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TR 76-8

TECHNICAL REPORT NO. 76-8

SEMIANNUAL REPORT, PROJECT T/4703
SPECIAL DATA COLLECTION SYSTEMS

JANUARY THROUGH JUNE 1976

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TELEDYNE
GEOTECH

TECHNICAL REPORT NO. 76-8

SEMIANNUAL REPORT, PROJECT T/4703
SPECIAL DATA COLLECTION SYSTEMS

January through June 1976

by

John R. Sherwin

Sponsored by

Advanced Research Projects Agency
ARPA Orders Nos. 2551 and 2897

TELEDYNE GEOTECH
3401 Shiloh Road
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The work performed under Project T/4703, Special Data Collecton Systems, during the period from 1 January through 30 June 1976 is described.

Five SDCS systems which had been deployed in early 1975 continued routine operations throughout the report period. Sites at Red Lake, Ontario, and Whitehorse Yukon, are standard SDCS units; the site at Cumberland Plateau Observatory in Tennessee uses that station's SP array as its SP input. The → next page

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20. ABSTRACT (continued)

cont.

Franklin, West Virginia, and Houlton, Maine sites use a Model 36000 Borehole Seismometer System. The five stations have routinely collected seismic data on a continuous basis throughout this period. Data analysis tasks for the program are being done at the SDAC in Alexandria, Virginia. During the period, 33 requests for event reports were received and all but 4 had been completed by the end of the period. In addition, a backlog of about 20 reports from the previous period was completed.

The last two of five digital data acquisition systems were installed during this period and operation of these systems has been incorporated into the normal SDCS routine with minimum difficulty.

A study of convection noise in boreholes was completed and reported separately in a technical report submitted in draft form on 30 June.

CONTENTS

ILLUSTRATIONS

IDENTIFICATION

AFTAC Project Authorization No.	T/4703
ARPA Order Nos.	2551 and 2897
Program Code No.	6F10
Contractor	Teledyne Geotech
Effective Date of Contract	01 August 1973
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Contract No.	F08606-74-C-0013
Program Manager	B. B. Leichliter (214) 271-2561, ext. 215
Short Title of Work	Special Data Collection Systems
Amount of Contract	$1,490,663
Contract Period covered by this report	1 January thorugh 30 June 1976

SEMIANNUAL REPORT, PROJECT T/4703
SPECIAL DATA COLLECTION SYSTEMS
January through June 1976

1. INTRODUCTION

The Special Data Collection System (SDCS) program, Project T/4703, is a continuation of work begun under the Long-Range Seismic Measurements (LRSM) program in 1960. This work is directed toward advancing the seismic detection, identification and location techniques necessary to detect and identify underground nuclear explosions.

This report describes the work performed under the SDCS program during the period from January through June 1976 and is submitted in accordance with Sequence No. A004 of the Contract Data Requirements list as amended under Modification P00005, 2 January 1975. This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by AFTAC/VSC, Alexandria, Virginia 22314, under Contract No. F08606-74-C-0013.

2. FIELD OPERATIONS

2.1 GENERAL

The five Special Data Collection Systems (SDCS) assigned to field locations have been operated continually during the report period. There have been few major malfunctions and little data have been lost due to equipment failure. Each unit is operated and maintained by a single technician who is also responsible for vehicle and site maintenance. The last two of five digital recording systems were installed during this period and operation of these systems has been incorporated into the normal SDCS routine with minimum difficulty.

2.2 FIELD LOCATIONS

Each field location is similar in the function of the instrumentation utilized and the data being recorded. The sites differ in the types of instrumentation employed and the environmental conditions under which operations are maintained. Figure 1 is a map showing the site locations for SDCS operations during the period from January through June 1976. The following paragraphs summarize the activities at each site during this report period.

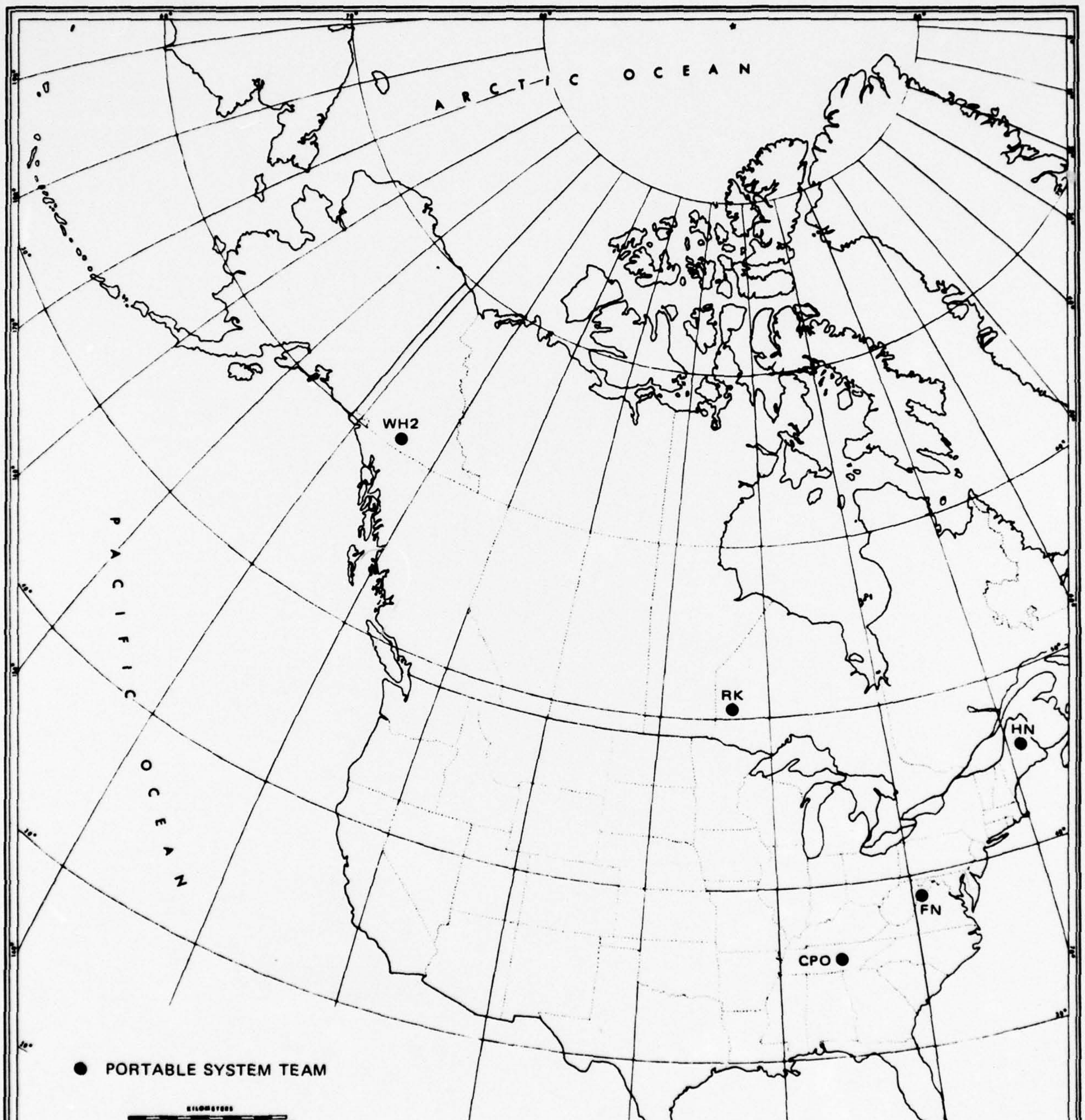

Figure 1. Site locations for SDCS operations during the period from January through July 1975

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2.2.1 Franklin, West Virginia (FN-WV), Team 56

The controller drawer for the Kinemetrics Model DDS-1103 Digital Data Acquisition System was reinstalled at the site on 17 February. It had been returned to the manufacturer for repair during December. The system operated normally until another apparent alternate memory problem was detected by the Alexandria QC during early April. The memory was replaced after several tests; however, the new memory had a different but similar problem. Another unit was installed on 6 May and, after an early failure which disappeared, has continued to operate normally since that time. On 10 May, the site was visited by Kinemetrics and Geotech representatives in order to observe the alternate memory problem under actual operating conditions.

On 21 March, the Model 36000 (KS), S/N 002, was removed from the borehole. The Humphrey, Inc., Gyrosurveyor Probe System, which had been delivered to the contract in late January, was used to determine the orientation of the KS holelock. This holelock had been installed in December 1975 and, therefore, the operating azimuths for the KS horizontal channels had been estimated. Using the azimuth determined (92 degrees), the KS orientation ring was set to orient the system on the Nevada Test Site coordinates as required. Thus, the orientations before and after this operation were as follows:

	17 Dec to 21 Mar	21 Mar to present
Radial	11 degrees	99 degrees
Transverse	101 degrees	189 degrees

While the KS system was out of the borehole, the modification described in paragraph 3.2 below was incorporated. This modification reduces the short-period signal level by 14 dB at the instrument output to provide better control of SP recording levels. The normal SP background settings at FN-WV now allow 24 to 30 dB signal attenuation for special events.

When the KS system was installed on 21 March, the wellhead seal assembly was not installed on the borehole. (This unit was temporarily used in Garland in connection with the convection noise study.) With the borehole unsealed, the LP horizontal background levels increased up to 6 dB during windy periods. When no longer needed in Garland, the wellhead assembly was returned to the site and was installed on 29 April. At that time, LP horizontal noise decreased and operating levels comparable to the period prior to 21 March were resumed. However the horizontal LP data have continued to show infrequent, high-amplitude pulses throughout this period. Tests have verified that the noise is due to instrument tilt, which may be due to poor cement bonding in the well casing.

On 15 June, a severe thunderstorm passed through the site area. In spite of the lightning protection devices installed, the KS electronics section was damaged. The station was inoperative until 23 June when KS, S/N 002, was replaced with S/N 004 which had been in use in Garland for the convection study. The damaged instrument was returned to Garland for repair.

The Timing System, Model 19000, was replaced with a modified unit on 15 June in order to correct a design problem in the circuitry related to the timing signals for the digital system (see paragraph 3.3 below).

2.2.2 Cumberland Plateau Observatory, Tennessee (CPO), Team 57

Operations at CPO have continued without major difficulty throughout this period. The 19-element vertical array has been reasonably trouble free except for SPZ-19. This channel started causing noise on the summation channel in early January and was finally removed from the sum in mid-January. The problem has been traced to cable leakage which the operator has not been able to correct since he is alone at the site. In addition to SPZ-19 other SP vertical channels have been inoperative at various times due to line leakage and maintenance. Such problems are corrected as weather and scheduling permit. Occasional line leakage continues to be a problem on the LP channels. This leakage causes spiking, low signal level, and occasional data outages. It is hoped that reduced rainfall during the summer will allow improvements in the drainage around the LP vault in order to reduce the occurrence of LP noise.

The CPO operation has continued to support other organizations requiring telemetered SP data. At the end of the period, three channels of SPZ data were being telemetered at Virginia Polytechnic Institute and State University. On 23 March, the U. S. Geological Survey (USGS) requested that SPZ-8 data be telemetered from CPO to Boulder, Colorado. In mid-April, USGS personnel visited the site and installed a JM vertical on a pier in the recording building. The line termination module was removed from the SPZ-8 circuit to complete this system. Data from this system were telemetered to Boulder throughout the remainder of this period. The SPZ-8 channel remained inoperative until mid-May when the module was replaced. Because the station's air conditioning system causes noise on the pier-mounted seismograph, operations continued throughout the period without air conditioning. USGS will be requested to allow return to one of the array instruments during the summer. The CPO station operator routinely calibrates all telemetered channels, performs frequency response calibrations as requested and maintains telemetry equipment at the station.

The digital recording system has operated very well. With the exception of a problem in external circuitry related to the time-of-day, the Alexandria Quality Control (QC) facility has reported only one malfunction which has not recurred.

2.2.3 Houlton, Maine (HN-ME), Team 58

When the DDS-1103 system was installed at this site, initial data indicated an occasional alternate memory problem. The problem caused an occasional 256-count spike on the data channels. When the problem finally became more serious, a replacement memory was requested on 21 May. The new memory was installed as soon as it was received, but exhibited even more serious alternate memory problems than the original unit. A third memory was ordered on 3 June which, when installed, was found to have a failure in one of the driver chips. This memory was returned to the vendor on 30 June. As of the close of this period, the original memory remains in the digital system at this site.

On 15 March, KS S/N 001 was removed from the borehole and the holelock azimuth was determined using the Gyrosurveyor system. Using the azimuth determined (105 degrees) the KS orientation ring was set to orient the system on the required azimuth. Horizontal seismograph orientations before and after this operation were as follows:

	11 December to 14 March	15 March to present
Radial	91 degrees	93 degrees
Transverse	181 degrees	183 degrees

While the KS was out of the borehole, it was also modified to lower the SP signal level. Normal SP background levels at this site now allow 18 to 24 dB signal attenuation for special events.

The KS system has operated very reliably at this site. Occasional bursts of noise on the horizontal LP channels were reduced by allowing more slack in the downhole cable. The experience at FN-WV with wind noise due to an unsealed borehole led to a similar study at HN-ME. When a definite correlation between wind and horizontal noise was verified, the wellhead seal was improved by generously greasing rubber parts of the Bowen line wiper. The LP horizontal background subsequently showed no obvious increase in noise during windy conditions.

2.2.4 Red Lake, Ontario (RK-ON), Team 59

In early January, a clutch mechanism failure in the FM magnetic tape recorder caused intermittent data outages at RK-ON. A replacement unit was shipped via air freight on a Government Bill of Lading (GBL) but was delayed about two weeks by the Canadian Customs Office in Winnipeg. On arrival at the site, the replacement unit was found to have been slightly damaged during shipment. On-site repairs were made using parts from both units, but several data outages occurred until the system was made completely operational in early March.

Installation of the digital recording system for this site was delayed in order to allow laboratory tests supporting the other four systems. In early March, the system was transported from Garland to the site via contract vehicle in order to avoid the entry problems with Canadian Customs which had been experienced with prior shipments. The system was installed routinely and digital recording started on 9 March. This system has continued to operate without problems throughout this report period. Minor problems had been anticipated due to the operation of this system on generator power, but none have occurred.

Air shipment of goods into Canada for the RK-ON site has been a continuing problem which began in October 1975 when routine mail shipments were stopped due to a Canadian Postal strike. Attempts were made to comply with the instructions both from Canadian officials and from U. S. Government contract personnel. With entry paperwork prepared as instructed, one shipment of magnetic tape was delivered in March without difficulty and another in May could not be cleared through customs. Finally, the whole problem was turned over to the Administrative Contract Officer (ACO) in Dallas. At the end of this period, progress has apparently been made because a tape shipment which had been held up about a year was finally released and a second try on the May shipment went through without difficulty.

2.2.5 Whitehorse, Yukon Territory (WH2YK), Team 60

The digital recording system which was installed in December, operated properly throughout the report period. A problem external to the system was rf pickup from a nearby broadcast transmitter which caused alias signals exceeding normal background on the digital records. On 11 February, this pickup was reduced to a level below that of normal seismic background by elimination of ground loops and by installation of filter circuits in the eight analog data lines at the input to the multiplexer in the DDS-1103.

In general, operations at this site have continued with only the usual maintenance required. Digital recordings were not made for four days in April when the operator was absent for surgery. In addition to this, a post-operative visit was required, and the system was operated by one of the Garland personnel from 18 through 28 June.

3. ENGINEERING SUPPORT

3.1 GENERAL

The engineering support function in Garland routinely provides for control of government property and replacement or repaired parts for SDCS operations. In addition, changes to system hardware are developed to improve operation or to correct deficiencies. In the following paragraphs, engineering support activities during this period are discussed.

3.2 MODIFICATION OF THE MODEL 36000 BOREHOLE SEISMOMETER SYSTEMS

The response characteristics of the Model 36000 System (KS) are such that seismic energy in the short period (SP) passband is greatly amplified. For example, it is not unusual for the 6-second microseismic and other high frequency background to measure 1/2 to 1 volt peak-to-peak at the output of the KS line driver. For this reason, the SP output levels - even after the heavy filtering required - are sometimes too high to satisfy the background level requirements in the SDCS system. The problem becomes especially serious when a KS-equipped station is required to attenuate for an expected event. In this case, attenuation greater than 6 dB at the output is impractical due to clipping in KS output and filter stages. Another problem developed when the digital recording systems were installed. Channel 4 of this system is SP vertical low gain; because the SP outputs could not be further attenuated, there was only 6-12 dB separation between normal high gain and low gain channels where at least 24 is desirable.

Several modifications to the KS electronics were considered as solutions to this problem. Modification of the response of the loop electronics was ruled out as it would seriously affect the loop response of the system. Three modifications to the line driver were considered. First, reduction of the line drive gain from 10 to 2 would reduce both SP and LP signal levels, and would not be a disadvantage with low-noise digital acquisition system. The SDCS systems would, however, require post-filter amplification of LP signals beyond the capabilities of the Signal Control Center (SCC) now used. A second method would be to add a single pole low-pass section at 6 seconds to each line driver. This option would have required redesign of the SP filter circuits to preserve the seismograph response characteristics. Finally, the existing filter corner in the line driver could be moved from 42 Hz to 15 seconds which would attenuate SP signals by a factor of five without seriously affecting the LP signal level. This last method was selected because it was easiest to implement. The HN-ME system was modified on 15 March and the FN-WV system was modified on 21 March.

The modification consists of replacing two resistors and one capacitor in each of the three line drivers in the KS electronics. Figure 2 shows the amplitude and phase response of this filter. The overall effect of this modification is to shift the normalized LP frequency response slightly toward the longer periods. The SP response is attenuated 12 to 14 dB and has slightly more gain at the longer periods. The appendix shows the total system amplitude and phase responses in tabular form for both the original and the modified cases.

3.3 MODIFICATION OF MODEL 19000 TIMING SYSTEM

When the Model 19000 Timing Systems were originally modified for use with the digital recording systems, signals necessary to provide time-of-day were taken from the 30 lamp circuits in the timer. At that time, provisions were made to assure proper digital data in the event of lamp failure and tests of all systems in the laboratory confirmed that all systems were operating properly. When QC of the digital records began routinely in Alexandria, numerous occasions were noted on several tapes from different stations when all "ones" were loaded on the digital tape header. With direction from Garland, station operators performed various tests to locate the cause of this problem. On 19 April, it was discovered that proper data were loaded only if the timer lamps were left on. Subsequent analysis of the circuit showed that the low-resistance lamps were effectively connecting all time inputs together when the lamp power was removed. The five teams were immediately notified to keep the timer lamps on at all times and this solved the problem.

As a permanent "fix," the timers are being further modified to take the required time-of-day signals directly from the logic circuits rather than from the lamp drivers. This modification is being performed in Garland on a rotating basis and all stations should have proper timers by the end of August.

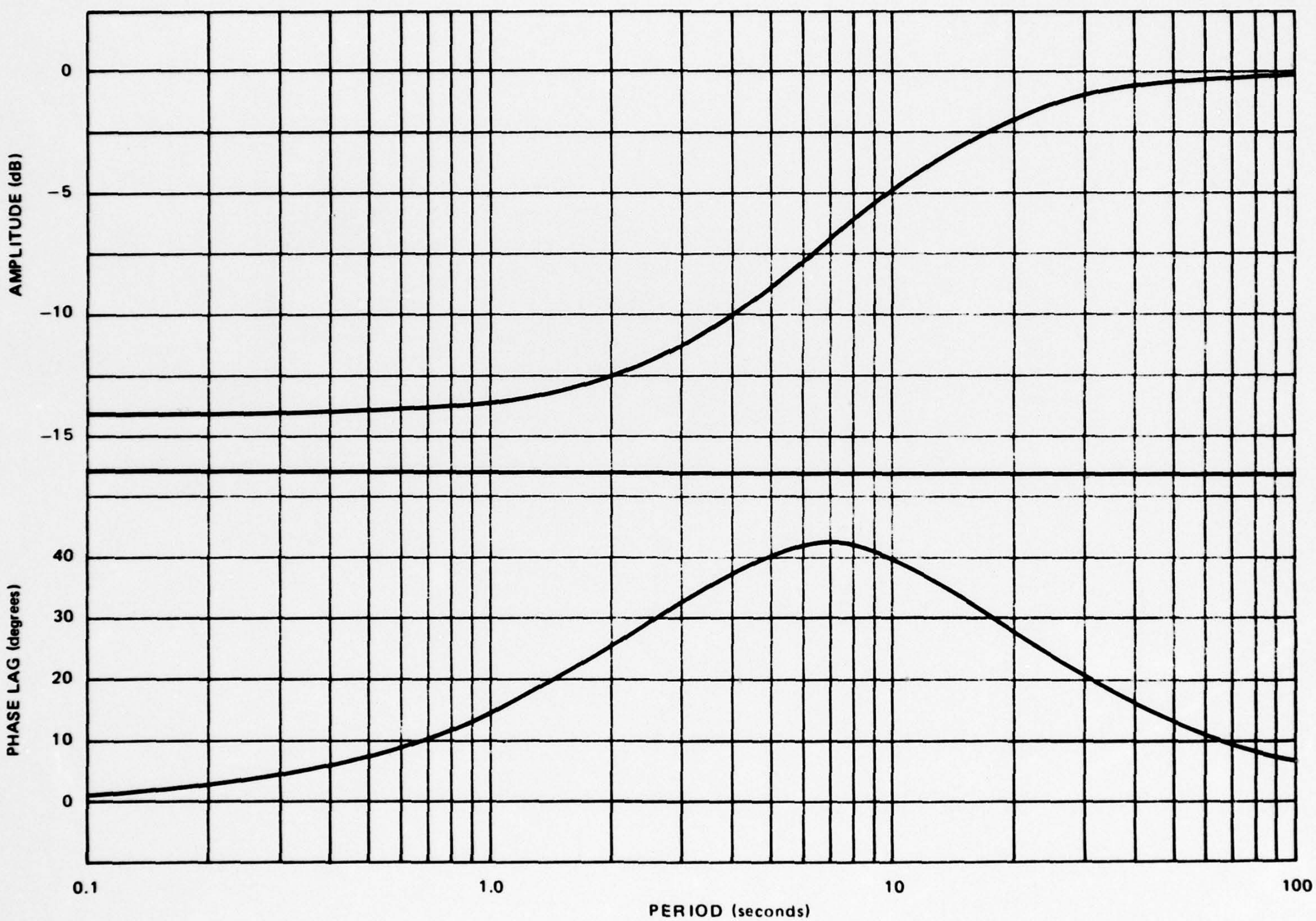

Figure 2. Amplitude and phase responses of the modified Model 36000 line driver filter

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3.4 DIGITAL RECORDING SYSTEMS

By 1 January, the digital recording systems had been installed at all sites except RK-ON. During their installation, there were indications that the Kinemetrics, Inc., Model DDS-1103 Digital Data Acquisition System was experiencing occasional problems in the memory circuits. Symptoms of the problem included either "missing" or "always on" bits during alternate memory cycles which sometimes affected one or two analog data channels but not the others. These failures result in apparent spikes with amplitudes depending on bit value on analog plots made from the digital data. This problem was especially perplexing to both Geotech and Kinemetrics personnel since, for example, data bits 2^{11} and 2^3 for all eight analog input channels are stored sequentially in the same memory chip, and it was, therefore, difficult to understand how one analog channel could be bad and an adjacent one be correct. This problem was discovered in December during system installation at FN-WV and occurred when the ambient temperature exceeded about 25°C (77°F). Because the system was in warranty, and because Kinemetrics had retained one complete system for earlier system troubleshooting, the FN-WV controller drawer (S/N 122) was returned for repair. The vendor was fully informed of the symptoms and conditions under which the failure occurred. In addition to the memory, the vendor was requested to repair a non-linear A-to-D converter.

After several tests, Kenemetrics was unable to duplicate the problems found at FN-WV. On 9 January, the Controller (S/N 122) and the complete system (S/N 116) were returned to Garland. On arrival, the controller was placed in an environmental chamber and the temperature raised to 50°C (122°F) - well under the 70°C operating specification for the unit. The two problems were again noted; replacement units were ordered from Kinemetrics. After repair, the Controller was operated for 48 hours at 50°C with no failure. A similar test was then performed on the Controller unit from the RK-ON system (S/N 122). The A-to-D Converter failed and was replaced. Following these tests, the equipment was installed as discussed in section 2 above.

Then during early April, the FN-WV system again began to exhibit an alternate memory problem. The failure was reported to Kinemetrics personnel who then made several suggestions concerning tests, resoldering printed circuit boards, voltage adjustments, etc. When all these attempts failed to correct the problem, a replacement memory was sent to FN-WV. This memory was installed routinely but had a similar alternate memory problem. At this time, Kinemetrics was requested to send a representative to visit the FN-WV site in order to observe the problem under actual opearating conditions. On 10 May, the site was visited by both Kinemetrics and Geotech engineers. A fourth memory installed on 6 May was found to be functioning normally after an early failure which disappeared; the third unit was re-installed and was found to have a consistent failure. It was then agreed that the problem was definitely in the memory and arrangements were made with Kinemetrics to immediately replace units exhibiting similar failures.

On 21 May, a replacement memory was ordered for the HN-ME system after QC had verified an alternate memory problem. The replacement unit failed and another was requested on 3 June. This last unit was found to have a defective driver chip and was returned on 30 June.

Kinemetrics' personnel report that the memory problem has been traced to chip failures in a single batch from Signetics, Inc. These failures occur only at the relatively slow scanning rate below 40 Hz. The present approach is to select memory chips which operate reliably at speeds of 10 Hz and below. It is hoped that these screening techniques will solve this last major difficulty with the DDS-1103 systems.

3.5 LIGHTNING DAMAGE TO THE MODEL 36000 AT FN-WV

On 15 June, a thunderstorm passed through the FN-WV site area and lightning struck two trees on a hill about 300 m behind the site. In spite of lightning protection devices, the KS electronics section was damaged. Because the system would not respond to digital commands from the Test Set/Controller, it was necessary to very carefully remove the system from the borehole with the KS module masses unlocked. On 23 June, the damaged unit (S/N 002) was replaced with KS, S/N 004, which had been in use in Garland for the convection study.

On arrival in Garland, the damaged system was immediately inspected in order to determine the extent of the damage and to determine an explanation for the failure. The electronics section was found to have six of the eight line driver operational amplifiers shorted. When these were replaced, all digital circuitry and power circuits operated normally. Preliminary checks of the mechanical section showed that no major damage was done to the modules. At the end of this period, the electronics section had not been fully tested to determine whether there was any further damage which could cause system noise. The complete system will be fully tested to normal specifications during July and August.

Figure 3 is a sketch showing the basic circuitry with its lightning protection. Note that each data circuit is protected both by double anode Zeners from both sides of the line to signal common and by an AEI gas diode protector whose common terminal is connected to a separate earth ground near the protector box. The Zener diode protection on the dc power lines was added as a result of lightning damage to the downhole power supply at Pinedale, Wyoming in 1974. Analysis of the failure at FN-WV has lead to the following conclusions:

a. The AEI protector probably did not fire because its 100 V + firing voltage would have resulted in far worse damage than that experienced;

b. The lightning surge did not come through the ±24 V power line to the KS because the power supply was undamaged as was other circuitry which it supplies;

c. Damage to the line driver operational amplifiers resulted from excessive voltages on their output terminals;

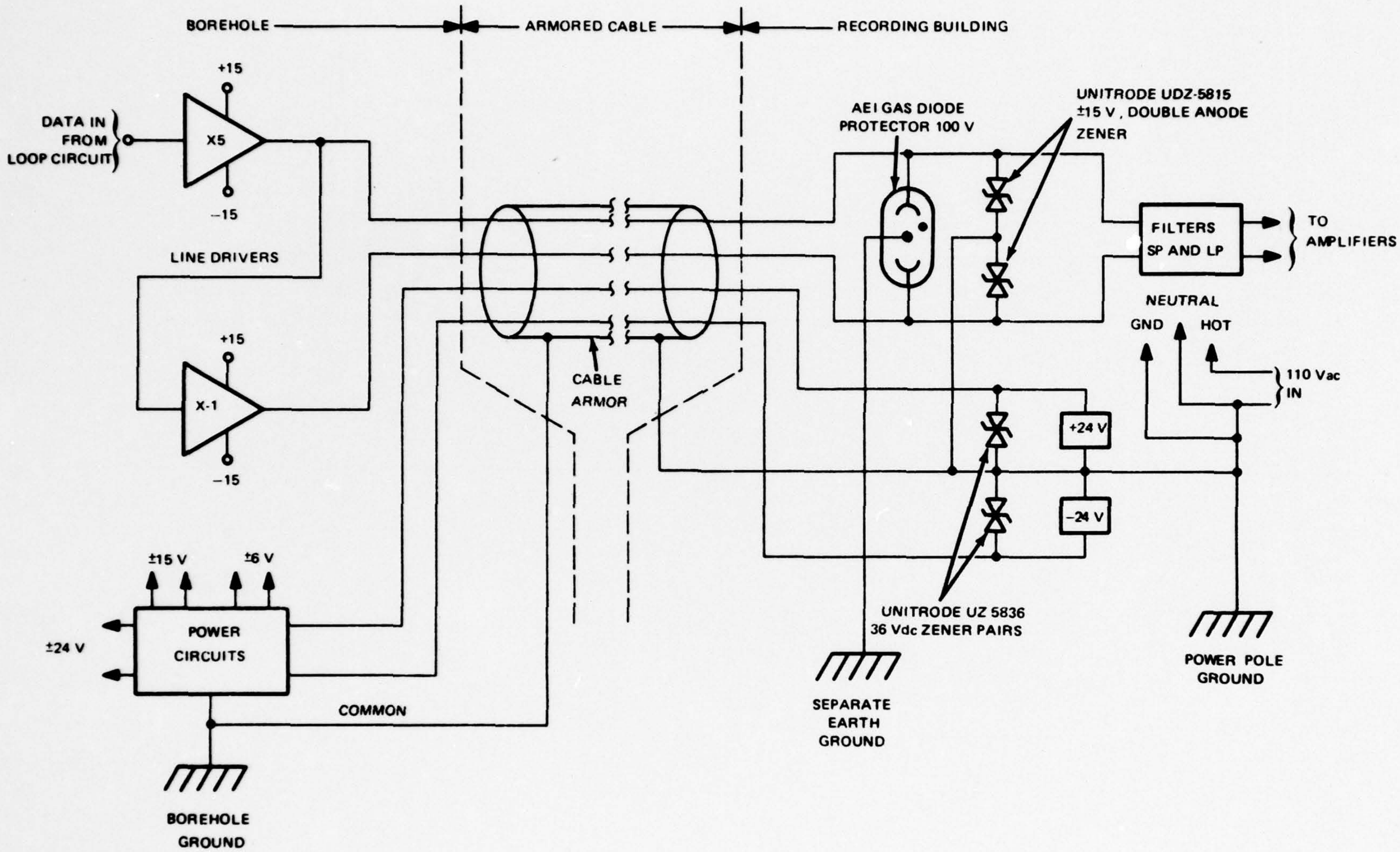

Figure 3. Simplified schematic diagram of basic KS data and power circuitry showing lightning protection devices as installed at Franklin, West Virginia and Houlton, Maine sites

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d. High voltage pulses did not pass through the filters because none were damaged;

e. Damage to the line drivers most likely occurred due to conduction of the lightning protection diodes. It is theorized that the lightning caused a high voltage potential between the borehole and power pole grounds and neither the earth nor the cable armor had sufficiently low resistance to keep it within safe limits; the UDZ-5815 Zeners conducted heavily when the uphole ground potential exceeded 15 volts, allowing the voltage on the operational amplifier outputs to exceed maximum ratings.

As a result of these findings, the following will be implemented and is recommended for all KS sites:

a. Remove all lightning protection devices on the four KS data lines, because filter circuits provide adequate isolation from external sources;

b. Retain diode protection on power and calibration lines leading downhole;

c. Connect a heavy ground line (#4AWG copper or heavier) between the borehole casing and the common ground point at the recording facility. Also, ground the cable armor to the bus at the wellhead.

It is thought that the lightning susceptibility of the KS system is increased at installations such as FN-WV where system power is supplied by commercial ac power. At installations where power is generated at the site (such as by a thermoelectric generator), it is likely that lightning damage would not have occurred. Geotech personnel familiar with the KS installations at Albuquerque. (SRO) and Iran (ILPA) have indicated that the above procedures are being generally followed. However, it has been suggested that grounding at the ILPA be improved by connecting both the surface conduit and the cable armor to the wellhead.

4. DATA PROCESSING

The data processing for this program has been divided into three parts; analog tape quality control performed at the Garland facility, event processing at the SDAC and the digital data quality control which is also performed at the SDAC.

4.1 ANALOG TAPE QUALITY CONTROL AT GARLAND

The Quality Control procedures as performed in Garland are very important to the success of the field operations as they provide the only effective control of on-site operations. The lack of continuous visual recordings of all data channels in the field limits the knowledge that the SDCS operator can have of instrumentation problems that are developing. The playout of data from the analog records provides a ready reference for support personnel to evaluate the performance of the instrumentation. Analog record QC for data through late June had been completed by the end of the report period. Analog FM tapes, copies of the QC sheet, and logs are routinely shipped to Alexandria to provide backup recordings while problems with the digital systems are being resolved.

4.2 EVENT PROCESSING AT THE SDAC

The processing of SDCS data into formal event reports as requested by the Project Office is being completed on schedule. As of 28 June, reports on 33 events had been requested and found to have adequate data to report, 29 reports were completed, and four reports were in process. In addition, a backlog of about 20 reports remaining at the start of this period was completed.

Event processing from the digital field tapes began in February when they started becoming available. However, the various problems which were discovered in these tapes resulted in delays in production of the reports through March. At that time, processing from analog FM tapes was resumed, and digital field tapes were not used unless prior QC indicated that the tape was error free. By the end of the period, digital field tapes were being routinely used for processing with the exception of those from the HN-ME site when the previously discussed alternate memory problem resulted in unusable data.

At the end of this period, the process of preparation of composite digital tapes (MERGE) from sites used for individual event reports was behind schedule. Added emphasis has been assigned to this task to bring it up to schedule.

4.3 QUALITY CONTROL (QC) OF DIGITAL FIELD TAPES AT THE SDAC

The QC function at Alexandria was very useful during early operations of the digital systems. The programs specially developed for the SDCS field tapes led to rapid diagnosis of system problems and facilitated requests for assistance from the manufacturer of the systems. By the end of the reporting period, QC of at least one tape per week from each field site was being completed and tapes through mid-June had been checked. The program DETECT is used for QC work to check tape data quality. For normal operations checks are made for SP and LP calibrations, plus two 30-minute data segments to determine both day and nighttime operating characteristics.

The specified background level on the digital systems was set to 25 to 50 counts (50 to 100 mV). This level satisfies requirements for both analog and digital recorders. Late during this period, the QC group noted several instances at the Canadian stations where nighttime background levels dropped below 25 counts, even though daytime levels (when operators measured backgrounds) were within specifications. Because much of the analysis being done involves small signals, all teams have been requested to operate with background levels near the upper limit. Meanwhile, personnel at the Alexandria facility are considering whether to request a 3 to 6 dB increase in these levels.

5. SPECIAL PROJECTS

5.1 LP CONVECTION NOISE STUDY

The LP convection noise study was conducted in Garland between March and mid-June. Its purpose was to determine the cause or causes of apparent tilt noise on Model 36000 horizontal data channels which are thought to be related to convections or moving air currents in the sealed borehole. Also, methods of reducing this noise were sought. The various tests showed that disturbances other than air convections, such as local surface loading from wind and cultural activity, caused some of the noise commonly referred to as "convection" noise. Also, it was demonstrated that detectable convection activity could be artificially generated which caused the characteristic noise on the KS horizontal traces. Finally, insulation techniques were developed which should reduce the effects of natural convection activity in air-filled boreholes. A complete discussion of the tests performed, conclusions reached, and recommendations made is contained in Technical Report No. 76-6, Shallow Borehole Convection Noise Study, which was submitted in draft form to the Project Officer on 30 June 1976.

5.2 GYROSURVEYOR PROBE SYSTEM

The Gyrosurveyor Probe System is a device manufactured by Humprhey, Inc., and is designed to determine the holelock azimuth for the Model 36000 system the borehole slant angle (tilt from vertical) and the slant angle bearing (direction of tilt). The system was first delivered in December 1975 and was subsequently returned to the manufacturer for correction of a few minor problems. The system was returned to the Garland plant in late December and, in January, it was operated to determine if it met specifications. When these tests indicated satisfactory operation, the Project Office officially accepted the system which was then transferred to this contract. The system is used to support KS operations associated with the SDCS program and is also made available by the Project Officer to the organizations needing it.

During this period, the system was used to check orientation of the holelocks at FN-WV and HN-ME. In addition, the system was used in conjunction with Project T/6102 to determine holelock orientation for an evaluation/training project at Pinedale, Wyoming. The system has operated well during all checks.

APPENDIX to TECHNICAL REPORT NO. 76-8

THEORETICAL AMPLITUDE AND PHASE RESPONSE DATA

THEORETICAL AMPLITUDE AND PHASE RESPONSE DATA

Short-period system responses at Model 36000 sites, FN-WV and HN-ME showing responses before and after system modification to lower short-period signal levels. (Effective 21 March 1976 at FN-WV and 15 March 1976 at HN-ME)

		Before		After	
Freq	Per	Amp	Ang	Amp	Ang
0.1000	10.0000	0.0016	267.4	0.0044	227.8
0.1500	6.6667	0.0056	256.8	0.0117	214.0
0.2000	5.0000	0.0132	247.9	0.0232	207.3
0.2500	4.0000	0.0255	239.8	0.0393	202.0
0.3000	3.3333	0.0437	231.9	0.0611	197.1
0.4000	2.5000	0.1007	216.8	0.1240	187.3
0.5000	2.0000	0.1888	202.0	0.2136	175.9
0.6000	1.6667	0.3087	187.4	0.3287	164.4
0.8000	1.2500	0.6270	159.4	0.6377	141.5
1.0000	1.0000	1.0000	133.9	1.0000	119.3
1.5000	0.6667	1.8599	81.8	1.8387	71.6
2.0000	0.5000	2.4241	42.0	2.3388	34.4
2.5000	0.4000	2.6786	9.6	2.5717	3.4
3.0000	0.3333	2.6877	-17.6	2.5676	-22.7
4.0000	0.2500	2.3246	-60.4	2.207	-65.2
5.0000	0.2000	1.8487	-92.3	1.7573	-95.2
6.0000	0.1667	1.4360	-117.3	1.365	-119.4
8.0000	0.1250	0.8648	-154.6	0.8221	-156.6
10.0000	0.1000	0.5343	-182.0	0.5079	-183.9

Long-period system responses at Model 36000 sites, FN-WV and HN-ME showing responses before and after system modification to lower short-period signal levels. (Effective 21 March 1976 at FN-WV and 15 March 1976 at HN-ME)

		Before		After	
Freq	Per	Amp	Ang	Amp	Ang
0.0100	100.0000	0.1010	220.7	0.1156	213.9
0.0125	80.0000	0.1857	191.5	0.2115	183.0
0.0167	59.9880	0.3685	149.7	0.4141	138.5
0.0200	50.0000	0.5298	120.3	0.5887	107.0
0.0250	40.0000	0.7523	80.9	0.8176	64.6
0.0333	30.0030	0.9736	25.3	1.0130	4.4
0.0400	25.0000	1.0000	-11.9	1.000	-36.0
0.0500	20.0000	0.8799	-57.9	0.8239	-86.2
0.0571	17.5009	0.7480	-84.9	0.6666	-115.4
0.0667	14.9993	0.5730	-115.1	0.4782	-148.8
0.0800	12.5000	0.3749	-149.0	0.2842	-185.5
0.1000	10.0000	0.1866	-187.7	0.1251	-227.3
0.1250	8.0000	0.0695	-223.3	0.0398	-265.5
0.1667	5.9999	0	-265.2	0	-307.4
0.2000	5.0000	0.0207	-109.7	0.0088	-135.8
0.2500	4.0000	0.0193	-138.0	0.0073	-175.7
0.3333	3.0000	0.0150	-172.8	0.0049	-205.8
0.4000	2.5000	0.0112	-194.3	0.0034	-223.8
0.5000	2.0000	0.0071	-220.8	0.0020	-246.9
0.5714	1.7500	0.0052	-236.8	0.0014	-260.7
0.6667	1.5000	0.0035	-255.6	0.0009	-276.6
0.8000	1.2500	0.0021	-279.1	0.0005	-297.0