
13	Tens of seconds	x
14	Units of seconds	x
15	Period	00111
16	Tenths of seconds	x
17	Space	00100
18	Space	00100
19	Units of size	x
20	Space	00100
21	Filter no	x
22	Space	00100
23	Van status	x
24	Space	00100
25	End of event data	00000

x	Code
0	01101
1	11101
2	11001
3	10000
4	01010
5	00001
6	10101
7	11100
8	01100
9	00011

Telex message		
321 1129 48		
322 0028 37.1	4 1 1	
322 0241 54.1	2 8 1	
322 1310 33.3	3 3 0	
322 1320 02.9	2 4 0	
323 0042 41.3	2 8 0	
323 0750 06.8	5 1 0	
325 0155 24.1	2 8 0	
325 0818 58.0	3 8 0	
325 0820 26.9	3 8 0	
325 1811 31.8	2 8 0	
326 0322 11.0	2 8 0	
326 2029 56.7	5 1 0	
327 0125 09.9	5 1 0	
327 0402 55.8	2 8 0	
327 0914 29.8	5 1 0	
327 1605 27.8	2 2 0	
327 1738 27.1	3 8 0	
327 2334 07.4	3 8 0	
329 0837 05.8	1 1 0	
329 1309 10.4	2 8 0	
329 1309 49.6	3 8 0	
329 1945 56		
329 2132 16.7	7 0 0	
329 2217 14.2	7 0 0	

Event detector tape



Code explanation		
1	Carriage return	
2	Line feed	
3	Figures	
4	3	Day
5	2	
6	3	
7	Space	
8	0	Hour
9	0	
10	4	Minute
11	2	
12	Space	
13	4	Second
14	1	
15	Period	
16	3	Tenths of second
17	Space	
18	"	
19	2	Units of size
20	Space	
21	8	Filter no
22	Space	
23	0	Van status
24	Space	
25	End of event data	

Figure 2.34 Example of Event Detector printout

2.3 The LP array

The LP array comprised installations at Øyer, Falldalen and Trysil, sites 1, 2 and 3 respectively (Figures 2.1 and 2.2). The distances between the sites, constituting an almost equilateral triangle, were approximately 100 km (60 miles). The installation at each site consisted of three seismometers sensing earth motion along the N-S, E-W and vertical axis.

2.3.1 Coordinates list

The coordinates of the seismic points are given in Table 2.2.

Seismic point	Cartesian		UTM-system		Altitude in meters above sea level
	°N	°E	X	Y	
Øyer-LPV	61°20'14.8863"	10°35' 7.5135"	6801569.030	584836.008	978.43
Fall-dalen LPV	60°36'23.0274"	11°28'50.9784"	6721668.190	635819.482	354.62
Trysil LPV	61°25'24.7539"	12°22'58.2546"	6814808.079	680475.193	688.08

Table 2.2 Long Period array coordinates list

For local maps of the various DRC areas refer to figures 2.4 (Øyer), 2.8 (Falldalen) and 2.11 (Trysil).

2.3.2 The LP front end (FE) system

The types of instruments used in the array, horizontal seismometers (Geotech model 8700D, Figure 2.35) and vertical seismometers (Geotech model 7505B, Figure 2.36) are both moving coil, velocity type instruments converting earth motion along the desired axis into electrical signals (specifications in Appendix A2.1). The natural period of the instruments, adjustable between 10 and 30 seconds, was set at 20 seconds (0.05 Hz).

The seismometers are housed in heavy steel boxes (Figure 2.37), which seal against water and air pressure changes. The dimensions are 394 mm (15.5 in) x 305 mm (12 in) x 610 mm (24 in) and the weights of the horizontal and vertical types are 52.2 kg (115 lb) and 72.5 kg (160 lb) respectively.

The seismometer boxes were mounted in steel tanks (Figure 2.38) moulded into the floor of the LP vaults, which are concrete bunkers resting on bed-rock and with the roof some 3 feet below the soil surface (Figure 2.39). The tank lids were fitted with gaskets and secured to make the tanks air pressure tight.

The seismometer base is equipped with three screws for manual levelling. Remote levelling, however, was necessary for calibration purposes, so the seismometers were installed with two levelling devices as shown in Figures 2.38 and 2.40. Each device (Figure 2.41), equipped with a DC motor, could be operated from a monitor control unit at the DRC.

Seismometer/cable interfacing equipment in the LPVs were a junction assembly for each seismometer and a common junction box (Figures 2.42 and 2.43).

The signal cables between the LPV and the DRC were buried in the ground at all three sites.

From the DRC junction box the signals went through a three channel Geotech amplifier (Figure 2.44) before they entered the recording system.

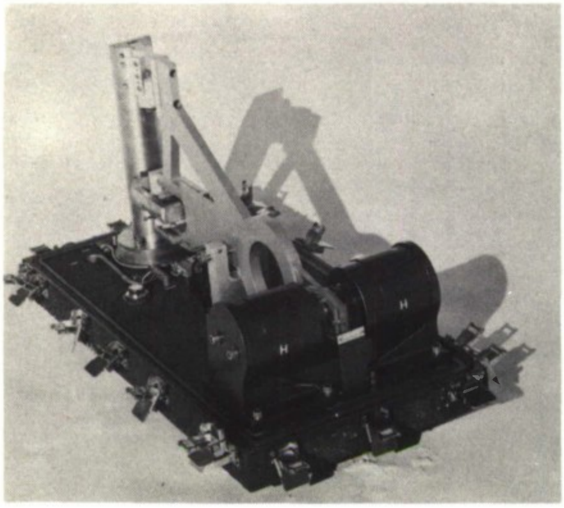


Figure 2.35 Horizontal LP seismometer, cover removed (Model Geotech 8700D)

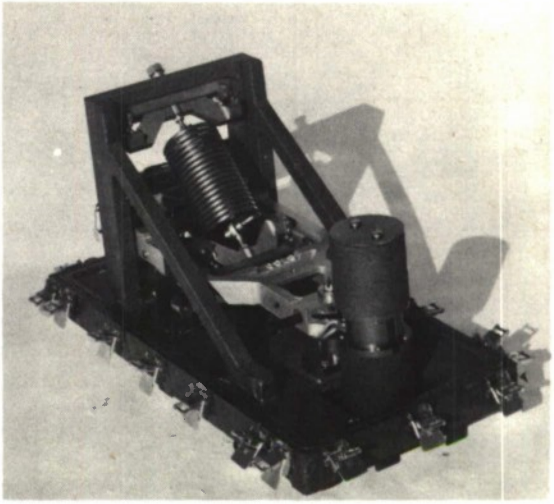


Figure 2.36 Vertical LP seismometer, cover removed (Model Geotech 7505B)

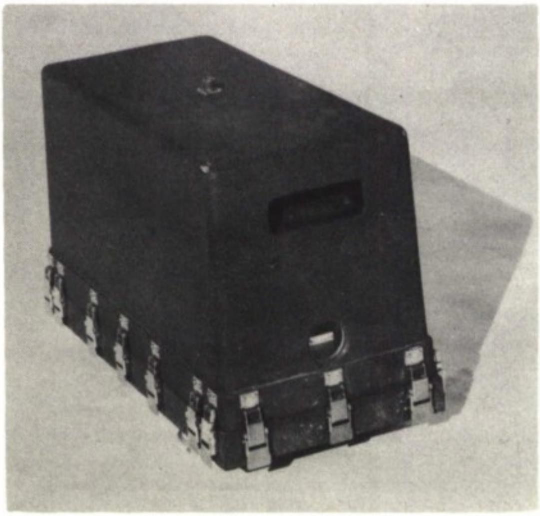


Figure 2.37 LP seismometer with cover

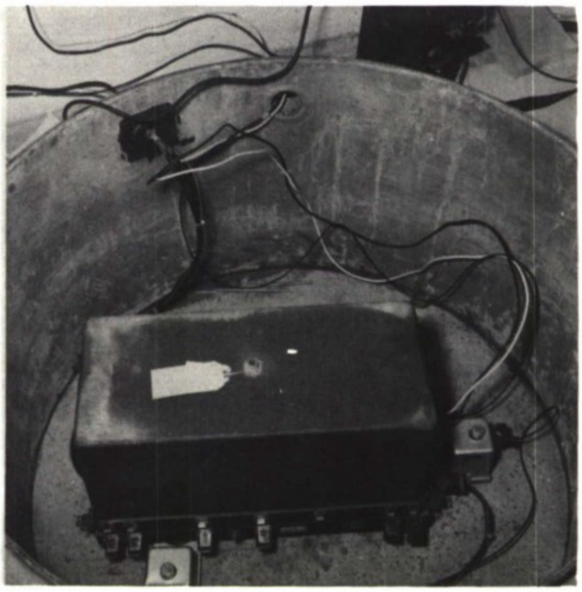
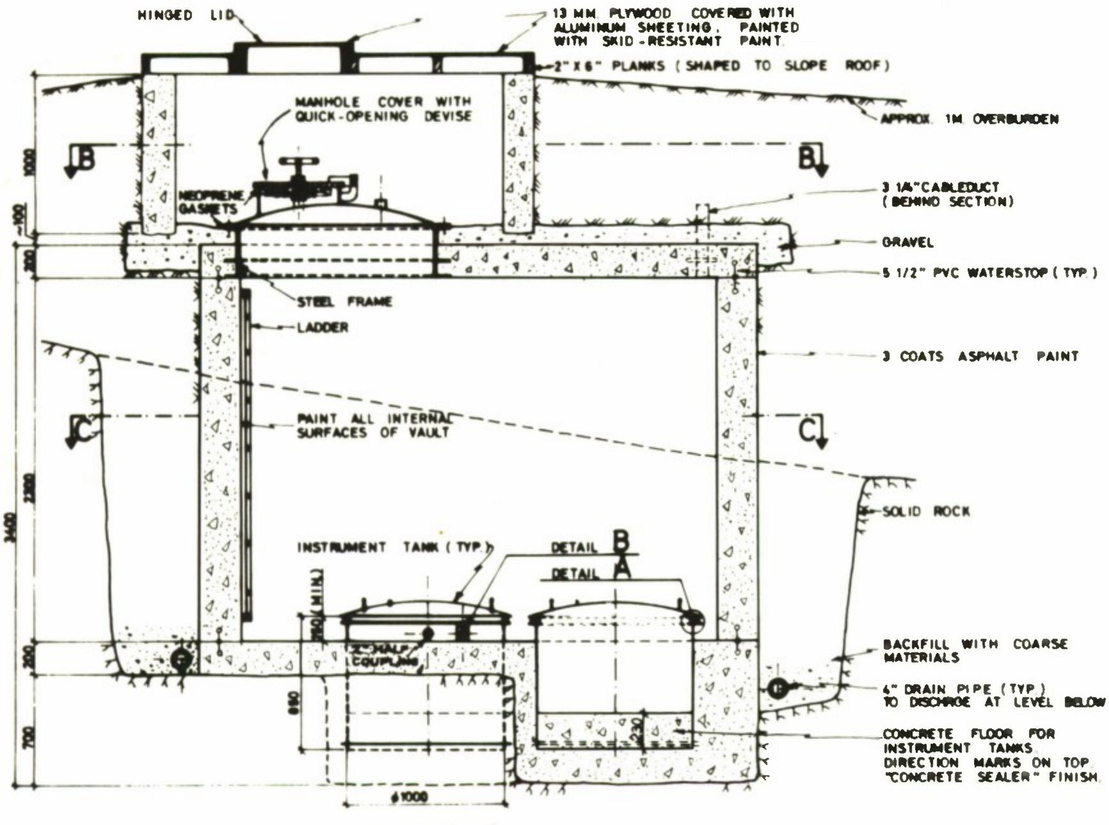
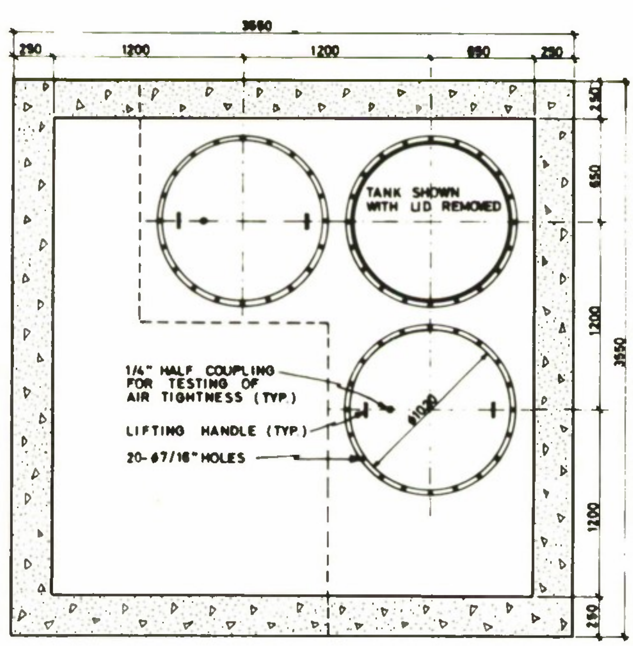


Figure 2.38 LP seismometer mounted in tank
(Remote levelling devices in front and to the right of the seismometer box)



SECTION A-A



SECTION C-C

Figure 2.39 Long Period vault

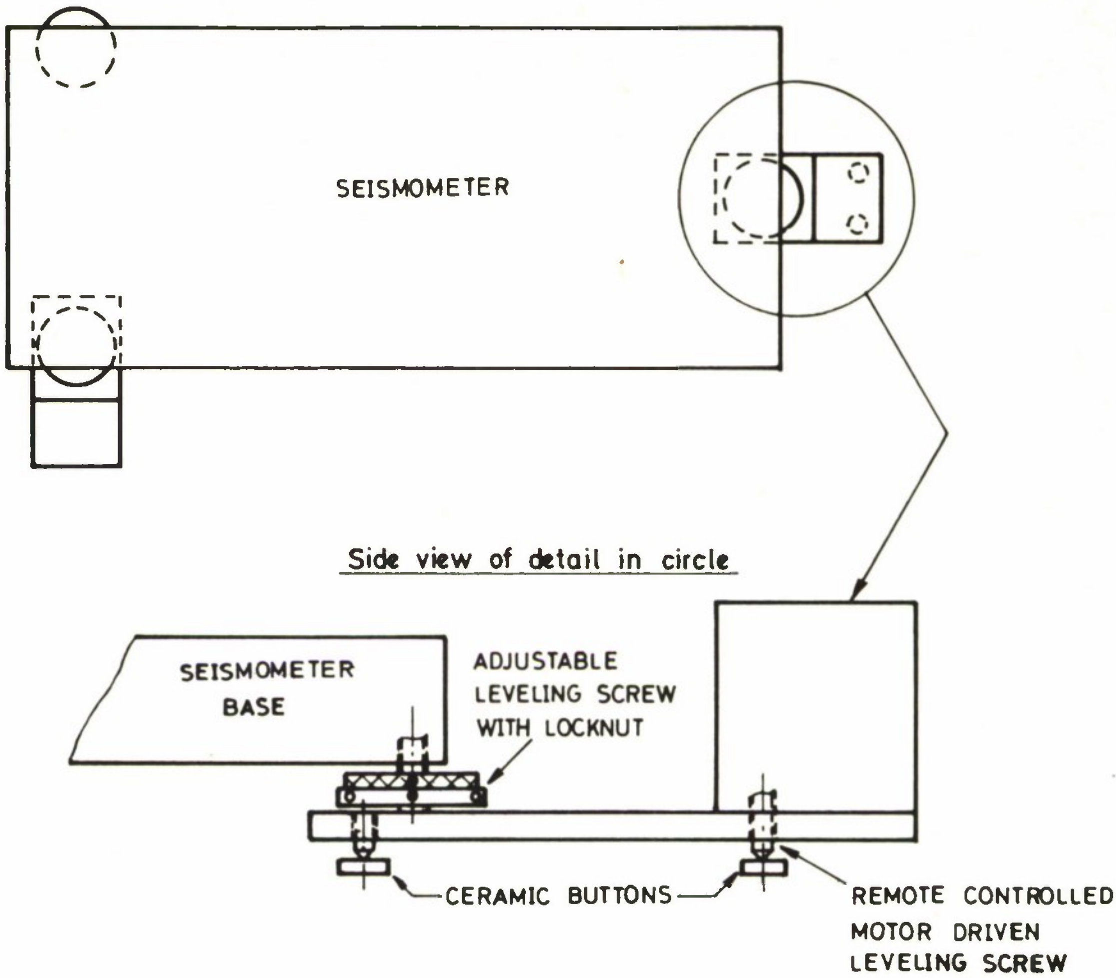


Figure 2.40 Mounting of LP seismometers with levelling devices

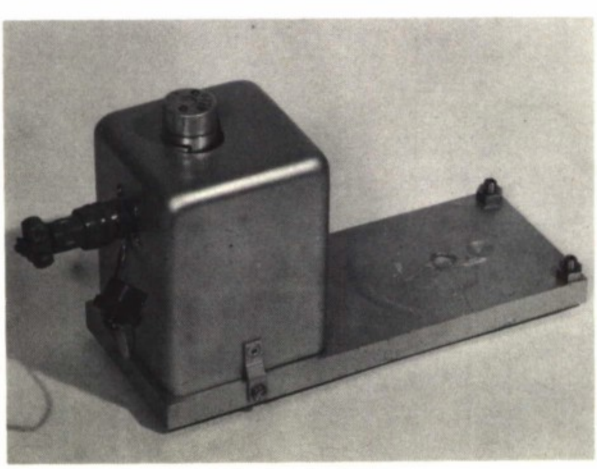


Figure 2.41 Remote levelling device for LP seismometers

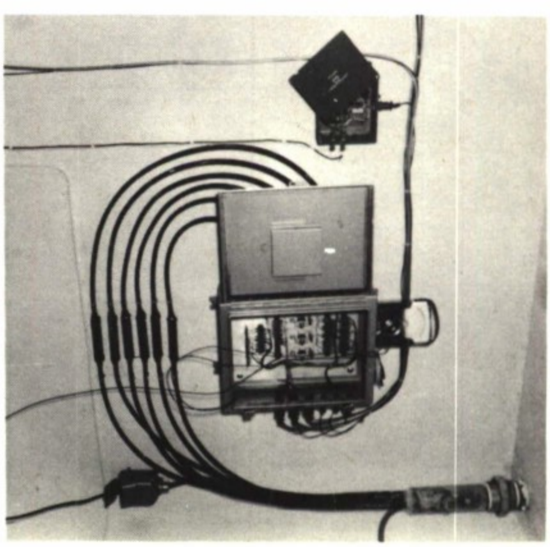


Figure 2.42 Seismometer/cable interfacing equipment in LPVs
Left: Junction assembly
Right: LPV junction box

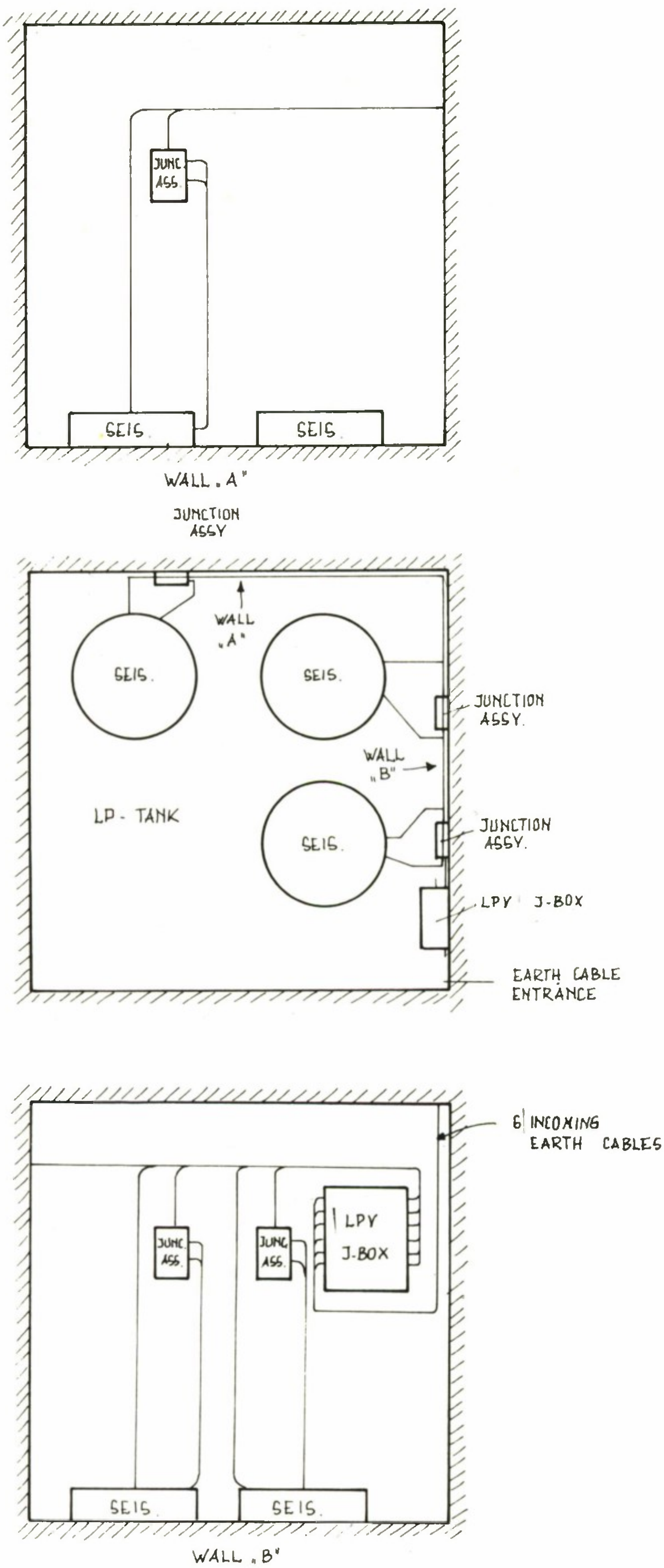


Figure 2.43 <u>Physical layout in LPV</u>

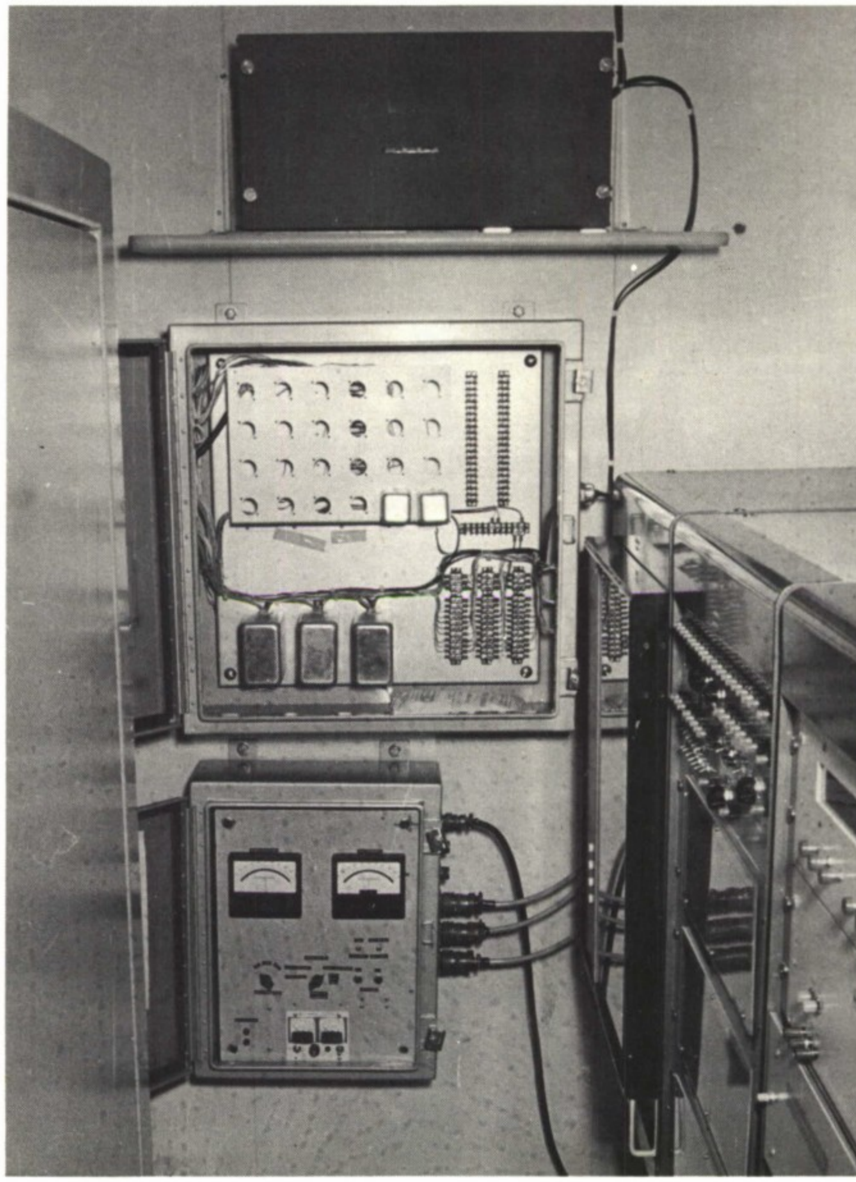


Figure 2.44 Cable/DART interfacing equipment in DRC
Top: three-channel Geotech amplifier
Middle: DRC junction box
Bottom: monitor control unit

A block diagram of the LP installations is shown in Figure 2.45 and wiring diagrams are found in Appendix A2.2.

2.3.3 Recording and auxiliary equipment

Recording at the LP sites was performed with LP-6 DARTs. The DART system is described in 2.2.3b.

The following arrangement of recording channels was identical at all sites:

Channel 1 - Vertical
Channel 2 - North-South
Channel 3 - East-West

At Falldalen, weather data were recorded in addition to this on channels 4, 5 and 6, see last paragraph of 2.4.4.

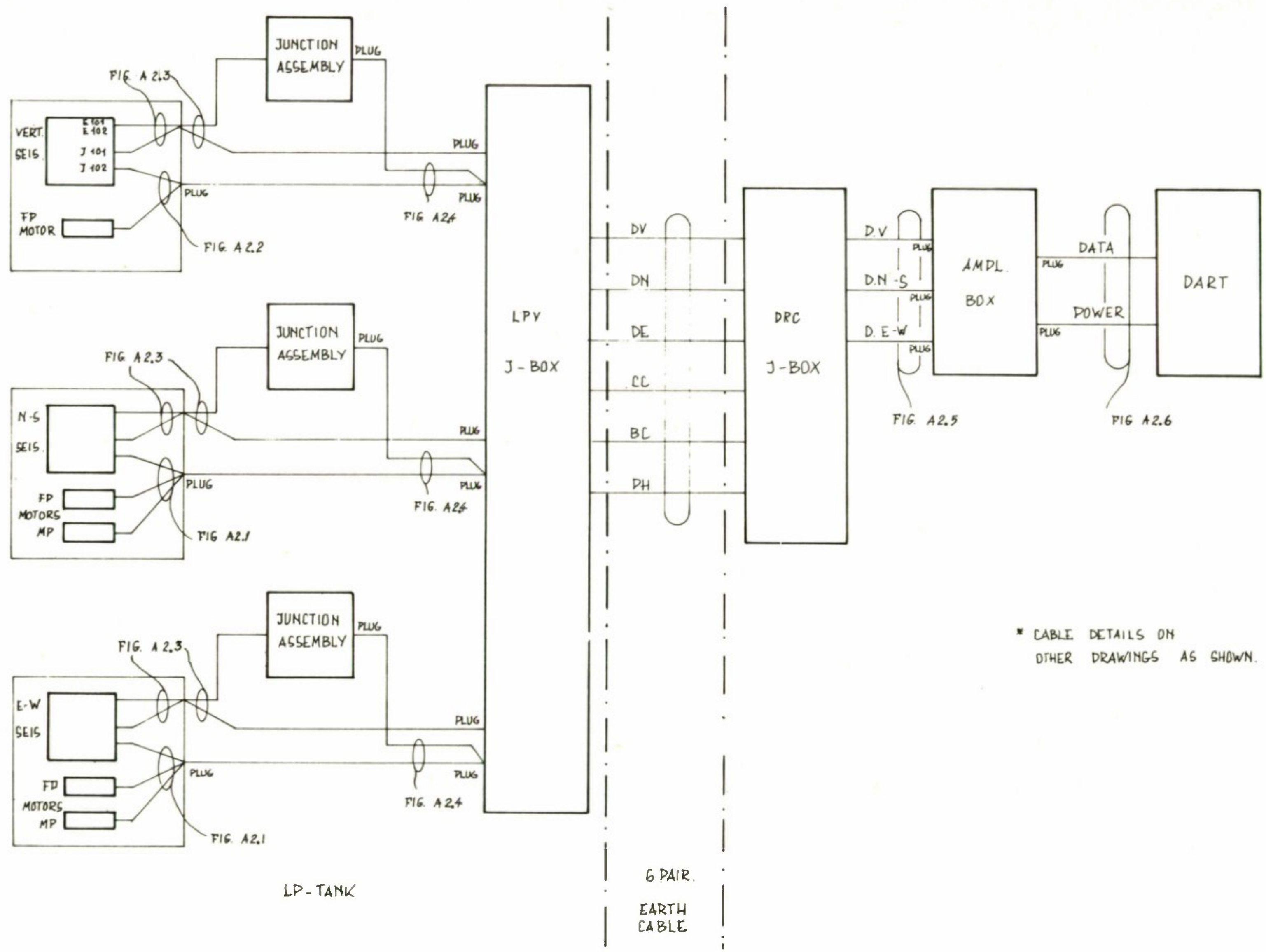


Figure 2.45 Block diagram of LP installation (identical at Øyer, Falidalen and Trysil)

2.4 The experimental noise study array

The experimental noise study array was located at Falldalen (Figures 2.1 and 2.2). Figure 2.46 shows the layout of the array. Five seismic points were arranged in a T-pattern, each with a borehole about 1.5 m deep (shallow hole), two of the points had in addition a 60 m hole (deep hole). The distance between neighboring points was approx 2 - 3 km.

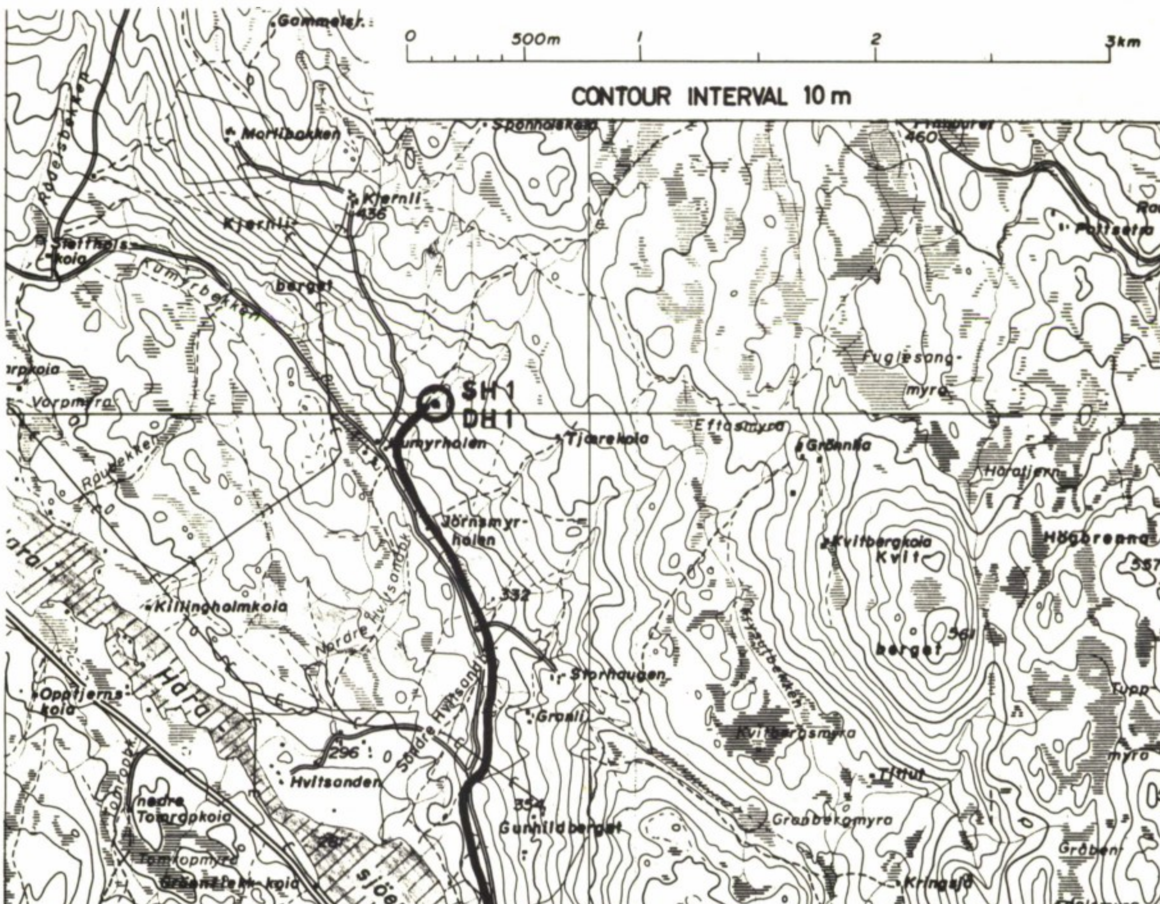


Figure 2.46 Noise study array configuration
—— = Cable route SH = Shallow hole DH = Deep hole

Since this was a temporary installation, all the signal cables were laid on the surface. This would also facilitate possible changes in the layout.

2.4.1 Coordinates list

The coordinates of the seismic points are given in the list below:

Seismic point	Cartesian		UTM-system		Altitude in meters above sea level
	°N	°E	X	Y	
SH 1 DH 1	60°38'18.1616" 60°38'18.2460"	11°28'13.3811" 11°28'13.1265"	6725207.163	635114.040	361.79
SH 2 DH 2	60°36'48.7306" 60°36'48.7338"	11°28'38.2305" 11°28'38.6270"	6722455.743 6722456.071	635595.715 635601.738	329.92 330.15
SH 3	60°36'14.2174"	11°29'13.0297"	6721408.416	636165.031	374.50
SH 4	60°36'12.7661"	11°27'25.3085"	6721301.932	634528.920	301.74
SH 5	60°36'47.6803"	11°30'24.5923"			

Table 2.3 Falldalen SP noise study array coordinates
SH = shallow hole DH = deep (60 m) hole

2.4.2 The front end (FE) system

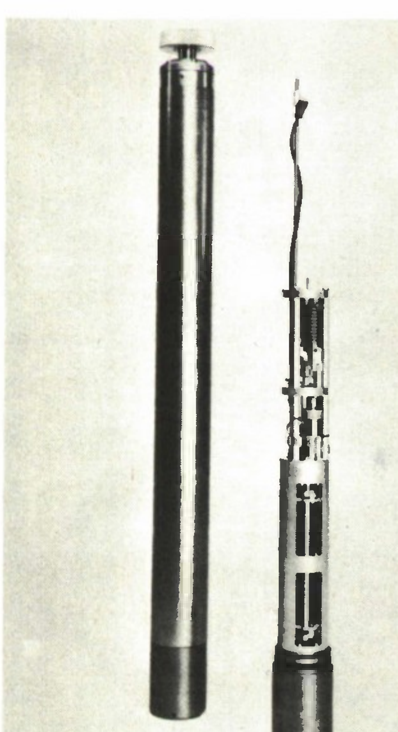


Figure 2.47 SP seismometer used in deep holes
(Model Geotech 20171A - with and without cover).

The seismometers used in the shallow holes in the noise study array were of the same type as the ones used at Øyer (ref 2.2.2). However, the limited depth (1.5 m) of the shallow hole did not allow the use of the steel rod on which the seismometers normally rest.

The seismometers used in the deep holes were Geotech model 20171A (Figure 2.47, specifications in Appendix A1.2), moving coil, velocity type instruments with a natural frequency of 1 Hz. The instrument has an outside diameter of 95 mm (3.75 in) and an overall length of 1.032 m (40-5/8 in). The weight is 30.8 kg (68.0 lb). It is designed for use at depths up to 300 m (1000 ft).

The purpose of the deep holes was to study the downward penetration of local surface noise as a function of depth. The seismometers were therefore equipped with a spring-loaded holelock device to enable positioning of the seismometers at any depth.

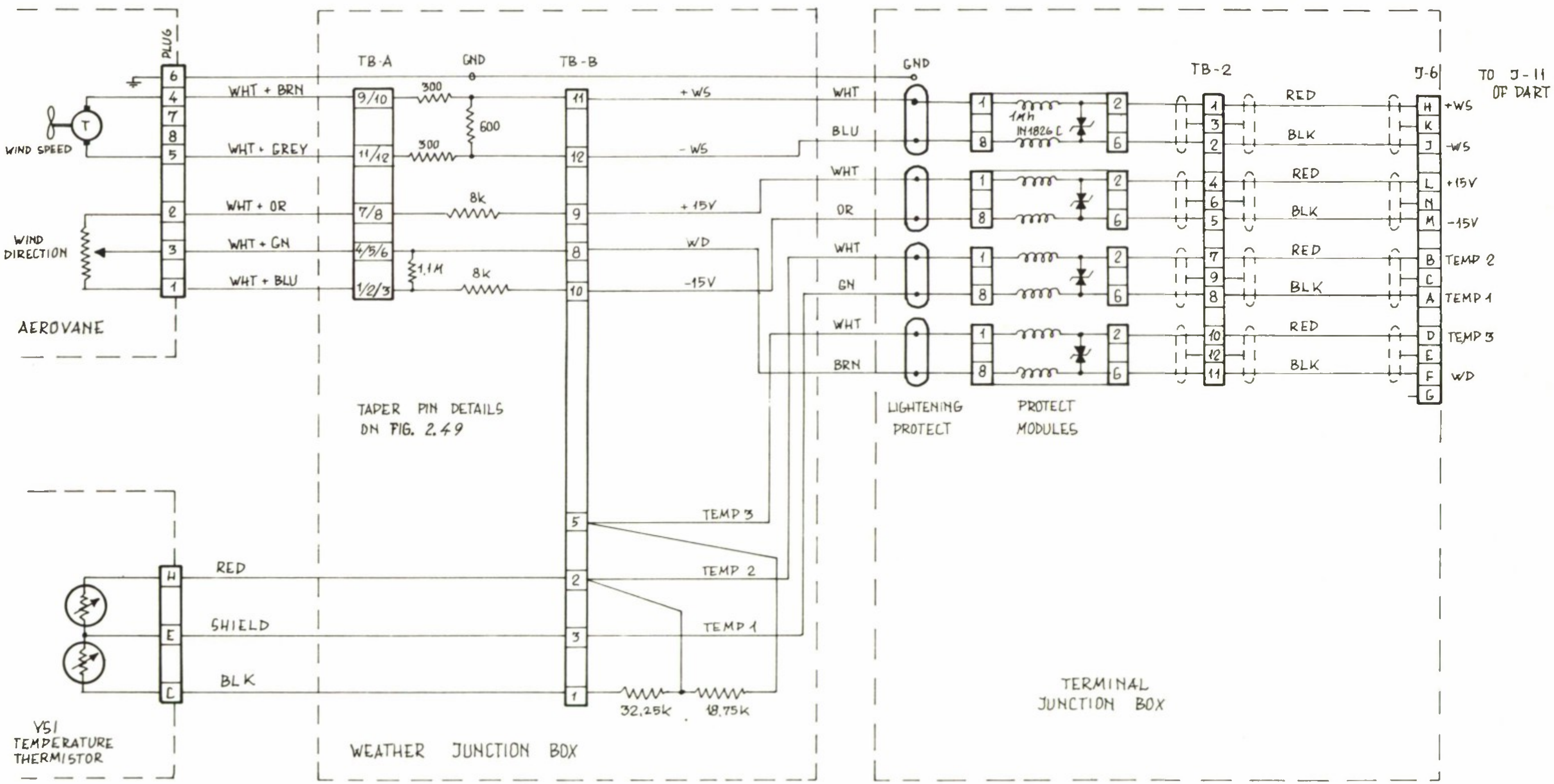


Figure 2. 48 Automatic weather station at Falldalen, wiring diagram

The boreholes with casing and WHV were largely similar to the construction at the Øyer subarray (cf 2.2.2). Also the seismometer/cable interfacing equipment was in principle similar to the equipment used at Øyer. This equipment, brought over from LASA in order to save time, was, however, built into a combined Amplifier and Junction Box and had a different amplifier (Ithaco model 154).

2.4.3 Automatic weather station

Associated with the noise study array was an automatic weather station. An aerovane mounted on a height 280 m (300 yd) from the DRC determined wind speed and wind direction. The signals were carried through a surface cable to the weather station junction box mounted outside the DRC (Figures 2.9 and 2.10).

Temperature was determined by a temperature bridge mounted underneath the weather station junction box. Figures 2.48 and 2.49 show wiring diagrams of the weather station.

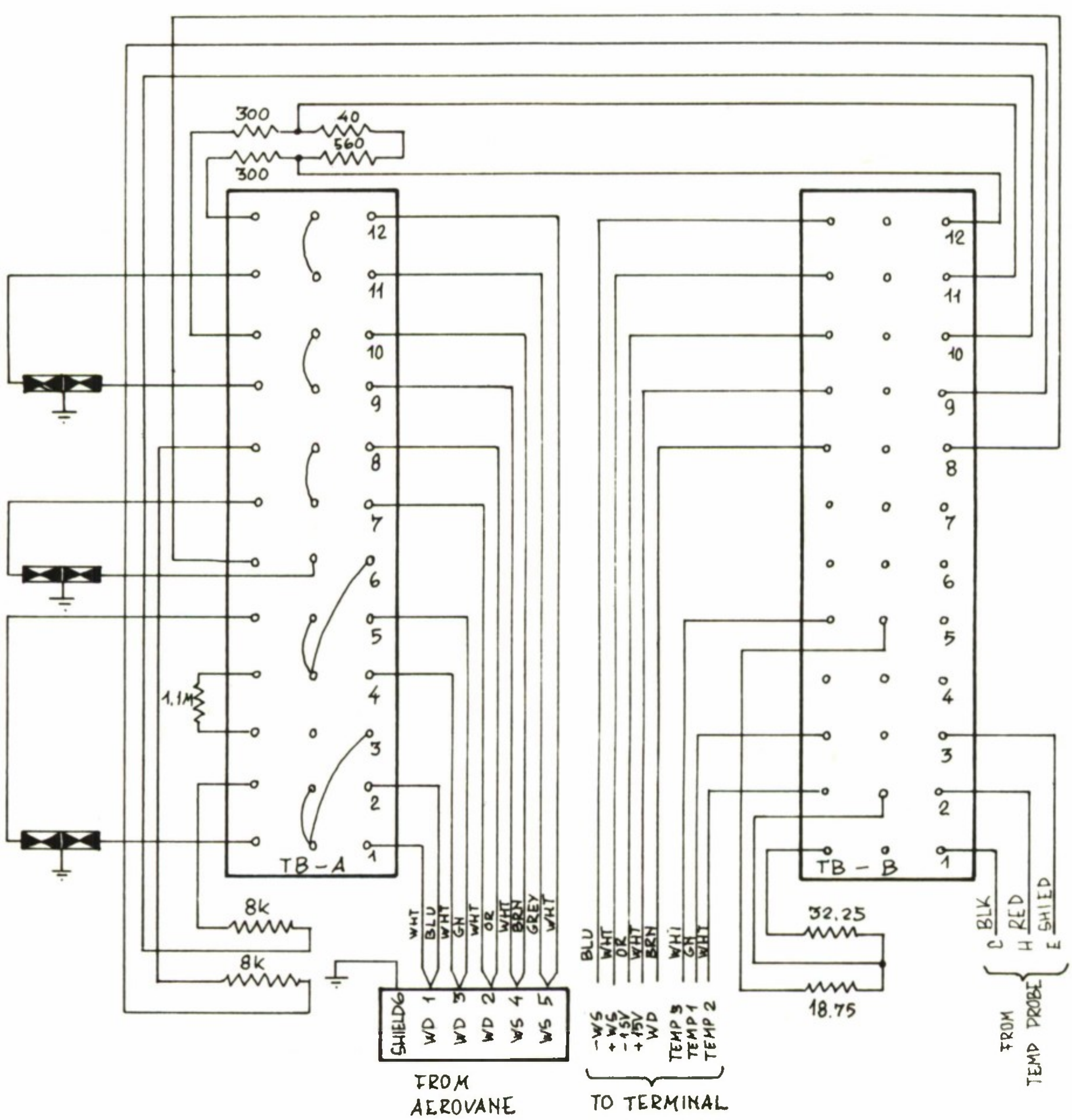


Figure 2.49 Automatic weather station at Falldalen, junction box wiring

2.4.4 Recording and auxiliary equipment

Recording of the signals at the noise study array was performed by an SP-6 DART system. The DART system is described in 2. 2. 3b.

Six input channels were available. From the beginning of the reporting period up to 2 April, the allocation of the channels was:

Channel 1	SH 1	(SH = shallow hole)
Channel 2	SH 2	
Channel 3	DH 2 (at 60 m)	(DH = deep hole)
Channel 4	SH 4	
Channel 5	SH 5	
Channel 6	DH 1 (at 60 m)	

Some changes in the array layout were made on 3 April and the following allocation was made for the remaining period:

Channel 1	SH 1
Channel 2	SH 2
Channel 3	DH 2 (at 20 m)
Channel 4	DH 2 (at 60 m)
Channel 5	SH 5
Channel 6	DH 1 (at 40 m)

The SH 3 was never in use during the whole reporting period.

The weather information was recorded on the LP-6 DART system along with the LP data. Channels 1, 2 and 3 were used for LP data, while channel 4 recorded temperature information, channel 5 wind speed information and channel 6 the wind direction information.

2.4.5 Recorder output

(See also section 2. 2. 4)

The following are the weather station specifications:

Temperature	$-20^{\circ}F$ to $+120^{\circ}F \pm 2^{\circ}F$ ($-29^{\circ}C$ to $+49^{\circ}C \pm 1^{\circ}C$) Output (Temperature Bridge Card) 0 to 700 mV 0 mV = $-20^{\circ}F$, 5 mV = $1^{\circ}F$, 700 mV = $+120^{\circ}F$
Wind speed	Manufacturer's specifications state: "With a resistance of 1150 ohms, the output is 9. 2 V at 87. 1 mph (1800 rpm) and linear". This output is attenuated to half of this value over a range of 0 V to +7 V. Therefore +7 V = 133. 33 mph (0. 052 V/mph). Starting threshold is 2, 5 mph, giving a range of 2. 5 mph to 133 mph.

Wind direction	Coverage - 355^o of arc, direction accuracy $\pm 5^o$ Starting threshold - 2.5 mph Assuming voltages of +7 V and -7 V across the direction pot, 355^o = 14 V or 0.039 V/degree. Crossover gap (electrical) is eliminated by connecting the slider arm of the direction potentiometer to the -7 V input through a 1.2 Mohm resistor. The crossover gap (physical) was centered at north.

3 OPERATION AND PREVENTIVE MAINTENANCE (O&M)

Regular operation of the system started in the beginning of February 1968. Prior to this an initial start-up period had taken place during January.

The task set forth in the O&M contract called for operation and maintenance of the stations at Øyer, Falldalen and Trysil to ensure the capability for continuous 24 hour acquisition of data.

3.1 O&M organization

The duties called for in the O&M contract necessitated a staff of 6 technicians to work in shifts, supervised by a project leader.

3.1.1 Staff

The O&M contract was entered into on 25 January and by the end of the month the contractor, Noratom-Norcontrol A/S (N-N A/S) had appointed a staff of 6 technicians for the job, selected from a file of applications previously assembled by NDRE for this particular project. The first member of the staff became available in the beginning of February, four in the beginning of March and finally one in the beginning of April. In the meanwhile, the contractor took on responsibility for the operation from the beginning of February, based on a temporary group from his existing staff.

3.1.2 Training by US consultants

US consultants, personnel from Philco-Ford, an LL subcontractor, were available for an initial period of time for training and guidance of the O&M staff.

The temporary group was trained for the purpose of operating the system until the O&M staff proper could take over, and also so that they later could serve as a stand-by reserve for the O&M staff. This group of 4 technicians was first given a brief, two-day course in the classroom and thereafter on-the-job training at the stations.

As for the training of the O&M staff proper, the Astrodata was the most complex part of the system and the training on it was given the highest priority. The personnel was divided into two groups. Three members of the staff and one from the preliminary group were stationed at Øyer site and were trained solely on the Astrodata system for one month. The other group, two members of the O&M staff, took care of Falldalen and Trysil sites during the same period and were trained by other instructors on the DART systems.

3.1.3 Working schedule, rotation of staff

From 1 April the O&M staff was complete in number and shortly afterwards the duties were organized on a more regular schedule. Øyer site was in operation 24 hours a day, 7 days a week. It was therefore necessary to have two men stationed at the site all the time. Continuous recording was also performed at the noise study array at Falldalen site from 10 April to 31 May. This required tape-change every 11 hours. Before and after this period the normal schedule called for recording of one tape a day, Monday through Friday. The normal routine for operation of the LP array was to perform calibration and tape-change every 9 or 10 days. The equipment at Øyer and Falldalen was checked daily and the Trysil site was visited once between every tape-change. The duties at Falldalen and Trysil kept two men occupied most of the time.

The standard schedule for rotation of the personnel is shown in Table 3.1. Average working hours were 40 hours a week.

Time / Staff member	Week								
	1	2	3	4	5	6	7	8	9
1	Ø	Ø	F/T	F/T	O	M	Ø	Ø	F/T
2	M	Ø	Ø	F/T	F/T	O	M	Ø	Ø
3	O	M	Ø	Ø	F/T	F/T	O	M	Ø
4	F/T	O	M	Ø	Ø	F/T	F/T	O	M
5	F/T	F/T	O	M	Ø	Ø	F/T	F/T	O
6	Ø	F/T	F/T	O	M	Ø	Ø	F/T	F/T

Table 3.1 Standard schedule for rotation of personnel
Ø = Øyer   F/T = Falldalen/Trysil
O = Off duty (compensation for weekends at Øyer)
M = Miscellaneous (various duties at the base in Oslo or other services)

3.2 Facilities

Apart from huts for accommodation of technical equipment and crew, the O&M staff requirements comprised means of transport to/from and within sites, test equipment for calibration and maintenance of instruments, spare units and components and storage space for these.

3.2.1 Vehicles

In addition to private cars for transportation on main roads in winter and all roads in summer, the O&M staff had at its disposal 3 vehicles, viz:

1 snow-track (type Aktiv Beltetraktor ST4 - make Aktiebolaget Westeråsmaskiner, Sweden) w/sledge

1 snow-scooter (type Evinrude Skeeter WIDE-TRACK 20 - make Outboard Marine Corporation) w/sledge

1 field vehicle (type Volvo L3314N - make Kongsberg Våpenfabrikk)

The two first mentioned are US Government Purchased Equipment (GFE), purchased by NDRE. They were used for access to the DRC and SP points at Øyer during the winter period. The latter was used in the summer and was on loan from the Norwegian Army. Maintenance of the vehicles has been carried out according to standard maintenance schedules.

The tracked vehicles have been subject to several breakdowns during field operations, introducing delays in the maintenance work. A complaint was lodged by NDRE in January 1968 in respect of the snow-track due to abnormal wear on the right-hand side belt supporting wheels.

3.2.2 Test equipment

The test equipment is Lincoln Laboratory property, to be returned to US when recording on sites ceases. A few major items were permanently placed at Øyer (oscilloscope, CPS cal oscillator, WHVT receiver). The rest of the available test equipment was used at the various sites according to running local requirements.

A complete record of the available test equipment is given in Appendix A4.1.

3.2.3 Spares

Spare parts for the Astrodata, DARTs and auxiliary equipment were stored in the DRCs at Øyer, Falldalen and Trysil. DART parts were in general placed at Falldalen, but a few essential items were also stored at Øyer and Trysil. Parts related to the Astrodata and auxiliary equipment were mainly located at Øyer.

Major spare units such as LP/SP seismometers, LP/SP amplifiers and junction- and amplifier-boxes were also available. These items were stored in the vicinity of the DRCs at Øyer and Falldalen.

A special spare parts record was established, listing type of item, part number, serial number, quantity, etc, and in general also reference to the mother system. An example of this record is found in Appendix A4.2.

Minor components such as transistors, resistors, etc are not covered by these lists.

3.2.4 Storage

Two farmhouses were rented in the fall of 1967 as storage for spare equipment such as seismometers, steel parts, etc. They are located near the Øyer and Falldalen DRCs.

When the recording at Falldalen ceased, all the spare parts and units located there were moved to a new storage in Brumunddal, which will also be used by the O&M staff as a central base for storage of test equipment necessary for operation of the new LP sites.

3.3 Routines and schedules

Certain routines were established for the O&M of the system in order to meet the demands for data and to keep the equipment in good working order.

3.3.1 Preventive maintenance and calibrations

A Preventive Maintenance Program (Appendix A5) listed the maintenance and calibration schedules for the various parts of the Phase 1 system and referred to Detailed Maintenance Description (DMD).

The DMD, a copy of which was available at each site, was a reference manual consisting of extracts from the manufacturers' manuals that were available, and otherwise worked out from general knowledge of the equipment.

3.3.2 Demands for and distribution of data

The general demands for and distribution of data were as follows:

a) Continuous recording at the LP array and forwarding of all data tape to Lincoln Laboratory

b) Continuous recording at the Øyer subarray and storing of tape for a minimum of 14 days, distribution as requested by the users. After 14 days tapes could be degaussed and used anew.

c) Recording of one tape (covering 11.5 hours) a day, Monday through Friday, at the Falldalen noise study array, storing and distribution as for Øyer subarray.

For a shorter period continuous recording and distribution to Lincoln Laboratory was called for.

3.4 Records

A number of forms were introduced in order to gather information on data-recordings as well as operation and maintenance in general.

3.4.1 Tape identification

All magnetic tapes used for recording at the NORSAR sites were identified by progressive numbers starting from 1 and with a prefix NL- (e g NL-728). The various sites were designated by blocks of numbers as required.

3.4.2 Tape Log

The log was kept and remained at the various sites. It contained successive start/stop times of data recordings and further references such as recorder number, tape number and distribution (Figure 3.1). The latter was to indicate the particular user to which the data were distributed, or re-recorded if so was the case.

This information was necessary for the operator in order to see which tapes could be re-recorded and at what time new tapes had to be taken into use.

3.4.3 Tape Record

A tape record with particulars about the recording was filled in for each recording in four copies (Figure 3.2). One of the forms accompanied the tape, one remained at site and two were filed at the O&M office in Oslo, one by tape number and the other chronologically.

3.4.4 Data Request and Tape Handling List

This list was used in connection with request for and distribution of data. It contained information concerning the request and the handling of the request, also certain particulars about the tapes covering the request (Figure 3.3). One copy accompanied the tapes, one was forwarded to the ESD technical project officer in Oslo and one was filed at the O&M office.

3.4.5 NORSAR-Log

This form was used for the O&M logs which served three purposes, viz:

a) To keep track of the maintenance and repair work on various parts of the equipment as well as the buildings and other facilities

b) To collect information for the maintenance statistics

c) To serve as a basis for the monthly O&M reports

The complete log for each site consisted of a number of sheets, one (or more if necessary) for each part of the equipment (Figure 3.4), as listed on the sheet, and in addition a sheet for the station.

The logs were kept in three copies. One copy was forwarded to NDRE monthly, one remained on site and one was filed at the O&M office.

SITE.010.. **TAPE LOG** SHEET.50...

YEAR.69..		START			STOP			REC.	TAPE NO.:	DISTR:	NOTES
DAY		H	M	S	H	M	S	NO.	NL-	TO	
	033	02	53	05	05	27	56	A2	1048		
	033	05	27	56	Run out			A1	1080		
	033	09	13	40	11	51	18	A2	1082		
	033	11	51	18	14	27	52	A1	1083		
	033	14	27	52	17	05	44	A2	1084		
	033	17	05	44	19	42	51	A1	1085		
	033	19	42	51	22	20	56	A2	1087		
034	033	22	20	56	00	56	29	A1	1088		
034		00	56	29	03	33	06	A2	1089		
034		03	33	06	06	09	28	A1	1090		
034		06	09	28	08	46	23	A2	1092		
034		08	47	15	11	23	21	A1	1093		
034		11	23	21	14	01	30	A2	1094		
034		14	01	30	16	37	41	A1	1095		
034		16	37	41	19	14	18	A2	1097		
034		19	14	18	21	49	43	A1	1098		
034	035	21	49	43	00	28	08	A2	1099		
	035	00	28	08	03	04	53	A1	1101		
	035	03	04	53	05	42	29	A2	1102		
	035	05	42	29	08	18	45	A1	1103		
	035	08	22	55	10	58	00	A1	1104		
	035	10	59	51	13	31	30	A2	1105		
	035	13	47	30	16	20	52	A1	1106		
036	035	22	36	00	01	10	10	A2	1107		
	035	16	21	00	22	36	00	2	1108		
036		01	10	10	03	43	37	A1	1110		
036		03	43	37	06	16	48	A2	1111		
036		06	16	48	08	50	19	A1	1112		
036		08	50	19	11	27	14	A2	1113		
036		11	27	14	14	02	16	A1	1114		
036		14	02	16	16	37	57	A2	1115		
036		16	37	57	19	13	10	A1	1116		
036		19	13	10	21	50	26	A2	1117		
036	037	21	50	26	00	24	46	A1	1118		
	037	00	24	46	02	58	46	A2	1119		
	037	02	58	46	05	32	20	A1	1120		
	037	05	32	20	08	05	51	A2	1121		
	037	08	05	51	10	41	01	A1	1122		
	037	10	41	01	13	18	58	A2	1123		
	037	13	18	58	15	53	46	A1	1124		
	037	15	53	46	18	29	45	A2	1125		
	037	18	29	45	21	04	06	A1	1126		
	037	21	04	06	23	38	46	A2	1127		
038	037	23	38	46	02	12	32	A1	1128		
038		02	12	32	04	47	26	A2	1131		

Figure 3.1 Page from Tape Log

SITE 1 RECORDER A1 DATA START: YEAR 68 DAY 173 GMT TIME 19.23.47 TAPE NO. NL 728

1-2: SP6 Dart
3-6: LP6 Dart
A: Astrodata

DATA STOP: DAY 173 TIME 22.01.15

No. of Recorded Channels 32

No. of Recorded Sensors 12 Seis. Cal. Interval: From 19.23.47 to 19.24.47

Channel 1 1OY	5	9 1C2	13 1D3	17 1F1
2 1A1	6	10 1C3	14	18
3 1A2	7	11 1D1	15	19 1F4
4 1A3	8 1C1	12 1D2	16	20

Remarks Tape broken during rewind. Silver-fish moved appx. 5 ft.

Tape disposition Rerecorded day 197

Project NORSAR Tape Record - White copy to accompany tape - Pink copy to remain on site - Green & yellow to Oslo office.

Figure 3.2 Tape Record

NORSAR

DATA REQUEST AND TAPE HANDLING LIST

RECEIVED 2. may. '68 FROM Lincoln Lab. BY Telex SIGN @AS

FORWARDED 2. may. '68 TO Øyer BY Telephone SIGN @AS

FORWARDED .... TO .... BY .... SIGN ....

DATA REQUEST				SITE	TAPE NO.: NL–	DATA START		DATA STOP		NOTES	FORWARDING
LP/SP	DAY		HOUR			DAY	HOUR	DAY	HOUR		
SP	18 apr.	109	03.12	1	294	109	01.05.19	109	03.41.48		Date of shipment May 8 1968. AWB 026-7467 2 51 Flight BE 763/09 PA 57/10 Due Boston May 10/1155
"	20 "	111	07.25	1	343	111	05.27.25	111	07.58.52		
"	"	"	14.06	1	349	111	13.08.51	111	15.48.34		
"	21 "	112	06.46	1	361	112	04.53.08	112	07.31.50		
"	"	"	10.34								
"	"	"	13.38	1	364	112	07.31.50	112	17.08.00	DART TAPE	
"	"	"	14.54							(TROUBLESHOOTING ON ASTR.D.)	
"	23 "	114	02.52	1	383	114	01.48.14	114	04.19.54		
"	"	"	06.53	1	385	114	04.19.54	114	07.03.04		
"	"	"	22.36	1	394	114	22.30.14	115	00.53.26		
"	24 "	115	10.43	1	431	115	08.45.17	115	11.15.50		
"	"	"	03.16	1	395	115	00.53.26	115	03.32.17		
"	25 "	116	04.32	1	446	116	02.42.56	116	05.24.56		
"	"	"	04.53								
"	"	"	06.18	1	449	116	05.24.56	116	07.58.19		
"	26 "	117	03.05	1	463	117	02.06.41	117	04.42.32		
"	"	"	06.41	1	465	117	04.42.32	117	07.24.10		
"	"	"	13.26	1	127	117	12.41.54	117	15.14.52		
"	"	"	15.11								
"	"	"	16.40	1	134	117	15.14.52	117	17.52.00		
"	"	"	18.00	1	136	117	17.52.00	117	20.17.52		
"	27 "	118	08.45	1						RECORDER FAILURE	
"	"	"	11.34	1	153	118	11.30.25	118	13.54.51		
"	28 "	119	09.30	1	189	119	07.46.03	119	10.13.05		
"	"	"	20.20	1	211	119	20.18.22	119	22.55.11		

Figure 3.3 Data Request and Tape Handling List

NORSAR - LOG

SITE 1 YEAR 68 MONTH Aug PAGE 1 OF 1

EQUIPMENT D4

SITES:
1: ØYER
2: FALLDALEN
3: TRYSIL

EQUIPMENTS:
D1-2.. : SP6 DART ELECTRONIC
D3-6.. : LP6 DART ELECTRONIC
D1R-6R: DART RECORDER
F.E. ....: FRONT END EQUIPMENT
AUX...: AUXILLIARY EQUIPMENT
T .....: TEST EQUIPMENT
A1: ASTRODATA RECORDER 1
A2: ASTRODATA RECORDER 2
A3: ASTRODATA ELECTRONIC
V1: SNOW-TRACK
V2: SNOW-SCOOTER
V3: JEEP

DAY	FAULT	ACTION	DOWNTIME H	DOWNTIME M
7	0910 GMT. System out for CAL. N/S seism. mass position not adjustable.	Diode connected across micro-switch (remote control) replaced. (Old one was shorted).	5	30
16	1510 GMT. System out for CAL.	Normal CAL. and adjustments performed.	2	20
23	Appx. 0930, system out of operation. Fan motor in multiverter burned.	New fan installed	3	10
26	1000 GMT. System out for CAL. N/S seism. mass position not adjustable.	seismometer mechanically centered, was all the way out on left side.	6	50

WHITE COPY: TO FFI
PINK COPY: REMAIN ON SITE
GREEN COPY: TO O & M OFFICE

TOTAL DOWN TIME 17 H 50 M

TOTAL RUN TIME 726 H 10 M

Figure 3.4 NORSAR Log

4 OPERATIONAL EXPERIENCES 1 FEBRUARY - 30 NOVEMBER 1968

The main O&M task during this reporting period has been to operate and maintain the equipment described in section 2. The organization of this operation, the introductory training period of the staff and the distribution of data tape have been dealt with in section 3. This section contains a short chronological narrative of the O&M, discussion of some technical problems and statistical information about the O&M carried out.

4.1 Short chronological narrative

The system was set in operation during an initial start-up period in December 1967/ January 1968 and some debugging problems were handled during that period. However, the system was fully operational when N-N A/S took on responsibility and started regular operation in the beginning of February.

One man from the temporary group (cf 3.1.1) was on duty at Øyer from 30 January and two others from 5 February in cooperation with personnel from NDRE and Tele-plan A/S, an NDRE subcontractor. The responsibility for the O&M was transferred from Tele-plan A/S to N-N A/S 13 February. The temporary group numbered four men by now; one of them was later on the permanent staff.

Another four men of the permanent staff reported for duty 4 March and part of the temporary group was relieved. The personnel went through a training period of one month.

Some changes in the layout of the Falldalen noise study array (cf 2.4.4) were implemented 3 April, and continuous recording was performed and all data shipped to LL from 10 April to 31 May.

Technical problems of various kinds occurred from time to time, but generally the operation proceeded fairly well until the spring thaw started.

The D-leg went out of operation 22 April, but snow melting made it impossible to reach the WHVs for some time. Later is was found that water in the 1D1 WHV as a result of the snow melting was the cause of the trouble.

A report from LL on poor data from the Falldalen SP-system resulted in change of recorder 27 April. This, however, was apparently not the only problem and after some trouble-shooting and dump-tests the cause was determined to be unreliable grounding. Improvement of the cabinet grounding was carried out 31 May with satisfactory result. The same improvements were carried out at Øyer and Trysil DART systems 12 June.

Sensor 1C2 at Øyer went out of operation 1 June and 1C1 and 1C3 had very low levels. The cause turned out to be water in 1C2 WHV.

A seasonal front end system check at Øyer was carried out during the last half of June. Improvements in sealing of the cable conduits of the WHV drums were carried out in this connection.

Another front end system check at Øyer was carried out 20 - 27 September.

The SP-recording at the Falldalen noise study array terminated 30 September.

During the first half of October the surface SP cables at Falldalen were collected, woundup on reels and stored near the DRC. All the SP seismometers and WHV electronics were also removed and stored at the storage near the DRC. The SP DART with accessories was demounted.

The recording ceased at all three LP sites 21 October. The equipment was later demounted and transported to storage or to new sites as they were readied. This was part of a plan for LP-recording under the phase 2 program.

A representative from MIT was at Øyer 25 October and modified three input channels on the Astrodata for a special test purpose.

The LP seismometers at Øyer were connected to the Astrodata system through three separate channels 31 October.

The DRC hut at Falldalen was moved to the new location at 06B 7 November. Later the LP DART, meanwhile stored at the new storage premises in Brumunddal, was also removed to 06B (phase 2).

The Trysil DRC hut was moved to the new location at 07B 11 November and the LP DART was re-installed 19 November (phase 2).

4.2 Special technical problems

The problems causing most of the downtime on the equipment during this period are discussed below.

4.2.1 High temperatures in the DRCs

The heat dissipated from the equipment in the relatively small DRCs caused a great deal of equipment failures in the first part of the period. This problem was at first most perceptible at the Øyer DRC and especially when the weather conditions made it necessary to close all windows. Later on, when the outside temperature began to rise, the problem also became apparent at the two other sites.

Temperature regulated fans were recommended by ventilation experts consulted. Such were installed and the result was satisfactory, except for a few cases at Øyer when abnormally high outside temperatures occurred.

It was mostly the electronic clocks that failed because of high temperature, but the Datamec recorders in the Astrodata system were also temperature sensitive.

4.2.2 Water in WHVs during spring thaw.

The spring thaw brought forth a new problem at Øyer, viz that water in some of the WHVs leaked into the amplifier and junction boxes.

The construction work had been halted last winter because of snow. For this reason some of the WHVs were in the midst of large open ditches, leaving them completely under water when the snow melting started. In some cases the WHVs were also unfavourably placed in the terrain. Secondly, the cable conduits into the WHV drums were not properly sealed, allowing the water to leak in that way.

It was also impossible to get to the WHVs during the snow-melting period.

The cable entrances have later been re-sealed and the ditches filled in.

4.2.3 Vacuum motors in the Datamec recorders (Astrodata)

The vacuum motors in the Datamec recorders have been a weak point in the system. The first problem occurred when it was disclosed that the spare brushes were of the wrong type. New ones were ordered, but because of long delivery time the wrong ones had to be used. This was made possible by some modifications. The wrong brushes did not seem to last very long, however, and they possibly also did some harm to the motors. Further troubles arose when the bearings started to get worn. New bearings were made several times.

4.2.4 Batteries for the Chrono-log clocks (DART)

The Chrono-log clocks used in the DART systems seemed to be beset by a serious problem in connection with the batteries.

After a short time in use it was discovered that the batteries in some of the clocks were damaged, apparently due to overcharging. One possible reason for this is that the clocks may have been left running on the batteries during transport and storage, completely discharging the batteries. The display does not operate on the batteries, so this may well have happened without being noticed. When reinstalled here, the batteries would then automatically be overcharged, since the normal battery charging rate in the Chrono-log clocks is too high for new and discharged batteries.

This problem also arose later in connection with long power breaks.

4.2.5 Data parity errors on the DART systems

High rates of data errors occurred from time to time on the DART systems. As far as it has been possible to check, these failures were generally related to bad plug connections on the cards.

4.3 Statistics

600 data tapes were shipped to LL, 116 tapes to the University of Bergen and 1 tape to KCIN (Kjeller Computer Installation) during the reporting period. Although replacement of tapes had not been intended because re-supply of tapes had been provided for in the contract, such tapes were received from LL.

Statistical information pertaining to downtime and preventive maintenance of various parts of the equipment has been obtained and is presented in Appendix A6.

5 CONCLUDING REMARKS

Since this report does not deal with the results of the final data-processing in USA and at the University of Bergen, it must, with respect to the end product of the operations, confine itself to a brief remark on the technical quality of the tape recordings.

In the beginning of the period a noticeable fraction of the recorded tapes could not or could only partially be used in the EDP analyses. Some of the equipment failures could be detected by the O&M crew during calibration or normal runs, e g from analog or digital displays; others were undetectable until an analysis of the data was performed by the user.

In some cases faults were allowed to prevail for too long a period, due either to lack of full familiarity with the equipment on the part of the O&M crew and/or to delayed feedback of information from the users on the quality of the data recorded. The reaction times were shortened considerably when the subcontractor, who had established the O&M service at short notice, became fully acquainted with the equipment and the users speeded up their control and information procedures.

The main experiences of technical and practical nature from the operation of the phase 1 system have been discussed in chapter 4, leaving room for only a brief comment on this.

The SP front end system troubles were largely caused by leakage of water into the WHV steel drums; mostly through the cable conduits. The remedies are use of improved sealing material and methods for the conduits, and better drainage of the soil surrounding the WHV.

The transport of men, materials and equipment to, from or within the sub-arrays met with little trouble most of the year. However, a few times in the winter season and for a period during the spring thaw the O&M crew became weather-bound, at least as far as access to some of the SP sites was concerned.

APPENDIX 1

SP FRONT END SYSTEM SPECIFICATIONS AND WIRING DIAGRAMS

A1. 1 HS-10-1 (ARPA) SP seismometer specifications

Generator constant	846 V/m/s at 3 c/s and 0. 707 critical damping
Natural frequency	1. 0 c/s ± 3%
DC resistance	50 000 ohms ± 5% (coil center tapped)
Moving mass	825 g ± 1. 5%
Calibration coil Motor constant	0. 0326 newtons/amp
Calibration coil Sensitivity	1 millimicron/microampere
Outer case test pressure	250 psi
Outer case dimensions	4. 75 in. OD by 11. 25 in. long

A1. 2 GEOTECH 20171A seismometer specifications

Natural frequency	adjustable 0. 75 to 1. 05 Hz with up to 10 deg tilt
Weight of inertial mass	5 kg ± 1%
Spring rate (3 to 1 lever)	3. 820 newtons/meter
Operating temperature range	-2^{o} to 49^{o} C
Mode of operation	Vertical adjustable for use with tilts up to 10 deg from vertical
Transducer generator constant	103 Vsec/m when using 22735-3 coil
Cal oil motor constant	adjustable from 0. 186 to 0. 206 newtons/amp
Weight	30. 8 kg
Length	1. 185 m
Diameter	95 mm

A1. 3 AB and JB circuitry diagrams

Figures A1. 1 through A1. 8 cover the WHV circuitry except for internal RA-5 amplifier.

A1. 4 Type RA-5 amplifier specifications

Power

Voltage	+18 V DC and -18 V DC
Current	Dependent on number of boards used. A 3-channel basic system requires approximately 16 ma at +18 V DC. With the addition of three each 24 db/octave filters, three each 26 db/octave filters and six each differential output amplifiers, requirements are approximately 25 mA at +18 V DC and 5 mA at -18 V DC.

Signal channel

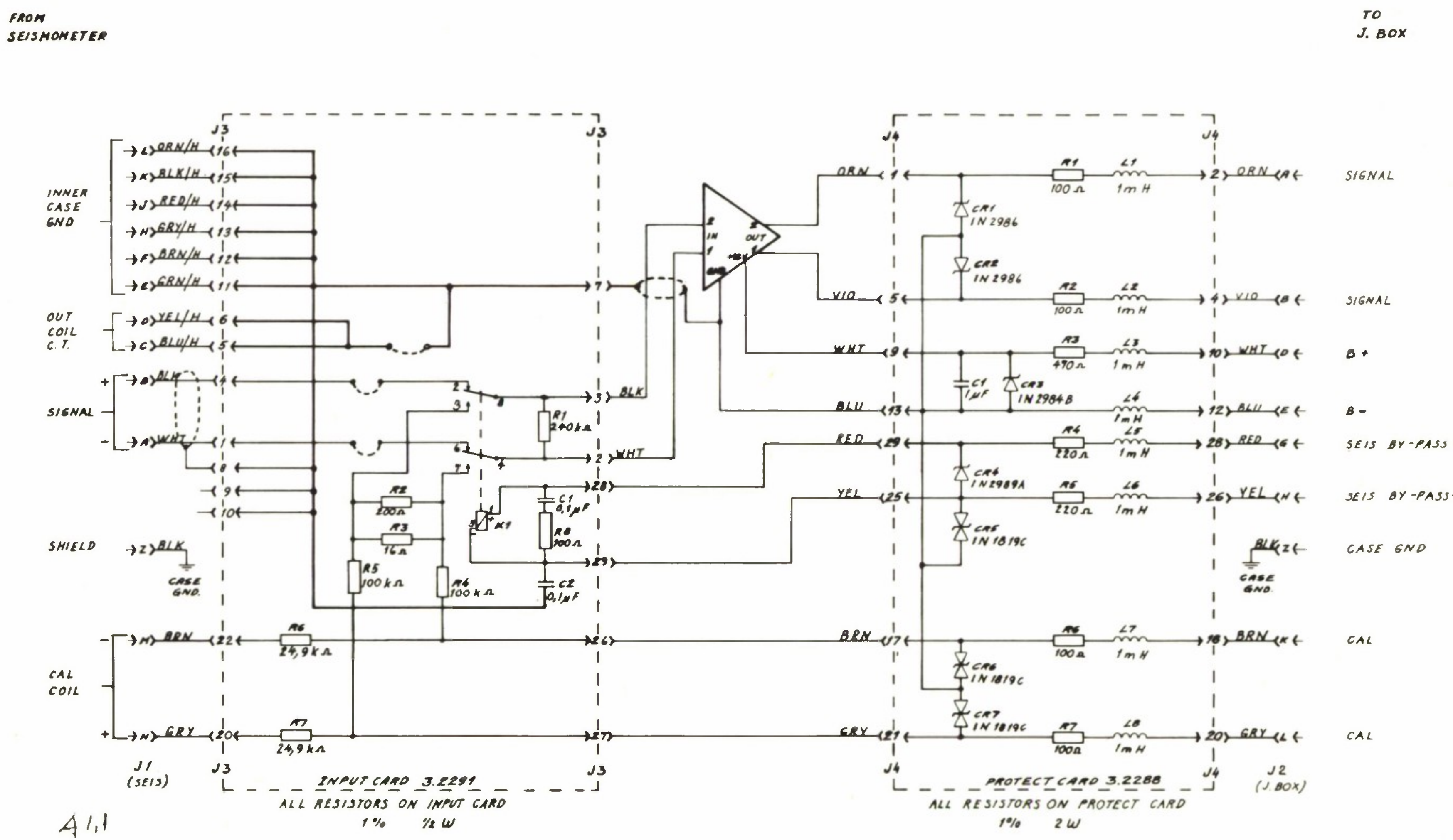
Input impedance	Set by input attenuator if one is used. Without attenuator, will consist of a capacitive component of approximately 800 μμF in parallel with a resistive component of more than 1000 megohms.
Input noise voltage (equivalent)	Less than 0.05 μV rms over a frequency band from 0.8 to 10.0 cps.
Input type	Differential and floating
Input voltage	30 mV-pp before clipping
Source requirements	Resistive path of 50 megohms or less must appear across input terminals either by source or by resistor added at input terminals of data channel.
Frequency response	Without optional filtering, not more than 3 db down at 0.005 cps and 1200 cps
Preamplifier voltage gain	180 at detector output. Variable from 100 to 250
High-level output voltage gain	To customer's specifications
Offset output voltage	
Detector output	Adjustable, 6 V DC (±2 V DC)
Multilevel amplifier	Adjustable, normally set at 0 V
Differential amplifier	Adjustable, normally set at 0 V
Output signal level	
Detector output	Minimum of 8 V-pp before clipping
Multilevel amplifier	Minimum of 28 V-pp with ±18 V DC power source
Differential amplifier	Minimum of 56 V-pp differential ±18 V DC power source
Dynamic range	
Detector output	106 db with gain of 180
High-level amplifier output	100 db with overall single-ended gain of 1000
Output impedance	
Multilevel amplifier	Less than 5 ohms
Differential amplifier	5 ohms, each leg
Filter Response	All similarly specified 3 db points (±1 db) will track from channel to like channel
Crosstalk	At least 54 db down between channels

Environmental gain stability

Temperature	Not more than 3 db variation from nominal over a temperature range from -30° C to $+50^{\circ}$ C
Power	Not more than 1 db variation from normal with change in positive supply from +15 V to +28 V or with negative supply change from -15 V to -28 V.
Detector DC offset variations related to temperature changes	Not more than ±3 V DC change with temperature change from -30° C to $+50^{\circ}$ C
Shock	Will withstand normal shipment by commercial carrier including air freight

Physical

Size	7 in. x 5 in. x $13\frac{1}{2}$ in.
Weight	Dependent on number of boards. Basic system weighs approximately 45 oz



NOTE
SHIELDED WIRING TO BE YF-OS-K 2 x 0,13 mm² GRAY
ALL OTHER WIRING TO BE SOFLEX TQ 0,25 mm² (30 x 0,10)

Figure A1.1 Amplifier box, wiring diagram

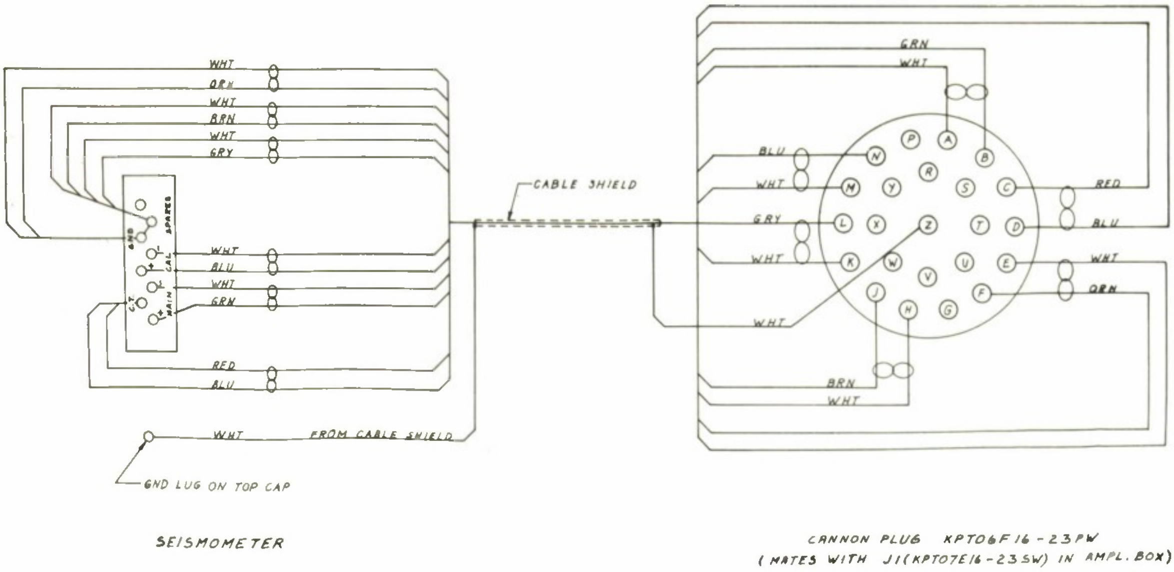


Figure A1. 2 SP seismometer to amplifier box connections

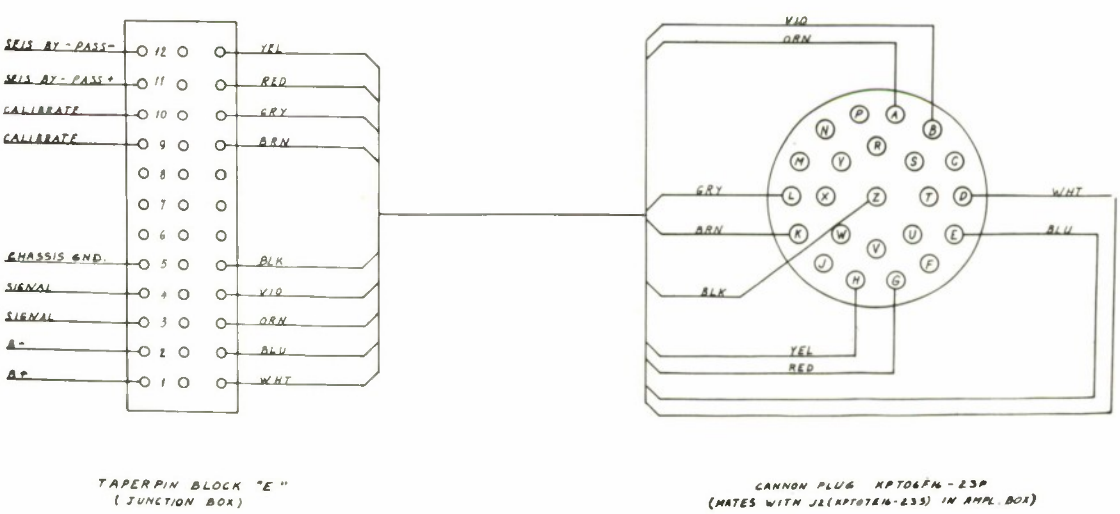


Figure A1. 3 Amplifier box to junction box connections

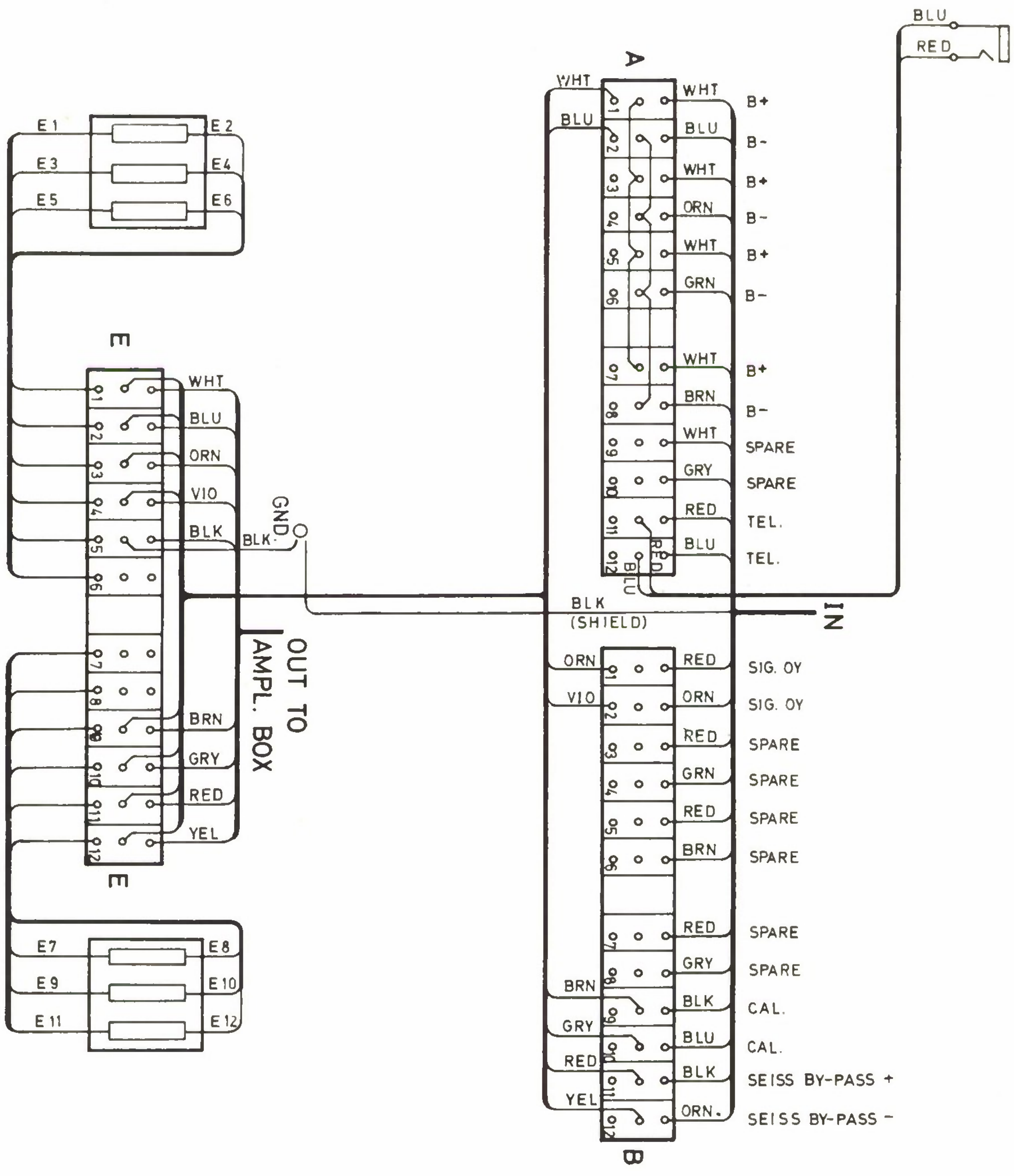


Figure A1.4 Junction box, wiring diagram; type 1OY(1)

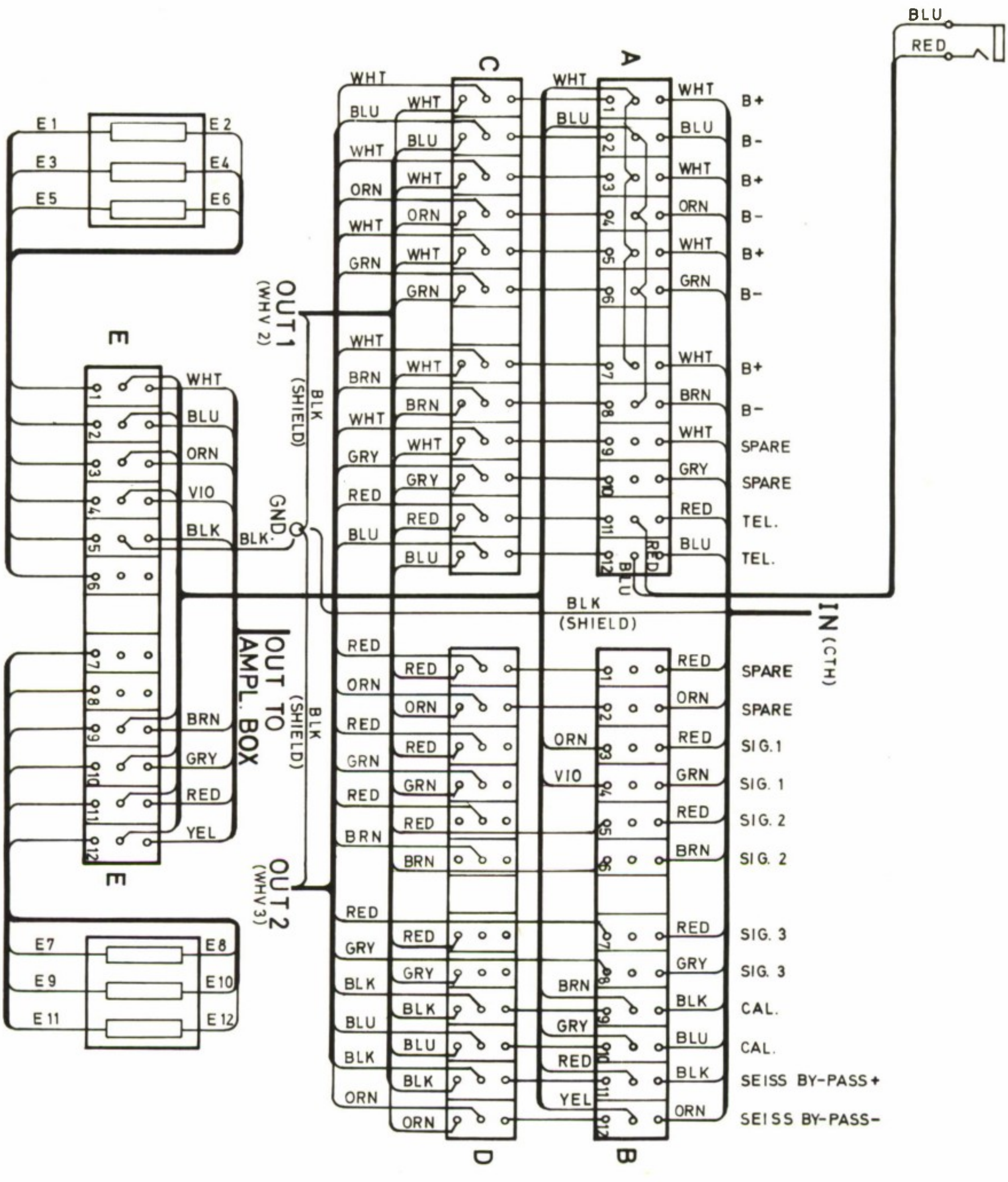


Figure A1.5 Junction box, wiring diagram; type branching point inner hexagon

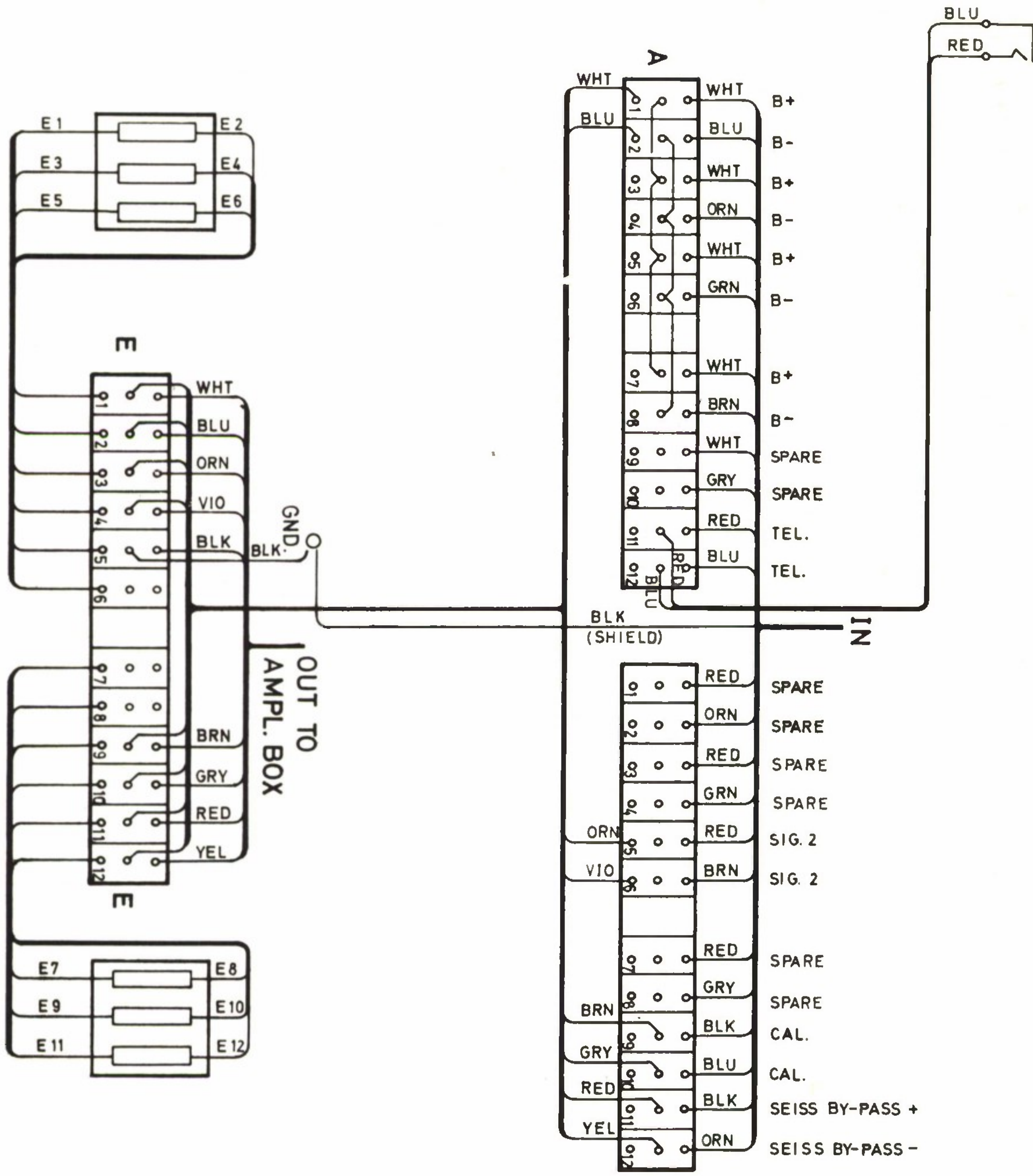


Figure A1.6 Junction box, wiring diagram; type outer hexagon, left branch

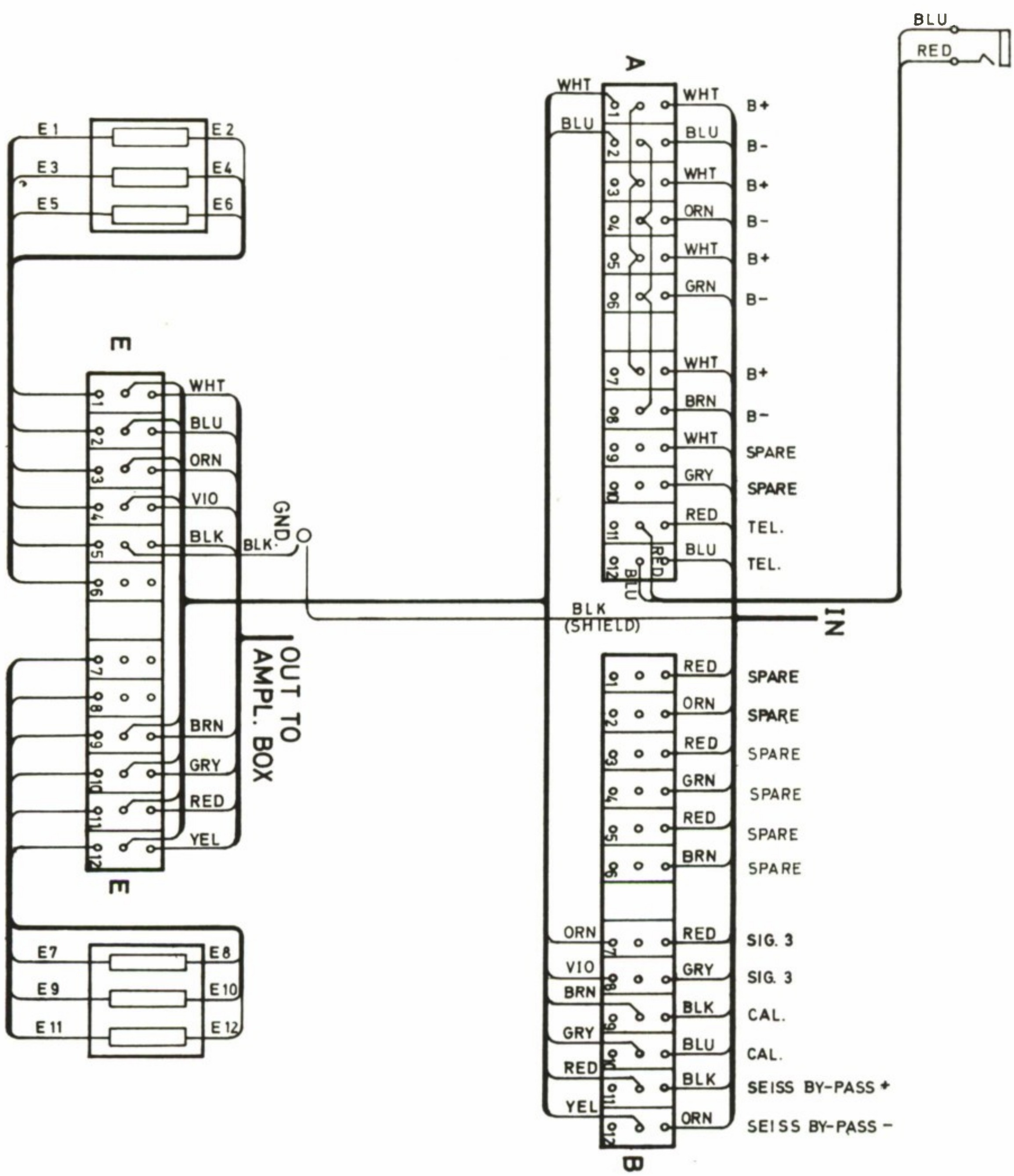


Figure A1.7 Junction box wiring diagram; type outer hexagon, right branch

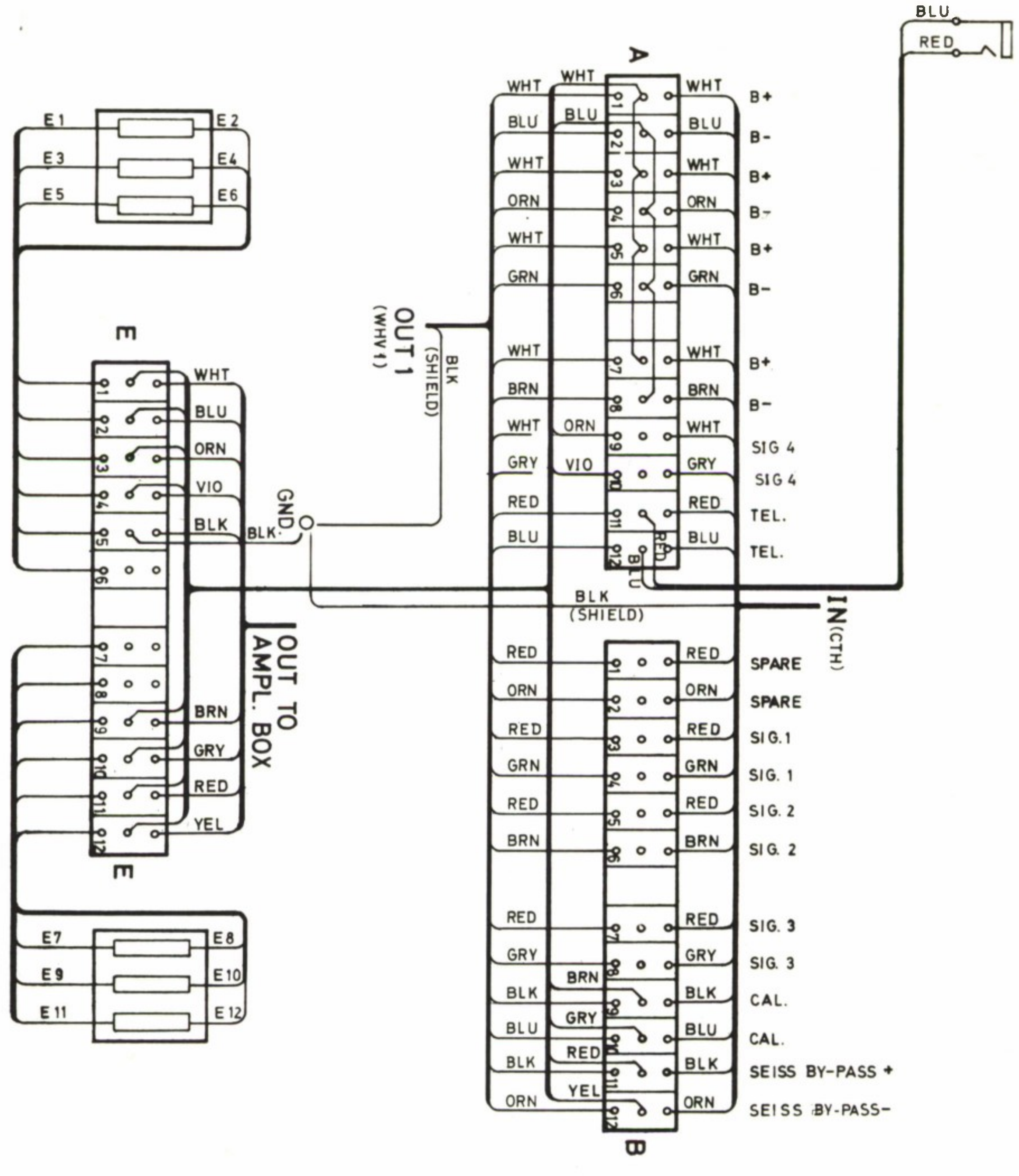


Figure A1.8 Junction box wiring diagram; type 1F4(20)

APPENDIX 2

LP FRONT END SYSTEM SPECIFICATIONS AND WIRING DIAGRAMS

A2.1 LP seismometer specifications

Model 7505B LP vertical seismometer

DC power required	4.0 V DC, 150 mA 24 V DC, 350 mA 18 V DC, 1.5 mA
Weight	160 lbs (72.5 kg)
Dimensions	15.5 x 12 x 24 inches 393.7 x 304.8 x 609.6 mm
Natural period	10 to 30 sec, adjustable
Weight of inertial mass	10 kg ± 1%
Spring rate	10.3 lbs/in. ± 3%
Critical damping resistance	90 times natural period, in ohms ± 3%
Transducer	
Type	Moving coil
Damping	Electromagnetic
Flux density in air gap	1950 ± 100 gauss (max)
Coils	
Data coil	
Number of coils	1
Terminal resistance	50 000 ohms ±10% at 25° C (77° F)
Turns	22 500
Wire size	No 47 AWG
Effective generator constant	750 V - s/m ± 2%
Calibration coil	
Number of coils	1
Terminal resistance	0.2 ohms ± 0.05 ohms at 25° C (77° F)
Turns	1
Wire size	No 36 AWG
Effective motor constant	0.032 newtons/amp ± 0.0025 newtons/amp
Damping coil	
Number of coils	1
Terminal resistance	580 ± 20 ohms at 25° C (77° F)
Turns	3260
Wire size	No 36
Mass position monitor (mounted on seismometer)	
Output	Zero to ± 1.5 V DC, zero to ± 50 μA
Power required	18.0 V DC, 1.5 mA 4.0 V DC, 150 mA
Remote centering unit (mounted on seismometer)	
Motor type	DC
Speed	60 rpm ± 10%
Power required	24 V DC, 100 mA
Remote centering device (external to seismometer)	
Motor type	DC
Speed	60 rpm ± 10%
Power required	24 V DC, 350 mA

Environmental characteristics

Temperature	0° C to 60° C (32° F to 140° F) OPERATE -20° C to 60° C (-4° F to 140° F) STORAGE
Relative humidity	0 to 95% OPERATE
Altitude	15 000 ft OPERATE 50 000 ft STORAGE
Vibration	Zero (Operate) Will withstand all vibration encountered in normal shipping and maintenance (transit)
Shock	Will withstand all shocks encountered in normal shipping and maintenance

Model 8700D LP horizontal seismometer

DC power required	4.0 V DC, 150 mA 24 V DC, 350 mA 18 V DC, 1.5 mA
Weight	115 lbs (52.2 kg)
Dimensions	15.5 x 12 x 24 in. (394 x 305 x 610 mm)
Natural period	10 to 30 sec, adjustable
Weight of inertial mass	10 kg ± 1%
Transducer	
Type	Moving coil
Damping	Electromagnetic
Flux density in air gap	1950 ± 100 gauss (max)
Coils	
Data coil	
Number of coils	1
Terminal resistance	50 000 ohms ± 10% at 25° C (77° F)
Turns	22 500
Wire size	No 47 AWG
Effective generator constant	750 V - s/m ± 2%
Calibration coil	
Number of coils	1
Terminal resistance	0.2 ohms ± 0.5 ohms at 25° C (77° F)
Turns	1
Wire size	No 36 AWG
Effective motor constant	0.032 newtons/amp ± 0.0025 newtons/amp
Damping coil	
Number of coils	1
Terminal resistance	580 ± 10 ohms at 25° C (77° F)
Turns	3260
Wire size	No 36

Mass position monitor (mounted on seismometer)

Output	Zero to ± 50 µA
Power required	18.0 V DC, 1.5 mA 4.0 V DC, 150 mA

Remote centering device (external to seismometer)

Motor type	DC
Speed	0.625 rpm ± 10%
Power required	24 V DC, 350 mA

A2.2 LP front end system cable connections and wiring diagrams

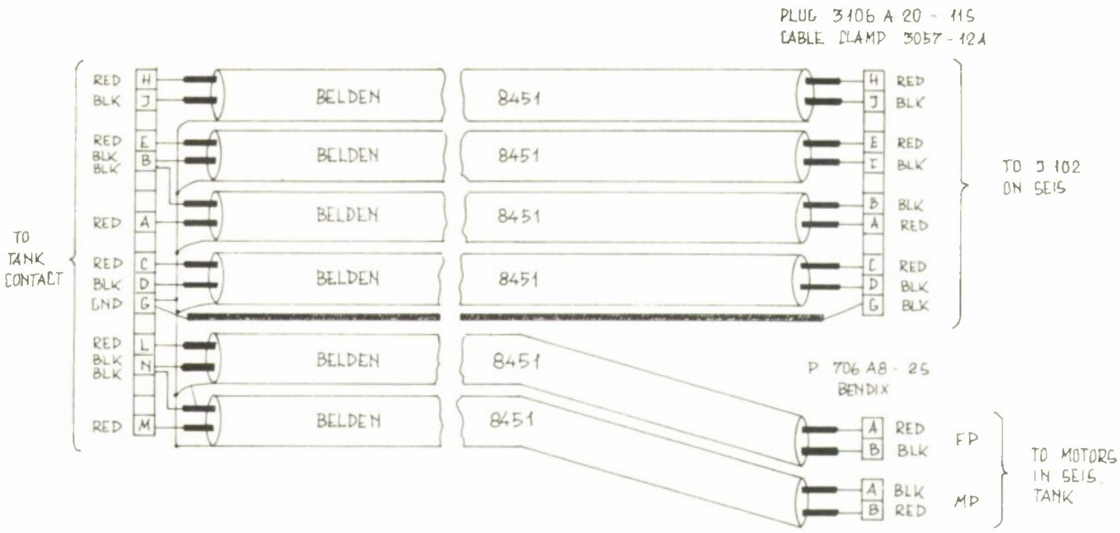


Figure A2.1 Internal LP tank connections, horizontal seismometer

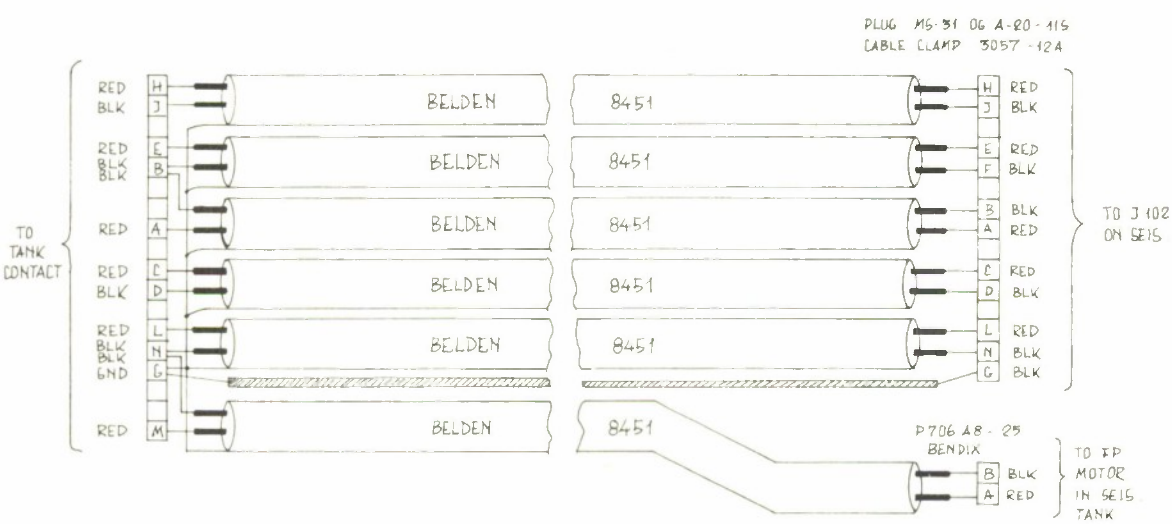


Figure A2.2 Internal LP tank connections, vertical seismometer

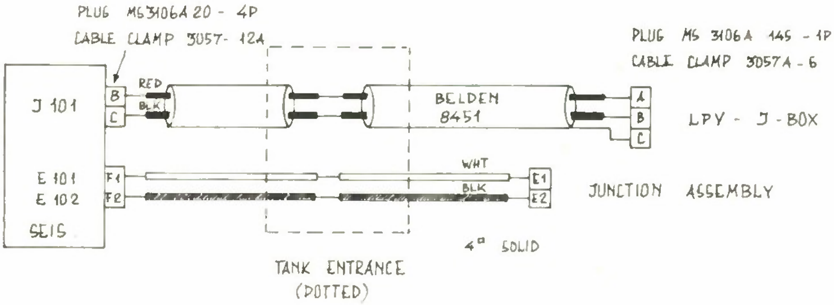


Figure A2.3 Data and damping cable, LPV installation

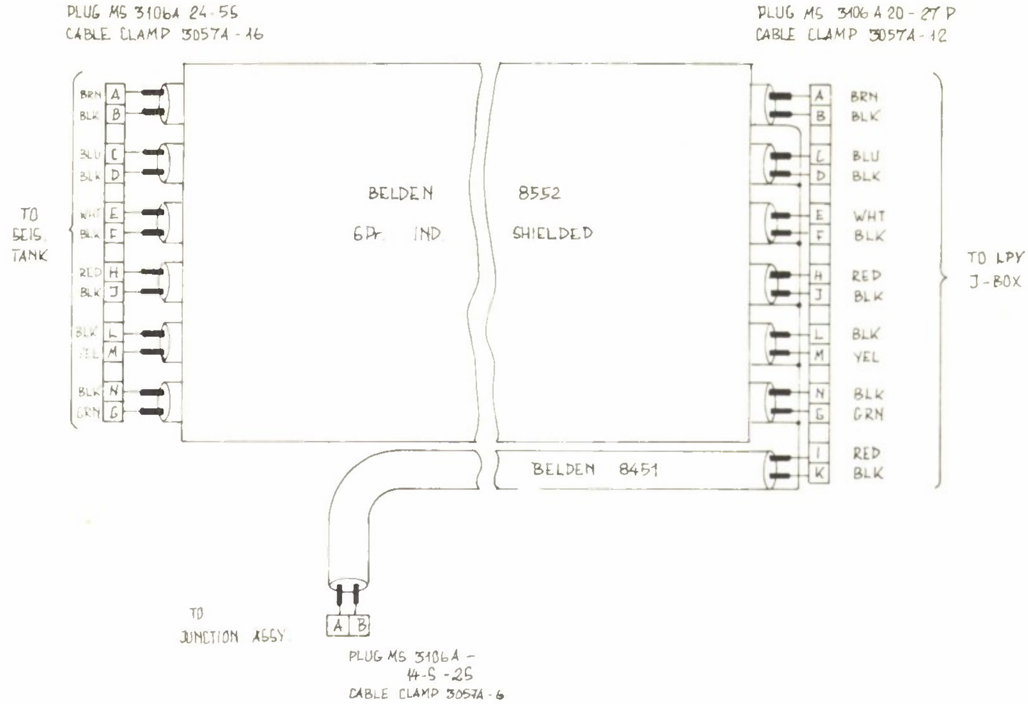


Figure A2.4 LPV cable connection

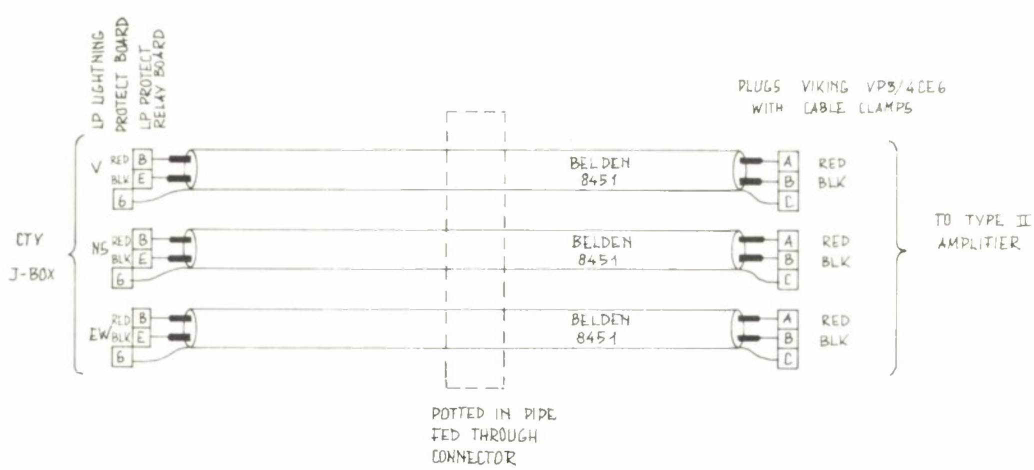


Figure A2.5 LP junction box to amplifier connection in DRC

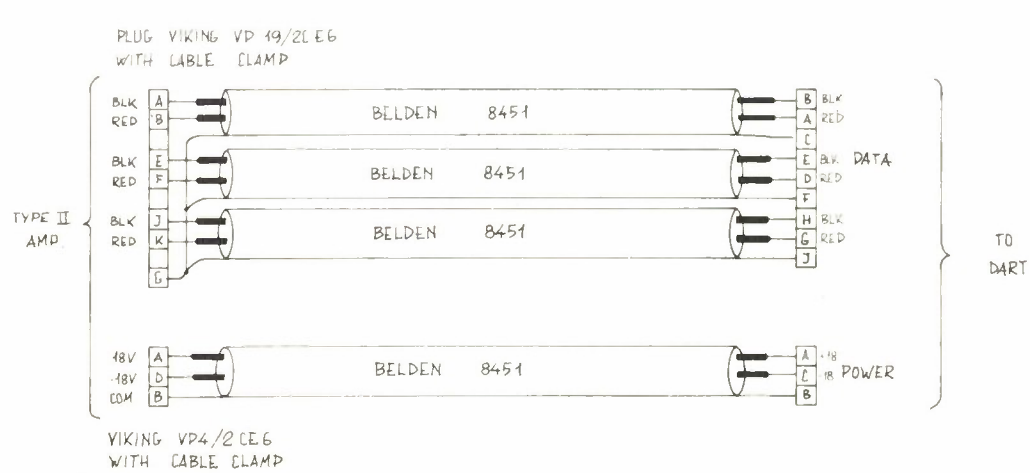


Figure A2.6 Data and power cable amplifier to LP recorder (DART) in DRC

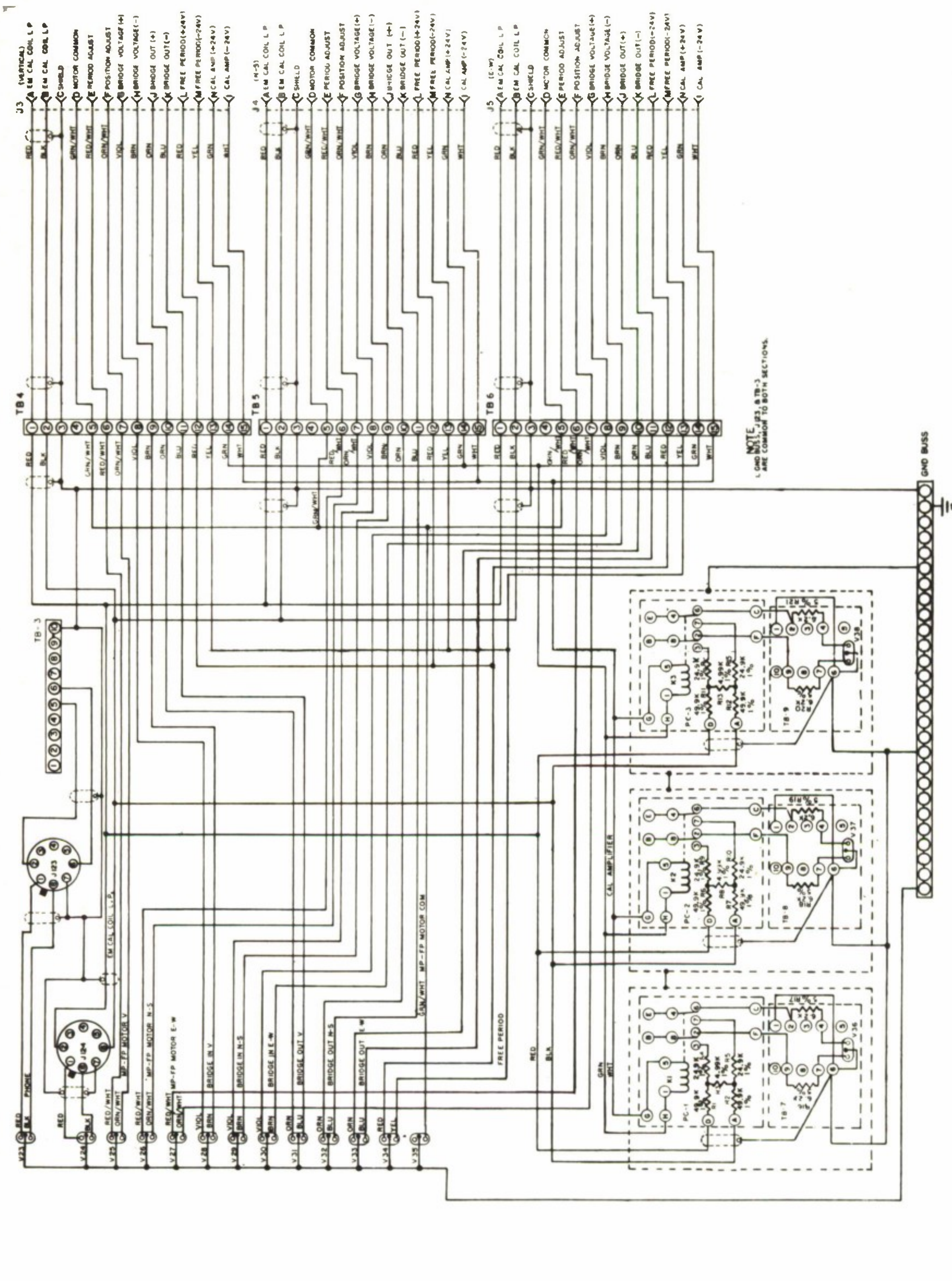


Figure A2. 7   LP DRC junction box

APPENDIX 3

RECORDING TAPE SPECIFICATIONS

Scotch computer tape No 777

Physical characteristics

Base material	Polyester (oriented polyethylene terephthalate)
Toxicity	Non-toxic
Flammability	Self-extinguishing
Thickness:	
Base	0.00142 inches nominal
Magnetic coating	0.00055 inches maximum
Total	0.0019 ± 0.0003 inches
Width	0.498 ± 0.002 inches
Splices	None
"E" value	1/8 inch minimum
Curvature	1/8 inch maximum per 36 inch length of tape
Cupping	0.010 inch maximum per 0.25 inch length
Elastic characteristic	325 to 550 lb
Yield force	11 lb minimum
Coating roughness	1 to 6 microinches
Surface resistance	0.5 megohms per sq (1.0 megohm per lineal inch) minimum 100 megohms per sq (200 megohms per lineal inch) maximum
Frictional drag:	
Coating to brass	130 grams maximum
Backing to rubber	80 grams minimum
Coating to backing	80 grams minimum
Adhesion - layer to layer	None
Dynamic skew - 800 bpi at 112.5 ips	2.0 microseconds maximum
Wear resistance of tape - 200 passes	An average of less than one permanent write error per pass with a maximum of two permanent write errors in any given pass

Magnetic characteristics

Signal level	± 5% at 556 bpi ±10% at 800 bpi ±10% at 3200 fci
Remanence (Ør)	1.45 ± 0.20 maxwells
Intrinsic coercivity (Hci)	275 ± 10% oersteds
Signal dropouts	No permanent errors at density specified
Noise	None exceeding 10%

Environment recommendations

Operating	60°F to 90°F	20% RH to 80% RH	78°F wet bulb maximum
Storage	40°F to 90°F	20% RH to 80% RH	80°F wet bulb maximum

Tape subjected to 120°F with a wet bulb maximum of 80°F may be reconditioned.

APPENDIX 4

TEST EQUIPMENT AND SPARE PARTS

A4.1 Available test equipment

DRC - Øyer

1 Multimeter, Triplett (Model 630 NA)

1 Oscilloscope Tektronix (Type 422) w/battery pack and charger, dual channel w/delay

1 Oscilloscope Tektronix (Model 555)

1 Tektronix Scope Cart (Type 202-2) w/drawer

1 Tektronix plug-in unit (Type 1A7)

1 " " " (Type W)

1 " dual trace plug-in unit (Type 1A1)

1 " " " " " (Type 1A2)

1 Wavetek Signal Generator (Model 116B)

1 Rustrack Recorder AC Volts (Model 91/135/8)

1 " " " (Model 93A)

1 Well Head Vault test box

1 Dart test box

2 AC transistor Voltmeter H-P (Model 403A)

1 Decade Voltage Divider (Type 1455A)

1 Precision Power Source Power designs (Model 2005)

1 Tektronix plug-in- dual trace (Model 1A2)

1 DC null Voltmeter H-P (Model 419A)

1 Precision Voltage Source EDC (Model US-11N)

1 Digital Voltmeter H-P (Model 3440A) w/3444A DC multifunction unit

1 WHV test box Mark I (Lincoln Laboratory built)

1 CPS Cal Oscillator (Lincoln Laboratory built)

1 WHVT Receiver (Model SR-7-R)

DRC - Falldalen

1 WHVT Receiver (Specific Product)

1 Multimeter Triplett (Model 630NA)

1 " " (Model 310C)

1 Professional Bulk Tape Eraser and Demagnitizer (Model ML 120)

1 Brush Recorder 2 channel

1 Oscilloscope Tektronix (Type 422)

1 Sanborn 2 channel recorder (Model 320)

1 Digital Voltmeter H-P (Model 3440A)

1 Ammeter (Model 425A)

1 Electronic Frequency Counter

1 Decade Resistor (Type 1432M

1 Test instrument Hewlett Packard (Scale Volts - decibles, Meter model 1051)

1 Dart test box

1 Test instrument (w/40 switches marked Time/sec - Time/min)

1 Test instrument (Black box, laboratory built for A/D converter)

1 Test instrument w/7 channels, 7 switches

1 Seismometer test box, Geotech (Laboratory built)

1 Well Head Vault test box

DRC - Trysil

1 WHVT Receiver (Specific Product)

A4.2 Example of spare parts record

List comprising spare parts for: DART
Site: Trysil
Project NORSAR Contract No AF 19(628)-5167

Item	Part No	Assy No	Ser No	Quant	Date	Remarks
Dart 1 Cards	65PW 5808	RSS		3	1/5-68	
" 2 "	" 5668	RAG-MVSA		2	"	
" 4 "	" 5719	PSR-MVSA		1	"	
" 5 "	" 5720	ADD-ADD		1	"	
" 6 "	" 5721	MEP-MVSA		1	"	
" 7 "	" 5768	RAG-MEP		1	"	
" 8 "	" 5769	RAG-MVSA		1	"	
" 9 "	" 5770	MVSA-MGP-F		1	"	
" 10 "	" 5779	PBR-PBR		1	"	
" 11 "	" 5809	MGP-H/MGP-F		1	"	
" 12 "	" 5810	BDP-BDP		1	"	
" 13 "	" 5812	BDP-BDP		1	"	
" 15 "	" 5836	GDP-GDP		1	"	
Neon Driver	" 5826			1	"	
Printed Cards	MVSA			4	"	
" "	MGP-H			3	"	
" "	MEP			2	"	
" "	MGP-F			2	"	
" "	GDP			2	"	
" "	RAG			1	"	
" "	PBR			1	"	
" "	PSR			2	"	

Figure A4.1 Page from spare parts record

APPENDIX 5

PREVENTIVE MAINTENANCE PROGRAM

The preventive maintenance program for the NORSAR Phase 1 System is given below.

This program is meant to cover the preventive maintenance of all the equipment and installations of NORSAR Phase 1 at Øyer, Falldalen and Trysil sites.

The program is divided into three parts as follows:

Part 1 Preventive maintenance and calibration schedule with reference to "detailed maintenance description"

Part 2 Maintenance work responsibility

Part 3 Record keeping

PART 1 - Preventive maintenance and calibration schedule with reference to "detailed maintenance description"

ASTRODATA	D'ly	W'ly	M'ly	Spring Fall	Y'ly	Detailed maint desc
Time check	x					1.1
Input amplifiers in connection with calibration (every 2nd tape)	x					1.1
887 amplifiers zero and gain		x				1.4
Offset channel 1		x				1.5
Temp, humidity		x				1.1
ADC bit configuration		x				1.10
ADC potentiometric amplifier adjustment			x			1.8
ADC comparator adjustment			x			1.10
887 differential DC amplifier input base current adjustment			x			1.5
ADC buffer variable clamp supply					x	1.13
Datamec recorder						
Clean tape path	x					1.18
Check tape tracking	x					1.19
Check pinchroller bearings	x					1.31
Check rotary guide bearings	x					1.32
Check pilot lamps	x					-
Check photosense lamp	x					-
Clean rack cabinet		x				1.19
Clean tape cleaners		x				1.19
Check pinchroller gaps		x				1.19
Check pinchroller wear		x				1.31

Astrodata (cont'd)	D'ly	W'ly	M'ly	Spring Fall	Y'ly	Detailed maint desc
Check photosense output voltage		x				1.20
Check data electronics adjustment		1)				1.21 - 1.27
Replace vacuum motor brushes		1)				1.45
Replace photosense lamp		1)				1.54
Check reel brake gap				x		1.20
Check drag brake tension				x		1.20
Check rewind jog setting				x		1.20
Replace pinchrollers				x		1.31
Replace pinchroller bearings				x		1.31 - 1.32
Replace vacuum motor				x		1.43
Replace capstan drive belt				x		1.36
Check capstan bearings					x	-
Replace rotary guide bearings					x	1.31
Replace capstan motor					2)	1.36
Replace capstan assembly					2)	-
Replace upper actuator assembly					2)	-
Replace lower actuator assembly					2)	-
Replace head assembly					2)	1.53
Replace vacuum chamber					2)	1.42
Replace fixed guides					2)	-
Replace vacuum chamber covers					2)	-
Replace supply reel motor assembly					2)	1.38
Replace take up reel motor assembly					2)	1.38

1) Bi-monthly, 2) Every fourth year.

DART	D'ly	W'ly	M'ly	Spring Fall	Y'ly	Detailed maint desc
Check from control panel	x					2.1 - 2.4
Clean tape path (every tape change)						2.1
LP calibration (every tape change)						2.5
Data waveform check			x			2.3
Adjustment of bal-unbal filter board		x				2.7
Adjustment of oscillator			x			2.7.1
Lubrication, cabinet blowers			x			-
Chrono-log clock:						
Oscillator adjustment				x		-
Multiverter:						
Complete calibration and check-out when necessary						2.8 - 2.26

DART (cont'd)	D'ly	W'ly	M'ly	Spring Fall	Y'ly	Detailed maint desc
Kennedy Recorder :						
Recorder check				x		2.4
Pressure roller adjustment SP				x		2.28
Pressure roller adjustment LP					x	2.28
Mechanical adjustments				x		2.28
Electrical adjustments				x		2.28
Stepper drive gear change SP					1)	2.28
Stepper drive gear change LP					2)	2.28

1) 2600 hrs, 2) 9000 hrs.

AUXILIARY EQUIPMENT	D'ly	W'ly	M'ly	Spring Fall	Y'ly	Detailed maint desc
Sanborn Recorder:						
Check		x				-
Lubrication, blower motor			1)			3.4
Lubrication gear box			1)			3.4
Lubrication of gears along wall of Recorder			1)			3.4
Lubrication drive chains			1)			3.4
Full check and adjustment					x	3.6 - 3.12
Event Detector:						
Check				x		-
Tape Punch:						
Cleaning and check			1)			3.13 - 3.16
Automatic Voltage Regulator:						
Check				x		-
Overhaul					x	3.16 - 3.18
Battery Charger:						
Check current and voltage	x					1.1
Battery:						
Check and refill distilled water						
Check cell voltage		x				1.1

1) Every three months.

FRONT END	D'ly	W'ly	M'ly	Spring Fall	Y'ly	Detailed maint desc
Signal flow and distortion from seismometers	x					1.1
Seismometer signals and WHV amplifier gain				x		4.1
Telephone communication				x		4.1
Vault condition				x		4.1
LP vault and seismometers				x		4.1

VEHICLES	1000 km	2000 km	8000 km	Spring	Detailed maint desc
Snow Trac:					
Lubrication and check	x				
Check and tightening of bolts		x			5.1
Complete workshop overhaul followed by summer storage				x	5.1
Snow Scooter:					
Lubrication and check	x				5.2
Complete workshop overhaul followed by summer storage				x	5.2
Volvo Jeep:					
Lubrication, check in accordance with instruction book	x	x	x		-

STATION AND ROADS	D'ly	W'ly	M'ly	Spring Fall	Detailed maint desc
Building conditions:					
Basement etc				x	-
Cooling fans, lubrication			x		
Water supply pump and related items				x	-
Roads:					
Check, and notify responsible authority				x	-

PART 2 - Maintenance work responsibility

A = Site personnel, B = Commercial firms, C = US authorities.

	A	B	C	Remarks
ASTRODATA				
Clock	x			
887 amplifiers	x		x	
Electronics	x			
Blowers	x			
Radios	x			
Datamec recorder	x			
Memory	x		x	
AUXILIARY EQUIPMENT				
Sanborn Recorder	x			
Tape punch	x			
Event detector	x		x	
LP calibration monitor	x			
Automatic voltage regulators	x			
DART				
Clock	x			
Multiverter	x			
Electronics	x			
Kennedy Recorder	x			
VEHICLES	x	x		
FRONT END				
Seismometers			x	
Amplifiers and junction boxes	x		x	
Cables	x	x		
Vaults	x	x		
STATION AND ROADS				
Building	x	x		
Water supply		x		
Roads		x		

PART 3 - Record keeping

NORSAR Log

This is a record of "Operation and Maintenance" comprised of separate sheets for various parts of the equipment.

Clock Graph

This is a graph that is filled in for each clock at site in order to keep track of possible time deviations.

Front End maintenance check list

This check list shall be made out whenever front end conditions are checked.

APPENDIX 6

OPERATIONS STATISTICS

The statistics will be presented in the form of graphs (Figures A6. 1 through A6. 43).

A6. 1 List of graphs

Figure No	Description	
Øyer - Astrodata		
A6. 1	Downtime and preventive maintenance (Total)	
A6. 2	Recorder No 1	- Downtime and preventive maintenance
A6. 3	Recorder No 2	- Downtime and preventive maintenance
A6. 4	887 amplifiers	- Downtime and preventive maintenance
A6. 5	Clock	- Downtime and preventive maintenance
A6. 6	Main power supply	- Downtime
Øyer - Auxiliary equipment		
A6. 7	Downtime and preventive maintenance (Total)	
A6. 8	Sanborn recorder	- Preventive maintenance
A6. 9	LP monitor control unit	- Downtime
A6. 10	Event detector tape punch	- Downtime
Øyer - SP DART		
A6. 11	Downtime and preventive maintenance (Total)	
A6. 12	Multiverter	Preventive maintenance
A6. 13	Clock	Preventive maintenance
A6. 14	Recorder	Downtime and preventive maintenance

Falldalen - SP DART

A6.15	Downtime and preventive maintenance (Total)	
A6.16	Electronics	Downtime
A6.17	Clock	Downtime and preventive maintenance
A6.18	Recorder	Downtime and preventive maintenance

Øyer - LP DART

A6.19	Downtime and preventive maintenance (Total)	
A6.20	Electronics	Downtime and preventive maintenance
A6.21	Clock	Downtime and preventive maintenance
A6.22	Recorder	Downtime and preventive maintenance

Falldalen - LP DART

A6.23	Downtime and preventive maintenance (Total)	
A6.24	Electronics	Downtime
A6.25	Recorder	Downtime and preventive maintenance
A6.26	Clock	Downtime and preventive maintenance

Trysil - LP DART

A6.27	Downtime and preventive maintenance (Total)	
A6.28	Electronics	Downtime
A6.29	Recorder	Downtime

Øyer - SP Front End

A6.30	Downtime and preventive maintenance (Total)	
A6.31	Seasonal downtime	
A6.32	RA5 amplifiers	Downtime and preventive maintenance
A6.33	No of SP-sensors in operation at various times	

Falldalen - SP Front End

A6.34	Downtime and preventive maintenance (Total)	
A6.35	WHV amplifiers	Downtime and preventive maintenance

Øyer - LP Front End

A6.36	Downtime and preventive maintenance (Total)	
A6.37	Seasonal downtime	
A6.38	Seismometers	Downtime
A6.39	Levelling devices	Downtime

Falldalen - LP Front End

A6.40	Preventive maintenance (Total)	

Trysil - LP Front End

A6.41	Downtime and preventive maintenance (Total)	
A6.42	Seismometers	Downtime

Øyer - Vehicles

A6.43	Downtime and preventive maintenance	

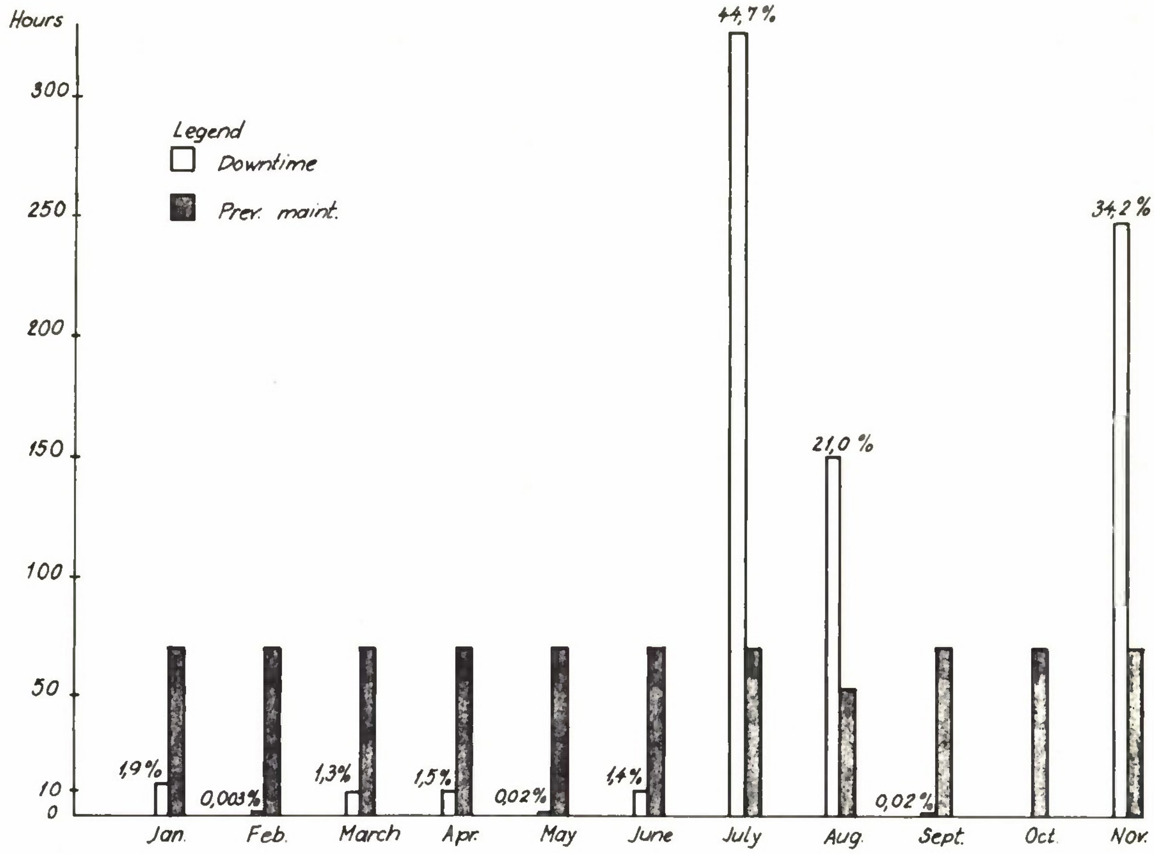


Figure A6.1 Øyer - Astrodata - Downtime and preventive maintenance (Total)

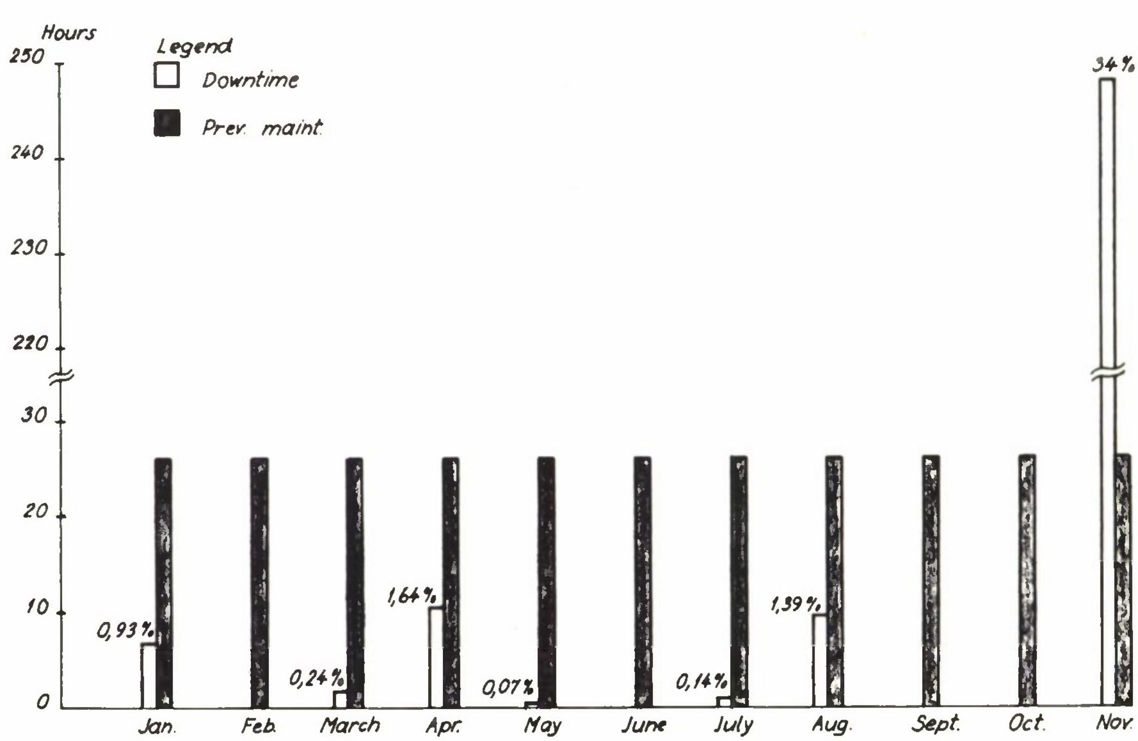


Figure A6.2 Øyer - Astrodata, recorder No 1 - Downtime and preventive maintenance

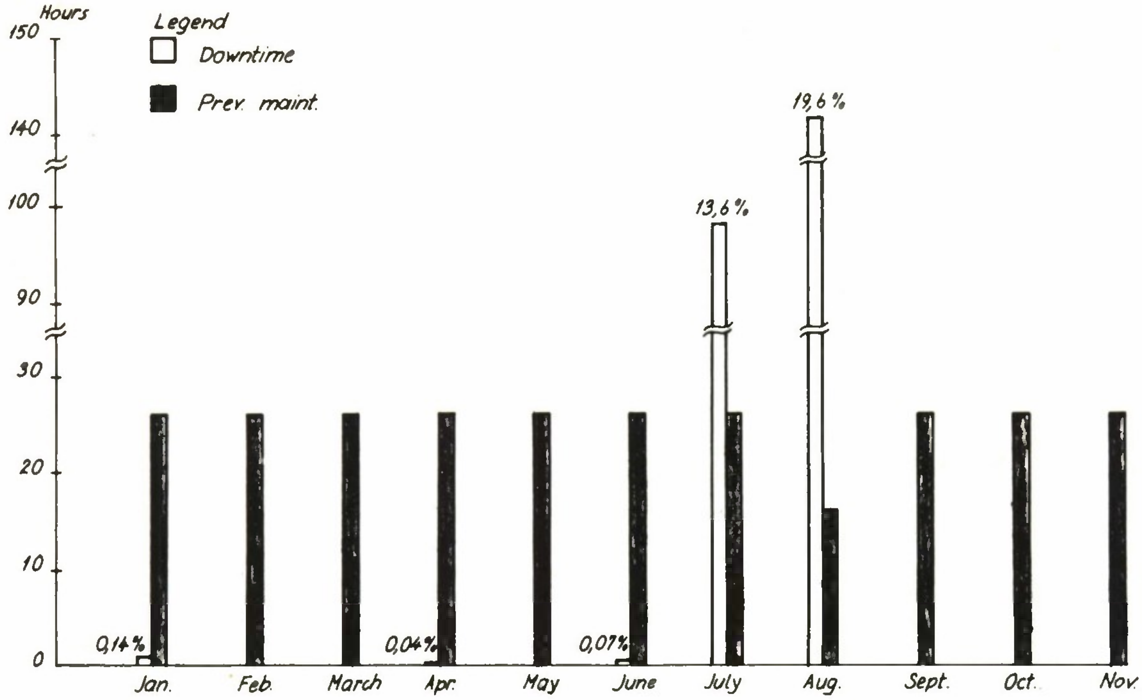


Figure A6.3 Øyer - Astrodata, recorder No 2 - Downtime and preventive maintenance

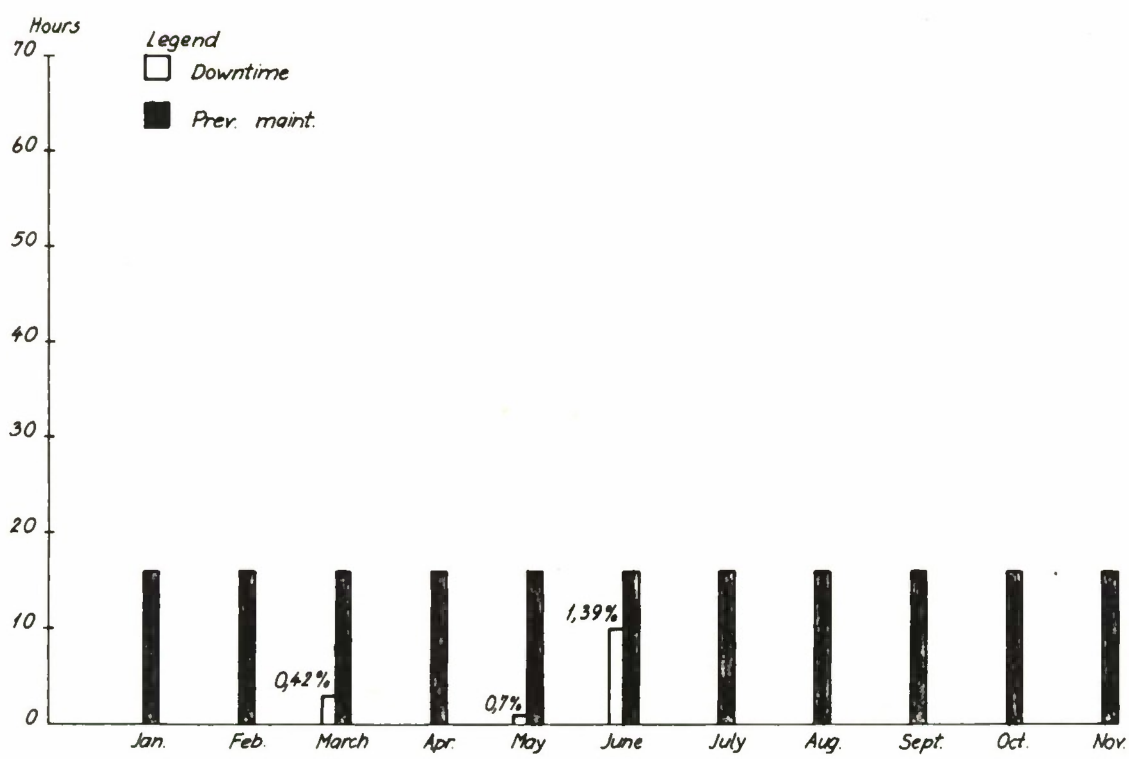


Figure A6.4 Øyer - Astrodata, 887 amplifiers - Downtime and preventive maintenance

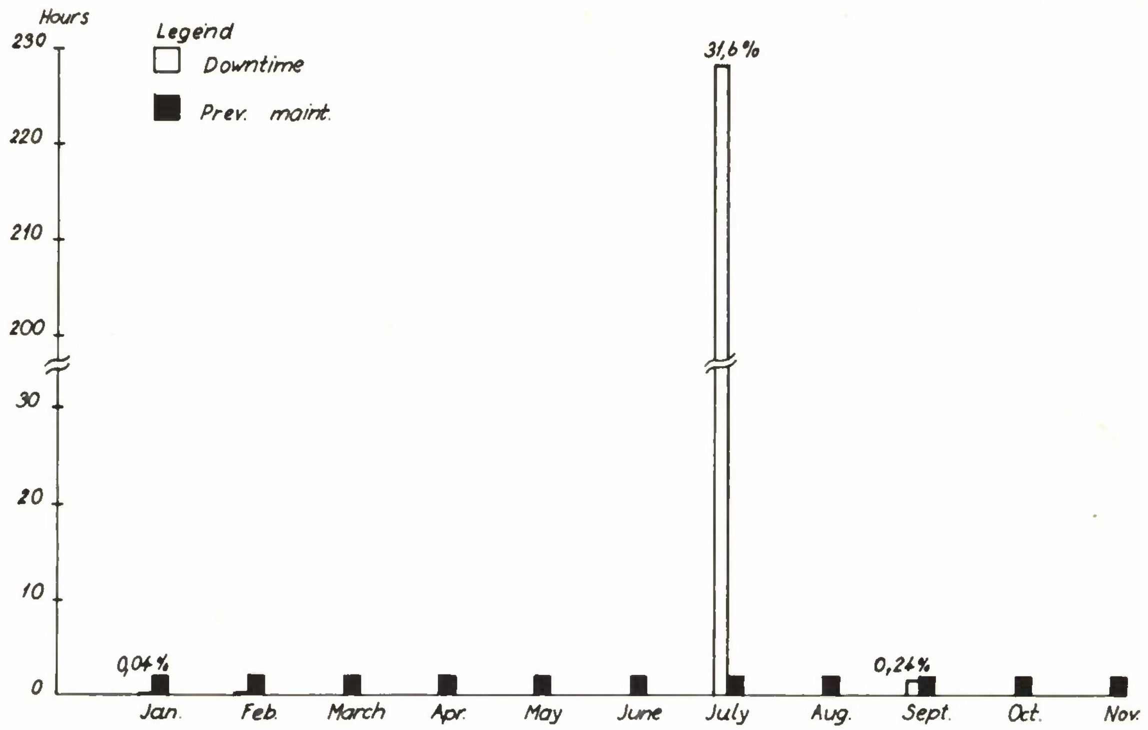


Figure A6.5 Øyer - Astrodata, clock - Downtime and preventive maintenance

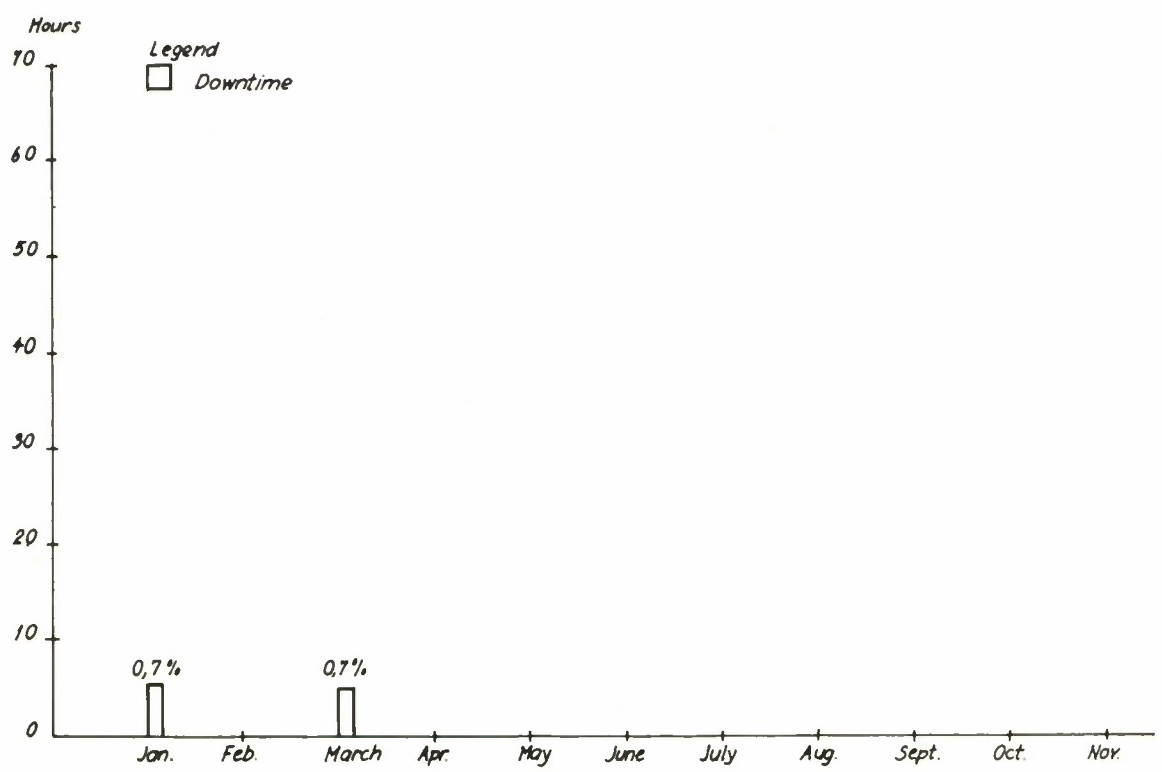


Figure A6.6 Øyer - Astrodata, main power supply - Downtime

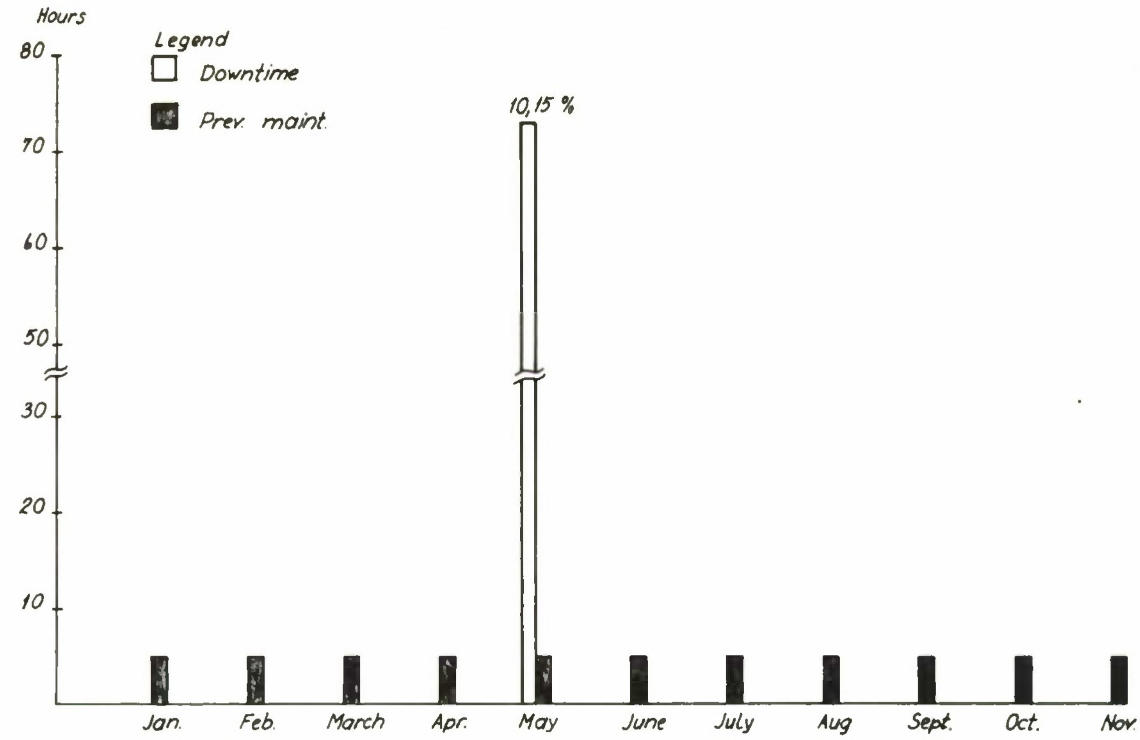


Figure A6.7 Øyer - Auxiliary equipment - Downtime and preventive maintenance (Total)

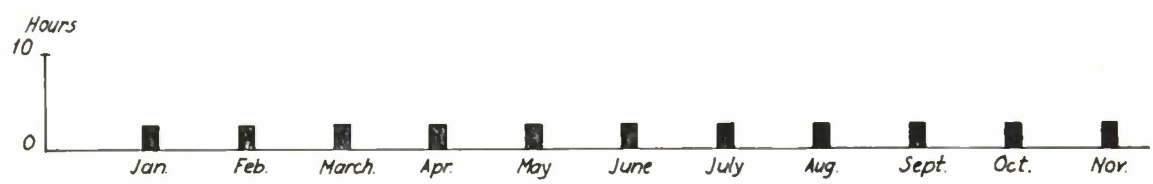


Figure A6.8 Øyer - Auxiliary equipment, Sanborn recorder - Preventive maintenance

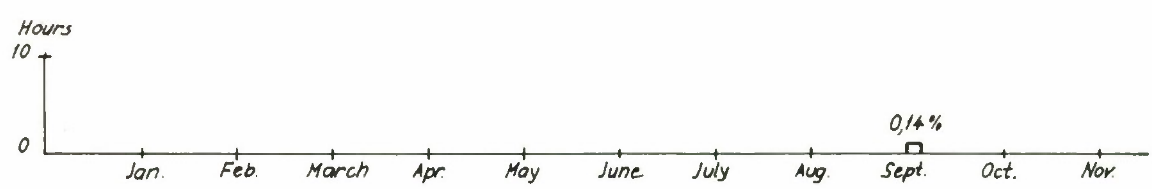


Figure A6.9 Øyer - Auxiliary equipment, LP monitor control unit - Downtime

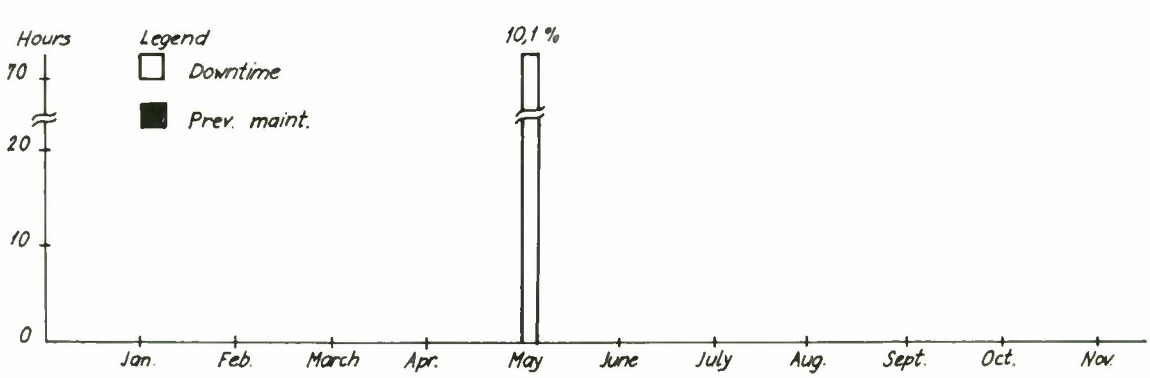


Figure A6.10 Øyer - Auxiliary equipment, event detector tape punch - Downtime

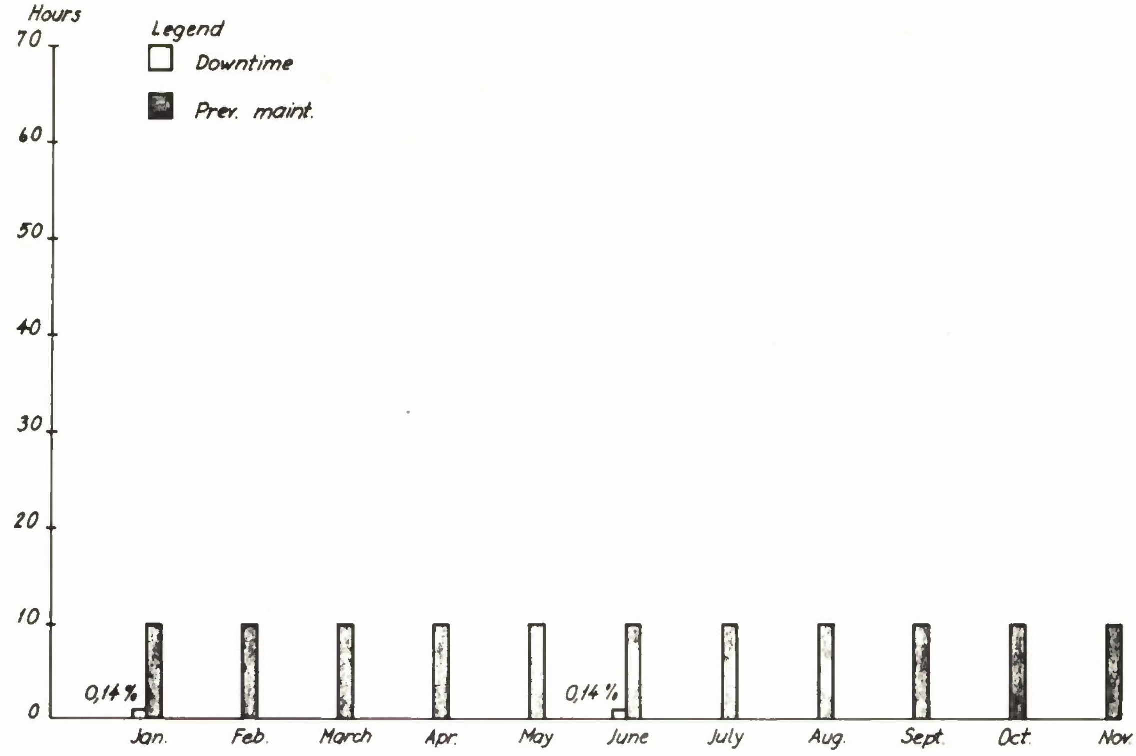


Figure A6.11 Øyer - SP DART - Downtime and preventive maintenance (Total)

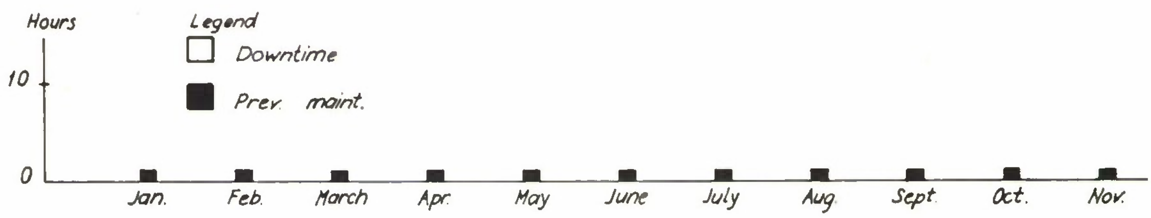


Figure A6.12 Øyer - SP DART, multiverter - Preventive maintenance

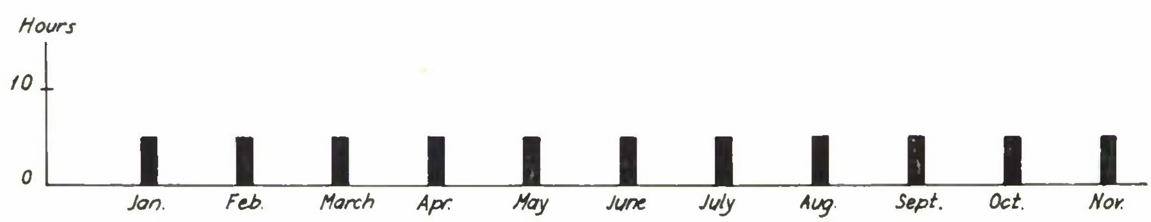


Figure A6.13 Øyer - SP DART, clock - Preventive maintenance

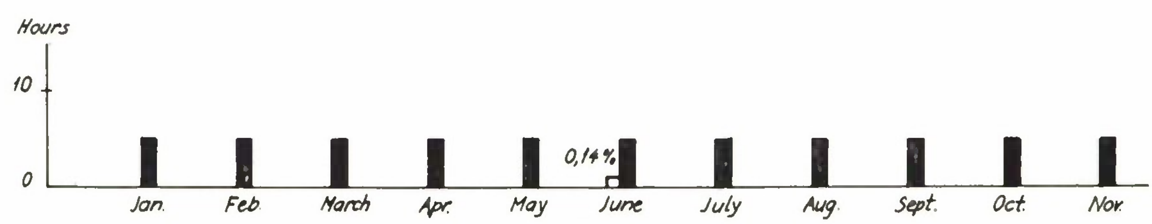


Figure A6.14 Øyer - SP DART, recorder - Downtime and preventive maintenance

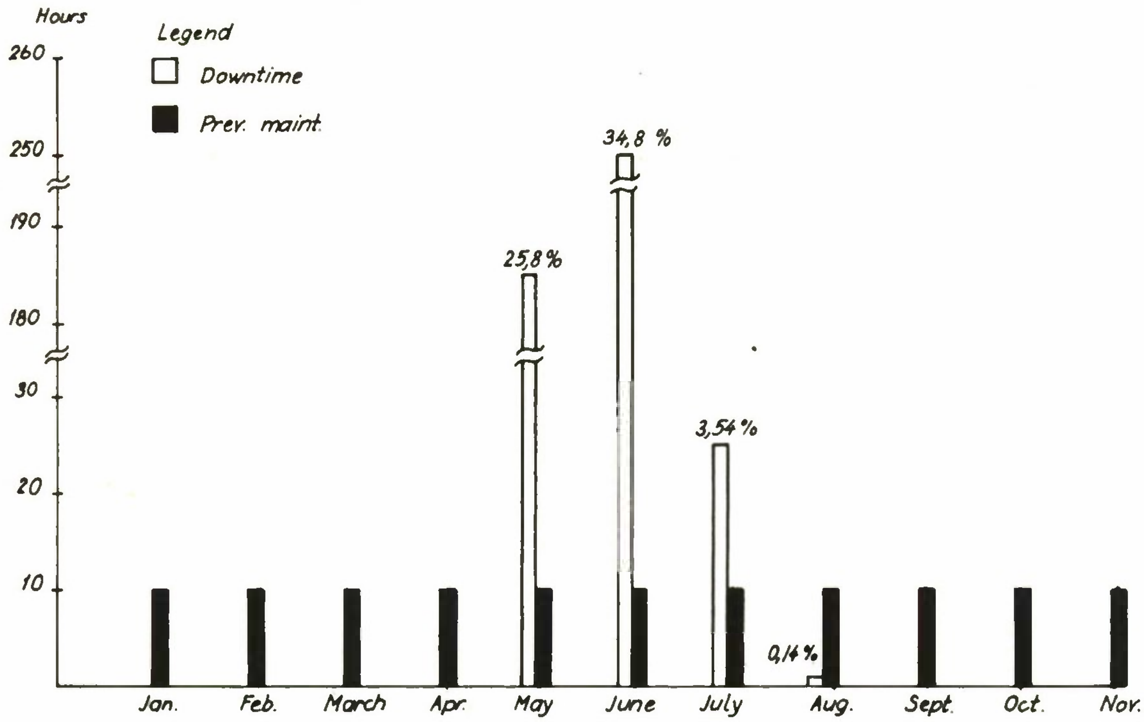


Figure A6.15 Falldalen - SP DART - Downtime and preventive maintenance (Total)

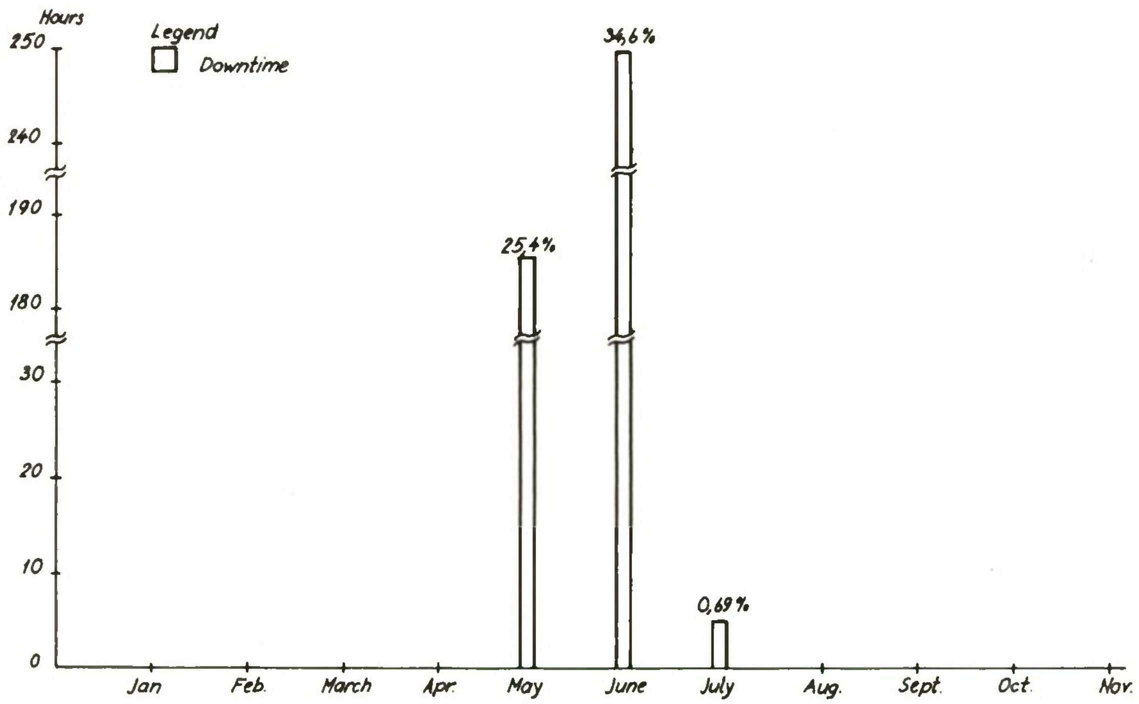


Figure A6.16 Falldalen - SP DART, electronics - Downtime

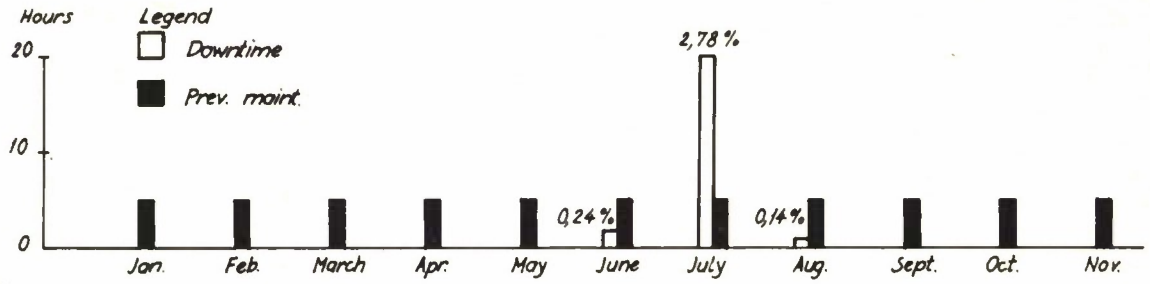


Figure A6.17 Falldalen - SP DART, clock - Downtime and preventive maintenance

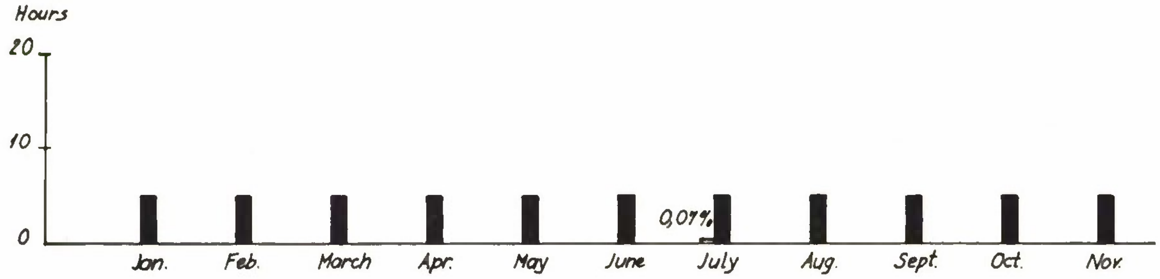


Figure A6.18 Falldalen - SP DART, recorder - Downtime and preventive maintenance

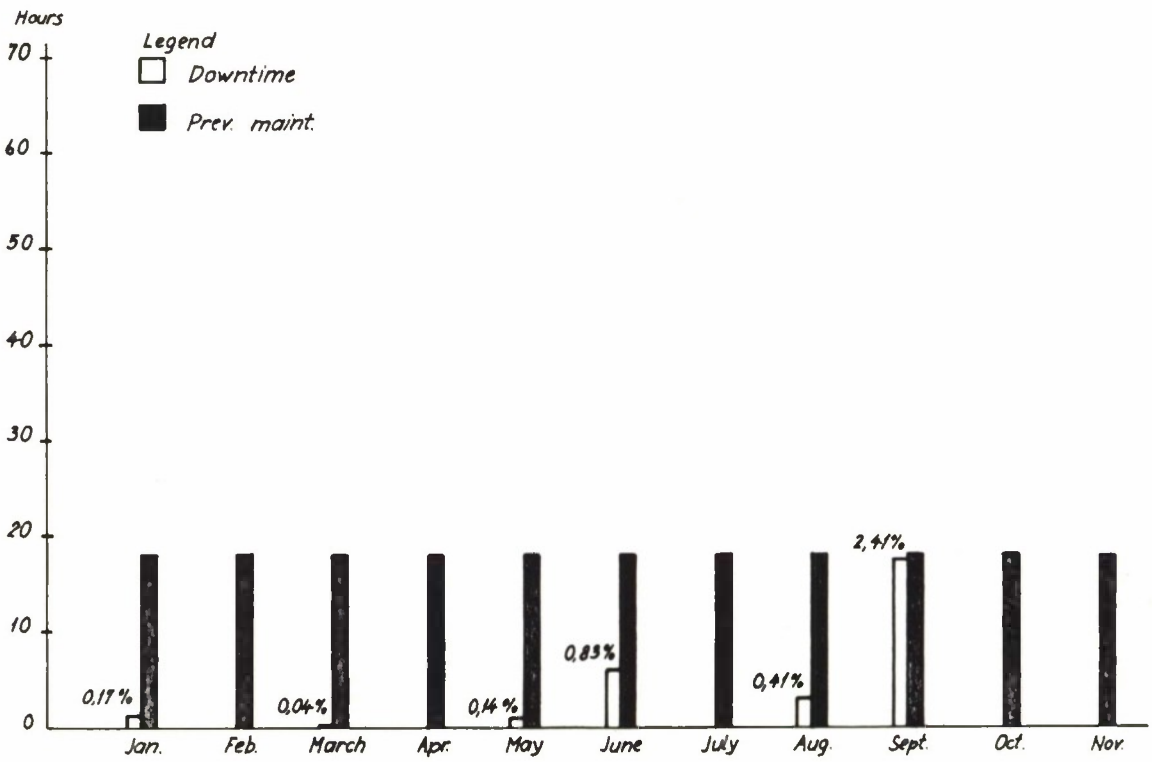


Figure A6.19 Øyer - LP DART - Downtime and preventive maintenance (Total)

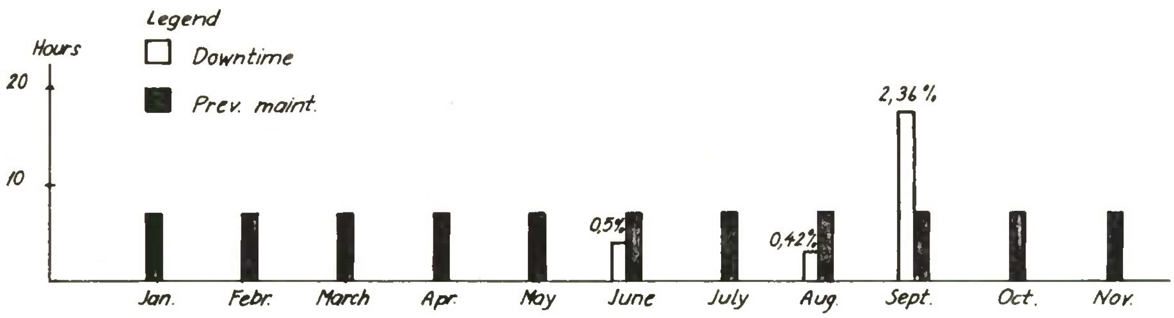


Figure A6.20 Øyer - LP DART, electronics - Downtime and preventive maintenance

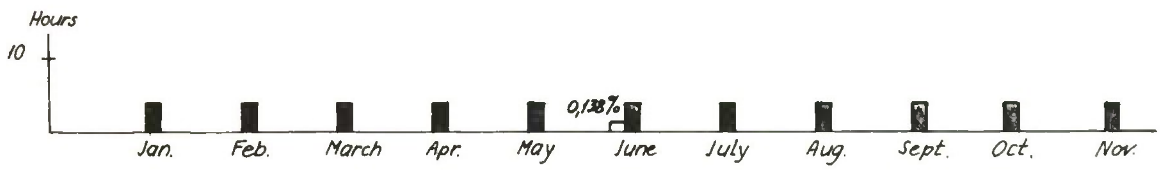


Figure A6.21 Øyer - LP DART, clock - Downtime and preventive maintenance

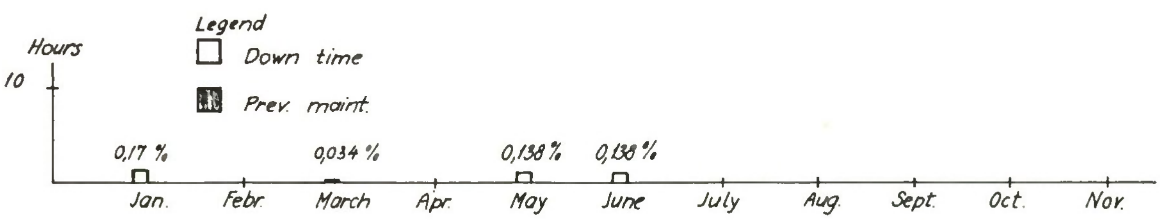


Figure A6.22 Øyer - LP DART, recorder - Downtime

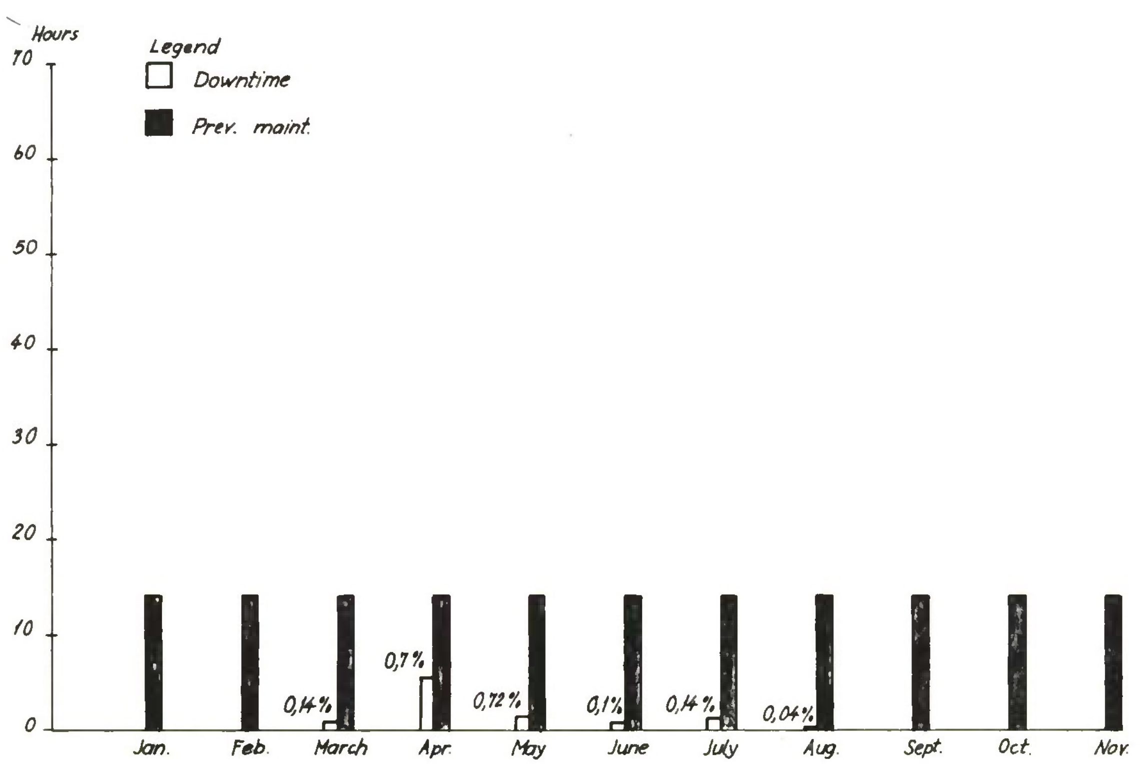


Figure A6.23 Falldalen - LP DART - Downtime and preventive maintenance (Total)

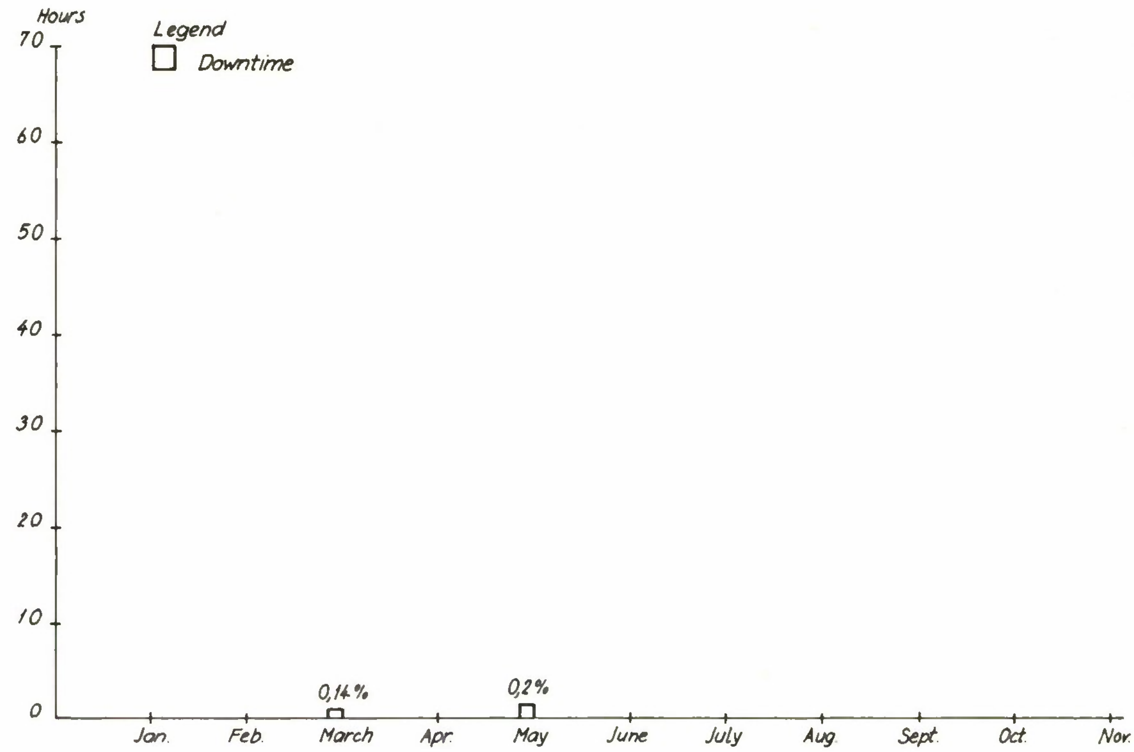


Figure A6. 24 Falldalen - LP DART, electronics - Downtime

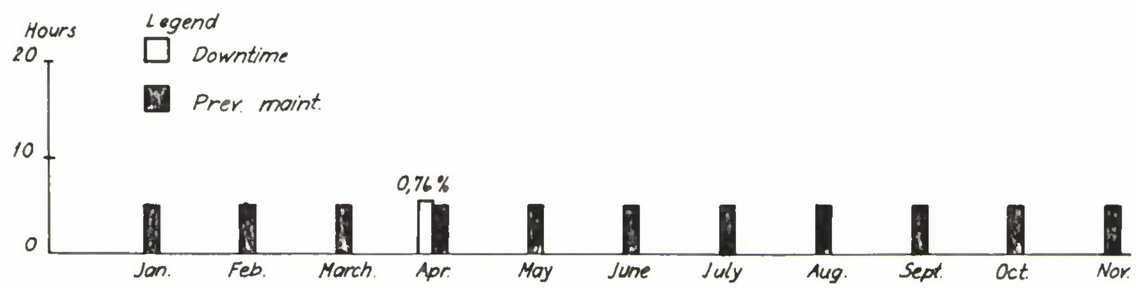


Figure A6. 25 Falldalen - LP DART, recorder - Downtime and preventive maintenance

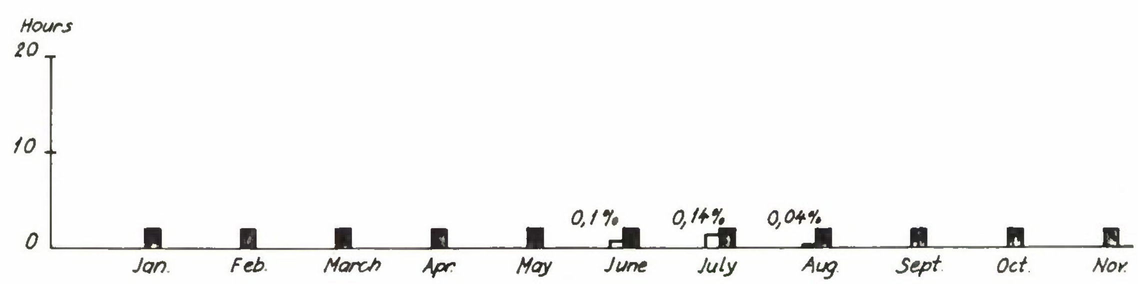


Figure A6. 26 Falldalen - LP DART, clock - Downtime and preventive maintenance

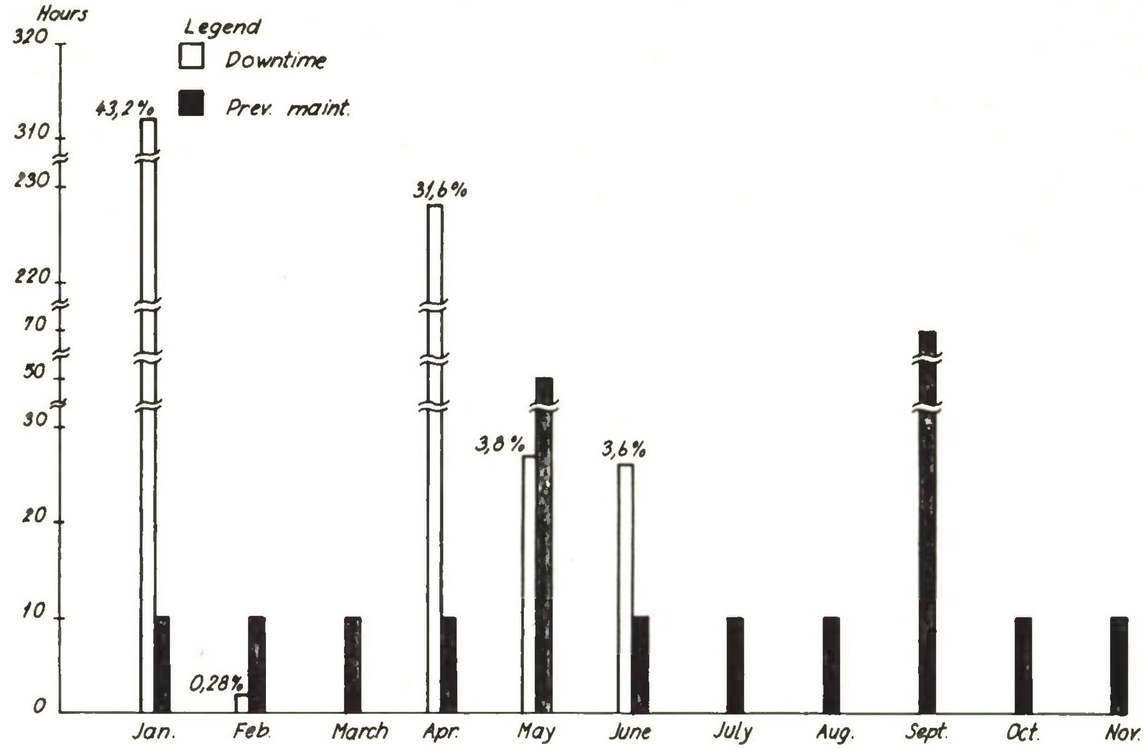


Figure A6. 30 Øyer - SP Front End - Downtime and preventive maintenance (Total)

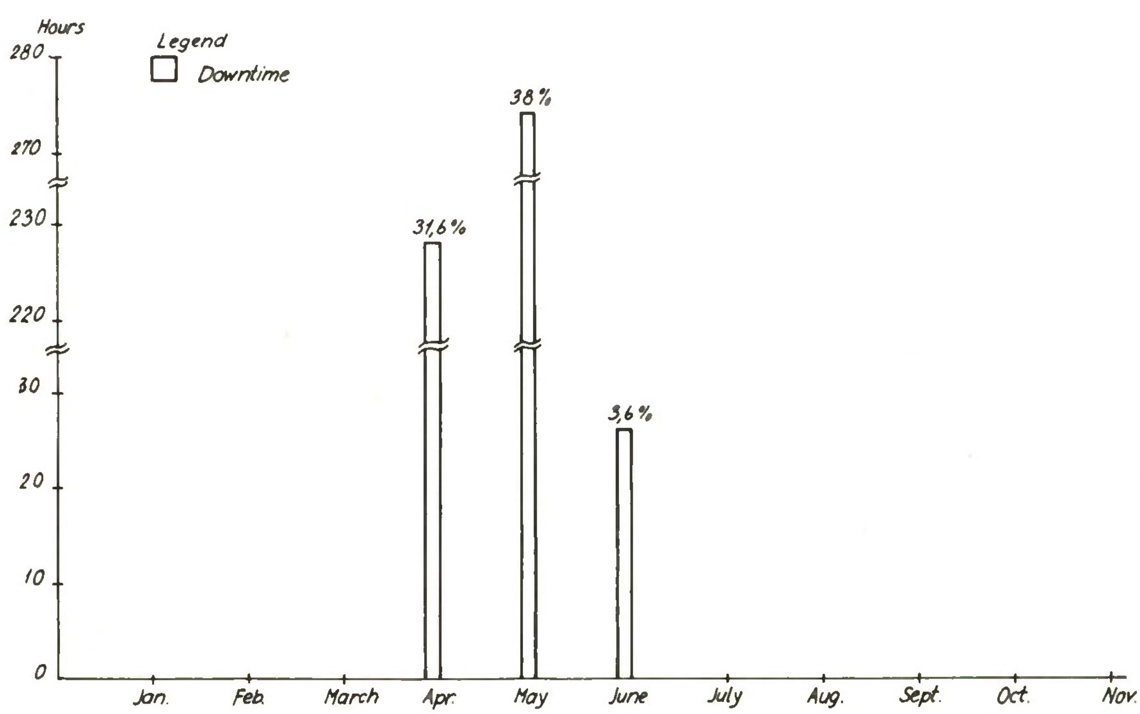


Figure A6. 31 Øyer - SP Front End - Seasonal downtime

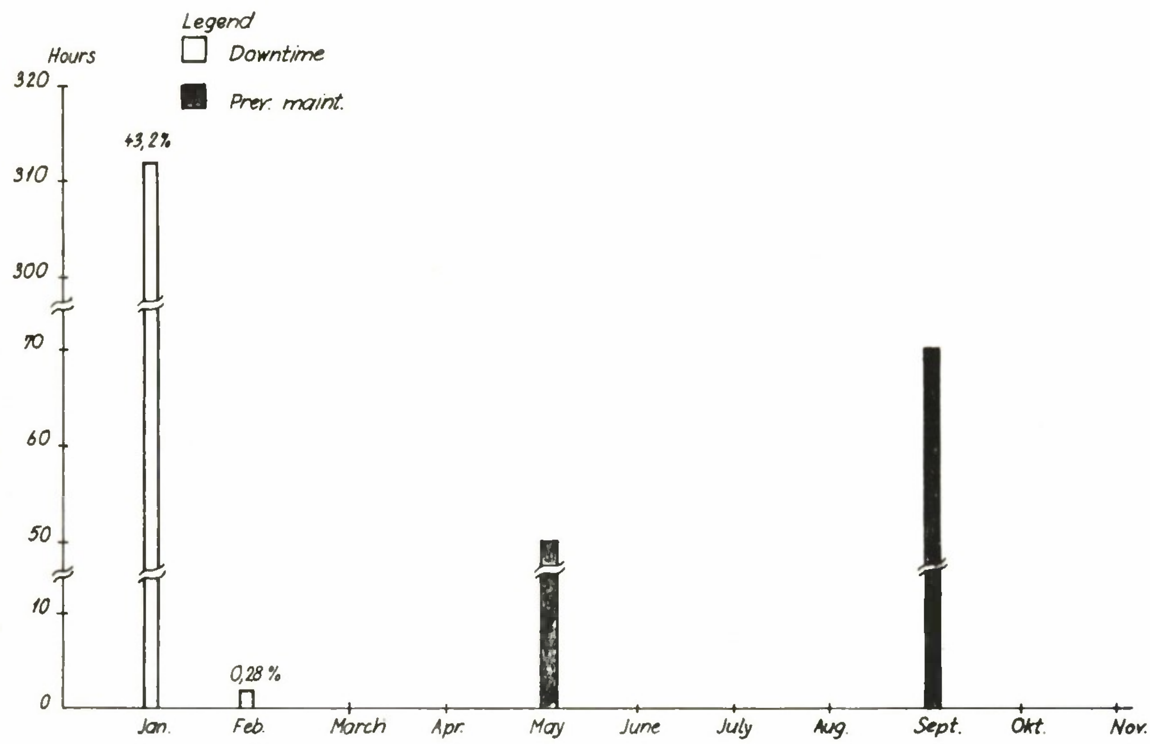


Figure A6. 32 Øyer - SP Front End, RA5 amplifiers - Downtime and preventive maintenance

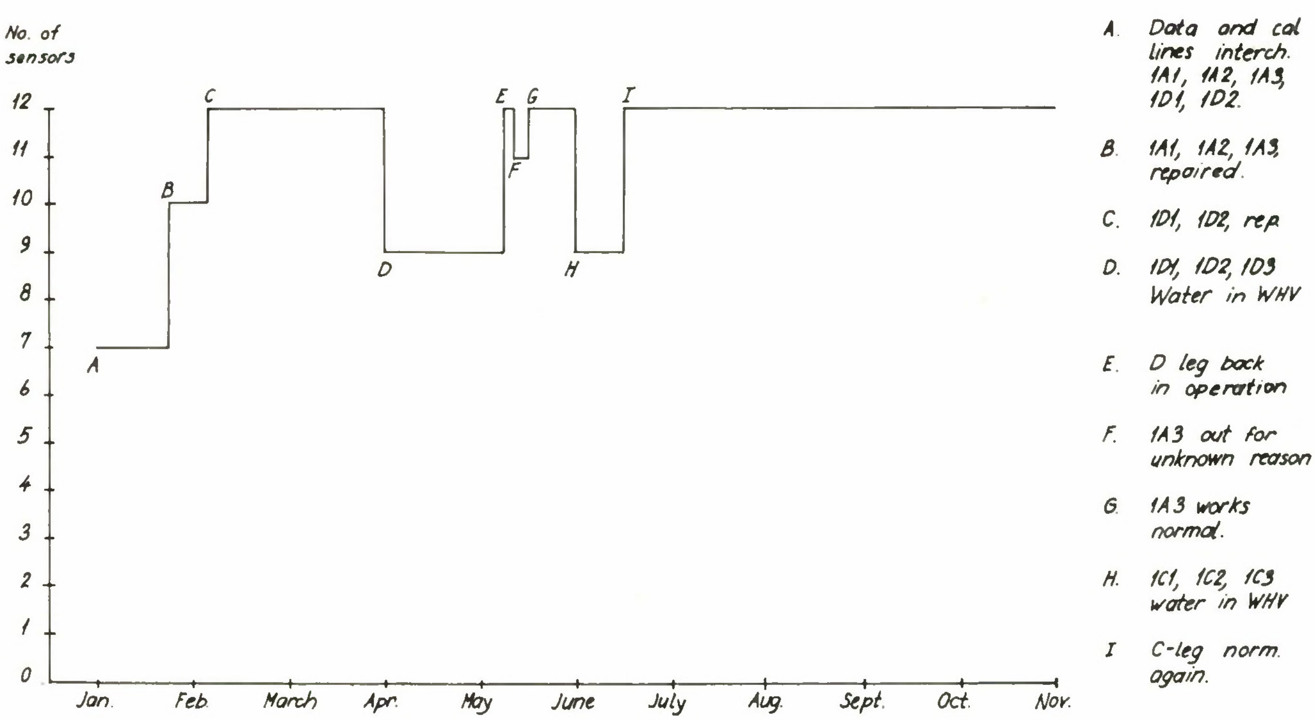


Figure A6. 33 Øyer - No of SP-sensors in operation at various times

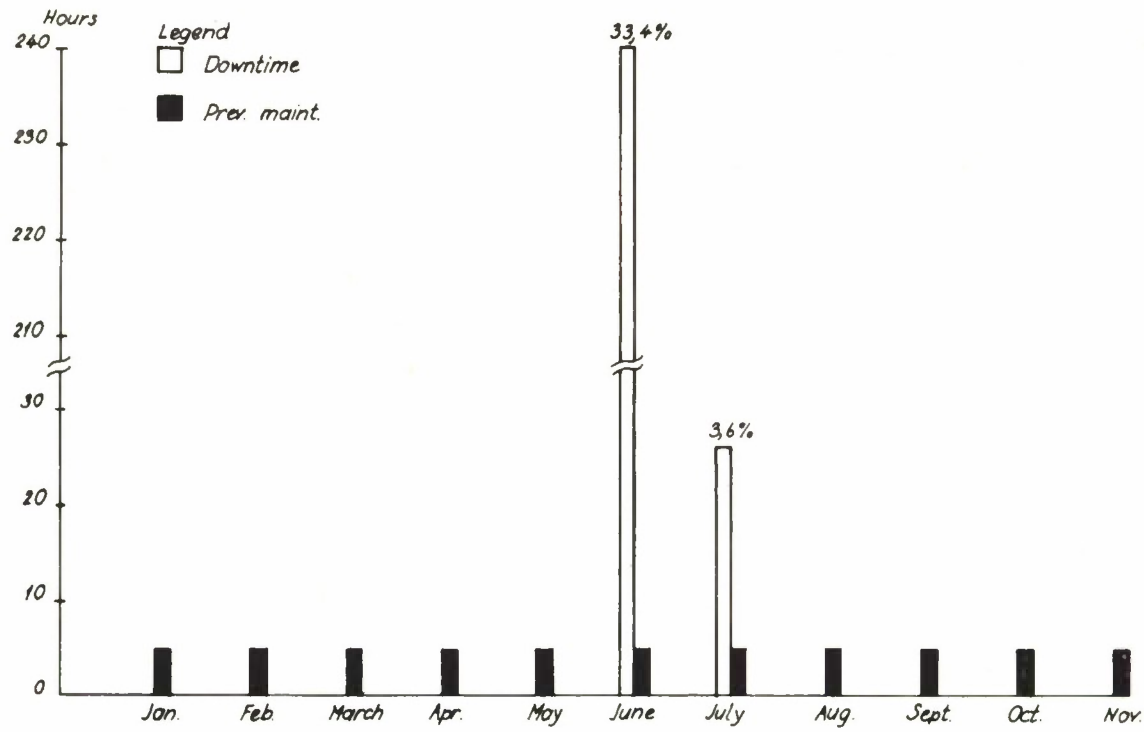


Figure A6. 34 Falldalen - SP Front End - Downtime and preventive maintenance (Total)

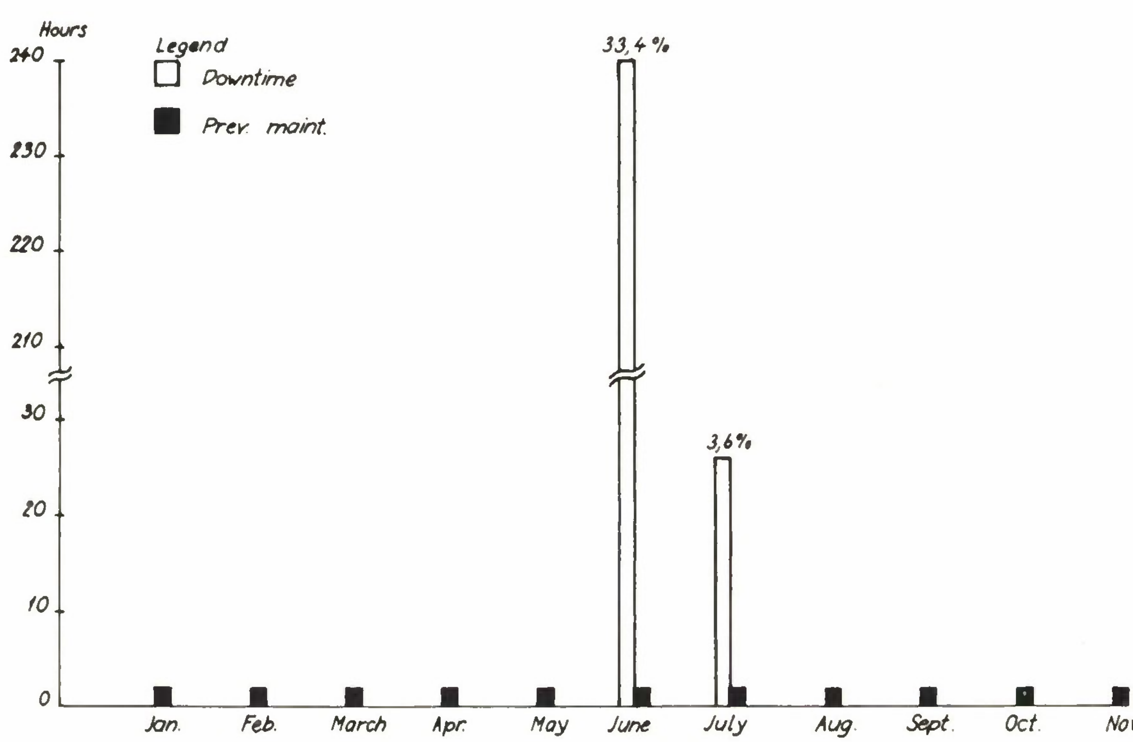


Figure A6. 35 Falldalen - SP Front End, WHV amplifiers - Downtime and preventive maintenance

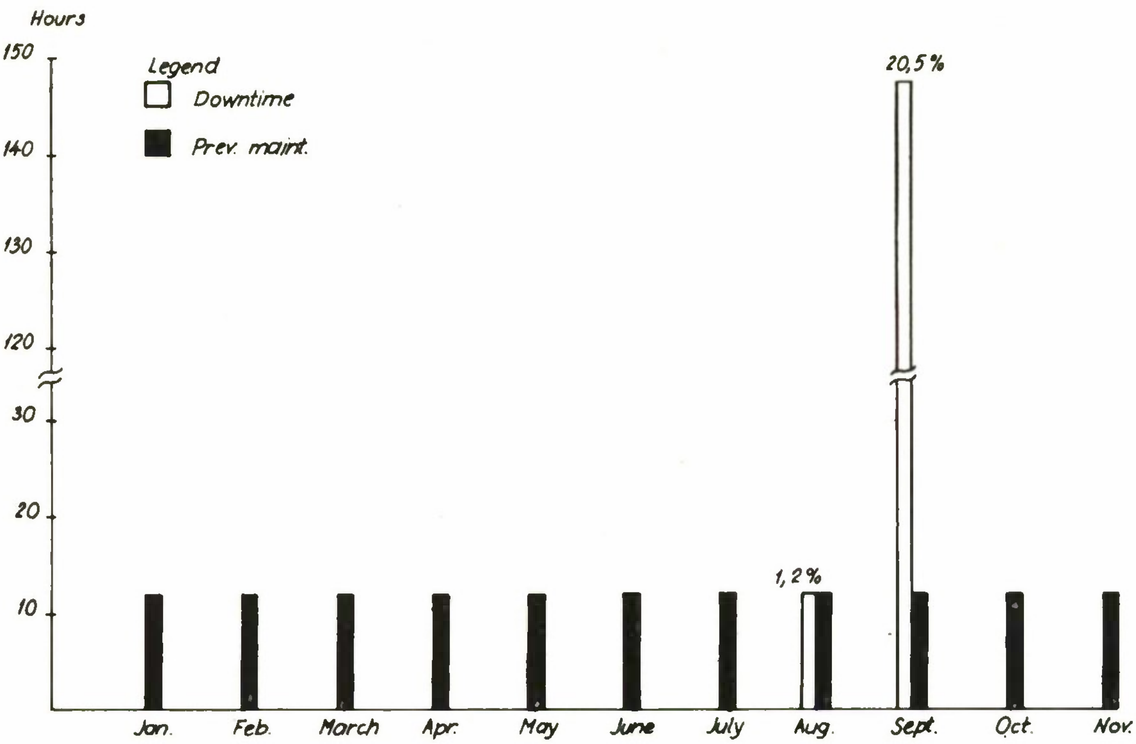


Figure A6.36 Øyer - LP Front End - Downtime and preventive maintenance (Total)

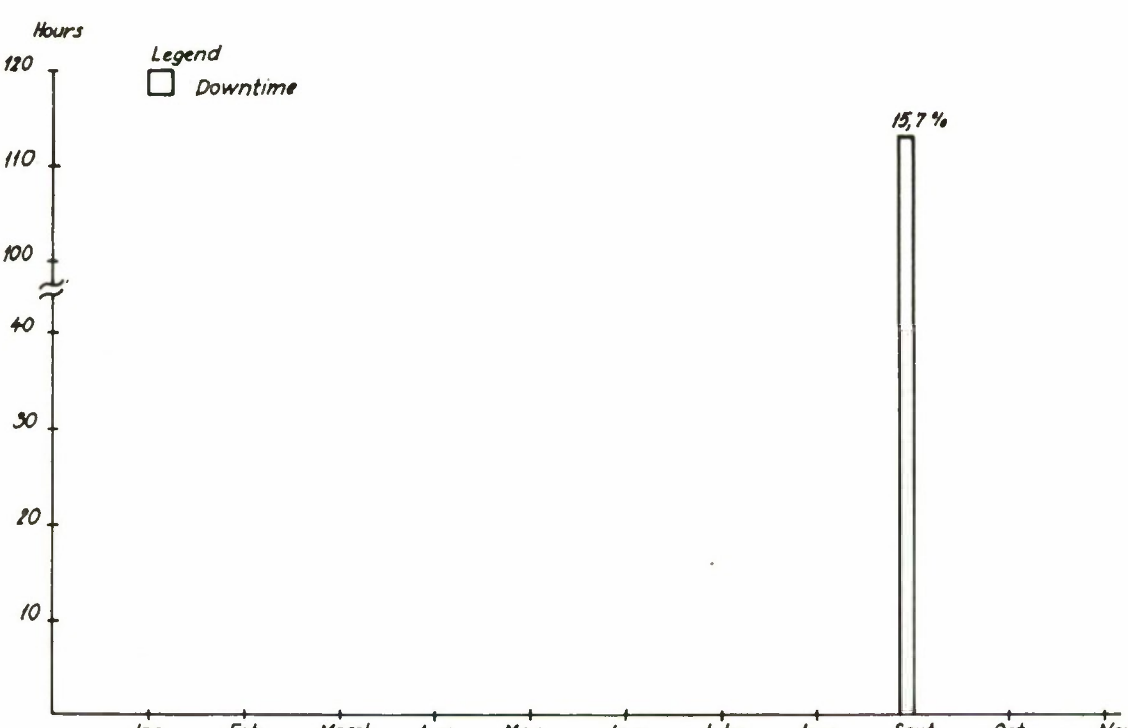


Figure A6.37 Øyer - LP Front End - Seasonal downtime

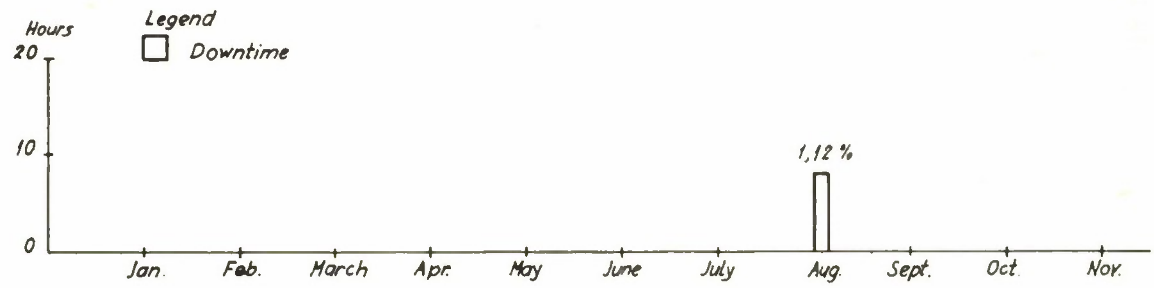


Figure A6. 38 Øyer - LP Front End, seismometers - Downtime

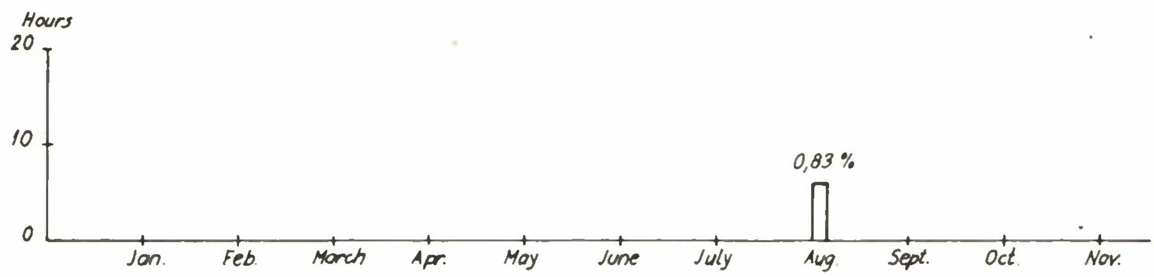


Figure A6. 39 Øyer - LP Front End, levelling devices - Downtime

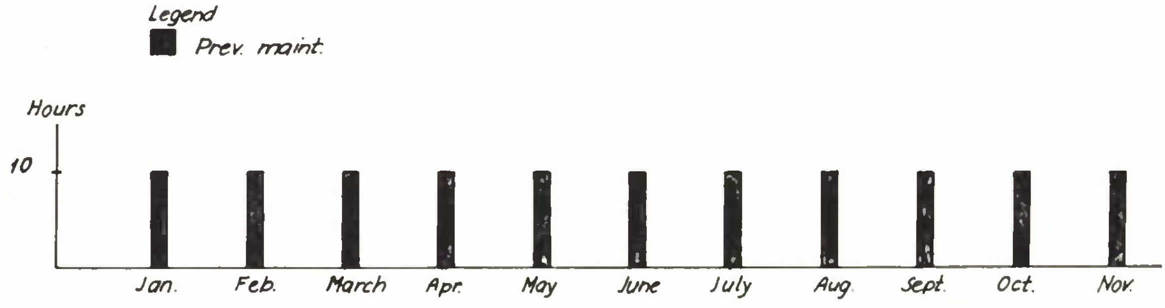


Figure A6. 40 Falldalen - LP Front End - Preventive maintenance (Total)

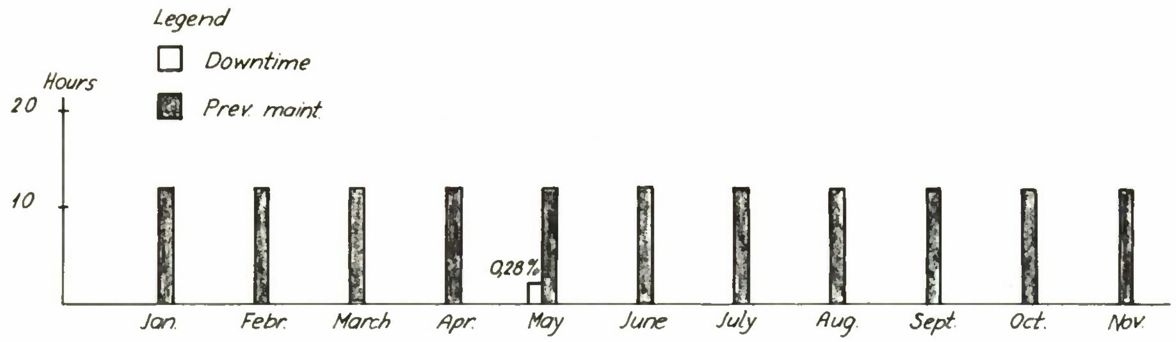


Figure A6.41 Trysil - LP Front End - Downtime and preventive maintenance (Total)

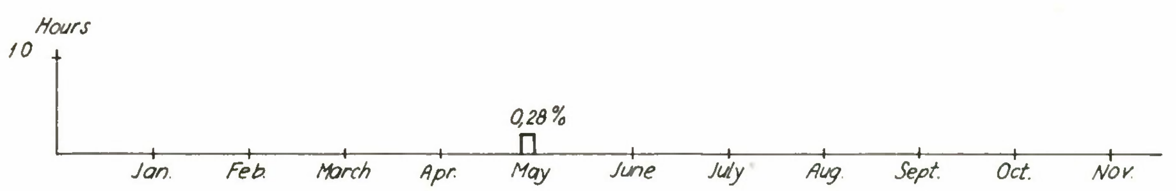


Figure A6.42 Trysil - LP Front End, seismometers - Downtime

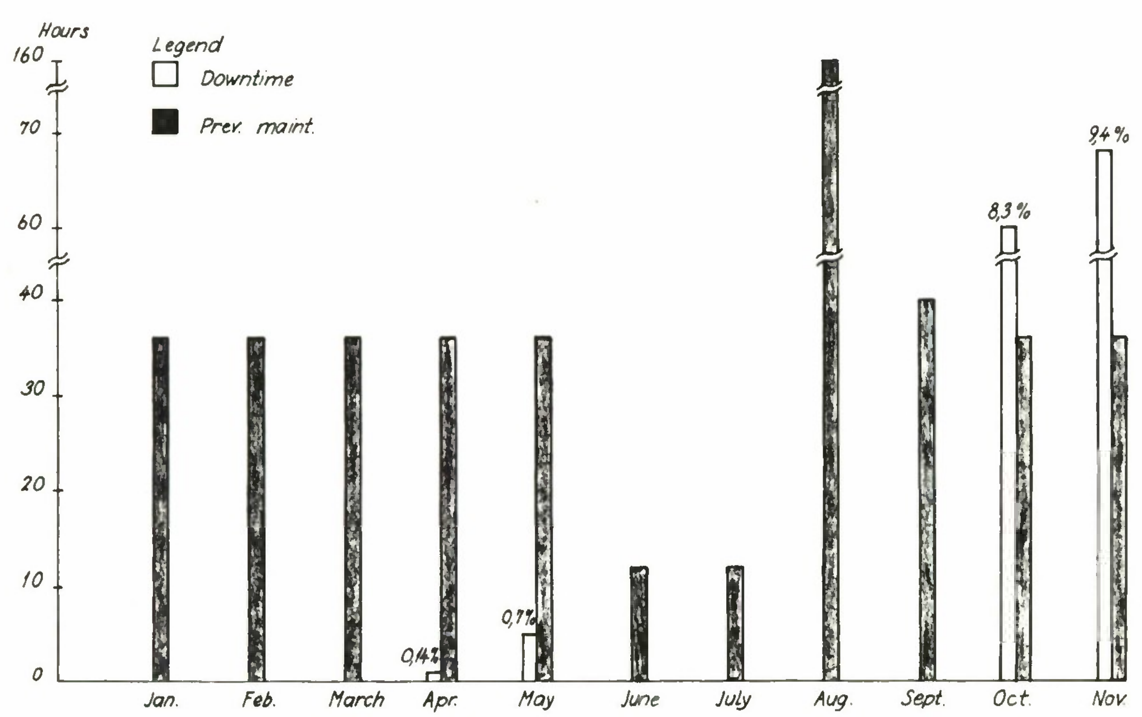


Figure A6.43 Øyer - Vehicles - Downtime and preventive maintenance

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13 ABSTRACT

This report covers the operation and maintenance of the NORSAR PHASE 1 seismic system during the period 1 February through 30 November 1968.

The report has four chapters:
A short introduction states the purpose of the operation of the Phase 1 system and defines the O & M tasks.
Then follows a rather detailed description of the system, covering geographical configurations, constructional and other technical layouts.
The third chapter describes the O & M organization and its facilities, and lists the working routines and records.
Finally the operational experiences are summed up, partly as a narrative of the operations, partly in the form of graphical statistics.

The report does not cover the results of the data processing.

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14 KEY WORDS

NORSAR - Norwegian Seismic Array
Norway - Large Aperture Seismic Array
Norway - Seismic Array, Operation and Maintenance of
Large Aperture Seismic Array
Seismic Array - Operation and maintenance of
Seismic Signals Recording
Seismic Noise Study