SAND Z 81-2

GEOTHERMAL LOGGING INSTRUMENTATION

DEVELOPMENT PROGRAM STATUS

JANUARY 1981

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DISCLAIMER

GEOTHERMAL LOGGING INSTRUMENTATION DEVELOPMENT PROGRAM STATUS

January 1981

Summary

Progress

* 275°C Temperature Tool Circuit Commercialization - Teledyne Philbrick has announced a preliminary specification for a high temperature measurement/transmitting system, called the 2700 system, that is capable of operating in ambient temperatures up to 275°C with a resolution of ± 0.2°C and an absolute accuracy of ± 0.5°C. In this system digital temperature information (a variable frequency pulse train) is serially transmitted over the same line that supplies power to the system. Compatibility with existing systems is maintained to allow operation on monocables or multi-conductor cables. The system consists of four metal, hermetically-sealed, triple-wide, dual-in-line packages each measuring 1.15 x 0.75 x 0.23 inches. This commercial system is an outgrowth of the 275°C hybrid developments by Sandia. A detailed description of this system is given in Appendix 1.

* Glaze Problem Eliminated - The problems reported last month concerning hybrid circuit passivation glaze have been eliminated; Teledyne Philbrick is no longer using any passivation on their circuits intended for 275°C operation.

* Gallium Phosphide Diode Packaging - A technique has been developed to bond and interconnect GaP diode chips into a complete metal can header. The chip is died down using a Au:Ge preform and a pulse heat hybrid bonder. Interconnection is made using Au wire and a molecular bonder. Previous packaging attempts resulted in breakage of the delicate chips or contamination by the bonding material. The new technique is readily adaptable to commercial processing.

* Industry Panel Reviews Program - Our industry based steering committee met in Bakersfield, California on January 15-16, 1981 to review and critique this program. The committee strongly recommended continuation of the high technology, high risk R&D into electronic components such as 275°C dielectrically insulated integrated circuits and GaP diodes and switches. Continuation was also recommended for R&D efforts with the acoustic televiewer, pressure instruments, casing and cement inspection techniques, and proof testing of experimental prototype 275°C tools. Less emphasis was recommended for work on amorphous metal films and field testing by Sandia of other DOE/DGE projects.

CONTENTS

ILLUSTRATIONS

I. Management Highlights - A. F. Veneruso (505) 844-9162

A. Contracts

1. Field Testing Amerada Gauges - A no cost agreement has been signed between Sandia National Laboratories and Well Production Testing (WPT) Company of Costa Mesa, California, for the field testing of the Sandia modified Amerada gauges which measure temperature and pressure and make a mechanical recording on a self contained clock driven chart. The modified mechanical gauges were originally supplied by Geophysical Research Corporation of Tulsa, Oklahoma, and the Kuster Company of Whittier, California. Under the agreement Sandia will loan the instruments to WPT who will run a series of field tests to evaluate them under geothermal logging conditions.

2. Multiplexer Fabrication - Negotations are underway with General Electric, Houston, to fabricate the electronic switch interface package that must accompany the ring counter type hybrid circuits to make a complete multiplexer ready for use with combination temperature, pressure, flow and caliper tools.

B. Meetings and Contractor Visits

1. Scientific Drilling, Incorporated - On January 7, 1981, Mr. Paul Engalder of Scientific Drilling visited Sandia and reviewed with Tony Veneruso, Stu Kohler and Al Watts Sandia's downhole instrumentation work.

2. Tri-State Oil Tool Industries, Inc. - On January 7, 1981, Messrs. F. W. Barrier and Winston Johnson visited Sandia and reviewed geothermal drilling and logging development activities.

3. Q-Flex Accelerometer - Sundstrand - On January 13, 1981, Messrs. R. F. Asmar, W. F. Lee, E. L. Balyeat and R. A. Hanson visited Sandia Labs and reviewed their Q-Flex accelerometer with G. M. Heck and S. M. Kohler of Sandia's Guidance and Control Division 2326 and with Tony Veneruso. The Q-Flex accelerometer may be of interest for use in downhole survey and position locating instruments.

4. Program Steering Committee Meeting - Our program's industry based steering committee held a meeting in Bakersfield, California, on January 15 and 16, 1981. Sixty-one representatives from geothermal production companies, logging service companies, suppliers and DOE laboratories participated. Highlights of the meeting included brief overviews from the Washington perspective by Mr. Raymond LaSala of DOE/DGE headquarters and Sandia's perspective by Dr. Dick Traeger. Other highlights included: a review of geothermal logging needs by Mr. Dick Dunlap of Aminoil; a report on the acoustic televiewer's field testing by Mr. W. Scott Keys of the USGS and Mr. Fred Heard of Sandia; and a report on commercially available 275°C circuits

by Mr. John Spoer of Teledyne. Progress reports were also given by Mr. A. Halpenny of Halpen Engineering on the metal sheath cable development and by Mr. Bob Creamer of G. E. on the 275°C multiplexer. In the Sandia presentations, Mr. Bruce Draper reviewed electronic component development, Ms. Peggy Bonn reviewed the fabrication of a 275°C temperature tool using new Teledyne hybrids, Mr. Joe Coquat reviewed cables and cableheads as well as presenting the preliminary designs for a combination tool. Dr. Tony Veneruso chaired the meeting and presented a detailed review of the Sandia program.

In the executive session following the meeting, the steering committee strongly recommended continuation of the in-house component and circuit R&D, and especially for the active semiconductor devices. In addition, they strongly recommended continuation of the dielectrically isolated integrated circuits with Harris Semiconductor and the longer range R&D on gallium phosphide diodes and solid state switches. Continuation was also recommended for efforts in the areas of the acoustic televiewer, experimental 275°C prototype tools (temperature, pressure, flow and caliper), and casing and cement inspection. They also recommended continuation of the R&D on the quartz pressure gauge if the current experiments are successful with the slotted quartz discs. On the negative side, the committee recommended less emphasis be placed on amorphous metal film research and on field testing by Sandia for other DOE/DGE projects.

5. New Zealand Geothermal - On January 27, 1981, Mr. E. Lindsay D. Fooks, Investigations Engineer for Geothermal Projects in New Zealand, visited Sandia and reviewed Sandia's geothermal logging program and the drilling and completion program activities.

6. Mineral Insulated Cable - On January 27, 1981, Mr. Barry W. Palmer of BICC Pyrotenax, Ltd., Prescot, England, visited Sandia and discussed the applications of mineral insulated cable. Concerning Sandia's interest in alternatives to MgO as an insulator, Mr. Palmer said that his firm prefers MgO because the other major alternatives, SiO_2 and mica powders, have severe handling and manufacturing problems. The SiO_2 powder is a health hazard, and the mica undergoes phase changes during annealing which result in volumetric expansion and consequent damage to the sheath.

7. Measurements-While-Drilling (MWD) - On January 27, 1981, Dr. R. E. Hanneman, Manager of Materials Programs and Evaluation Operation, Corporate Research and Development, General Electric Company, Schenectady, New York, visited Sandia and reviewed Sandia's geothermal logging activities with Mr. Joe Coquat and Dr. Tony Veneruso. Dr. Hanneman stressed the growing importance of high temperature electronic components for geothermal and for deep/hot oil and gas. Dr. Hanneman also suggested that Sandia

explore the possibility of making generic technical contributions in the measurements-while-drilling (MWD) area to speed up industrial developments in that area as Sandia has done for high temperature wireline logging.

8. Geothermal Logging Field Operations - On January 27, 1981, Dr. Tony Veneruso met, in separate meetings, with Mr. Jack Dye, Regional Manager for Gearhart Wireline Services, Bakersfield, California, and with Mr. Roy E. Dahna, District Operations Manager for Dresser Atlas, Bakersfield, California. In both meetings the message which came across to the Sandia/DGE program was ". . you are on the right track with the geothermal logging technology development but the field people need the high temperature tools now to start bringing in revenue from geothermal logging services."

C. Publications and Presentations

1. Presentation to SPWLA-Bakersfield, CA Chapter - On January 27, 1981, Dr. Tony Veneruso made a presentation on geothermal logging instrumentation to 42 members of the Society of Professional Well Log Analysts (SPWLA) in Bakersfield, California.

D. Upcoming Events

1. GRC-GLIP Technical Training Course - A training course, entitled "Introduction to Geothermal Log Interpretation" will be held in Reno, Nevada, on April 22 and 23, 1981. A brief summary of the course purpose and outline is included as Appendix 2.

II. Internal R&D

A. High Temperature Components - B. L. Draper (505) 844-2132

Objective - Develop and commercialize the high temperature electronic component technology which industry requires for 275°C (527°F) geothermal borehole instrumentation.

1. Passive Electronic Devices - B. L. Draper (505) 844-2132

An investigation of capacitors in the 1000 pF to 1 µF range has begun in an effort to find components suitable for use in 275°C hybrids. Parts from several manufacturers have been ordered and initial tests will begin in February, with life testing to follow.

2. Active Devices - B. L. Draper (505) 844-2132

Diodes - Aging tests were begun on high-lifetime p^+nn^+ silicon diodes fabricated from 0.3 Ω-cm material in Sandia's IC processing facility. These diodes, which were originally discussed in July 1980's Progress Report, display very low leakage current density (<30 mA/cm^2 at 300°C) but there was some concern that impurity diffusion at 300°C could degrade minority carrier lifetime (and increase leakage current). At the end of January only 60 hours of testing at 300°C had been completed, with no change in characteristics observed. More complete information will be reported next month.

JFETs - Testing of ~20 different types of commercial n- and p-channel JFETs was done in January (Kyle White). Transfer characteristics at $|V_{DS}|$ = 5 volts for some of the more interesting devices are shown in Figures 1a through 1g. (All devices to be discussed in this report were from Intersil. As noted in many previous reports, transistor characteristics are very manufacturer-dependent.) The 2N4860 (n-channel), 2N3329 (p-channel), 2N5116 (p-channel), 2N3993 (p-channel), 2N2607 (p-channel), and IT100 (p-channel) all had well-defined zero-temperature-coefficient (ZTC) regions (somewhat unusual in commercial p-channel devices), low gate leakage, and low drain current at pinch-off. In addition, the 2N5432 (n-channel) was found to have a high I_{DSS} at 275°C with relatively low gate and drain leakage. This device shows promise for use in a modified version of the 275°C voltage regulator; the output current capability might be greatly improved over the 30 mA now available.

Circuits - Two single-package voltage regulators delivered to Sandia from Teledyne/Philbrick have failed after fewer than 50 hours at 275°C. Failure analysis is now underway at Sandia (Peggy Bonn). One problem (which may or may not be related to the early failures) that was discovered early in the tests was excessive heating above ambient. The inclusion of the pass transistors and their associated heat in the same package as the rest of the electronics may cause regulation and aging problems

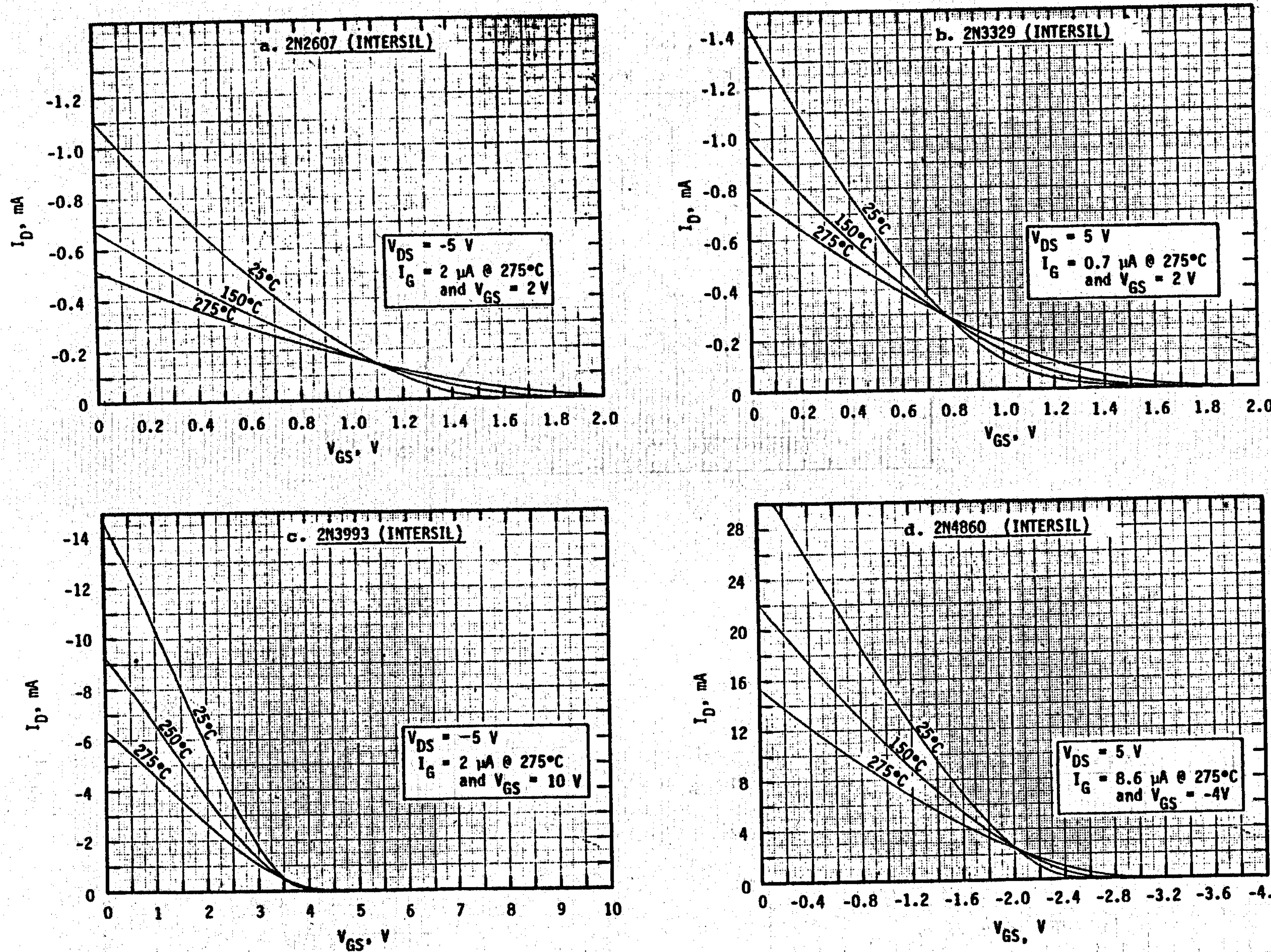

Figure 1. Transfer Characteristics for Various JFETs

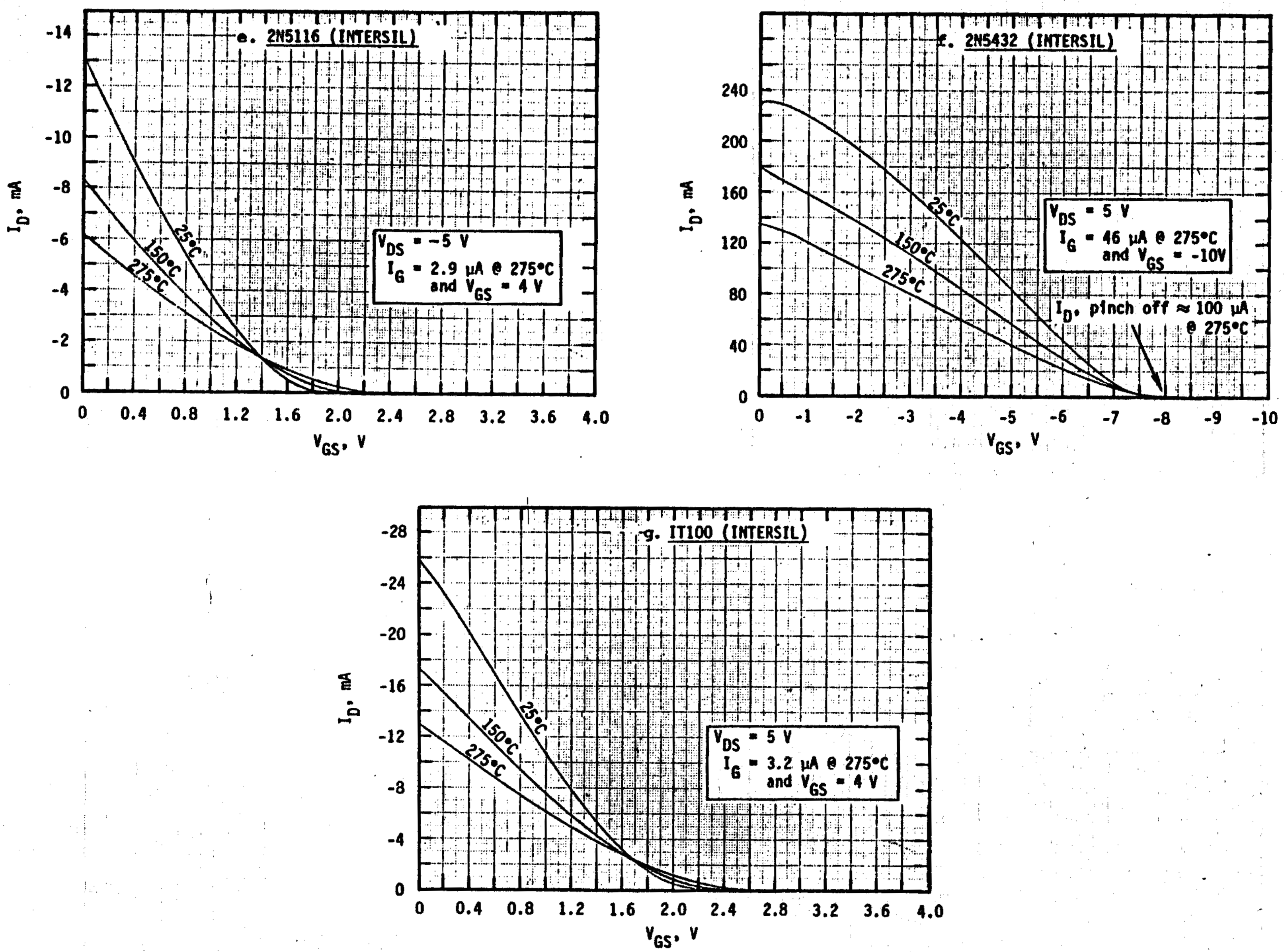

Figure 1 (Continued). Transfer Characteristics for Various JFETs

in 275°C ambient operation. The problems reported elsewhere last month concerning passivation glaze have been eliminated; Teledyne/Philbrick is no longer using any passivation on circuits intended for 275°C operation. Unfortunately, the parts discussed last month were already in the "pipeline" when the problem was discovered. For further information on the glaze problem see "High Temperature Hybrids for Use Up to 275°C-Drift and Lifetime" by A. F. Veneruso, D. W. Palmer, and M. G. Reagan in the 1980 Proceedings of the ISHM Microelectronics Symposium.

3. Compound Semiconductors - J. A. Coquat (505) 844-1910

The objective of this project on compound semiconductors such as gallium phosphide (GaP) and gallium arsenide (GaAs) is to develop and commercialize a signal diode, a power rectifier and a switch SCR that can operate at 275°C for at least 1000 hours.

a. Diode Packaging - J. A. Coquat (505) 844-1910

GaP diodes (Fig. 2) produced by Sandia's Divisions 5154 and 5133 have been successfully packaged. Since the devices are made by liquid phase epitaxial techniques, care must be taken not to damage the thin epitaxial layer. The devices were died down (Peggy Bonn/4742) to the package header using a Unitek Pulse Heat Hybrid Die Bonder and Au:Ge preforms. The preform melts at 400°C and a 50 Hz scrubbing action is applied to the die. A Weltek Molecular Bonder was used to bond (J. Snelling/5133) 1.5 mil Au wire from the top electrode to the leads of the package.

These devices will be age tested at 300°C for 1000 hours over the next two months.

b. Gallium Phosphide - T. Zipperian (505) 844-6407

Work was continued on the development of a gallium phosphide (GaP) high temperature bipolar junction transistor (BJT). Using essentially the same physical dimensions and resistivities as for the GaP BJT fabricated by liquid phase epitaxy (Fig. 3) during December 1980 (and reported on in the December report), a structure fabricated by metallorganic chemical vapor deposition was attempted. The resultant p^+npp^+ transistor had a peak common-emitter current gain of approximately 0.1 and a collector-emitter breakdown voltage of approximately -15 V. These results are discouraging and imply that lifetimes in vapor phase GaP are too short for use in a minority carrier device such as a BJT. The possibility still exists for majority carrier devices such as pn junction field effect transistors or MESFETs.

A nonorganic lift-off procedure has been developed for sputtered metallization systems. The technique, employing a double layer of sputtered titanium followed by plasma enhanced CVD Si-N, is applicable to the patterning of any complex sputtered metallization required for ohmic contacts or interconnects on GaP.

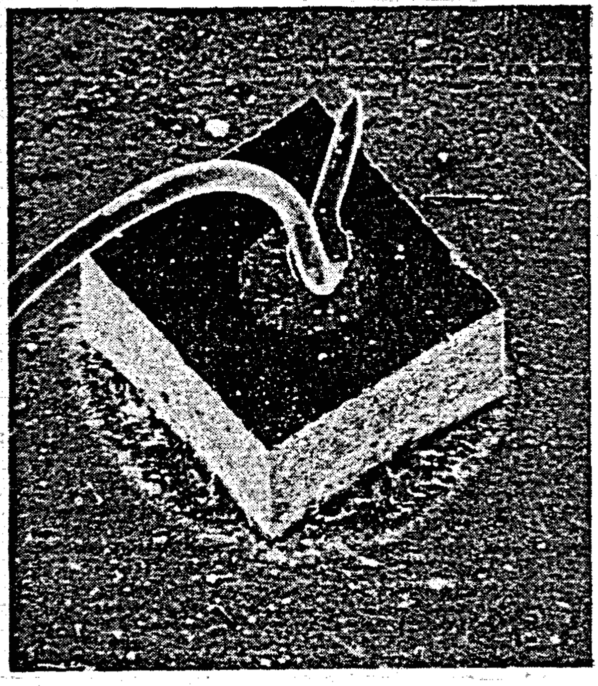

Figure 2. Scanning Electron Micrograph of Prototype p^+n GaP High Temperature Diode (chip size is 380 μm x 380 μm)

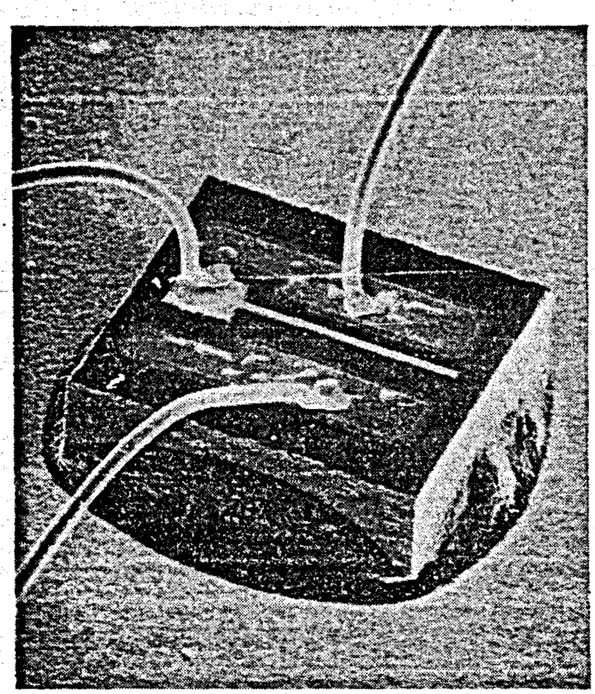

Figure 3. Scanning Electron Micrograph of Prototype pnp GaP High Temperature Bipolar Junction Transistor (BJT)* (chip size is 500 μm x 750 μm)

B. <u>Develop 275°C Temperature Tool</u> - J. A. Coquat (505) 844-1910

One new set of electronics was assembled, and the voltage to frequency converter was replaced on the tool that failed during calibration in December.

C. <u>Develop 275°C Pressure Tool</u> - T. McConnell (505) 844-7185

Pressure tests were begun on the slotted quartz resonator but results have not yet been analyzed.

D. <u>Upgrade Televiewer</u> - F. Heard (505) 844-2377

As reported in the December monthly, failure of an O-ring on the high pressure feedthrough caused oil and subsequently borehole fluid, to be forced through the tool in the field test at Fenton Hill. Damage was found in the flooded electronics section. The

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*The GaP transistor shown in Figure 3 may also be driven as an n-channel junction field effect transistor (JFET) where the base region serves as the channel and the collector and emitter regions function as upper and lower gates, respectively.

transducer backing material was crushed by the Teflon®* window due to the pressure differential put on the window by the feedthrough failure. The pressure bulkhead will be redesigned to accept either brazed-in feedthroughs or a self sealing NPT type thread. While O-rings will usually make one or two runs, the inconvenience of changing all ten O-rings in the almost inaccessible bulkhead assembly warrants a new design using some other type of seal.

The televiewer has been cleaned up and repaired in order to be tested in the high temperature and pressure test vessel at Wyle Labs, El Segundo, California, in early February.

The existing rotating transformer assembly was reconfigured to allow a larger gap between the rotor and stator assemblies to simplify the alignment procedure. A new design is in the works to make it a self aligning single unit with its own bearing, thereby making assembly and maintenance much simpler.

E. Develop 275°C Flow Tool - J. A. Coquat (505) 844-1910

A commercial magnetic pick-off coil from Flow Technology, Inc. of Phoenix, Arizona has been modified for use in the flow tool designed to work with a reed switch pick-up. The pick-off coil, which is rated to 400°C (750°F), yields a voltage output in the form of a complete sine wave cycle for each revolution of the impeller. The drawings for the flow tool--which will be used in conjunction with the caliper tool--were completed in January. Shop orders for fabrication should be placed in February.

F. Develop Caliper - J. A. Coquat (505) 844-1910

Final drawings were completed and signed off during January. Shop orders will be placed in February.

G. Develop Combination Tool - J. A. Coquat (505) 844-1910

The drawings were completed during January. Shop orders for fabrication will be placed in February. The original design specified Monel K-500 for a number of the parts. A new source for welding rods for this alloy has not been located. Until such a source is found, type 304 stainless steel will be used in place of the Monel K-500 wherever the latter is specified.

H. Upgrade Casing and Cement Inspection Tools - Hsi-Tien Chang (505) 844-7588

A high temperature oscillator and an amplifier have been designed using junction field effect transistors (JFETs). A high temperature circuit for the acoustic cement bond logging tool was presented at the Geothermal Logging Instrumentation Development Program Steering Committee Meeting on January 15, 1981, in

*®Dupont tradename

Bakersfield, California. This circuit contains a Sprytron switch, a voltage multiplier, an oscillator, an amplifier, a magnetostrictive transmitter, and a piezoelectric receiver. Comments and suggestions from the committee members are being studied.

I. Additional Field Tests - F. Heard (505) 844-2377

The Sandia field test hoist unit trailer is out of service temporarily so that it can be fitted with new diesel generators and repairs made to the hydraulics and mechanical systems. Completion is expected by the beginning of March.

J. Pump Dielectric and Seal Components - A. Veneruso (505) 844-9162

A review of laboratory test techniques and a literature search were initiated to investigate the thermal and hydroscopic behavior of Kapton® electrical insulation up to 200°C. The Kapton is used to insulate motor windings in the downhole geothermal pumps. An investigation of chemical indicator techniques has been started to find a method of detecting and recording the presence of water in the motor's oil insulation bath.

K. Geopressured Logging - T. McConnell (505) 844-7185

Gain measurements were started on the chopper-stabilized amplifier circuit. Results indicate an excessive, ~20%, change in gain over the temperature range of 0-200°C. Further analysis will continue to determine the cause.

L. Components Handbook - P. Bonn (505) 844-4775

A major portion of the data for the components handbook has been gathered and arranged according to component type. The information to be included for each component type is being discussed with Sandia Technical Staff members. A rough draft should be ready for review during the early part of February.

III. External R&D

A. High Temperature Operation of Active Devices

Contractor:	Clemson University (E. E. Dept.)
Principal Investigators:	Profs. L. Fitch and J. Prince Phone (803) 656-3379
Sandia Tech. Monitor:	Bruce L. Draper Phone (505) 844-2132
Contract Duration:	October 1980 to September 1981
Contract No.:	28-7356
Supported By:	DOE/DGE Geothermal Logging Development Program

Objective - Characterize commercial and experimental integrated circuits (linear and digital) and RF devices up to 325°C. Correlate these test results in order to produce design rules for high temperature ICs and RF transistors.

Status - Quantitative results of testing the CMOS/SOS inverter made by interconnecting complementary SOS CMOS transistors on the RUBIE test chip during December are shown in Figures 4 and 5. Recognizable and potentially useful I-V curves were obtained at temperatures to 375°C without excessive supply current drain. Above 200°C the output short circuit currents decreased. This is attributed in part to self heating, inasmuch as the decrease was more than that predictable from carrier mobility. Above 225°C some leakage through the gate oxide was observed (2.7 x 10^3 A/cm^2 at 375°C ambient). Schottky or Poole-Frenkel emission from silicon to the SiO_2 conduction band is suggested as a possible mechanism since the calculated activation energy is in the neighborhood of 1.5 eV and is stable with time.

The MK 4116 NMOS Poly II Dynamic RAM behaves differently from other RAMs tested in that the outputs are all low, rather than high, after returning from the amnesia temperature, 100°C, and the supply current does not show the increase typical of CMOS. The high value of the load resistors used in the NMOS circuits seems to be the current limiting factor for this case.

Zener diodes, Schottky diodes, step recovery diodes, and a number of normal switching diodes have been tested in the RF switching regime. A current controlled resistor has also been tested as a switch. The best results to date have been with the Hewlett Packard 5082-0180 step recovery diode which gave an on-off isolation of 9.6 dB at 5 MHz and 275°C, and had a recovery time of less than 1/2 cycle or 0.1 μs. Under similar conditions, an HP 5082-2080 Schottky diode gave only 3 dB isolation, but showed little storage time effect. The current controlled resistor gave good isolation at 275°C, but had a time constant of 2 μs, or 10 cycles of the switched wave.

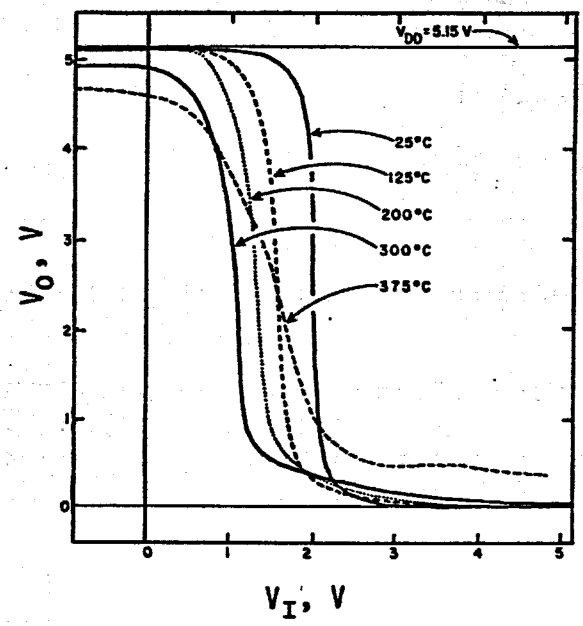


Figure 4. Voltage Transfer Characteristic Curves for SOS Inverter at Various Temperatures

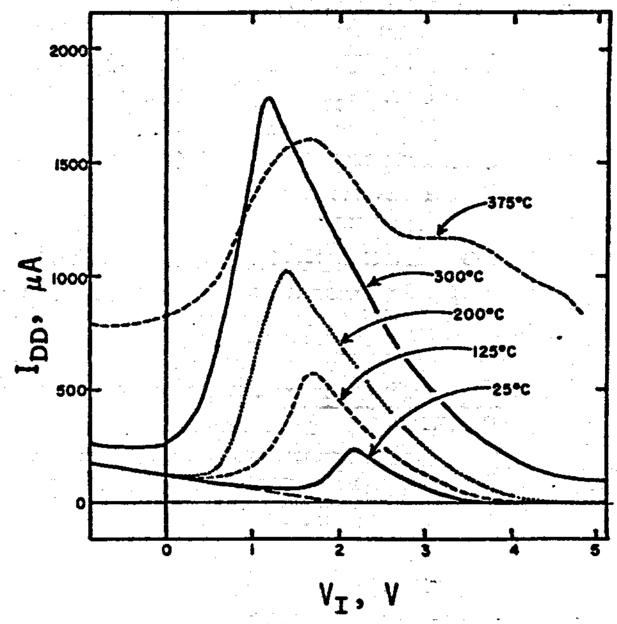


Figure 5. Supply Current Demand of SOS Inverter at Various Temperatures

B. Development of 300°C Operational Amplifier

Contractor: Harris Semiconductor

Principal Investigator: Jim Beasom
Phone (305) 724-7567

Sandia Tech. Monitor: Bruce Draper
(505) 844-2132

Contract Duration: September 1980 to May 1981

Contract No.: 49-2759
Supported by: DOE/Division of Fossil Fuel Extraction

Objective - Develop a quad, general purpose solid state operational amplifier for use at 300°C.

Status - Noise simulations were continued in January. New pnp device designs with lower R_{cs} and R_b values were introduced into the device models; noise was reduced from 6.00 nV/rt Hz to 4.69 nV/rt Hz.

The low temperature gain of the circuit was shown to be improved by the addition of a transistor to shield the collector of one npn grounded base stage from the voltage excursions of the high impedance node. The addition of the shield transistor required the addition of another diode as well as a shield transistor to another npn grounded base stage. With these changes in the modelling, the 25°C gain was 119,300 or 101.5 dB at 10 Hz and noise referred to the input was 4.70 nV/rt Hz. At 300°C the gain was about the same as it was without the shields, or 5700 (70.1 dB), and noise referred to the input was 10.68 nV/rt Hz.

The above changes are being incorporated in the layout.

C. High Temperature Thick Film Development

Contractor: Purdue University (Materials and E. E. Depts.)

Principal Investigator: Prof. R. W. Vest
Phone (317) 749-6244

Sandia Tech. Monitor: Bruce Draper
Phone (505) 844-2132

Contract Duration: October 1980 to March 1981

Contract No: 28-7200
Supported by: DOE/DGE Geothermal Logging Development Program

Objective - Develop a family of ceramic thick film materials (conductive, resistive, dielectric, and semiconductive) which retain useful electrical and mechanical characteristics for both extended periods (10^5 h) at 300°C and short periods (1000 h) at 500°C.

Status - Previous results on medium κ dielectrics indicated that it was possible to fabricate a capacitor with $\Delta C/C_o$ of 23% (25-500°C) and dissipation factor (D.F.) of 26% at 500°C in the Frit 1B-$SrTiO_2$-$BaTiO_3$ system with a three-step process (Dielectric No. 17). However, thermal storage tests demonstrated that $\Delta C/C_o$ (25-500°C) increased to 182% and D.F. at 500°C increased to 250% after 1000 hours storage at 350°C. Research this month was concentrated on simplifying the fabrication process and improving the thermal storage behavior. Eight compositions in the Frit 1B-$SrTiO_3$-TiO_2-$BaTiO_3$ system were studied in terms of different fabrication processes and thermal treatments. Both one-step and two-step fabrication processes were used, and the dielectric properties of the capacitors were measured either as fabricated or after annealing at 500°C. The frequency dependence of dielectric properties as a function of DC bias from room temperature to 500°C of one composition was also studied. The most promising results obtained so far were for a one-step processed capacitor with composition 35 v/o Frit 1B - 40 v/o $BaTiO_3$ - 25 v/o $SrTiO_3$. The capacitor was annealed at 500°C for 5 minutes and then furnace cooled to room temperature after the top electrode was applied. The relative change of capacitance was +8.69% (25-63°C), -32.90% (25-338°C), -32.68% (25-350°C) and -15.31% (25-500°C). Extensive studies, including variation of firing temperature, firing time, and dielectric thickness, will be carried out on this composition in order to obtain the optimum dielectric properties in the temperature range of interest.

Adjustment of the TCR for the low end number (100 ohm/sq) resistor was continued with the goal of decreasing the TCR to <100 ppm/°C. Addition of rhodium resinate to formulations containing

RuO_2 and Frit 2A produced resistors with the properties listed in Table 1.

Table 1. Sheet Resistance and TCR for Several Resistor Compositions

Frit 2A (v/o)	RuO_2 (v/o)	Rh_2O_3 (v/o)	Sheet Resistance (ohm/sq)	TCR (ppm/°C) 25-235°C
81.5	15.5	3.0	82	240
81.0	15.4	3.6	81	220
80.4	15.3	4.3	80-90	170
79.5	15.1	5.4	102	208

Sheet resistance after storage at 500°C was studied for the resistor compositions containing rhodium. A formulation with 12 v/o RuO_2 relative to Frit 2A and 16 v/o Rh_2O_3 relative to RuO_2 had a relative resistance change of only -1.6% after 250 hours of 500°C storage, compared to -3% for 12 v/O RuO_2 relative to Frit 2A composition without rhodium additions.

D. High Temperature Magnetic Material Research

Contractor:	Texas A&M University (E. E. Department)
Principal Investigator:	R. K. Pandey Phone (713) 845-7030
Sandia Tech. Monitor:	B. L. Draper Phone (505) 844-2132
Contract Duration:	October 1980 to March 1981
Contract No.:	28-7235
Supported by:	DOE/DGE Geothermal Logging Development Program

Objective - Measure magnetic properties of commercially available soft and hard materials from 25° to 400°C. Complete a literature search for promising developmental high temperature magnetic materials.

Status - The literature survey and theoretical materials study on high temperature effects and high temperature limitations of high frequency transformer core materials has been completed.

The experimental data on permanent magnets has been completed.

Several commercial Ni-Zn ferrites with high Curie temperatures have been selected for testing. Procurement is planned in the near future.

E. High Temperature GaP and GaAs Devices

Contractor: Texas A&M University (E. E. Department)

Principal Investigator: Prof O. Eknoyan
Phone (713) 845-7030

Sandia Tech. Monitor: J. A. Coquat
Phone (505) 844-1910

Contract Duration: October 1980 to September 1981

Contract No.: 62-9929
Supported by: DOE/DGE Geothermal Logging Development Program

Objective - Investigate metallization, passivation and doping techniques to establish a technological basis for the fabrication of high temperature (GaP, GaAs) diodes, controlled rectifiers, and the eventual design of JFETs/MESFETS.

Status - Thermally alloyed and laser annealed Au:Ge/Ni contacts have now been aged beyond 1000 hours. The results are shown in Figure 6. Overall, the relative increase in the contact resistance was 411% for the thermally alloyed contacts versus 24% for the laser annealed contacts. The aging behavior results are similar to those reported in the December monthly report for the Sn-Au contact system and indicate much better stability for laser annealed contacts in these two metal systems than for thermally annealed contacts. Similar investigations are now in progress for a Si-Au system.

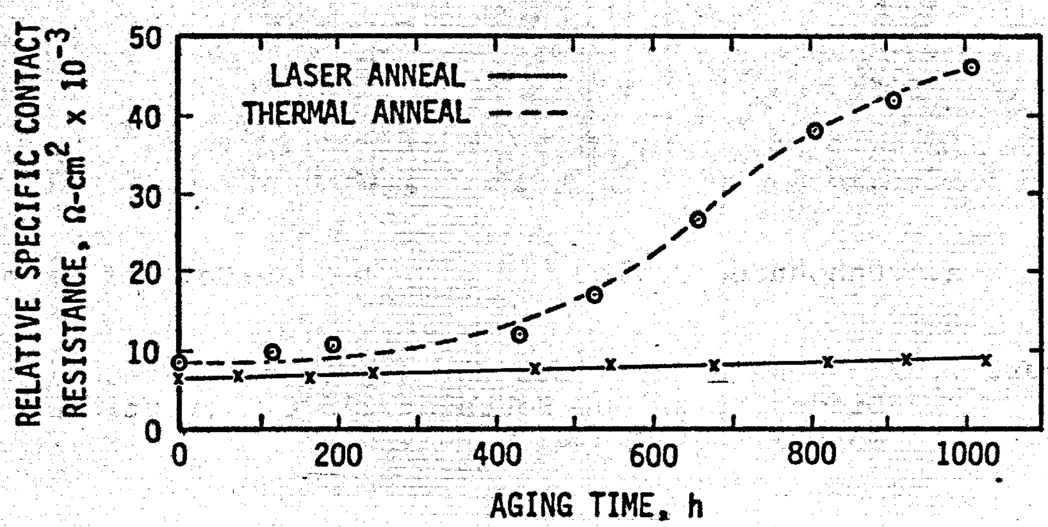
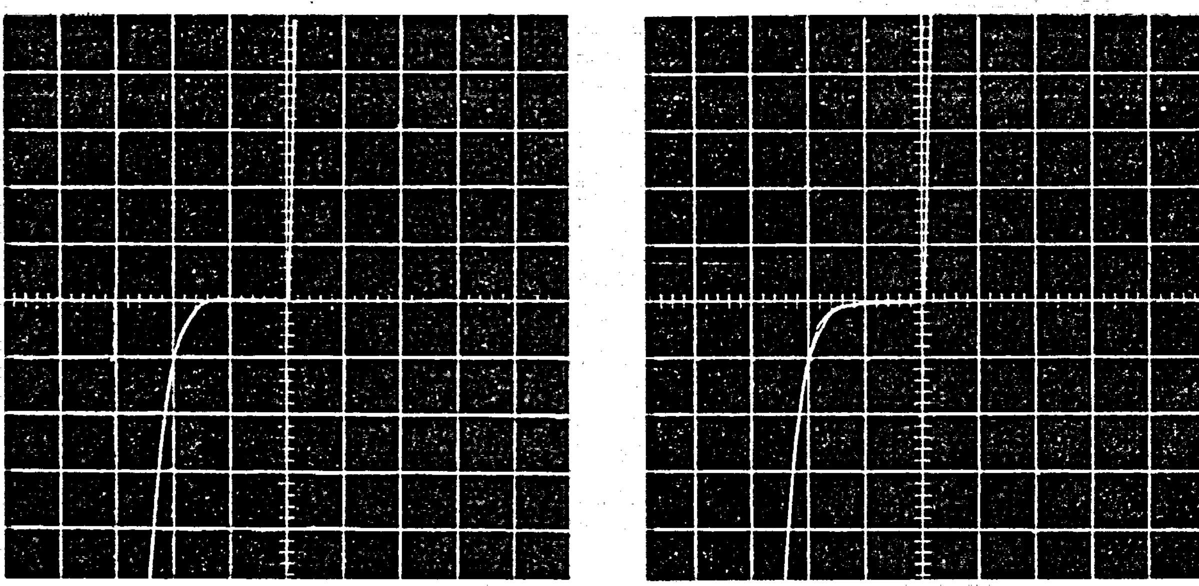


Figure 6. Aging Behavior of Thermally Alloyed and Laser Annealed Au:Ge/Ni Contacts at 275°C

Investigations have also been continued on the Si_3N_4 passivated Ni Schottky diodes. The I-V characteristics for both unbounded and for Au:Ge preform bounded devices after 500 hours of aging are given in Figure 7. The Schottky barrier heights and reverse leakage current at 3 V are listed in Table 2. All measurements were made at 275°C.

Table 2. Schottky Barrier Height and Leakage Current Density as a Function of Aging Time at 275°C for Si_3N_4 Passivated Schottky Diodes (with V_R = 3V)

	Barrier height, eV		Leakage Current Density, mA/cm²	
Aging Time, h	Bounded	Unbounded	Bounded	Unbounded
0	1.29	1.19	0.14	0.910
100	1.23	1.22	3.00	0.140
200	1.23	1.20	3.70	0.178
300	1.20	1.18	3.60	0.280
400	1.23	1.15	3.80	0.320
500	1.25	1.16	2.20	0.350



a. Unbounded device b. Au:Ge preform bounded

Figure 7. I-V Characteristics for Si_3N_4 Passivated Ni Schottky Diodes after 500 Hours at 275°C. (Vertical = 0.5 mA/Div, Horizontal = 20 V/Div)

F. Commercial Production of 300°C Hybrid Microcircuits

Contractor: Teledyne Philbrick

Principal Investigator: M. Reagan and R. Cook
Phone (617) 329-1600

Sandia Tech. Monitor: Richard Heckman
Phone (505) 844-5446

Contract Duration: November 1979 to September 1980

Contract No.: 13-0338
Supported by: DOE/DGE Geothermal Logging Development Program

Objective - Production of 50 high temperature hybrid microcircuit versions of Sandia designed and prototyped 25° and 300°C voltage regulators, voltage to frequency coverters, line drivers, and pulse stretchers. This effort is to include further miniaturization and improved hermeticity from Sandia's original prototypes.

Status - Materials orders were received and work will be resumed in February.

Teledyne has announced preliminary specifications for the 2700 system that consists of all the hybrid packages required to build the 275°C temperature tool. See Appendix 1 for details. All the hybrids under development by this contract are now being marketed and orders are being received.

G. Investigation of Amorphous Metalization for Semiconductor Circuits

Contractor:	University of Wisconsin
Principal Investigator:	J. D. Wiley Phone (608) 262-3736
Sandia Tech. Monitor:	Roger J. Chaffin Phone (505) 844-2609
Contract Duration:	January 1980 to September 1981
Contract No.:	74-2536
Supported by:	DOE/DGE Geothermal Logging Development Program

Objective - To investigate the related phenomena of diffusion and electromigration in amorphous metals and to obtain experimental data needed to assess the feasibility of amorphous metal films as metallization on high temperature semiconductor integrated circuits to improve reliability.

Status - Work is continuing to characterize electromigration and recrystallization kinetics of the Ni-Nb amorphous films.

H. Multiplexer

Contractor:	General Electric/Houston
Principal Investigator:	R. E. Creamer Phone (713) 332-4511
Sandia Tech. Monitor:	K. R. White Phone (505) 844-4775
Contract Duration:	June 1980 to April 1981
Contract No.:	49-2507
Supported by:	DOE/DGE Geothermal Logging Development Program

Objective - Commercial fabrication of 50 ring counter multiplexers for use at 275°C.

Status - After delivery of the 2N5265 transistors, fabrication of the uphole triggered clock was completed. Packaging has, however, been delayed. Packages were ordered and received from Isotronics but, because of delivery schedules, lids had to be ordered from another supplier. After delivery it was discovered that the radius of curvature at the lid corners was incorrect, and that GE's package sealer will not function properly with the discrepant radius. Alternate sealing methods are being investigated.

Thick film capacitors for the multiplexer circuit were fabricated and sent to Sandia for evaluation.

I. Development of 300°C CMOS Process

Contractor: Harris Semiconductor

Principal Investigator: Jim Beasom
Phone (305) 724-7567

Sandia Tech. Monitor: B. L. Draper
Phone (505) 844-2132

Contract Duration: November 1980 to April 1981

Contract No.: 28-1345
Supported by: DOE/Division of Fossil Fuel Extraction

Objective - Develop a dielectrically isolated (DI) CMOS logic integrated circuit technology capable of operation at 300°C.

Status - DI material fabrication for the NAND gate and test structures mask set was begun.

The first DI SAJI NMOS run to be built with an existing mask set was completed with mixed results. The desired V_T was achieved; however, breakdown voltage was only 5 V due to a masking error which resulted in a p^+ drain-source implant into the p-field regions. The same problem prevented measurement of field thresholds. A second run with this mask set was started.

Study of the logic realization continued. Most of the effort this month was devoted to planning a minimal set of chips which will offer a full set of SSI functions. Each chip will contain several logic functions, with the desired one being selected and powered up by an internal decode and control function in response to the input on function selection pins.

J. Metal Sheath Cable Development

Contractor: Halpen Engineering Inc.

Principal Investigator: Arthur Halpenny
Phone (716) 856-3185

Sandia Tech. Monitor: J. A. Coquat
Phone (505) 844-1910

Contract Duration: January 1980 to February 1981

Contract No.: 13-5163
Supported by: DOE/DGE Geothermal Logging Development Program

Objective - Develop a metal sheath, single-conductor electromechanical logging cable for continuous operation in geothermal wells at temperatures up to 350°C.

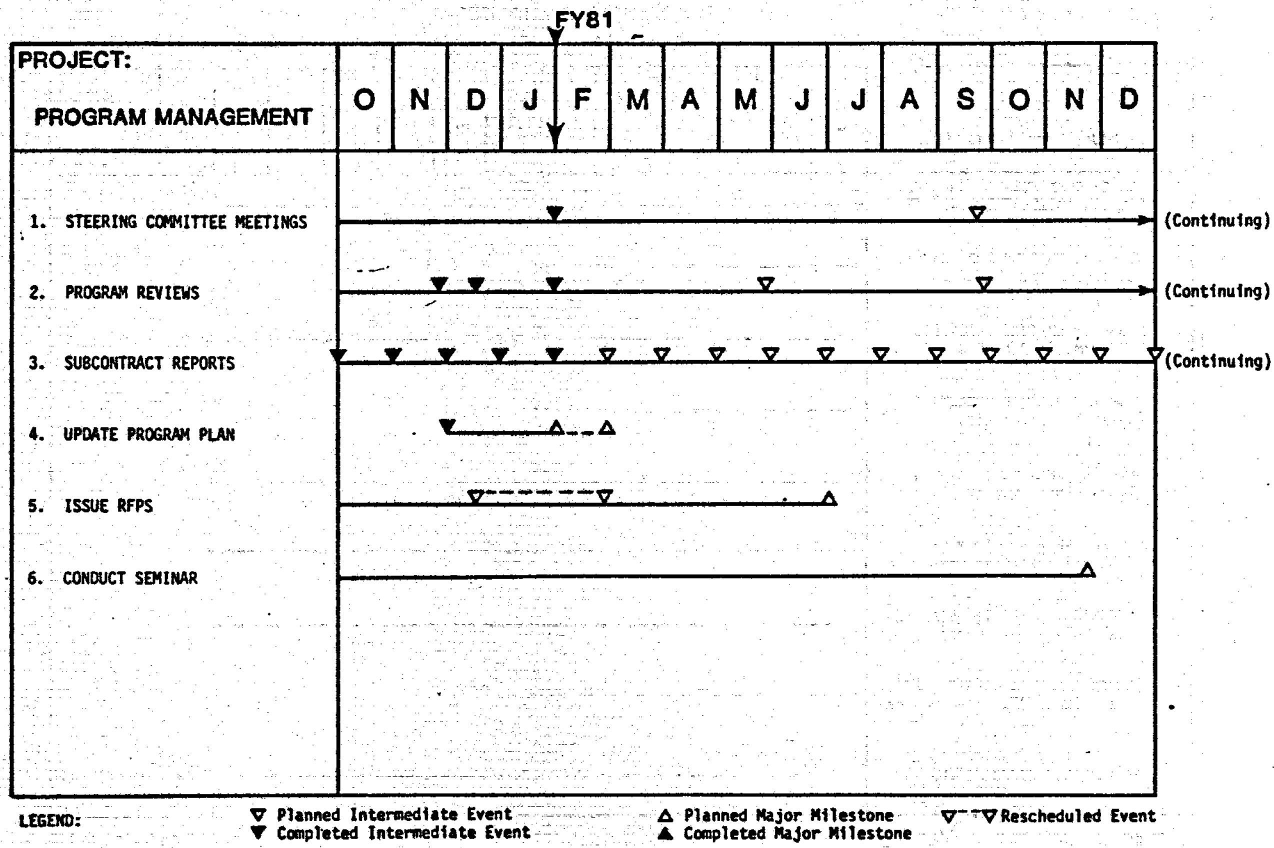
Status - The portable oven and the cable mechanical testing machines were completed at Tension Member Technology, Inc., and the first 500' length of cable was introduced into the machine for running-in and checkout procedures.

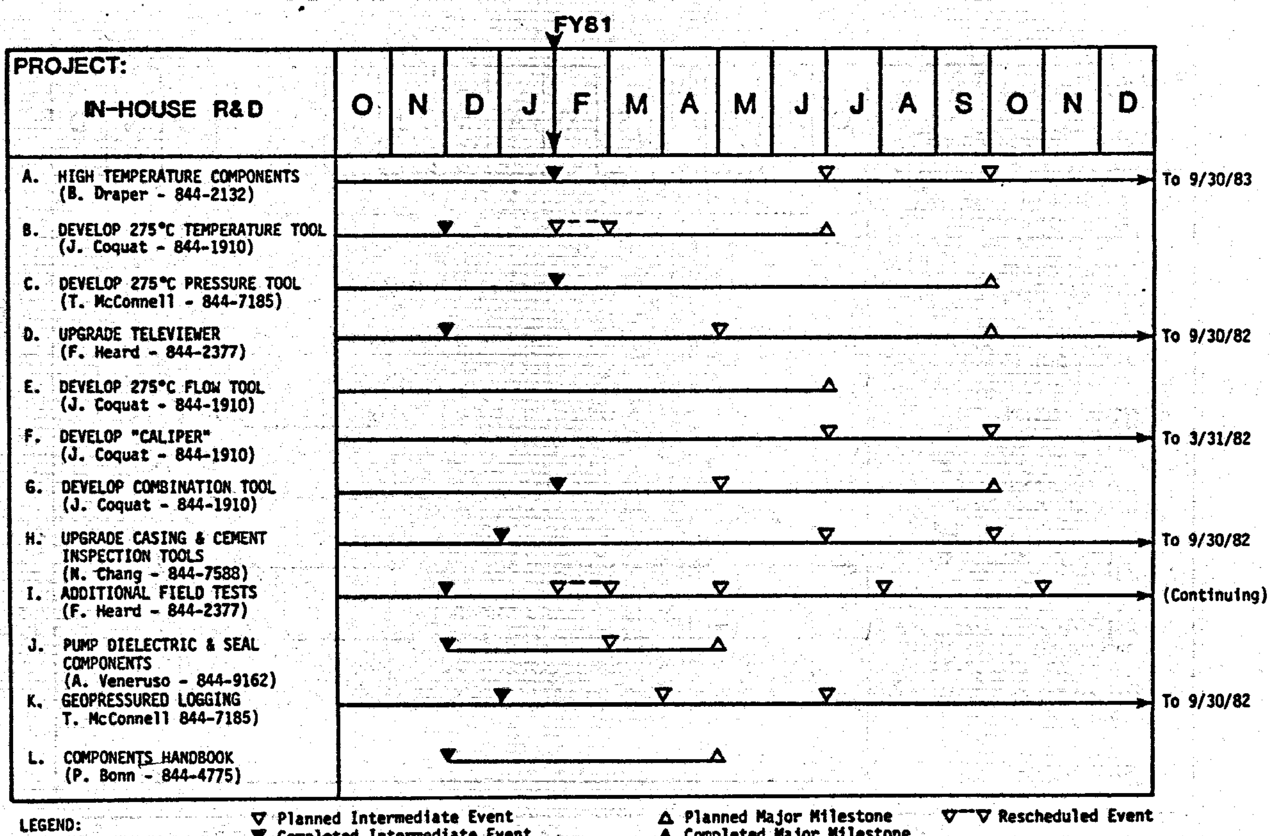
The second 500' length of cable was manufactured.

The report on the Aerospace Research testing program was completed and sent to Halpen. It will be distributed in February.

Investigations were made regarding the possibility of corrosion testing. This led to a quotation from Battelle on a 6 week testing procedure which is now under review.

GEOTHERMAL LOGGING INSTRUMENTATION DEVELOPMENT PROGRAM
MAJOR MILESTONE STATUS





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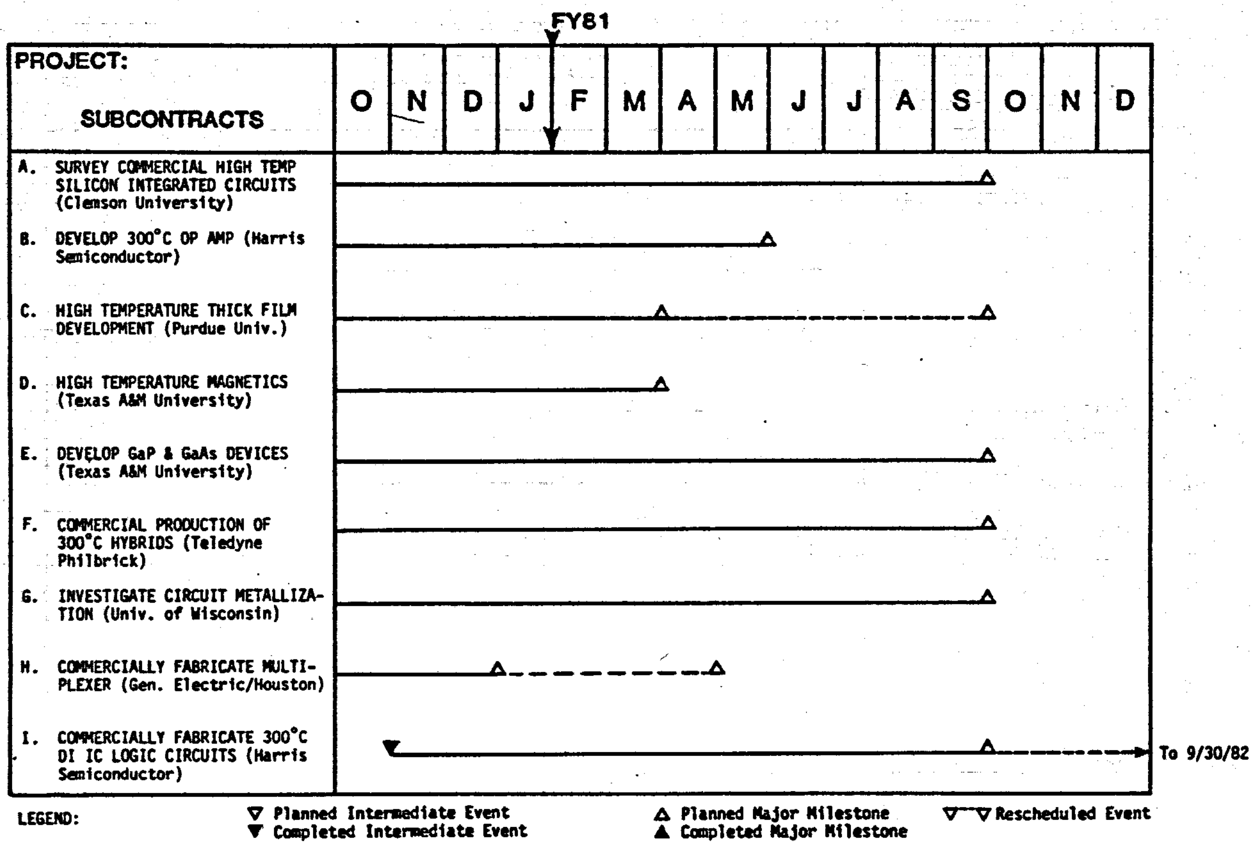
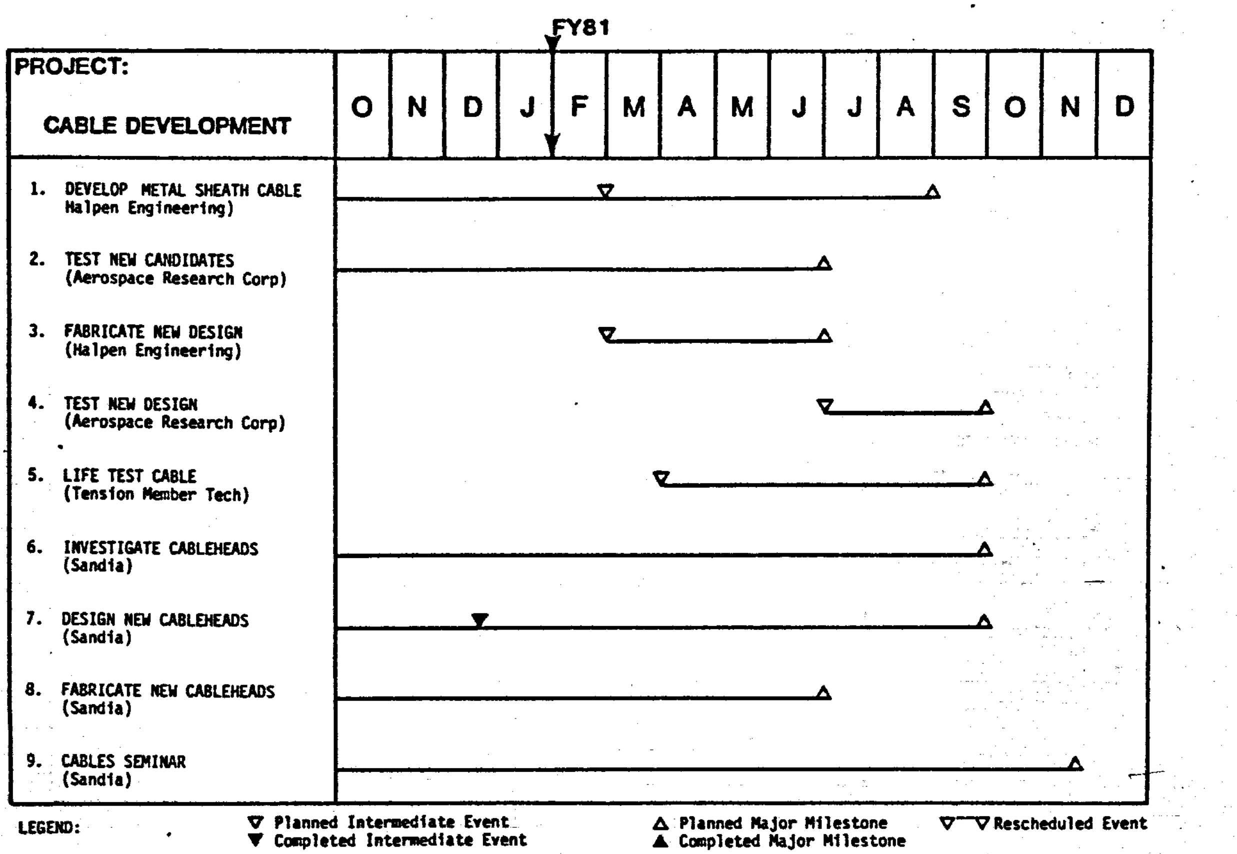
MAJOR MILESTONE STATUS





APPENDIX 1

TELEDYNE PHILBRICK HIGH TEMPERATURE MEASUREMENT/TRANSMITTING SYSTEM

(The following 8 pages are from preliminary specification information released by Teledyne Philbrick.)

TELEDYNE PHILBRICK

High Temperature Measurement/ Transmitting System

PRELIMINARY SPECIFICATION

2700

DESCRIPTION

The 2700 is a high temperature measurement/transmitting system capable of operating in ambient temperatures up to +275°C. It was originally designed for geothermal probing tools but is equally well suited for oil well logging tools, jet engine monitors, chemical process monitors, etc. The 2700 is basically a digital system. Digital temperature information is serially transmitted over the same line that supplies power to the system. With a resolution of 0.02C° and an accuracy of ±0.5C°, the 2700 approaches the performance of very specialized and expensive analog systems (with accuracies up to ±0.1C°) while overcoming the 200°C limitation of digital tools (normally accurate to only ±2C° with resolutions down to 0.1C°). Compatibility with existing logging techniques is maintained to allow operation on monocables or multiconductor cables. The system utilizes a minimum number of active and passive components to minimize the effects of drifts in electrical properties and improve reliability.

The system consists of four metal hermetically-sealed triple-wide dual-in-line packages each measuring 1.15 x 0.75 x 0.23 inches.

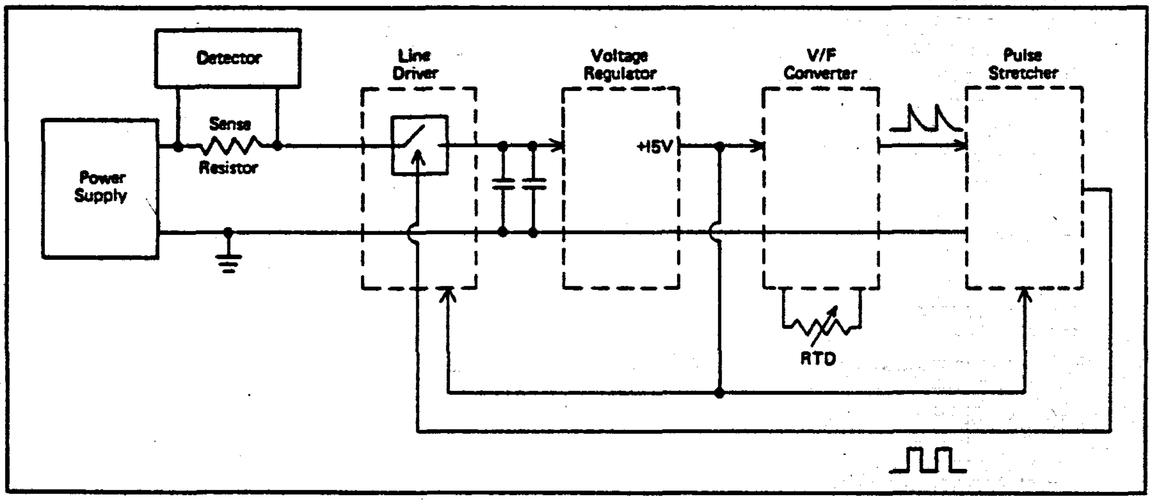
SPECIFICATIONS

Operating Temperature Range (ambient)	0°C to +275°C
Resolution	0.02C°
Accuracy (calibrated)	±0.5C°
Thermal Time Constant	60 seconds
Supply Voltage	+25V to +45V at voltage regulator (see Theory of Operation)
Repeatability Error	<0.1% up to 25 hrs. continuous at +275°C following calibration
Output Frequency	10kHz at +25°C to 30kHz at +275°C

Note: System output frequency is calibrated against precision reference to obtain custom calibration curve used to process tool output into temperature.

THEORY OF OPERATION

The basic temperature sensing/transmitting system consists of five function blocks (see Functional Block Diagram), a temperature transducer, a voltage-to-frequency (V/F) converter, a pulse stretcher, a voltage regulator, and a line driver. Two lines--a positive voltage supply and a system ground--are all that is necessary to send power to and receive information from the system. A series current sensing resistor must be placed in the power supply line at the location at which transmitted information is to be received. Information is transmitted by periodically interrupting the current in the supply line resulting in a pulse modulation of the voltage across the sensing resistor. The line driver, therefore, functions simply as a switch. When the switch is closed, current flows to the system resulting in a positive voltage across the series resistor. When the switch is open, current flow is zero, and the voltage across the series resistor drops to zero. In order for the line driver and the subsequent voltage regulator to function normally, the DC voltage of the supply line at the line driver should be between +25V and +40V. This means the voltage drop across the series resistor and voltage drops due to cable or line resistance may necessitate using a power supply of significantly higher voltage (+35V to +50V). Because the V/F converter, the line driver, and the pulse stretcher are all designed to operate from a single +15V supply, the system requires a voltage regulator to eliminate the effects of the line driver and the effects of changes in cable conductor resistance. The voltage regulator maintains the 50dB line and load regulation required to produce a stable supply voltage. In order to have the regulator driven from a fairly constant DC voltage, two large (33μF) capacitors are placed in front of it. Therefore, once the capacitors have charged, the regulator input is somewhat immune to the power supply line modulation.



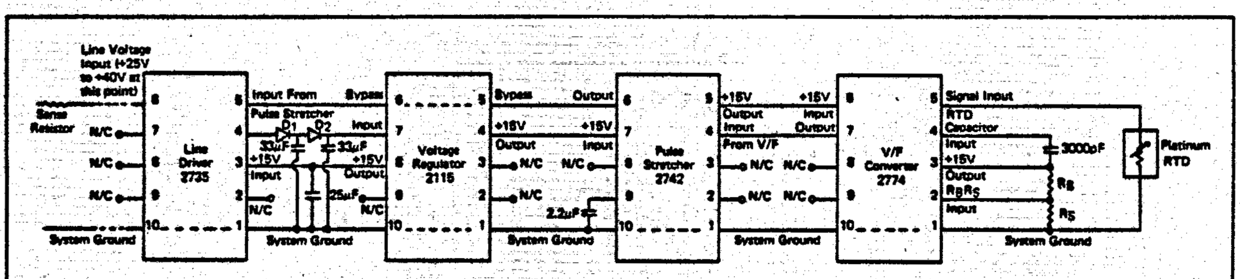
Functional Block Diagram

The recommended temperature transducer for the system is a platinum resistance temperature detector (Weed Instrument Co., RTD model no. 201-10-C-2-A-3-1-0) with a resistance of approximately 1000Ω at 0^{o}C and approximately 2046Ω at 275^{o}C. Internal to the V/F package is a constant current source and a series resistor. The platinum RTD is connected in series with this resistor to form a voltage divider with the voltage across the RTD acting as the actual drive voltage for the V/F converter. The V/F converter is a device that outputs a pulse train whose frequency is proportional to its drive voltage. Since the resistance of the RTD is proportional to temperature, the voltage divider output (the voltage across the RTD) and hence the V/F output frequency, are also proportional to temperature. When the line driver transmits the V/F's output pulse train back to the power supply line's current sensing resistor, detecting circuits can be used to count the pulses over some reference interval to yield a number proportional to the temperature at the transducer.

The pulse stretcher between the V/F converter and the line driver is necessary because the V/F's output pulses have a duration of only 1.5 to 2µsec. Since the impedance of the power supply cable will probably rapidly attenuate signals with higher harmonics, the duration of the pulse must be lengthened to ensure its detection at the other end of the line. The pulse stretcher increases the pulse duration to approximately 12µsec.

SYSTEM LAYOUT AND INTERCONNECTION

The four packages that comprise the 2700 system have pin assignments that allow them to be physically laid out next to each other in a line on one side of a PC card (see Pinning/Interconnection Diagram). Pins 1 and 10 on each package are system ground connections. Ground runs within each device are of low enough impedance to allow all the ground connections to be made serially. In other words, with pin 10 of the line driver connected to the same ground as the system power supply, pin 10 of the voltage regulator can be connected to pin 1 of the line driver. Pin 10 of the pulse stretcher can then be connected to pin-1 of the voltage regulator and so on, until the ground connection of the RTD is made to pin 1 of the V/F converter. The +15V output of the voltage regulator is brought out on two pins (pins 4 and 8) so it can drive the line driver (pin 3) and the pulse stretcher (pin 7) directly. The +15V supply for the V/F (pin 6) is conducted through the pulse stretcher (pin ~~7~~ to pin 5). The output of the pulse stretcher (pin 6) is given a direct path through the voltage regulator (pin 5 to pin 6) to the line driver (pin 5). Pins 1-5 of the V/F converter are such that the two external resistors (R_S and R_B), the external capacitor, and the RTD can be laid out without crossing runs. The need for and the technique for determining the magnitude of the two resistors are discussed in the section describing the V/F converter.



System Layout and Interconnection Diagram
(Top View)

PRELIMINARY SPECIFICATION

2115

HIGH TEMPERATURE HYBRID VOLTAGE REGULATOR

DESCRIPTION

The 2115 Voltage Regulator operates from a single +25V to +40V supply and produces a +15V output. It is designed for use in the Teledyne Philbrick 2700 High Temperature Measurement/Transmitting System.

SPECIFICATIONS:

Typical over operating temperature, +15V supply unless otherwise specified.

Operating Temperature (ambient)	0°C to +275°C
Supply Voltage	+25V to +40V
Output Voltage	+15V ±1%
Output Current	50mA
Line Regulation	
Vin 25-40V Iout 5-15mA	±20mV (57dB)
Vin 25-40V Iout 15-50mA	±10mV (63dB)
Load Regulation	
Iout 5-15mA	±20mV
Iout 15-50mA	±10mV
Output Drift +25°C to +275°C (Iout = 25mA)	±0.5V
Output Stability vs. Time (1 hour)	±25mV

PIN DESIGNATIONS

Bypass	o 5		6 o	Bypass
+15V Output	o 4		7 o	Input
N/C	o 3	View Toward Pins	8 o	+15V Output
N/C	o 2		9 o	N/C
System Ground	o 1		10 o	System Ground

Green glass designates pin 1.

Note: Unit requires a 25μF capacitor from pin 8 to ground to maintain above specifications.

PRELIMINARY SPECIFICATION

2735

HIGH TEMPERATURE HYBRID LINE DRIVER

DESCRIPTION

The 2735 Line Driver is designed for use as a signal/supply line switch in the Teledyne Philbrick 2700 High Temperature Measurement/Transmitting system.

SPECIFICATIONS:

Typical over operating temperature, +15V supply unless otherwise specified.

Operating Temperature (continuous)	$0^{o}C$ to $+275^{o}C$
Supply Voltage	+15V ±5%
Line Voltage Input	+25 to +40 volts
Input Pulse Width	5 to 15μsec
Input Pulse Amplitude	+15V ±5%

PIN DESIGNATIONS

View Toward Pins

Pulse Stretcher Input	o 5	6 o	Line Input
Line Output	o 4	7 o	N/C
+15V Input	o 3	8 o	N/C
N/C	o 2	9 o	N/C
System Ground	o 1	10 o	System Ground

Green glass designates pin 1.

PRELIMINARY SPECIFICATION

2742

HIGH TEMPERATURE HYBRID PULSE STRETCHER

DESCRIPTION

The 2742 Pulse Stretcher is designed to receive a 1.5 to 8μsec pulse and convert it to a consistent 12μsec pulse. It is designed for use in the Teledyne Philbrick 2700 High Temperature Measurement/Transmitting System.

SPECIFICATIONS:

Typical over operating temperature, +15V supply unless otherwise specified.

Operating Temperature (ambient)	$0^{o}C$ to $+275^{o}C$
Supply Voltage	+15V ±5%
Input Pulse Width	1.5 to 8μsec
Input Pulse Amplitude	+10V to +15V
Output Pulse Width	12 ±2μsec
Output Pulse Amplitude	+15V ±5%
Power-on Delay (with external 2.2μF capacitor)	100msec

PIN DESIGNATIONS

View Toward Pins

Function	Pin	Pin	Function
+15V Output	5	6	Output
Input	4	7	+15V Input
N/C	3	8	N/C
N/C	2	9	C_X
System Ground	1	10	System Ground

Green glass designates pin 1.

Note: In the 2700 system, the 2742 requires an external 2.2μF capacitor at pin 9.

PRELIMINARY SPECIFICATION

2774

HIGH TEMPERATURE
HYBRID VOLTAGE-TO-FREQUENCY CONVERTER

DESCRIPTION

The 2774 Voltage-to-Frequency Converter transforms a voltage to a frequency that is proportional to the sensed temperature. It is designed for use in the Teledyne Philbrick High Temperature Measurement/Transmitting system.

SPECIFICATIONS: Typical over operating temperature, +15V supply unless otherwise specified.

Operating Temperature (ambient)	0^oC to $+275^oC$
Supply Voltage	+15V ±5%
Output Pulse Width	2 to 5μsec
Output Pulse Amplitude	+12V ±3V
Output Frequency	
1 volt input	5kHz to 10kHz
2 volt input	15kHz to 20kHz
Voltage Input Range	0.5V to 3.5V
Resistance Input Range	500Ω to 4kΩ

PIN DESIGNATIONS

View Toward Pins

Signal Input RTD	5	6	+15V Input
C_X	4	7	Output Frequency
+15V Output	3	8	N/C
R_B/R_S Input	2	9	N/C
System Ground	1	10	System Ground

Green glass designates pin 1.

Note: See Applications Information for external capacitor and resistor requirements.

APPLICATIONS INFORMATION

The voltage-to-frequency converter must have an external capacitor with a value of approximately 3000pF between pin 3 (+15V output) and pin 4 (C_X). This capacitor must be of a stable thick film type and its value at +25°C and +275°C known.

The photograph supplied with each V/F describes I_D versus V_{GS} over temperature for an internal J FET. Information extrapolated from the curves together with the values of C_X at +25°C and 275°C is used in the following equations to determine the values of R_S and R_B (see Interconnection diagram).

The V_{GS} corresponding to I_{D+25^oC} on the I_D curve is the V_{GS+25^oC} value.
The V_{GS} corresponding to I_{D+275^oC} on the I_D curve is the V_{GS+275^oC} value.

$$I_{D+25^oC} = \frac{(5.0V)(C_{X+25^oC})}{98.0 \times 10^{-6} \mu sec}$$

$$I_{D+275^oC} = \frac{(4.8V)(C_{X+275^oC})}{31.3 \times 10^{-6} \mu sec}$$

$$R_S = \frac{13.04 - 15(V_{GS+25^oC} - V_{GS+275^oC})}{(13.83 - V_{GS+25^oC})\, I_{D+275^oC} - (12.96 - V_{GS+275^oC})\, I_{D+25^oC}}$$

$$R_B = \frac{13.04 - 15(V_{GS+25^oC} - V_{GS+275^oC})}{(V_{GS+25^oC} + 1.17)\, I_{D+275^oC} - (V_{GS+275^oC} + 2.04)\, I_{D+25^oC}}$$

APPENDIX 2

The following is an outline of the GRC-GLIP Technical Training Course, "Introduction to Geothermal Log Interpretation," to be given at the El Dorado Hotel, Reno, Nevada, on April 22 and 23, 1981:

<u>Wireline Well Logging</u>
- Purpose and Uses
  - Subir Sanyal/Consultant
  - Mark Mathews/Los Alamos National Laboratory
- Objectives and Pitfalls
  - Scott Keys/U.S. Geological Survey
- Tools, Tool Responses, and Planning of Logging Programs
  - Larry E. Wells/Scientific Software Corp.
- Benefit of Log Interpretation
  - Fred A. Rigby/Science Applications, Inc.

<u>Lithology, Samples and Core</u>
- Geological Description
  - Jeff Hulen/University of Utah Research Institute
- Petrophysical Properties
  - Iraj Ershaghi/University of Southern California
- Drilling Information
  - Dwight Walters/R. F. Smith Corporation
- Slim Hole Logging, Heat Flow, and Surface Geophysics
  - Donald G. Hill/Chevron Resources Co.
  - Fred Rigby/Science Applications, Inc.

<u>Quality Control and Calibration</u>
- Primary and Secondary Calibration
  - Mark Mathews/Los Alamos National Laboratory
- Field Control and Monitoring
  - Larry E. Wells/Scientific Software Corp.

<u>Interpretation Problem</u>
- Preliminary Interpretation at Well Site
  - Donald G. Hill/Chevron Resources Co.
- Diagnostic and Semi-Quantitative Interpretation of Common Log Combinations
  - Larry E. Wells/Scientific Software Corp.
  - Subir Sanyal/Consultant
  - Scott Keys/U.S. Geological Survey

<u>Case Histories</u>
- East Mesa
  - Subir Sanyal/Consultant
- Cerro Prieto
  - Iraj Ershaghi/University of Southern California
- Raft River
  - Scott Keys/U.S. Geological Survey

Surprise Valley
Fred Rigby/Science Applications, Inc.
Desert Peak
Darshan Sethi/Dresser Atlas

Summary and Conclusions

For information regarding this course, contact:

Ms. Beverly A. Hall, Assistant Director
Coordination, Educational Programs
Geothermal Resources Council
P.O. Box 98
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J. T. Spoer	Teledyne Philbrick
E. J. Kennedy	Tennessee, University of
J. Eknoyan	Texas A&M University
R. K. Pandey	Texas A&M University
R. Skinner	Thermal Power Co.
M. S. Gulati	Union Oil Co. of Calif.

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A. Harrigan	Woodward Clyde Associates

U.S. DEPARTMENT OF ENERGY

FORM DOE 536 (1/78)

CONTRACT MANAGEMENT SUMMARY REPORT

FORM APPROVED OMB NO. 38R-0190

1. Contract Identification: Geothermal Logging Program Management

2. Reporting Period: 1-1-81 through 1-31-81

3. Contract Number:

4. Contractor (Name and Address): Sandia National Laboratories, Division 4742, P.O. Box 5800, Albuquerque, NM 87185

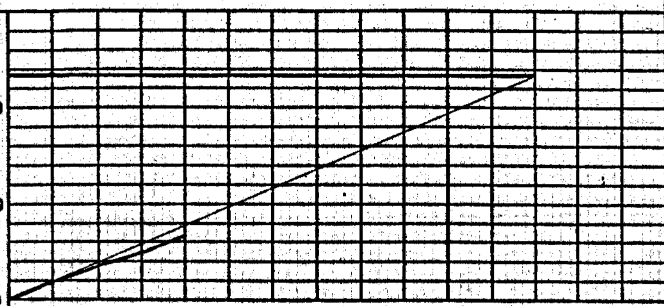
5. Contract Start Date: 10-1-80

6. Contract Completion Date: 9-30-81

7. Months: O N D J F M A M J J A S O N D — 8. FY 81

9. Cost Status

a. Thousands of Dollars



b. B&R Numbers: AM-10 05-25

Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
c. Planned	20	20	19	20	20	20	20	20	19	19	20	20			
d. Actual	19	17	12	19											
e. Variance	(1)	(3)	(7)	(1)											
f. Cum. Variance	(1)	(4)	(11)	(12)											

g. Cost Plan Date: 10-1-80

h. Planned Costs Prior FYs: 192,000

i. Actual Costs Prior FYs: 198,000

j. Total Estimated Costs for Contract: 237,000

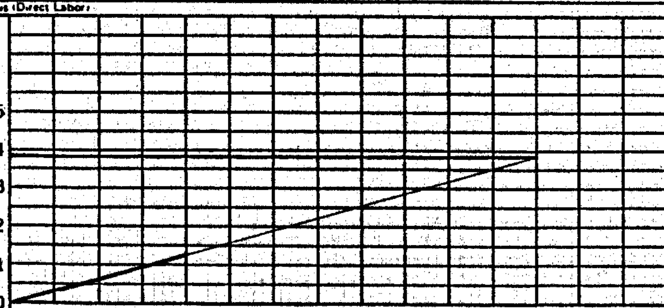
k. Total Contract Value: 237,000

l. Unfilled Orders Outstanding: 0

m. Estimate for Subsequent Reporting Period: 20,000

10. Manpower Status (Direct Labor)

a. Thousands of Man Hours



Manpower	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
b. Planned	.32	.32	.32	.32	.32	.32	.32	.32	.32	.32	.32	.32			
c. Actual	.32	.32	.32	.32											
d. Variance	0	0	0	0											

e. Manpower Plan Date: 10-1-80

f. Planned Manpower Prior FYs: 4800

g. Actual Manpower Prior FYs: 4800

h. Total Estimated Manpower for Contract: 3840

i. Total Contract Manpower: 3840

U.S. DEPARTMENT OF ENERGY

FORM DOE 536 (1/78)

CONTRACT MANAGEMENT SUMMARY REPORT

FORM APPROVED OMB NO. 38R-0190

1. Contract Identification: Geothermal Logging Development - In-House R&D

2. Reporting Period: 1-1-81 through 1-31-81

3. Contract Number:

4. Contractor (Name and Address): Sandia National Laboratories, Division 4742, P.O. Box 5800, Albuquerque, New Mexico 87185

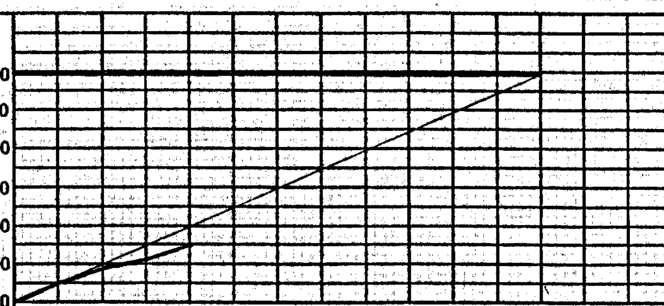
5. Contract Start Date: 10-1-80

6. Contract Completion Date: 9-30-81

7. Months: O N D J F M A M J J A S O N D — 8. FY 81

9. Cost Status

a. Thousands of Dollars



b. B&R Numbers: AM-10 05-25

Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
c. Planned	100	100	95	100	100	100	100	100	100	100	100	100			
d. Actual	100	73	43	79											
e. Variance	0	(27)	(52)	(21)											
f. Cum. Variance	0	(27)	(79)	(100)											

g. Cost Plan Date: 10-1-80

h. Planned Costs Prior FYs: 935,000

i. Actual Costs Prior FYs: 921,000

j. Total Estimated Costs for Contract: 1038,000

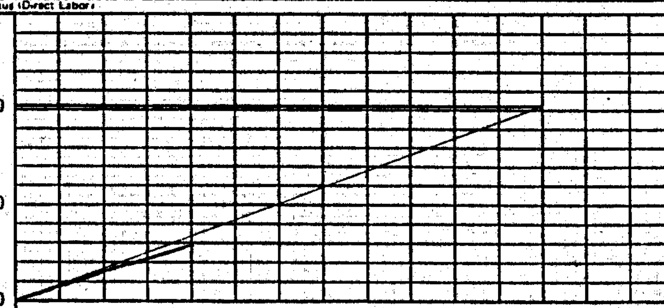
k. Total Contract Value: 1038,000

l. Unfilled Orders Outstanding: 22,000

m. Estimate for Subsequent Reporting Period: 100,000

10. Manpower Status (Direct Labor)

a. Thousands of Man Hours



Manpower	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
b. Planned	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68			
c. Actual	1.44	1.55	1.34	1.49											
d. Variance	(.24)	(.13)	(.34)	(.19)											

e. Manpower Plan Date: 10-1-80

f. Planned Manpower Prior FYs: 18,800

g. Actual Manpower Prior FYs: 20,352

h. Total Estimated Manpower for Contract: 20,160

i. Total Contract Manpower: 20,160

U.S. DEPARTMENT OF ENERGY

FORM DOE 536 (1/78)

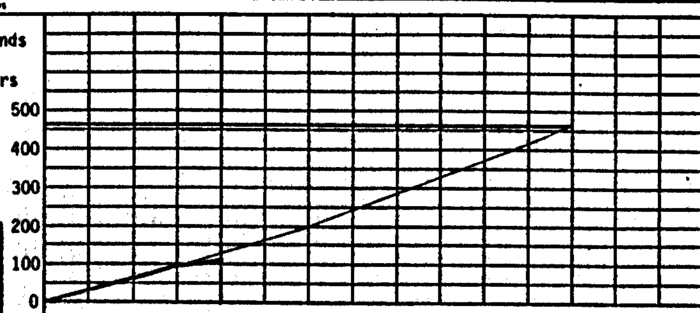
CONTRACT MANAGEMENT SUMMARY REPORT

FORM APPROVED OMB NO. 38R-0190

1. Contract Identification: Geothermal Logging Subcontracts
2. Reporting Period: 1-1-81 through 1-31-81
3. Contract Number:
4. Contractor (Name and Address): Sandia National Laboratories, Division 4742, P.O. Box 5800, Albuquerque, New Mexico 87185
5. Contract Start Date: 10-1-80
6. Contract Completion Date: 9-30-81
7. Months: O N D J F M A M J J A S O N D
8. FY 81

9. Cost Status

a. Thousands of Dollars



b. B&R Numbers: AM-10 05-25

Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
c. Planned	30	30	35	35	35	35	40	45	45	45	45	48			
d. Actual	30	32	34	18											
e. Variance	0	2	(1)	(17)											
f. Cum. Variance	0	2	1	(16)											

g. Cost Plan Date: 10-1-80
h. Planned Costs Prior FYs: 443,000
i. Actual Costs Prior FYs: 390,000
j. Total Estimated Costs for Contract: 468,000
k. Total Contract Value: 468,000
l. Unfilled Orders Outstanding: 243,000
m. Estimate for Subsequent Reporting Period: 35,000

10. Manpower Status (Direct Labor)

a. No Sandia Man Power

Manpower	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
b. Planned															
c. Actual															
d. Variance															

e. Manpower Plan Date:
f. Planned Manpower Prior FYs:
g. Actual Manpower Prior FYs:
h. Total Estimated Manpower for Contract:
i. Total Contract Manpower:

U.S. DEPARTMENT OF ENERGY

FORM DOE 536 (1/78)

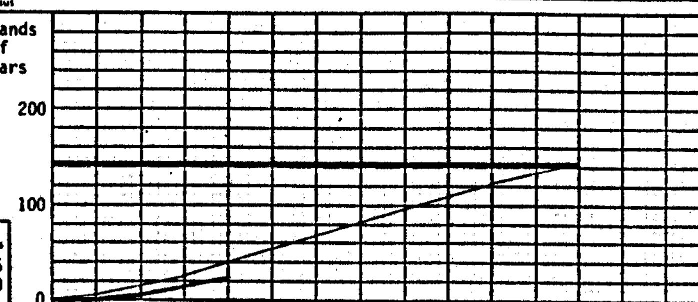
CONTRACT MANAGEMENT SUMMARY REPORT

FORM APPROVED OMB NO. 38R-0190

1. Contract Identification: Geopressure Instrumentation Development
2. Reporting Period: 1-1-81 through 1-31-81
3. Contract Number:
4. Contractor (Name and Address): Sandia National Laboratories, P.O. Box 5800, Albuquerque, New Mexico 87185
5. Contract Start Date: 10-01-80
6. Contract Completion Date: 09-30-81
7. Months: O N D J F M A M J J A S O N D
8. FY

9. Cost Status

a. Thousands of Dollars



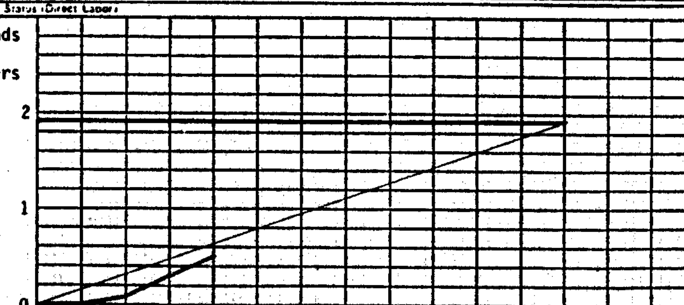
b. B&R Numbers: AM-05 15-00

Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
c. Planned	5	10	10	15	14	14	14	14	13	13	11	10			
d. Actual	0	5	8	11											
e. Variance	(5)	(5)	(2)	(4)											
f. Cum. Variance	(5)	(10)	(12)	(16)											

g. Cost Plan Date: 11-30-80
h. Planned Costs Prior FYs: 0
i. Actual Costs Prior FYs: 0
j. Total Estimated Costs for Contract: 143,000
k. Total Contract Value: 143,000
l. Unfilled Orders Outstanding: 0
m. Estimate for Subsequent Reporting Period: 14,000

10. Manpower Status (Direct Labor)

a. Thousands of Man Hours



Manpower	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
b. Planned	.16	.16	.16	.16	.16	.16	.16	.16	.16	.16	.16	.16			
c. Actual	0	.08	.22	.19											
d. Variance	.16)	(.08)	.06	.03											

e. Manpower Plan Date: 11-30-80
f. Planned Manpower Prior FYs: 0
g. Actual Manpower Prior FYs: 0
h. Total Estimated Manpower for Contract: 1920
i. Total Contract Manpower: 1920

U.S. DEPARTMENT OF ENERGY

FORM DOE 536 (1/79)

CONTRACT MANAGEMENT SUMMARY REPORT

FORM APPROVED OMB NO. 38R-0190

1. Contract Identification: Geothermal Cable Development

2. Reporting Period: 1-1-81 through 1-31-81

3. Contract Number:

4. Contractor (Name and Address):
Sandia National Laboratories, Division 4742
P.O. Box 5800
Albuquerque, New Mexico 87185

5. Contract Start Date: 10-1-80

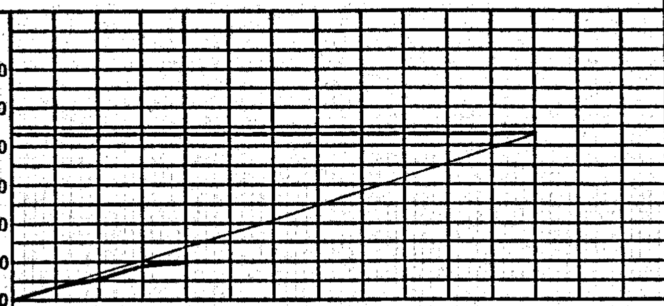
6. Contract Completion Date: 9-30-81

7. Months: O N D J F M A M J J A S O N D

8. FY 81

9. Cost Status

a. Thousands of Dollars



b. B&R Numbers: AM-10 05-20

g. Cost Plan Date: 10-1-80

h. Planned Costs Prior FYs: 450,000

i. Actual Costs Prior FYs: 471,000

j. Total Estimated Costs for Contract: 432,000

k. Total Contract Value: 432,000

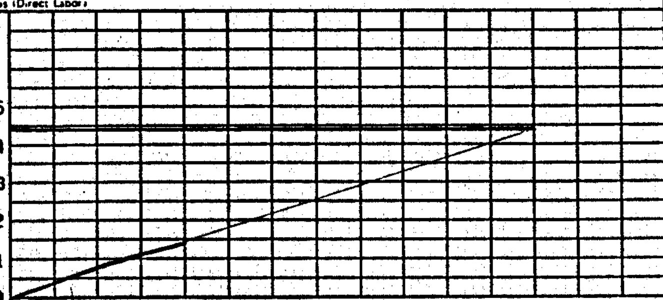
l. Unfilled Orders Outstanding: 143,000

m. Estimate for Subsequent Reporting Period: 35,000

Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
c. Planned	35	35	35	35	35	35	35	35	35	37	40	40			
d. Actual	33	19	35	12											
e. Variance	(2)	(16)	0	(23)											
f. Cum. Variance	(2)	(18)	(18)	(41)											

10. Manpower Status (Direct Labor)

a. Thousands of Man Hours



e. Manpower Plan Date: 10-1-80

f. Planned Manpower Prior FYs: 3,000

g. Actual Manpower Prior FYs: 3,072

h. Total Estimated Manpower for Contract: 4,400

i. Total Contract Manpower: 4,400

Manpower	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
b. Planned	.368	.368	.368	.368	.368	.368	.368	.368	.368	.368	.368	.368			
c. Actual	.38	.400	.340	.272											
d. Variance	.012	.032	(.028)	(.096)											

45,46