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GEOTHERMAL DRILLING AND COMPLETION TECHNOLOGY DEVELOPMENT PROGRAM QUARTERLY PROGRESS REPORT

OCTOBER-DECEMBER 1979

MASTER

Samuel G. Varnado, Editor

Prepared by Sandia Laboratories, Albuquerque,
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GEOTHERMAL DRILLING AND COMPLETION TECHNOLOGY DEVELOPMENT PROGRAM QUARTERLY PROGRESS REPORT

October-December 1979

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ABSTRACT

This report describes the progress, status, and results of ongoing Research and Development (R&D) within the Geothermal Drilling and Completion Technology Development Program. The work reported is sponsored by the Department of Energy/Division of Geothermal Energy (DOE/DGE), with program management provided by Sandia Laboratories. The program emphasizes the development of geothermal drilling hardware, drilling fluids, and completion technology. Advanced drilling systems are also under development. The goals of the program are to develop the technology required to reduce well costs by 25% by 1982 and by 50% by 1986.

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GEOTHERMAL DRILLING AND COMPLETION TECHNOLOGY

QUARTERLY PROGRESS REPORT

October-December 1979

INTRODUCTION

The high cost of drilling and completing geothermal wells is an impediment to the timely development of this resource in the U.S. The Division of Geothermal Energy (DGE) of the Department of Energy (DOE) has initiated a development program aimed at reducing well costs through improvements in the technology used to drill and complete geothermal wells. Sandia Laboratories has been selected to manage this program for DOE/DGE. Based on analyses of existing well costs, cost reduction goals have been set for the program. These are to develop the technology required to reduce well costs by 25% by 1982 and by 50% by 1986.

To meet these goals, technology development in a wide range of areas is required. The near-term goal will be approached by improvements in conventional rotary drilling technology. The long-term goal will require the development of an advanced drilling and completion system. Currently, the program is emphasizing activities directed at the near-term cost reduction goal, but increased emphasis on advanced system development is anticipated as time progresses.

The program is structured into six sub-elements: Drilling Hardware, Drilling Fluids, Completion Technology, Lost Circulation Control Methods, Advanced Drilling Systems, and Supporting Technology. Technology development in each of these areas is conducted primarily through contracts with private industries and universities. Some projects are conducted internally by Sandia.

This report describes the program, status, and results of ongoing R&D within the program for the quarter October-December 1979.

HIGHLIGHTS

The following are the highlights of the October-December 1979 activities performed under the Geothermal Drilling and Completion Technology Development Program.

* Management -- A workshop on Geothermal Drilling Fluids was sponsored by Sandia Laboratories for DOE/DGE on 9 October 1979 in Houston, Texas.

* Management -- The semi-annual meeting of the Geothermal Drilling and Completion Advisory Panel was held on 11-13 December 1979 in Washington, D.C.

* Internal Research and Development--Drill Stem Corrosion -- Quantities of silicon-based dual-phase steel were made at Sandia in October 1979. Investigation of the properties of this new steel is now proceeding at an accelerating pace.

* PDC Bit Development--GE(CRD) -- The S-1, modified, bit and the C-1 cast hard matrix bit were field tested in the Baca Field, New Mexico, in October 1979. The S-1 bit demonstrated a penetration rate several times greater than typical rates for rock bits in similar formations.

* Modification and Extension of Testing Capabilities--Drilling Research Laboratory, Inc. -- A new project to specify and acquire rock samples and to increase capabilities for high-speed/high-torque bit testing, high-speed data acquisition, and high-pressure jet drilling testing was initiated this quarter.

* Inert Gas Generation from Diesel Exhaust--Engelhard Minerals and Chemicals Corp. -- The initial report on the project to demonstrate the generation of nitrogen from diesel engine exhaust using a catalyst system is included in this quarter's report.

* Percussion Drilling Hammers and Bits--Drilling Research Laboratory, Inc. -- A new project to evaluate percussion drilling devices for geothermal application was started at the close of this quarterly reporting period.

Problems

* Mud Instrumentation--NL/Baroid -- Approval of the cost of the pressure vessel and the cooling jacket and the schedule impact of the new location of the drilling test facility remain unresolved issues. A 5-month delay in the delivery of the pressure vessel and cooling jacket presents a new project schedule impact. Also, a reevaluation of the effort required to complete the control system hardware and software indicates a major increase in the work needed. The project costs and schedules are being reviewed, and a proposal is being developed for contractual actions necessary to resolve these problems.

GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

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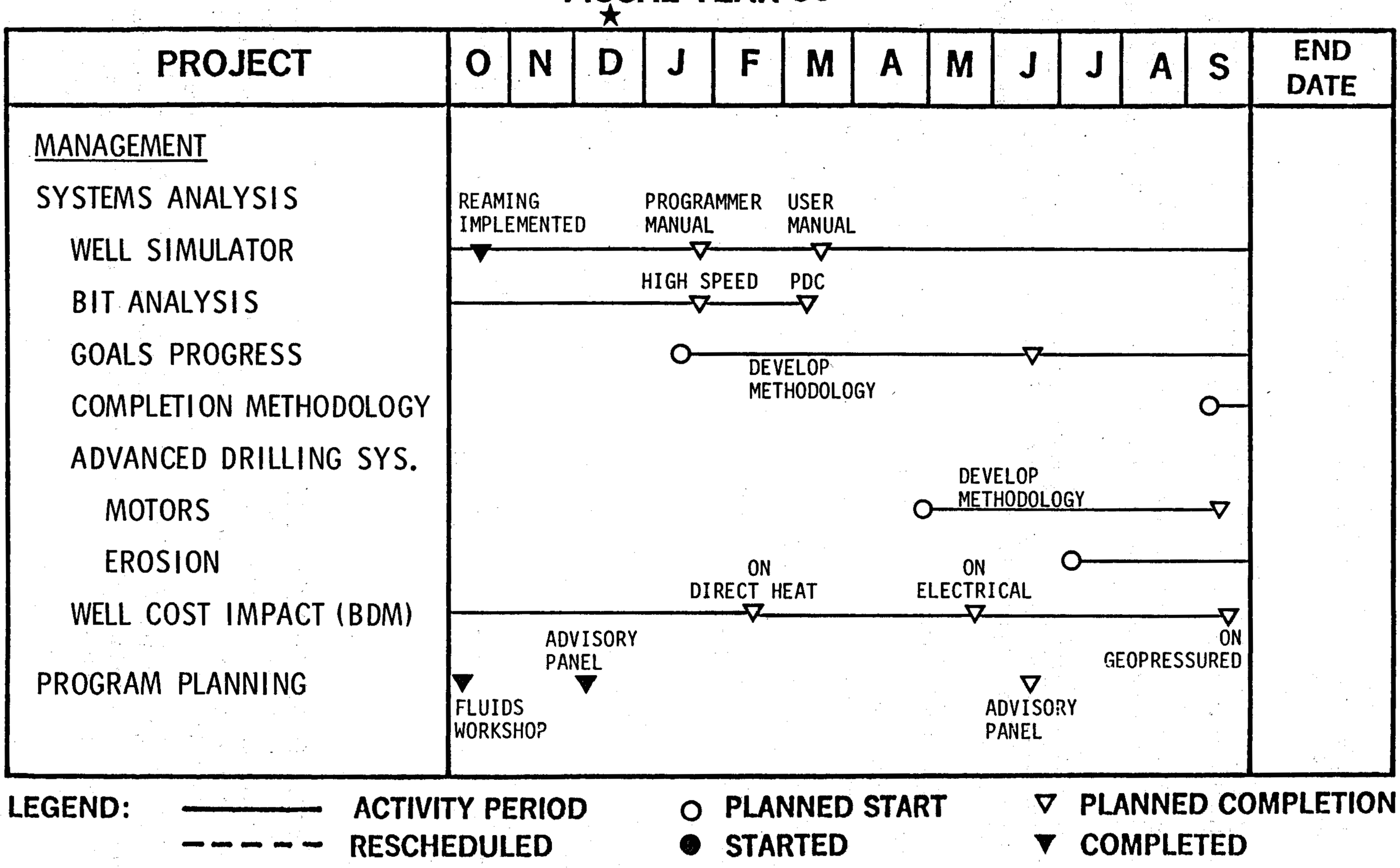


MANAGEMENT

Workshop on Geothermal Drilling Fluids

A workshop on Geothermal Drilling Fluids was sponsored by Sandia Laboratories for DOE/DGE on 9 October 1979 in Houston, Texas. Presentations describing ongoing fluids research sponsored by Sandia/DOE were given by Sandia technical consultants and by the contractors. Presentations by industry on their activities concerning drilling fluids were also made. A separate report of the workshop proceedings has been published by Maurer Engineering, Inc., for the Department of Energy and Sandia Laboratories.

Systems Analysis

J. Polito presented a paper on the well cost simulation program at the Joint National Meeting of the Institute of Management Science and the Operations Research Society of America on 14-17 October 1979, in Milwaukee, Wisconsin. He also participated in the Sandia effort to outline a drilling research program for geopressured resources.

Work continued on the revision of the draft of the programmers' manual for the simulation program and on a preliminary analysis of the trade-off between high-performance bits and drilling motors.

A new tape of GEOCITY was received from Pacific Northwest Laboratory. Also, tapes of the GEOCOST programs were received. BDM has both of these codes running now; the company is gaining experience in using the programs. Differences between published output from GEOTHM and those obtained by BDM have not been resolved with Lawrence Berkeley Laboratory.

Geothermal Drilling and Completion Advisory Panel

The semi-annual meeting of the Geothermal Drilling and Completion Advisory Panel was held 11-13 December 1979 in Washington, D.C. Sandia Laboratories hosted the meeting for DOE/DGE. After opening remarks by B. DiBona, DOE/DGE, an overview of the Geothermal Drilling and Completion Technology Development Program was presented by S. Varnado, Sandia Laboratories. The remainder of the meeting was devoted to presentations by Sandia and contractor personnel reviewing ongoing R&D projects and to daily executive sessions of the panel at which the project reviews were discussed and commented upon.

The reviews of internal Sandia projects were given as follows: P. Rand, Development of Geothermal Drilling Foams; A. Ortega, Planned Study of Aqueous Foam Flow with Heat Transfer; C. Carson, Systems Analysis of High-Pressure Jet Drilling; J. Finger, Development of Percussion Drilling Systems for Geothermal Applications; J. Polito, Analysis of Geothermal Well Costs; R. Salzbrenner, Drill Stem Corrosion Studies; and D. Glowka, Drill Bit Hydraulics Studies.

Contractor and other participant reviews were presented as follows: R. Hendrickson, Drilling Research Laboratory, Developments in Geothermal Bits; L. Hibbs, General Electric, STRATAPAX™ Bit Development for Geothermal Applications; J. Bonacci, Engelhard Industries, Generation of an Inert Drilling Fluid by Conversion of Diesel Exhaust Gas; R. Hamaker, Production Operators, A Portable Cryogenic System for Generating Nitrogen; N. Guven and L. Carney, Texas Tech University, Chemical and Temperature Effects on Clay-Based Drilling Fluids; E. Blick, University of Oklahoma, Flow Loop for Testing Geothermal Muds; K. Walter, Baroid, High-Temperature and -Pressure Mud Instrumentation; G. Tibbetts, Drilling Research Laboratory, Development of Downhole Motor Bearings and Seals; W. Maurer, Maurer Engineering, Performance of a Geothermal Turbodrill in the Los Alamos Scientific Laboratory (LASL) Hot Dry Rock Project; V. Johnson, Hydronautics, Development of Cavitating Jets for Geothermal Drilling; B. Radtke, NL Hycalog, Planned Field Experiments with Cavitating Jets; D. Summers, University of Missouri-Rolla, Development of Water Jet Erosion Drilling for Geothermal Applications; R. Snyder, Completion Technology Company, Geothermal Well Casing Design Study; L. Kukacka, Brookhaven National Laboratories, Development of Cements for Use in Geothermal Wells; D. Enniss, Drilling Research Laboratory, Interaction of Drilling Fluids with Producing Formations; B. Bohli, Daedalean Associates, Use of Cavitating Jets for Wellbore Descaling; and G. Wooley, Enertech, Wellbore Thermal Simulator Development.

Discussion of the presentations in the executive sessions of the advisory panel resulted in a wide range of recommended actions that included

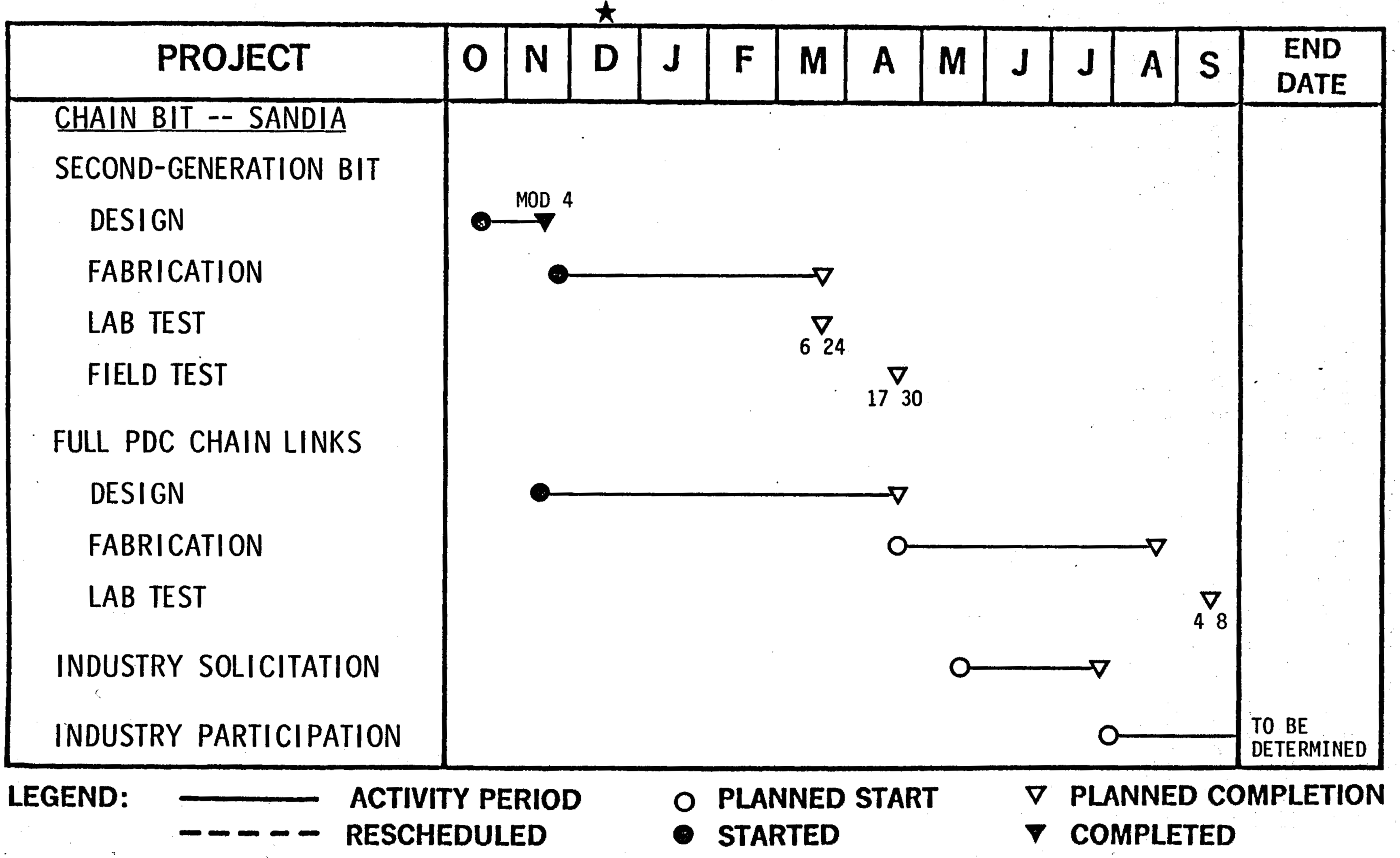
1. Early assessment of the program's progress toward achievement of the goal of a 25% reduction in geothermal well costs,
2. Directing more emphasis toward metal-to-metal seals for lubricated roller cone bits,
3. Extending polycrystalline diamond compact (PDC) drill bit field test parameters to include life and wear tests,
4. Expanding the investigation of foams as drilling fluids to include breakdown and disposal after use, heat transfer and thermal stability, and the effect of indigenous wellbore gases,
5. Investigating the feasibility of fluidized bed combustion for nitrogen generation,
6. Acquiring more information on the time-temperature morphology-change sequence of sepiolite as well as rheological properties after alteration,
7. Focusing the downhole motor bearings and seals test program on slanted seals with GRAFOIL®, on redundant seals, on effects of mud invasion into bearing lubricant reservoirs, and on hydrodynamically lubricated seals,
8. Expanding the overall coordination among the high-pressure jet drilling projects,

9. Extending the percussion drilling project to include full field tests and investigation of hammer materials and control,
10. Exploring the feasibility of developing a well casing design handbook for geothermal wells,
11. Increasing the inquiry into the time-temperature response of wellbore permeability to drilling mud invasion,
12. Collecting additional data on high-speed bit performance, and
13. Incorporating high-temperature cycling in the corrosion-fatigue tests on the newly developed drill stem steel compositions.

The detailed recommendations of the panel are delineated in the meeting minutes, which are being distributed by separate correspondence.

GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80



INTERNAL R&D

Project: Continuous Chain Bit
Technical Consultant: J. St. Clair (505) 264-7678

Project Objective

The objective of this project is to design, fabricate, and test a prototype downhole replaceable drill bit.

Project Status

The Prototype II, Mod 2, continuous chain drill bit field tests were conducted at NTS during the period 5-20 June 1979. The results were included in the September Semi-Annual Report. A followup field test at NTS was initiated in mid-September 1979. Unexpected rapid wear of the chain link cutting surfaces was experienced, and the tests were terminated after determination that field repair of the drills could not be made. Post-test analysis of the Mod 3 chain drills revealed that the mud flow channel in both bit bodies had ruptured. The failure is believed to have occurred during pre-drilling surface cycling tests.

Redesign and fabrication of a Mod 4 chain drill is underway. Additional field tests are currently scheduled for April 1980. A parallel effort to develop an all-polycrystalline diamond compact (PDC) chain link has also been initiated.

Continuous Chain Bit
Quarterly Progress for October-December 1979

A program schedule for FY 1980 was completed. The primary thrust of the program is to conduct a field test to more fully demonstrate the potential of the continuous chain bit. An all-PDC chain link will be developed in parallel with this effort. When a successful field test is achieved, a private industry partner will be sought to participate in building a chain bit to implement transfer of this technology.

The primary project emphasis during the quarter was on determining the cause of the failure of the two Prototype II, Mod 3 chain bits, during the September 1979 tests at NTS. Redesign to correct the failure and rebuilding of the two bits were also initiated.

Post-test analysis of the two chain bits revealed that the mud flow channel in both bit bodies had ruptured (see Figures 1 and 2). This failure is believed to have occurred during surface cycling tests prior to drilling operations. The resultant internal leakage of drilling mud caused each of the four cutting surfaces to fail prematurely because of water starvation. The evaluation showed the weld joint structural strength was marginal. This condition, coupled with stress concentration and fatigue, caused the joints to rupture.

The preliminary design effort for replacing the ruptured section in both bodies has been completed. The stress analysis of two different methods for repairing the ruptured flow channels in the bit bodies continued during the reporting period. The weld joint that failed must be capable of withstanding pressures as great as 20.7 MPa (3 000 psi). This strength criterion should provide protection against high-pressure spikes that are experienced for periods of short duration during cycling of the chain links.

Final tear-down of the spline tube assemblies was completed after milling away six hardened pins on each bit. Inspection of piece parts revealed only minor damage to one of the hooks that is used to cycle the chain links. Vibration had caused a locating roll pin to fail. Both the male and female splines were in very good condition.

Procurement actions were started to purchase new chain bit piece parts and commercial equipment needed for the field test scheduled for April 1980. Rework of the larger chain bit subassemblies has been scheduled in the Sandia heavy machine shop for January 1980.

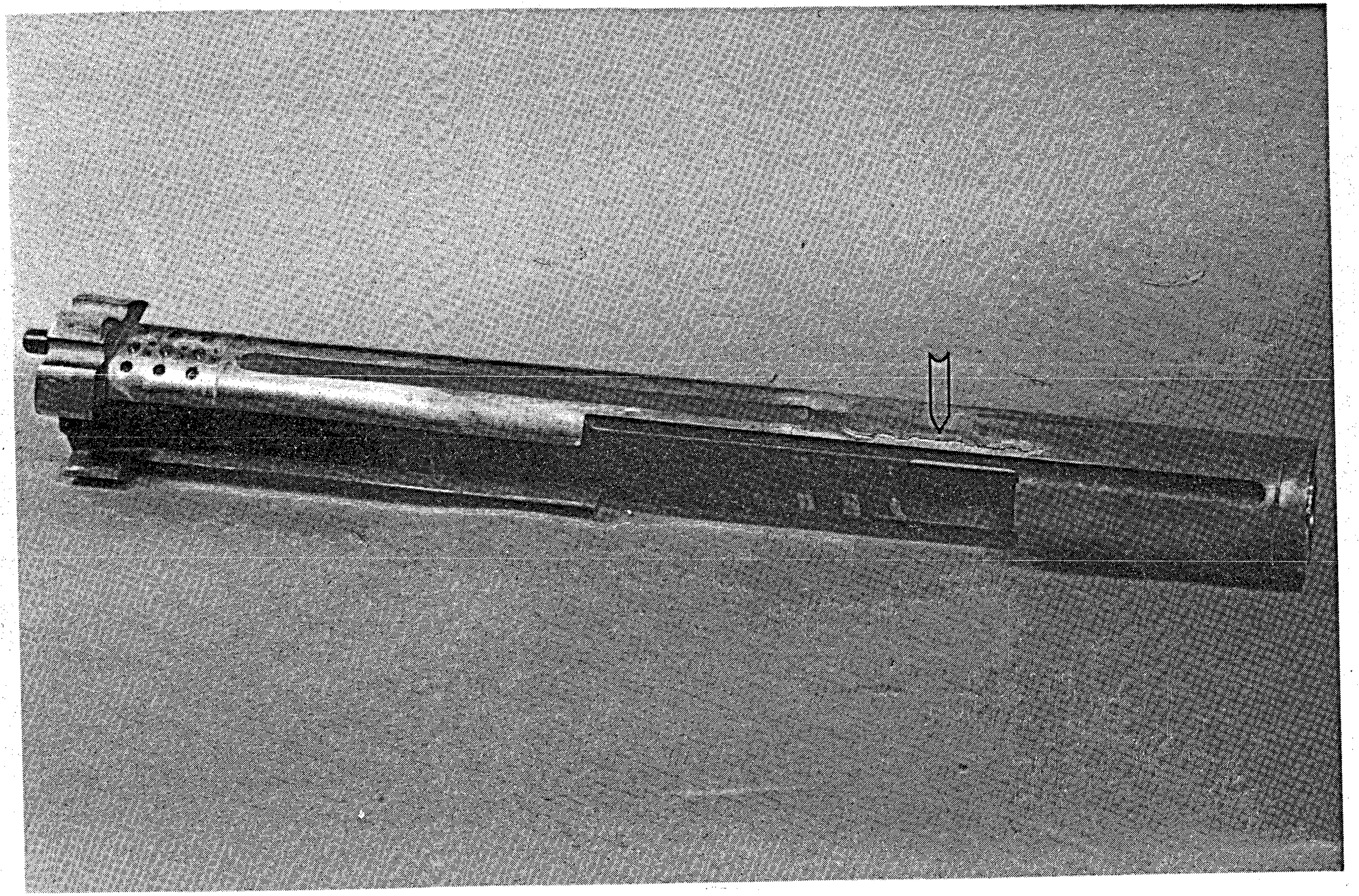


Figure 1. Ruptured Mud Flow Channel in Continuous Chain Bit Body

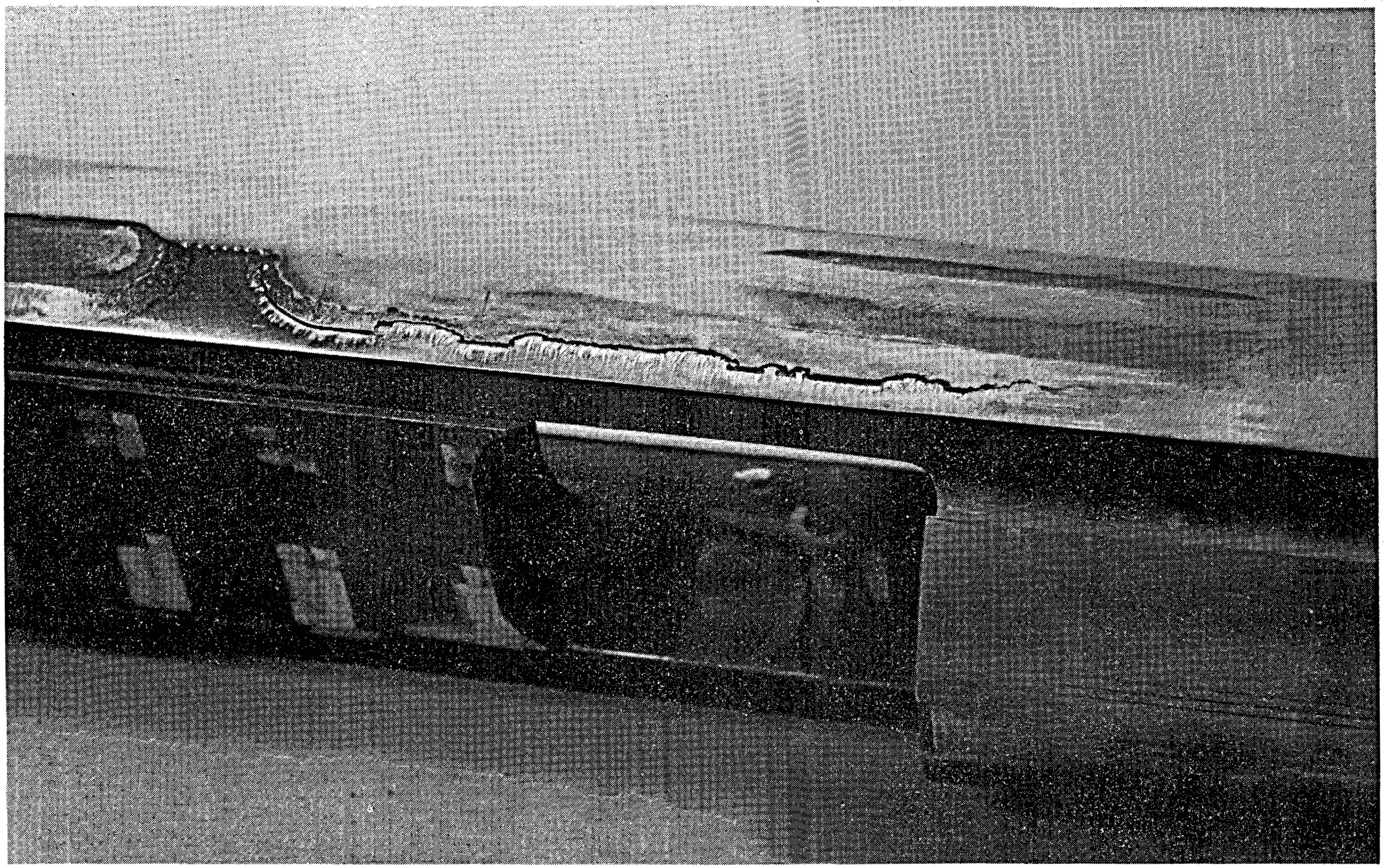


Figure 2. Close-Up View of Ruptured Mud Flow Channel

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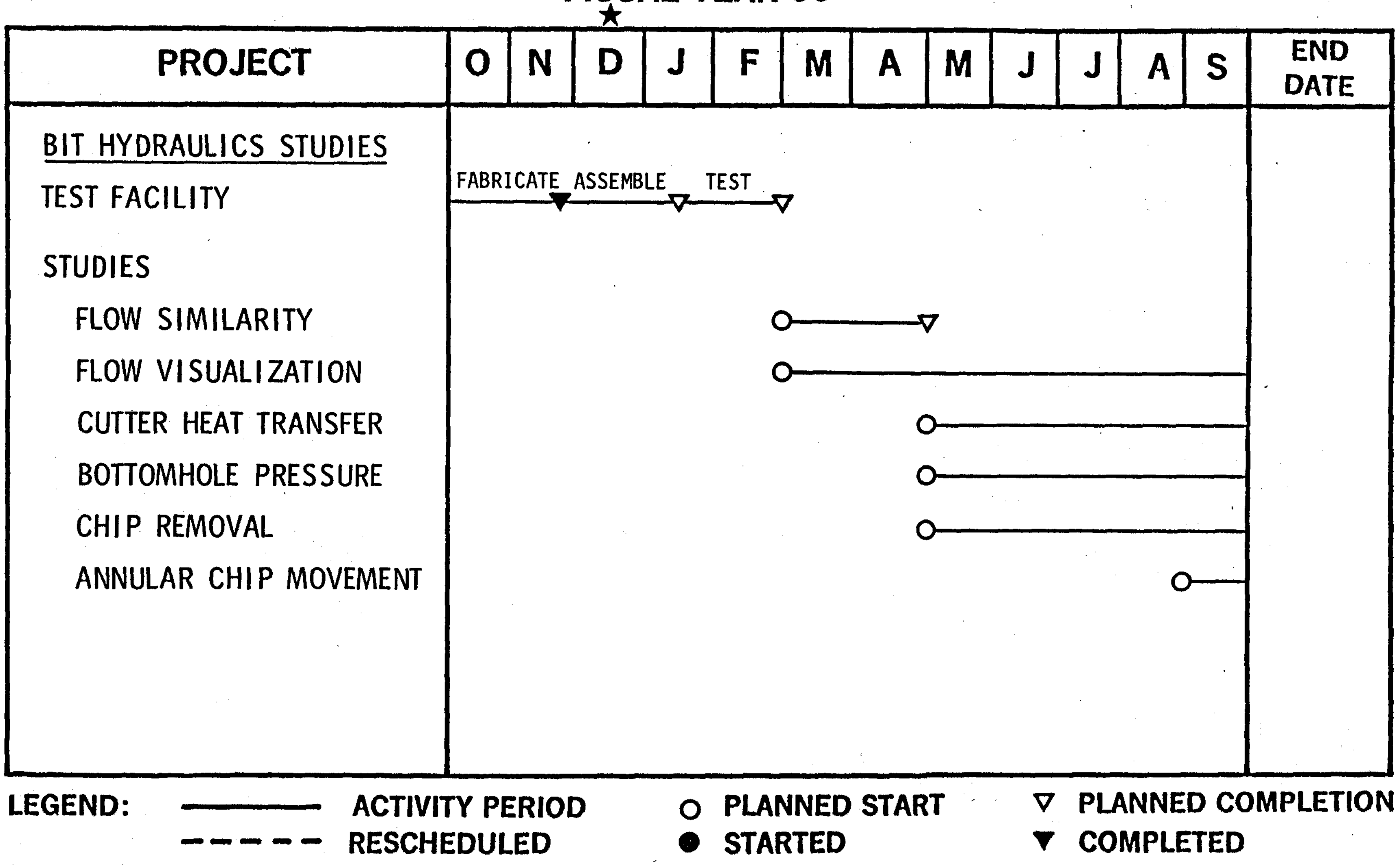

INTERNAL R&D

Project: Bit Hydraulics Studies
Technical Consultant: D. Glowka (505) 264-3601

Project Objective

The objective of this project is to optimize the design of bit hydraulics for geothermal drill bits. Analytical and experimental investigations will be conducted to determine optimal position, size, and placement of nozzles used for cooling and cleaning purposes. A bit hydraulics laboratory will be built in order to visualize the flow field along the bit face.

Project Status

Design of the test facility has been completed. An internal R&D report has been issued with recommended designs for the test apparatus. A technical investigation procedure for the study has been updated. Design and detailed stress analysis of special-order items for the test stand have been completed. Instrumentation design and survey of available instrumentation are continuing. Fabrication of the test stand is underway.

Bit Hydraulics Studies
Quarterly Progress for October-December 1979

The FY 1980 milestone schedule for the Bit Hydraulics Studies Project was revised to reflect more realistic estimates for the fabrication and check-out of the test stand. Also, more detail concerning specific studies has been added to the schedule to reflect refinements and additions to the program plan since the original milestones were proposed in January 1979.

These study additions are the result of the increased capability designed into the test stand. The ability of the test stand to withstand full-scale flow rates has led to the inclusion of a flow similarity study in the program plan. This study will assess the validity of Reynolds-number scaling by comparing the flow patterns across the bit face that result from full-scale flow rates with those that result from flow rates reduced according to scaling laws. These laws were discussed in the December 1978 progress report.

The ability to instrument the bit through a slip-ring assembly has led to the inclusion of a cutter heat-transfer study. In this study, the convective heat-transfer coefficient for the various cutters in the bit will be measured under a variety of test conditions. This will be accomplished with thin-film, temperature-dependent resistors. These resistors, similar to strain gages in size and shape, can be mounted at various positions on the cutter faces and studs. By using electronic circuitry to maintain the resistors at a constant temperature above the ambient fluid and by measuring the current passing through each resistor, the convective heat transfer coefficients can be calculated. These values, together with theoretical and experimental heat generation values during cutting, can be used to compute cutter temperatures. This will allow an assessment of the ability of the hydraulics to effectively cool the cutters.

As reported in July 1979, the increased capability of the test stand has resulted in project schedule slippages. Fabrication of the test stand is taking longer because of the more stringent structural and tolerance requirements imposed by this increased capability. Three of the five separate fabrication orders for machined parts of the test stand have been delivered. The remaining two orders were encountering delivery delays into the latter part of the reporting period. Assembly of the parts received has begun. Any impact on the project schedule because of late parts delivery will be assessed in the next quarterly reporting period. Efforts will be made to expedite the assembly and proof-testing of the test facility.

The Lexan material for the simulated borehole was delivered, and a task was undertaken to machine the material to the required dimensions. The borehole consists of two parts, a cylinder and a bottom plate. The Lexan cylinder [30.5-cm (12-inch) o.d.] was bored with conventional machining methods to the 16.5-cm (6.5-inch) bit diameter. The bottom of the simulated borehole consists of a circular Lexan plate that fits against the bottom of the cylinder and is sealed with a static O-ring.

In order to simulate the actual shape of the borehole to the greatest possible extent, a decision was made to attempt to cut the bottomhole pattern of the stud-mounted polycrystalline diamond compact bit into the Lexan plate. To accomplish this, the plate and bit were chucked into a lathe. The bit was forced into the plate while the latter was rotated. Although there were initially some doubts about the ability of the bit to successfully cut smooth patterns in such a plastic material, the results were excellent. Individual cuts within the bottomhole pattern were so smooth that the clarity required for flow visualization experiments was easily achieved.

During this machining test, observations revealed that the cutting action of individual cutters could be clearly seen through the opposite face of the Lexan plate. This discovery raises the possibility of studying the mechanical cutting action of the bit, as well as hydraulics, with high-speed photography during a simulated drilling operation. Although drilling in Lexan would not accurately simulate rock drilling, the relative engagement of individual cutters into the material and the effects of this engagement on hydraulics performance can be studied. These studies could lead to improvements in cutter placement and hydraulic configuration. Such studies are planned when the drilling rig test facility, currently under construction, is completed.

GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

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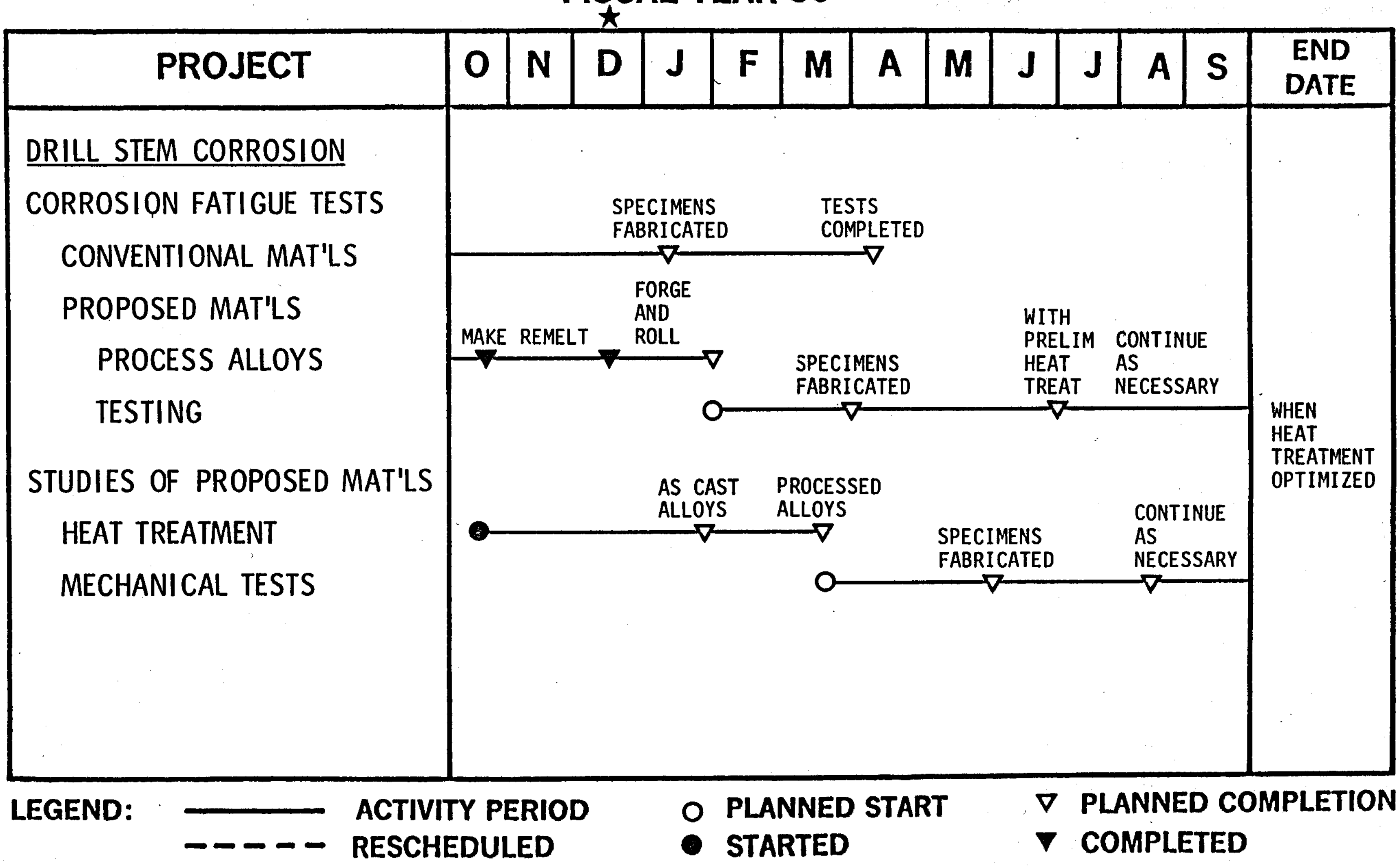

INTERNAL R&D

Project: Drill Stem Corrosion
Technical Consultant: R. Salzbrenner (505) 264-5041

Project Objective

The project objective is to study the metallurgical composition of drill stem presently available and to make compositional changes in drill stem material to maximize its chemical resistance to the geothermal H_2S environment without large sacrifices to its mechanical properties or cost.

Project Status

An Internal R&D research report has been issued. The test facility design has been completed, and the facility will be built by the time test specimens are ready for test. Compositional changes to the drill stem material have been defined, and conventional drill stem material suitable for the corrosion fatigue study has been ordered. Unavoidable delays in the delivery of the steel for test specimens delayed the test program start. However, the dual-phase steel alloys have now been made, and the conventional drill stem material is in the process of being shipped to Sandia. General corrosion tests have been initiated. Processing of the dual-phase alloys has been initiated.

Drill Stem Corrosion
Quarterly Progress Report for October-December 1979

The silicon-based dual-phase steels were vacuum-induction melted and cast by the Sandia Melting Laboratory. The steels were made in two separate runs: the first on 12 October and the second on 17 October. Each run contained about 227 kg (550 pounds) of steel and was split between two compositions. Table 1 lists the alloy designations and compositions.

Table 1

Silicon-Based Dual-Phase Steel Alloys

Run	Alloy Designation	Alloy Composition Fe plus (by weight percent)		
		Si	C	V
1	V-12-1	2.0	0.1	--
	V-12-2	2.0	0.1	1.0
	V-12-3	2.0	0.1	1.0
2	V-13-1	2.0	0.1	0.1
	V-13-2	2.0	0.1	0.2

The ingots of each alloy were prepared for vacuum arc remelting in order to homogenize each alloy. Subsequently, each ingot will be sent to the Rocky Flats Plant for "breaking down," which will consist of hot forging and rolling into plate approximately 1.27 cm (0.5 inch) thick.

The as-cast ingot material was tested for hardness. Table 2 shows the hardness and the corresponding approximate tensile strength for each of the alloys.

Table 2

As-Cast Hardness and Tensile Strength of Alloys

Alloy Compositions	Hardness R_B	Approximate Tensile Strength MPa	(ksi)
Fe - 2.0 Si - 0.1 C	78.1	482.6	(70.0)
Fe - 2.0 Si - 0.1 C - 0.1 V	79.8	498.5	(72.3)
Fe - 2.0 Si - 0.1 C - 0.2 V	83.4	533.7	(77.4)
Fe - 2.0 Si - 0.1 C - 1.0 V	83.0	528.8	(76.7)

NOTE: Alloys listed in order of increasing vanadium content

The hardness values indicate tensile strengths in the 483 to 538 MPa (70 to 78 ksi) range for the as-cast alloys. These values are below those required for grade E pipe, approximately 655 MPa (95 ksi). This result is expected since the alloys have not undergone mechanical processing or heat treatment.

The conventional pipe ordered through Loffland Brothers Drilling Company is currently being prepared for shipment to Sandia. On arrival, sections of the material will be machined into test specimens and tested along with the Sandia-made alloys in order to calibrate the results.

Samples of the as-cast ingots of the silicon-based dual-phase steels were cut, and some initial heat treating studies were performed. Since the samples were from the ingot, a number of problems with this initial characterization may exist. These possible problems include macrosegregation and nonhomogeneity in the ingot. Thus, the sample taken from one particular area may not be representative of the overall composition. The as-cast material also has a very large grain size compared to forged or worked material. The large grain size may affect the strength as well as the time response to the various heat treatments. In spite of these possible problems, an indication of heat treat response of these alloys can be gained through work on as-cast ingot material.

Figures 3 through 6 show the hardness of alloys V-12-1 (Fe-2.0Si-0.1C) and V-13-1 (Fe-2.0Si-0.1C-0.1V) as a function of heat treatment. Figure 3 shows the hardness (as well as the approximate ultimate tensile strength) as a function of the austenitizing temperature for samples of alloy V-12-1 in the as-quenched condition as well as in the quenched and tempered condition. The samples were tempered at 550°C (1022°F) for 1 hour. Figure 4 shows the same information for alloy V-13-1. Each of these alloys behaves as expected; the hardness and strength increase as the austenitizing temperature increases, because more carbides are dissolved at higher temperatures. Consequently, on quenching, an increased amount of carbon is released for hardening of the martensite. The tempering, after quenching, allows carbides to form in the fully martensitic matrix. The carbon level in solid solution decreases, thus decreasing the hardness but increasing the toughness of the alloy. The addition of 0.1 vanadium to the base composition increases slightly the strength of the alloy in both the as-quenched and the quenched and tempered conditions.

When samples of the alloy are given intercritical annealing treatments after austenitizing and quenching, the final hardness again depends on the temperature of the initial austenitizing treatment. Hardness as a function of various intercritical annealing temperatures is shown in Figures 5 and 6. The irregularity of the curves may have resulted in large part from the use of as-cast ingot material. The general trend of these curves indicates that, in both alloys, the samples which are austenitized at the lower temperature have the highest hardness after the intercritical anneal treatment. The cause of this phenomenon has not been determined at this time, but the effect seems to be connected again with the amount of carbide dissolved during the austenitizing treatment. The higher austenitizing treatment puts more solute of C, Si, and V, if present, back into solid solution. In this state, the hardening, primarily in the ferrite, is not as great as that provided by the V-carbides and/or Si-carbides. The prime

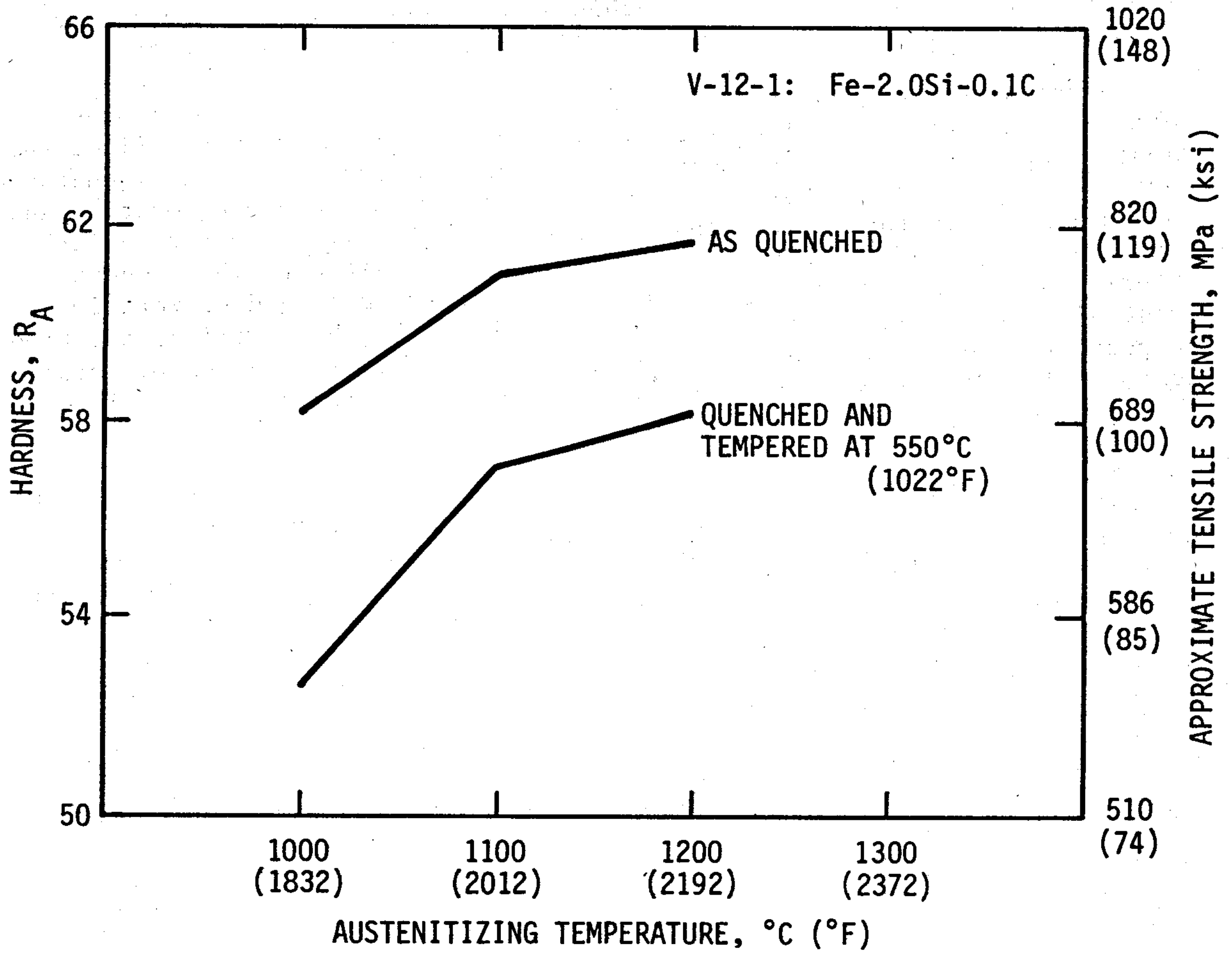

Figure 3. Hardness and Approximate Tensile Strength of Alloy V-12-1 as a Function of the Austenitizing Temperature

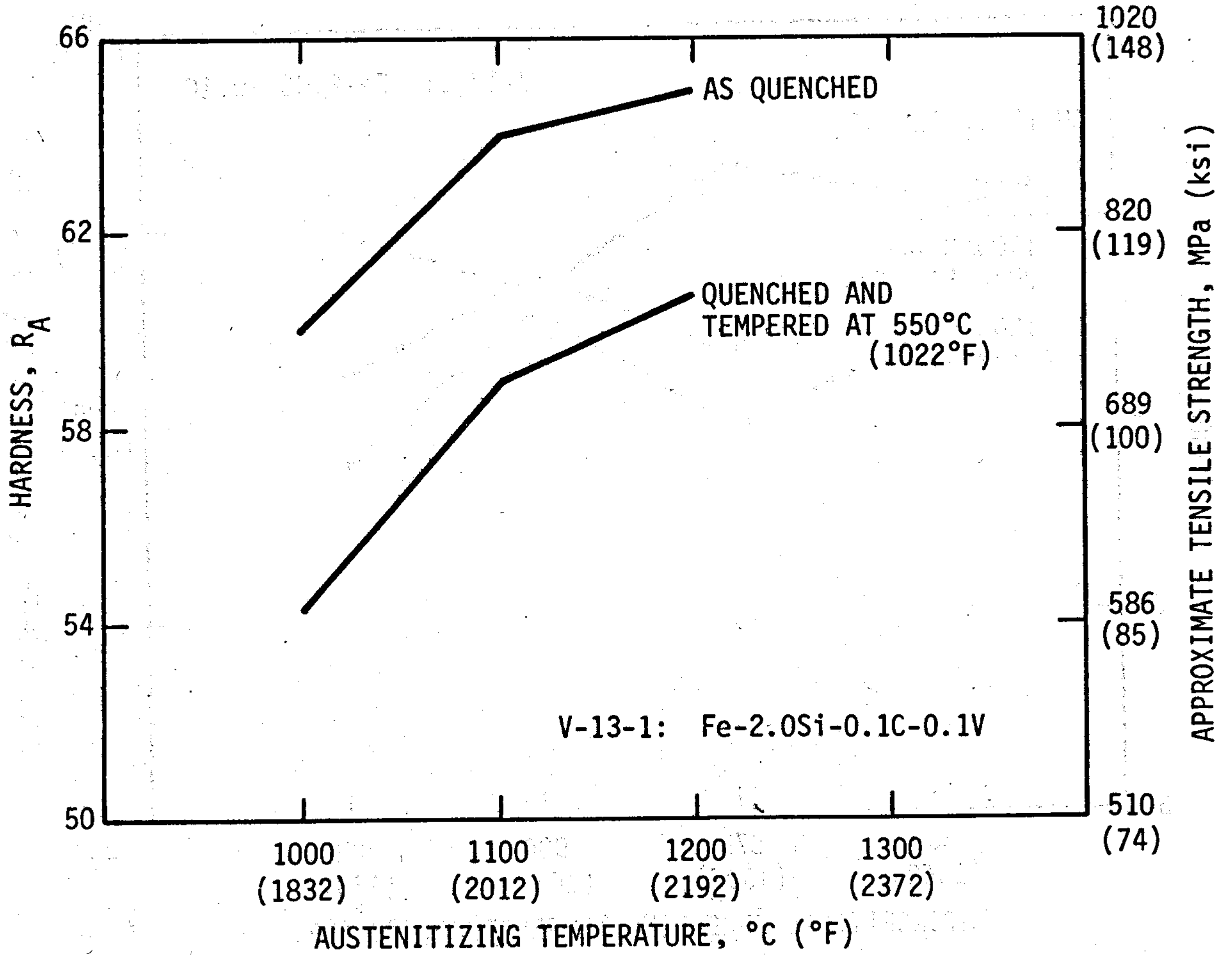

Figure 4. Hardness and Approximate Tensile Strength of Alloy V-13-1 as a Function of the Austenitizing Temperature

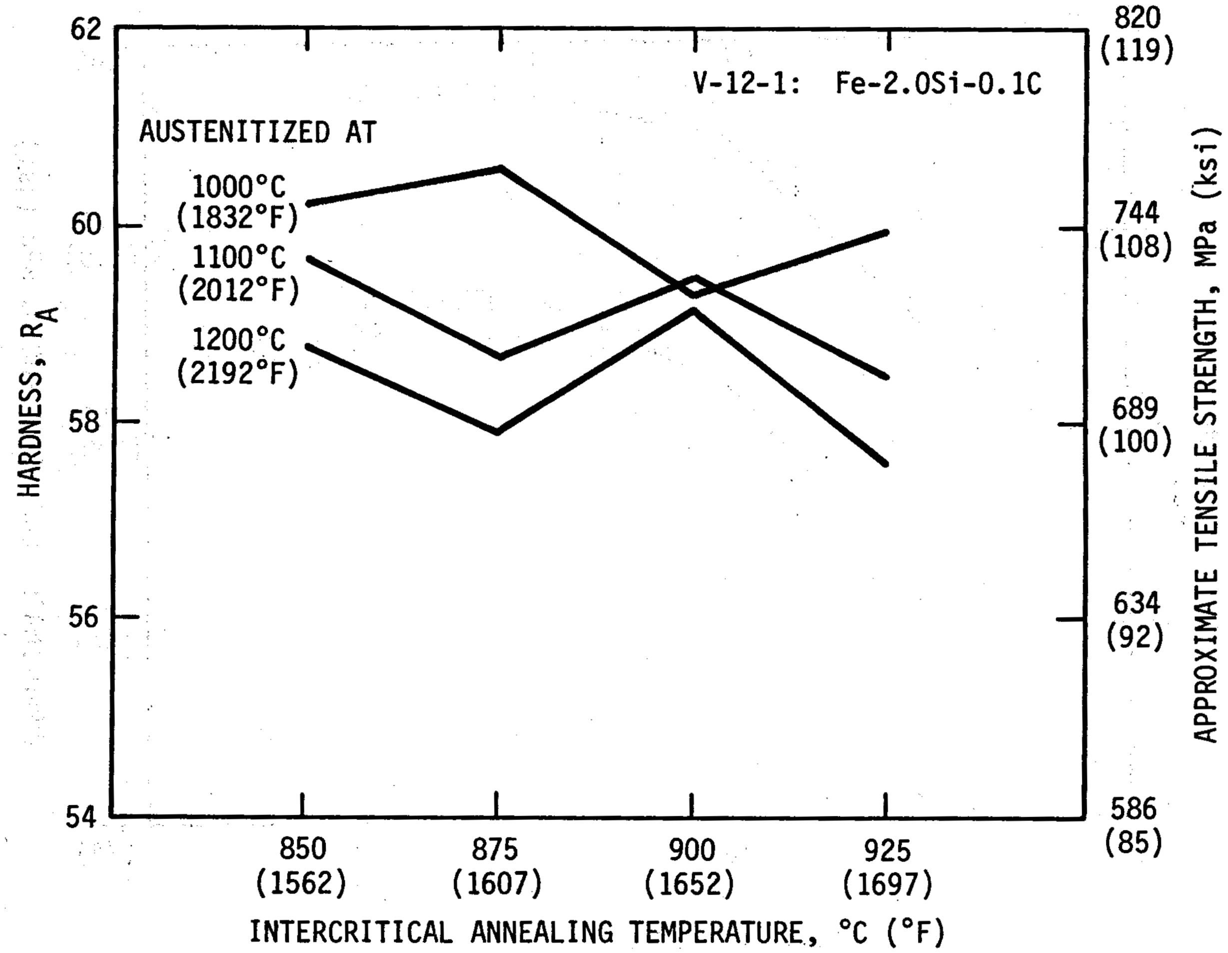

Figure 5. Hardness and Approximate Tensile Strength of Alloy V-12-1 as a Function of Various Intercritical Annealing Temperatures

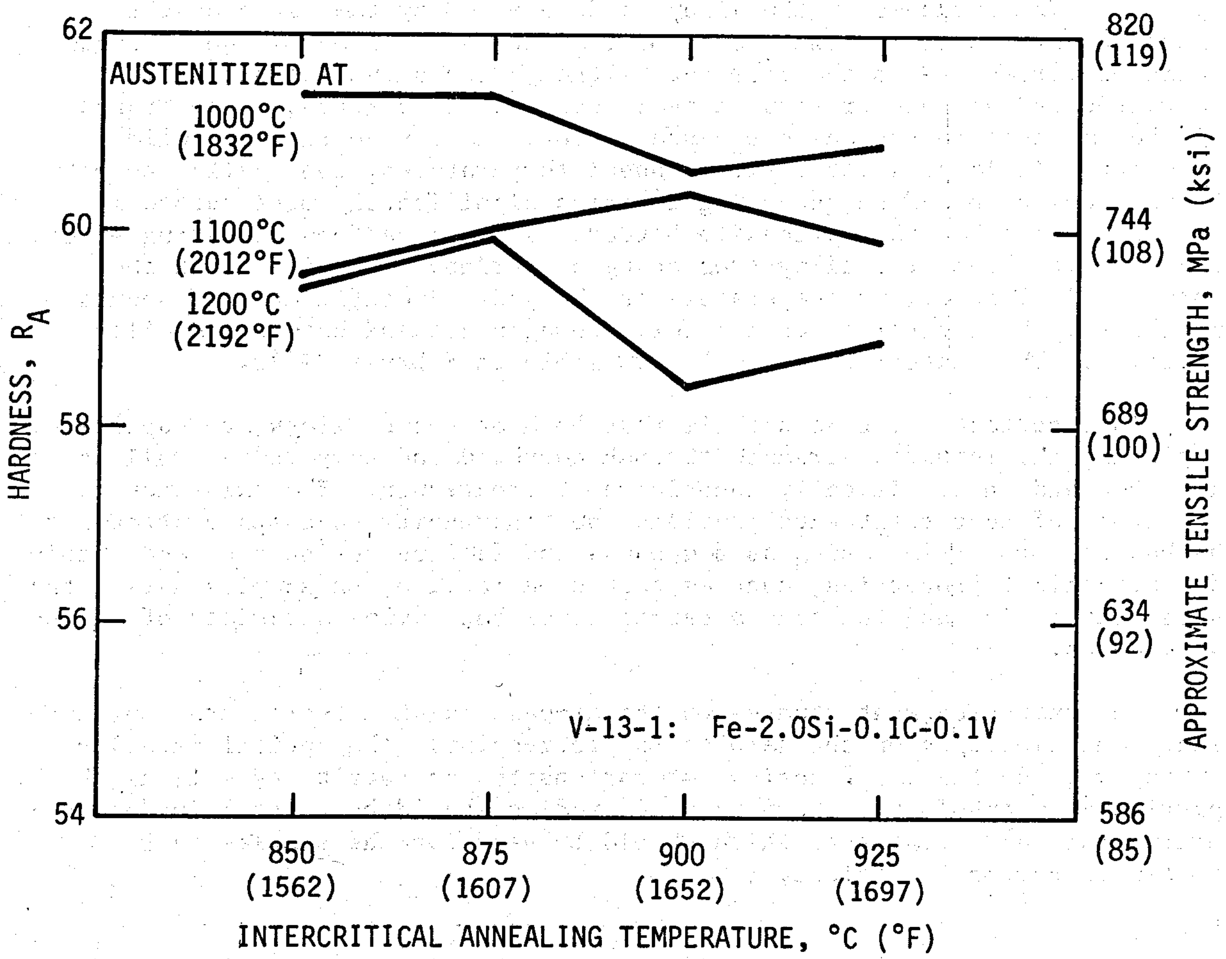

Figure 6. Hardness and Approximate Tensile Strength of Alloy V-13-1 as a Function of Various Intercritical Annealing Temperatures

factor for determining the hardness differences produced by the different austenitizing temperatures seems to be the strength of the ferrite. Verification of this explanation will require transmission electron microscopy studies of the samples in various heat treat conditions.

The particular intercritical annealing temperature determines the fractions of ferrite to martensite. The higher the intercritical anneal temperature is, the higher the fraction of martensite in the quenched alloy will be. The hardness of the alloy is determined by the ratio of the amount of martensite to the amount of ferrite, as well as by the strength ratio of martensite to the ferrite. Although the amount of martensite increases as the intercritical anneal temperature increases, the hardness of that martensite decreases because it contains less carbon in solid solution. At lower intercritical anneal temperatures, the smaller amount of martensite formed on quenching contains significantly more carbon in solution and makes the martensite harder. Thus, a self-compensating effect occurs which keeps the alloy from changing hardness drastically as the intercritical annealing temperature is changed. Specific changes should more easily be determined on the fully homogenized and hot-worked alloy material. This material should be available in February 1980.

An important point to note is that both of these alloys are capable of achieving the required strength through quenched and tempered as well as quenched and intercritically annealed heat treatments. The existence of two types of heat treatments provides the opportunity to compare attendant mechanical properties, such as toughness and fatigue resistance, and chemical-mechanical properties, such as corrosion fatigue, on samples having the same composition and the same strength level but having a variety of microstructures.

The heat treatment studies on the as-cast ingot material are continuing. Metallography on the samples is progressing. The optical metallography will define the fractions of martensite and ferrite as well as the particular morphology. These initial studies should be helpful in determining the heat treatments which should be used for the samples to be tested in corrosion fatigue.

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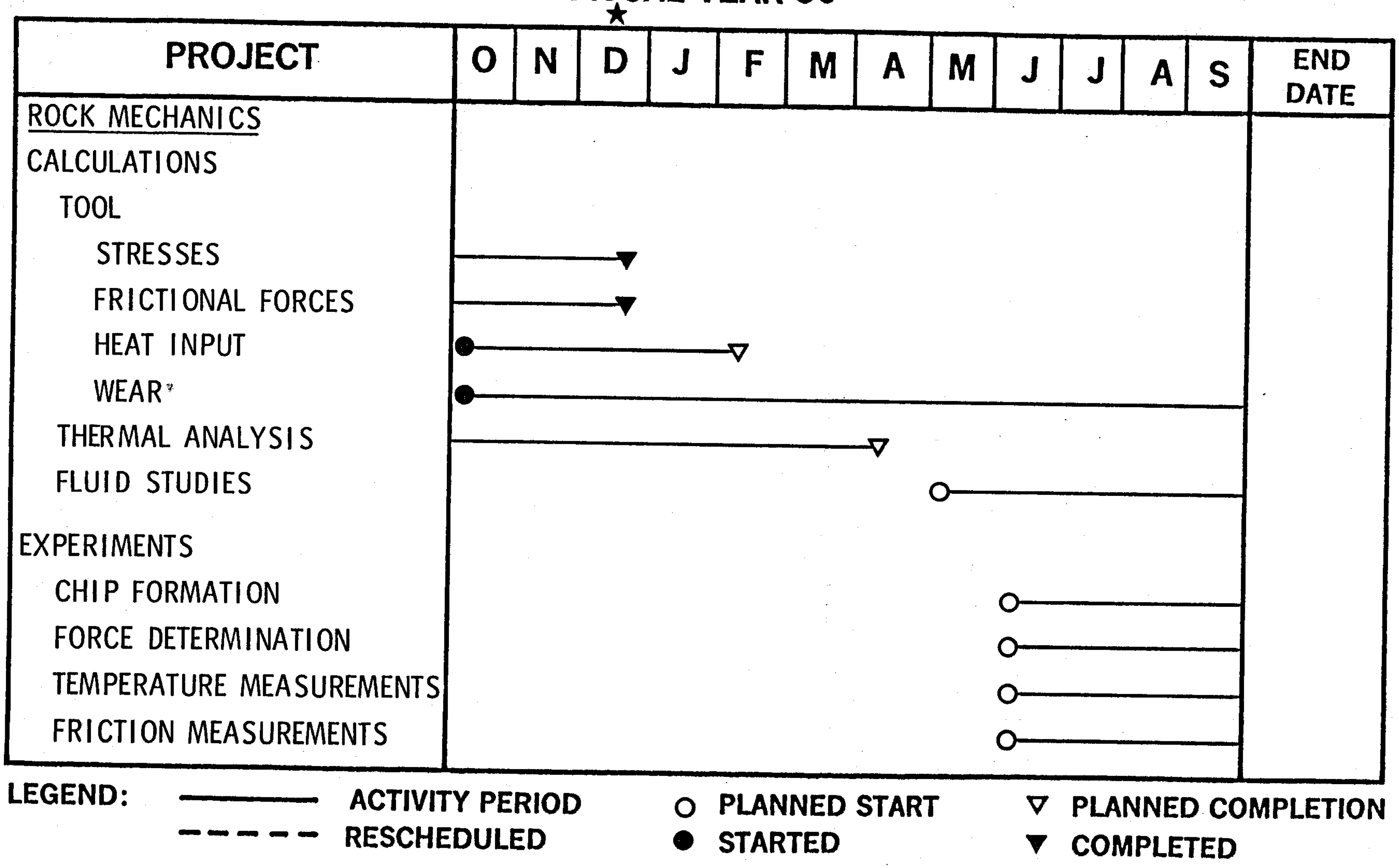

INTERNAL R&D

Project: Rock Mechanics for Polycrystalline Diamond Compact Cutters
Technical Consultant: D. Wesenberg (505) 264-0129

Project Objective

The project objective is to conduct research and testing of the chip formation process of rock cutting tools utilizing polycrystalline diamond compact (PDC) cutters in order to optimize the design of bits using these cutters.

Project Status

A study of the procedures necessary for conducting chip formation testing has been initiated. Modeling of the rock/tool interface has begun. Calculations of tool stresses and frictional forces have been completed. Calculations of heat input and wear are being made. A thermal analysis is being conducted.

Rock Mechanics for Polycrystalline Diamond Compact Cutters
Quarterly Progress for October-December 1979

Work continued on the thermal analysis, and calculations of tool stresses and frictional forces were completed. In addition, effort was initiated this quarter on tool heat input and wear calculations.

TOODY was used to model the drag tool/rock interaction for a drag tool with a -20° rake angle. The tool force histories were similar to those observed for other rake angles. The predominant failure mechanism was tensile failure. The position and orientation of the cracks in the rock were similar to those calculated for other rake angles. Stress and velocity histories on the bit and rock surface were generated for A. Ortega and used in his frictional heating studies.

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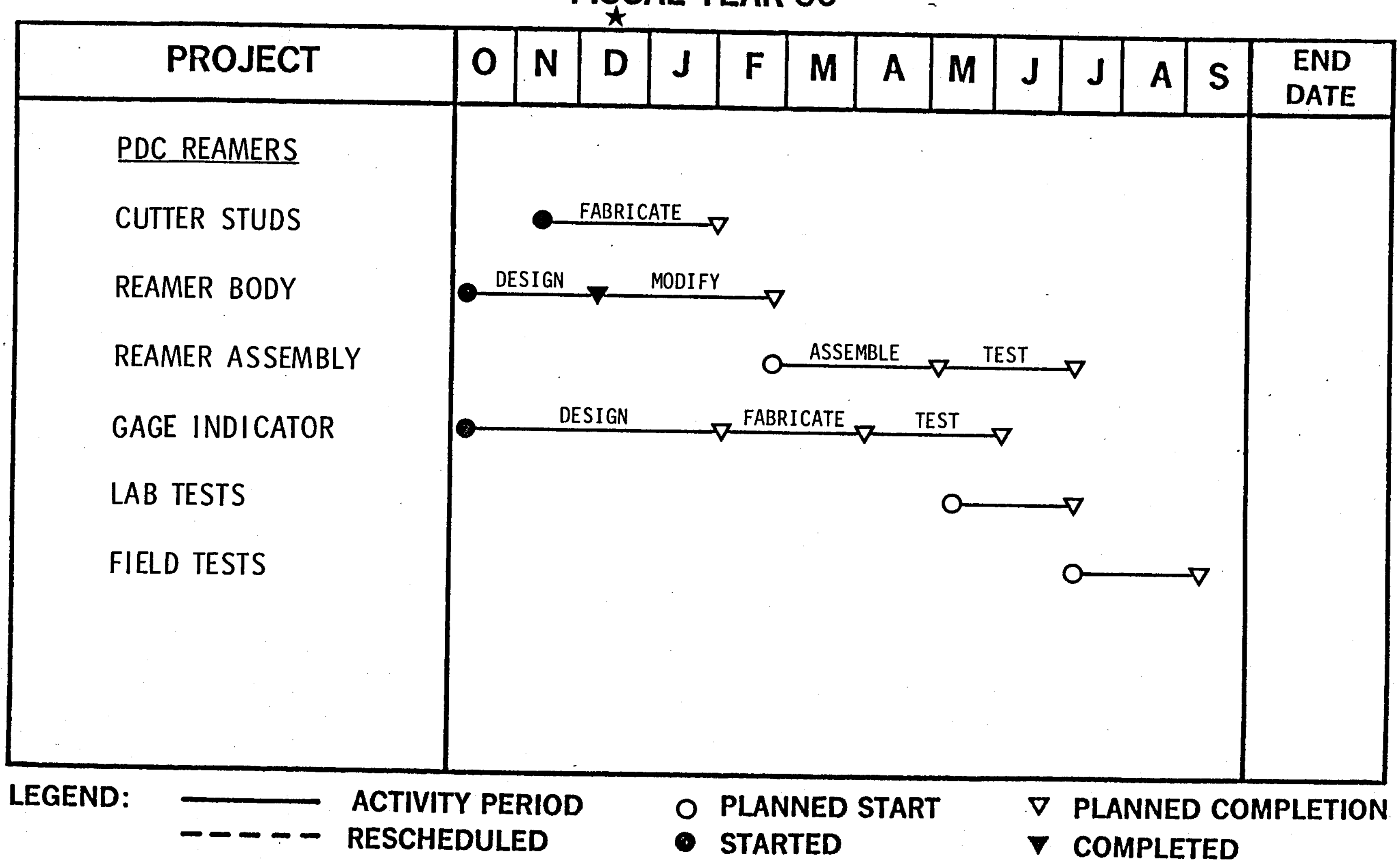

INTERNAL R&D

Project: Polycrystalline Diamond Compact Reamers
Technical Consultant: L. Baker (505) 264-2176

Project Objective

The project objectives are to modify existing, conventional reamers to allow placement of manmade diamond cutters on the periphery; to field test the modified reamer for substantiation of expected life increase of the reamer; and to determine anticipated improvement in ability of the reamer to size the wellbore.

Project Status

The conventional drilling reamer has been received at Sandia. Preliminary design for cutter location on the reamer has been initiated. Modification of a bottomhole roller-reamer body for installation of cutters has been completed, and the mounting hardware has been designed and is currently being fabricated.

Polycrystalline Diamond Compact Reamers
Quarterly Progress for October-December 1979

The FY 1980 project schedule was restructured to be compatible with Sandia machine shop priorities and manpower. Field tests of the polycrystalline diamond compact (PDC) reamer in the Geysers known geothermal resource area (KGRA) have been tentatively scheduled for the August-September 1980 time frame. A current industry shortage of PDC half-round cutters is expected to be resolved in time to meet the new schedule.

During this reporting period, a review of the captivation and attachment design for the PDC cutter blocks and for the air-drilling gage indicator assemblies was undertaken. This redesign effort was considered prudent in view of the failure of certain fasteners during the field tests of the continuous chain bit. Post-test examination of the chain bit revealed that some fasteners, although staked and welded, had come loose and/or fallen out of their mounting location. This condition apparently resulted from the severe downhole vibrations encountered. The redesign effort is seeking to prevent any similar failure of the PDC reamer fasteners during field tests.

Design of the downhole gage wear indicator for the reamer was initiated during this quarter. Evaluation of the DynaDrill wireless tool indicator for use as a signal generator for gage wear indication in fluid drilling applications was undertaken. Fabrication of cutter studs and improvement of the diffusion bonding process for mounting the cutters continued during the reporting period.

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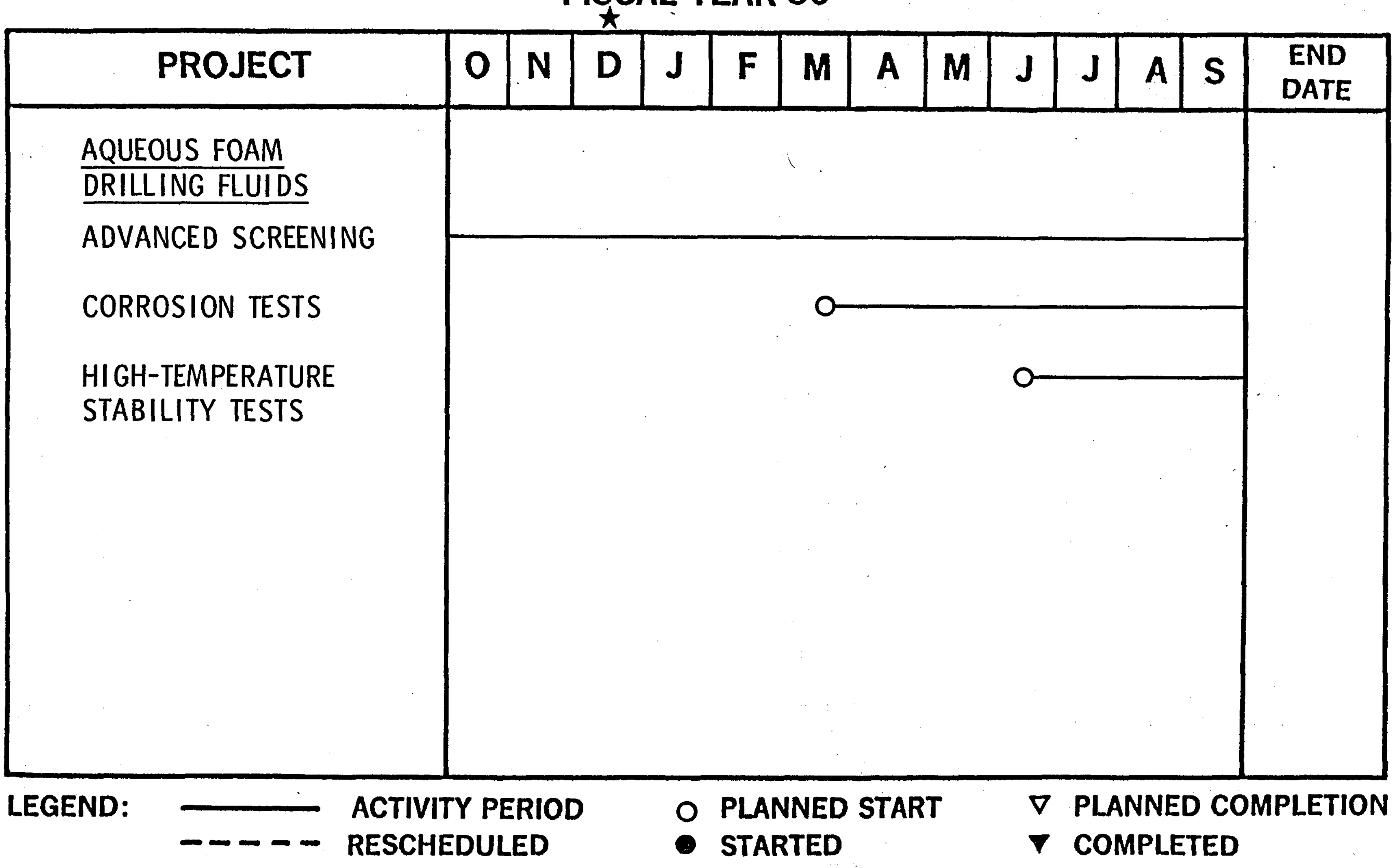

Project: Aqueous Foam Drilling Fluids for Geothermal Applications
Technical Consultant: P. Rand (505) 264-7953

Project Objective

This project will identify and develop aqueous foams for use in geothermal applications. The foams will be capable of operating in elevated temperature environments to 310°C (590°F) and will exhibit chemical and foaming stability and anticorrosive and antioxidant properties.

Project Status

An initial report has been issued defining the basic problems to be encountered, the various solutions thought to be obtainable, and a project procedure. Initial surfactant screening has been completed. Fifty-six surfactants have been evaluated before and after exposure to a 260°C (500°F) temperature cycle. Twelve surfactants were selected for further testing. The evaluation of these surfactants in various chemical environments at 260°C (500°F) has been completed. Six surfactants, selected because of their good performance in the chemical environment tests, have been evaluated after exposure to 310°C (590°F) in deionized water. Four of these surfactants showed good to excellent performance and will now be evaluated in various chemical environments at 310°C (590°F). Surfactant evaluation at 260°C (500°F) will be continued on new surfactants that have been recommended.

Foam Drilling Fluids
Quarterly Progress for October-December 1979

A Sandia Laboratories report, "Aqueous Foam Surfactants for Geothermal Drilling Fluids: I. Surfactant Screening," was prepared and was under review during the reporting period. The report includes trade names, suppliers, and all of the data generated during the screening study.

A review of the data from the chemical environment tests showed that some surfactants performed well in all tests. A summary of the results of the chemical environment tests is given in Table 3. The qualitative ratings in the table are determined from the foam and solution tests run after exposure to the various environments. Table 3 will be updated as more data are generated.

Table 3

Effect of High Temperatures and Various Environments on Surfactant Solutions-Qualitative Ratings

				Temperature/Environment						
				310°C (500°F)						310°C (590°F)
Chemical Type	Trade Name	Ref. No.	Wt-% Active Ingredient	DI-H_2O Air	DI-H_2O Nitrogen	1.0MNaCl Air	0.1MNaOH Air	0.1MHCl Air	Brine I Air	DI-H_2O Air
Alpha Olefin Sulfonate	Lakeway 301-10	1	0.5	E	E	E	E	E	E	G
Alpha Olefin Sulfonate	Sulframin 14/16 AOS	2	0.5	E	E	G	E	E	E	G
Coco Betaine	Velvetex BC	3	0.5	E	E	E	G	E	E	U
Proprietary Anionic	Thermophoam BW-D	4	0.5	E	E	E	E	G	E	E
Alkyl Aryl Sulfonate	Ninex N-300	5	0.5	G	G	U	G	U	NT	NT
Alkyl Amide Sulfonate	Igepon TC-48	6	0.5	P	E	U	P	U	NT	NT
Alkyl Aryl Polyether Sulfonate	Triton X-200	7	0.5	G	G	U	U	U	NT	NT
Alkyl Aryl Ethoxylate	Witconol NP-120	8	1.0	P	E	P	P	P	NT	NT
Amine Ethoxylate	Varonic K215 LC	9	0.5	P	P	U	E	E	NT	NT
Alkyl Ethoxylate	Witconol SN-90	10	1.0	E	E	E	E	U	E	E
Alkyl Ethoxylate	Tricol LAL-23	11	1.0	G	E	E	P	U	E	P
Alkyl Ester Sulfonate	Lanthanol LAL-Flake	12	0.5	U	U	U	U	U	NT	NT

Ratings:
E -- Excellent
G -- Good
P -- Poor
U -- Unsatisfactory
NT -- No Test

Note: DI-H_2O indicates deionized water

Preliminary design was initiated on a facility that will be used to test flowing aqueous foams at high temperature and pressure. The facility will be a modification of the equipment used to test the long-tube heat exchanger that was designed for magma research. The facility consists of a 0.9-metre (36-inch) casing containing a two-concentric-tube heat exchanger centered in a vertical array of coil resistance heaters. Total heater length is 10.7 metres (35 feet). The heat exchanger internal diameter is 10.2 cm (4 inches), and the operating pressure will be at least several hundred thousand pascals (hundred psi). As the foam flows through the heat exchanger, data will be taken on annulus temperature profile, axial pressure drop, wall heat flux, and other parameters necessary to characterize the foam. The facility is expected to be in operation in the third quarter of FY 1980.

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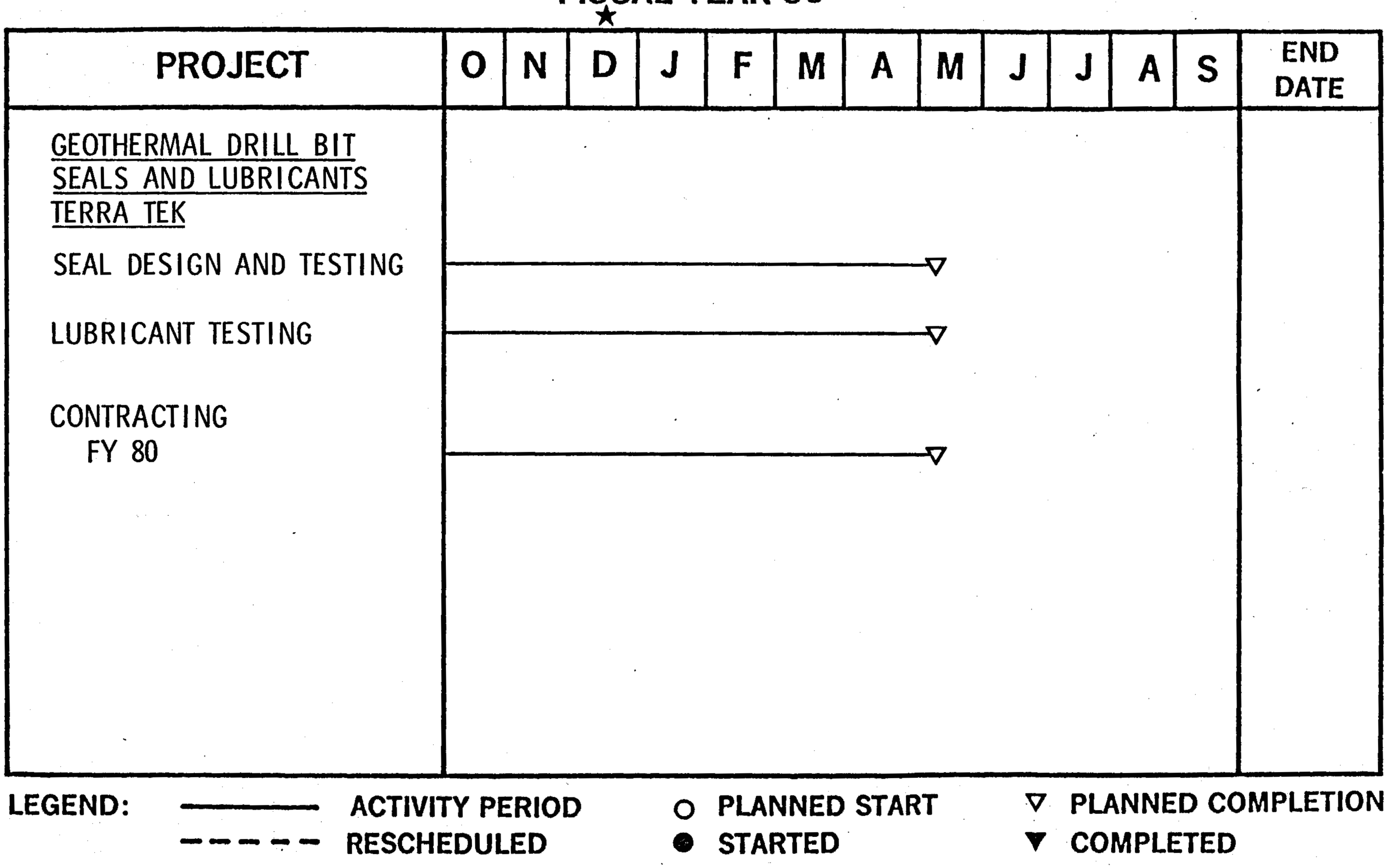


EXTERNAL R&D

Project:	Geothermal Drill Bit
Contractor:	Terra Tek, Inc.
Principal Investigator:	R. R. Hendrickson (801) 582-2220
Contract Period:	10 July 1979 to 10 May 1980
Contract Number:	13-8783 (Sandia)
Technical Consultant:	D. Wesenberg (505) 264-0129

Project Objective

The objective of this project is to design and develop improved tricone roller bits for geothermal applications. The project has two thrusts: (1) to substitute high-temperature steels in unlubricated bearings and (2) to develop high-temperature seals and lubricants for lubricated bearings.

Project Status

Research bits incorporating steels with higher hardness at high temperatures have demonstrated less wear than production bits in the simulated downhole environment. Third-generation unsealed bits have been field tested successfully, and this new technology is being commercialized by a leading bit manufacturer.

A seal tester and a lubricant tester have been fabricated to simulate in-use conditions: 300°C (572°F), 34.5 MPa (5 000 psi), translation, rotation, and eccentricity. Most available elastomers have been tested and shown to be inadequate. Nonelastomeric seals and coated-elastomer seals are being designed and tested. Six life tests have been run on coated-elastomer seals, and results compare favorably with previous, successful Viton seal tests. Spring-loaded face seals have undergone preliminary tests, and the elastomeric side seal system has been perfected.

Lubricant screening tests, while eliminating several products from further consideration, have established the exceptional high-temperature performance of Pacer PLX-014 oil. A grease based on this oil has also been compounded and is ready for field evaluation. An oil (PLX-022), not compatible with elastomers, has been developed for use with all-metal seals.

A follow-on program of seal and lubricant tests was initiated in July 1979 under a new contract. Two elastomeric seals of ethylene propylene diene (EPDM) compounds and two Utex Industries proprietary elastomeric seals have been tested. Only the EPDM seal supplied by L'Garde, Inc., did well; however, confirmation tests of this seal will be required. Two new oils for all-metal seals were tested but both have been rejected.

Geothermal Drill Bit
Quarterly Progress for October-December 1979

Seal Development

Metal Bellows Face Seal — The three seal assemblies were completed by Bel-Flex Products, Inc., in November. The test fixtures, high-temperature springs, and the primary seal surfaces (mating discs) are onhand. The first test began this quarter.

Elastomeric Seals — An EPDM candidate supplied by L'Garde, Inc., did exceptionally well in a trip-in simulation seal test. The seal survived the 2-hour soak at a temperature of 288°C (550°F), after which it was run at 90 rpm for 104 hours. The trip-in simulation test cycle is illustrated in Figure 7. The proprietary compound was created for static seal applications in geothermal well logging tools. The base polymer is DuPont Nordel EPDM (ethylene propylene diene), molded in the 2-329 O-ring configuration (see Figure 8). The seal experienced very little chemical degradation from the Pacer PLX-014 grease, which utilizes a synthetic hydrocarbon oil, as evidenced by a durometer shift from 91 to 85, Shore A. This was considered very significant, since EPDM compounds are generally incompatible with hydrocarbons.

An identical test was run on a Parker EPDM seal (Reed oval configuration) to compare the effect of the PLX-014 grease. The seal failed by ripping at the seal interface after 9-1/2 hours, indicating poor elastomer surface lubricity. The durometer shifted from 72 to 66, indicating that the PLX-014 does not readily attack EPDMs.

The L'Garde EPDM seal survived the highest soak temperature to date, surpassing Parker 4205 Viton's 260°C (500°F) limit by 28°C (50°F). Additional tests are required to confirm the EPDM test; unfortunately, no additional seals are available. L'Garde believes the compound could be further optimized for the rock bit seal application.

These tests indicate that seals are now available to drill the vast majority of the hydrothermal reservoirs, including most of the Imperial Valley KGRAs.

Utex Industries supplied two new proprietary grades of elastomeric seals in the oval configuration, designated RD-217 and RD-231. Two of the RD-231s were subjected to the same 288°C (550°F) trip-in simulation test described above (Figure 7). Seal lives were 1-1/2 and 4 hours, with failures due to abrasives intrusion and tearing of the sealing surface. Compression-set was also evident.

Radial Lip Seals — The second-generation radial lip seals from Fluorocarbon, Inc., are now available for testing. Tests will be initiated as soon as possible.

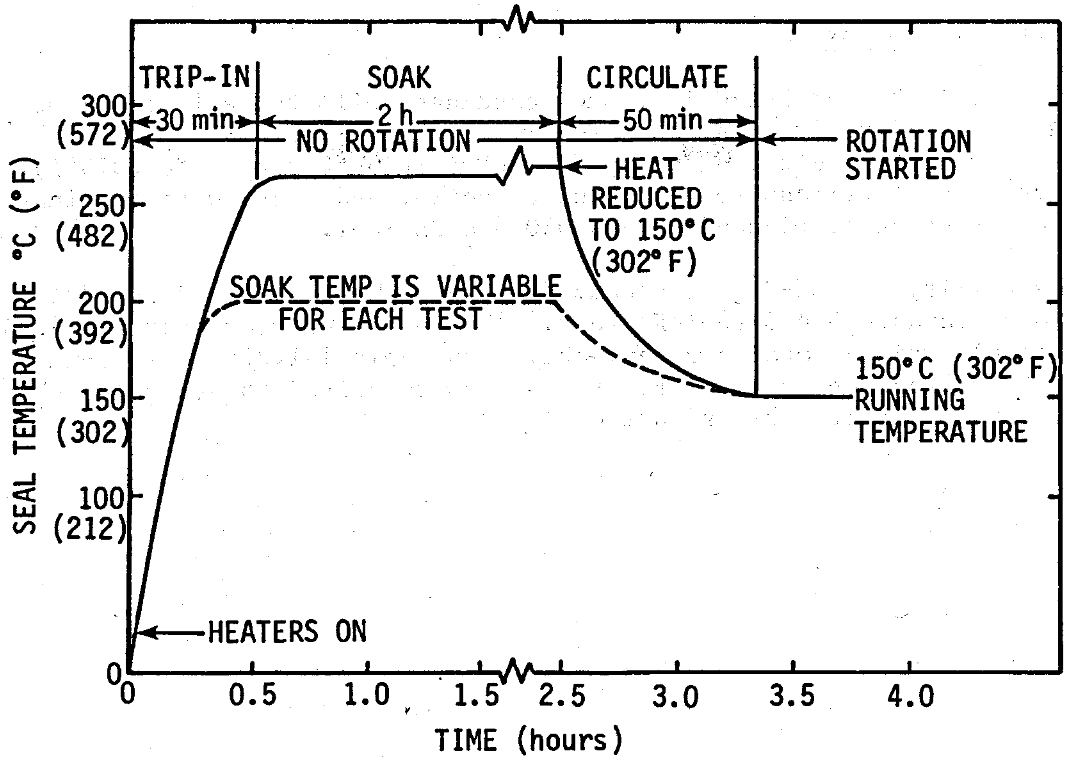
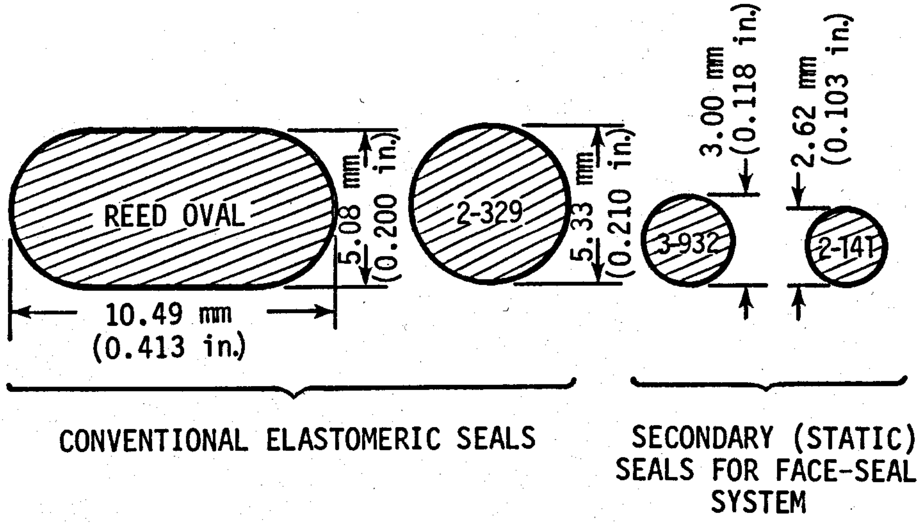


Figure 7. Trip-In Simulation Test



INNER DIAMETERS:

REED OVAL	53.49 mm (2.106 in.)
2-329 O-RING	50.17 mm (1.975 in.)
3-932 O-RING	59.36 mm (2.337 in.)
2-141 O-RING	58.42 mm (2.300 in.)

Figure 8. Elastomeric Seal Cross Sections

Lubricant Development

Pacer PLX-030 and PLX-031 are new candidate oils for all-metal (non-elastomeric) sealing systems, and are similar to PLX-022 oil. The new candidates contain additives to improve lubrication below 135°C (275°F). Both caused the lubricant test machine to seize, and tests were terminated. No further testing is planned on PLX-030 and PLX-031.

The ability of PLX-014 to accommodate water was evaluated by adding 10 drops to a standard 316°C (601°F) test. The resulting wear scar was 4.34 mm (0.171 inch), which compares unfavorably with typical 1.27- to 1.91-mm (0.050- to 0.075-inch) scars. Pacer has been consulted to determine what can be done to rectify this situation.

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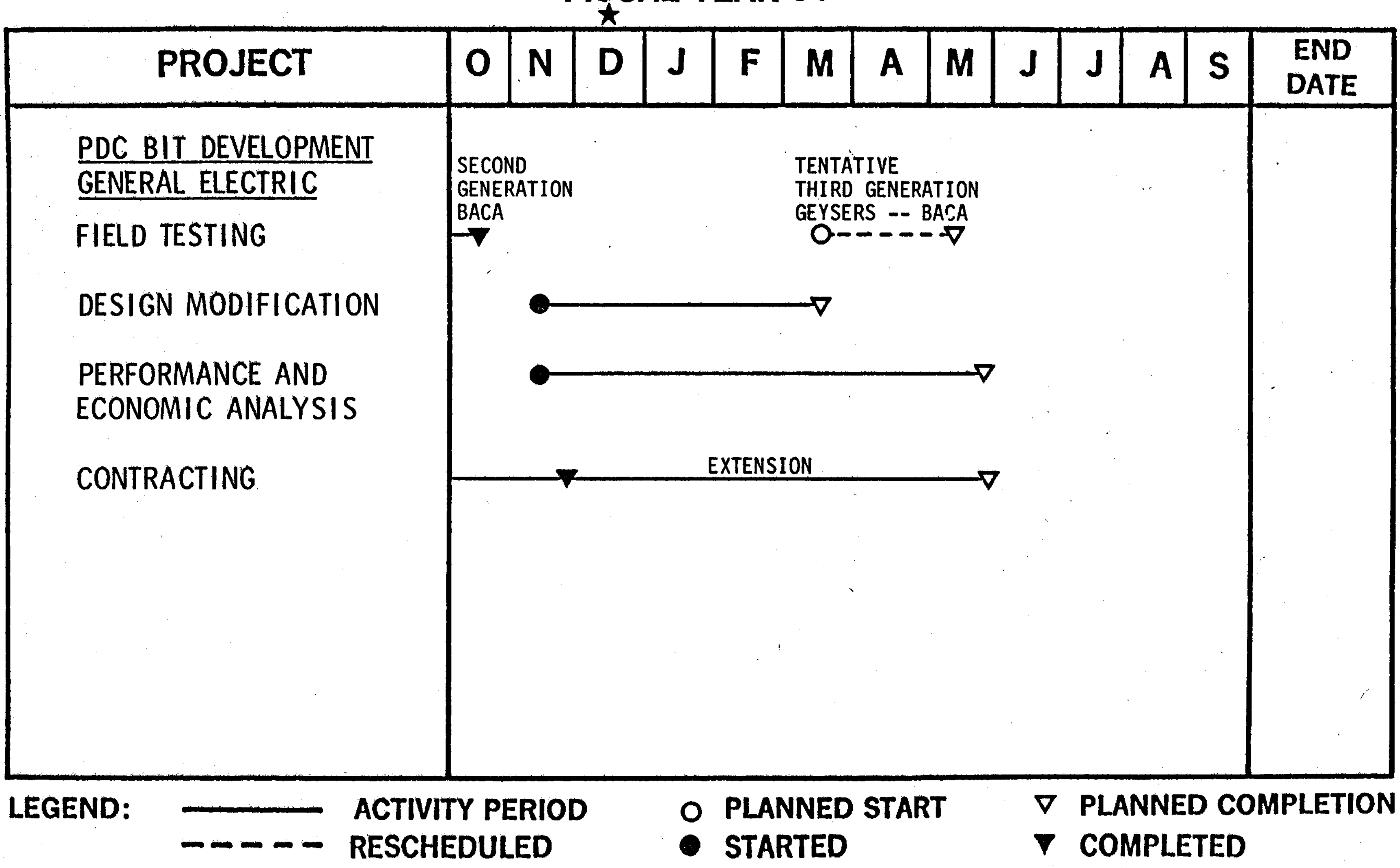

EXTERNAL R&D

Project: Geothermal Polycrystalline Diamond Compact Drill-Bit Development
Contractor: General Electric Company, Corporate Research and Development (CRD)
Principal Investigator: L. E. Hibbs, Jr. (518) 385-8330
Contract Period: 30 June 1976 to 31 May 1980
Contract Number: DE-AC04-76ET27142
Technical Consultant: C. Huff (505) 264-8796

Project Objective

The overall objective of this project is to develop and demonstrate the performance of a new type of drill-bit design that will provide increased penetration rates and/or longer bit life with high-pressure, sintered polycrystalline diamond compacts (PDCs) for the cutting edges. The scope of this contract includes instrumented, rock-cutting experiments, diamond compact wear and failure mode analysis, rock removal modeling studies, bit design and construction, full-scale laboratory testing, and field testing.

Project Status

From experiments at atmospheric conditions on the cutting of rock with individual PDC cutters, a predictive capability has been established for the performance of full-scale bits. This has been demonstrated with laboratory testing of full bits. Single-cutter tests have been run at simulated downhole conditions, and the data have been analyzed. The redesign and fabrication of the S-1 bit, modified, necessitated by the catastrophic failure during the November 1978 field test, has been completed. Both the S-1, modified, bit and the C-1 cast hard matrix bit were field tested in the Baca Field, New Mexico, in October 1979. The S-1 bit demonstrated a penetration rate several times greater than typical rates for rock bits in similar formations. The contract has been extended 6 months at no cost, and final bit design is progressing.

Polycrystalline Diamond Compact Drill Bit
Quarterly Progress for October-December 1979

Both the C-1 hard matrix and the S-1, modified, steel-bodied PDC bits were tested at a location in the Baca Field in New Mexico. Testing was in Andesite, the basement formation for the geothermal wells being drilled by the Union Geothermal Company of New Mexico. Testing was at a depth of approximately 1 676 to 1 707 metres (5 500 to 5 600 feet).

The C-1 hard matrix bit drilled successfully with penetration rates up to 0.007 m/s (85 ft/h) at bit weights up to 88 964 newtons (20 000 pounds) and rotary speeds as high as 70 rpm. Cutter wear was not excessive, and the bit was still usable after the test. On the average, a 50% increase in penetration rate over that of a conventional bit was obtained.

The S-1, modified, steel-bodied bit was found to be so aggressive in drilling this formation that bit weights greater than 44 482 newtons (10 000 pounds) could not be used. Instantaneous penetration rates as high as 0.014 m/s (170 ft/h) were obtained at a rotary speed of 60 rpm. In general, the penetration rate was so fast that a bit weight of 44 482 newtons (10 000 pounds) could not be maintained.

One PDC cutter was lost, and most of the remaining wear was on the gage of the bit. Some stud chipping was experienced, but there was no catastrophic wear like that which occurred when the original S-1 bit was tested last year.

These field test results are encouraging in that the observed penetration rate for the PDC bits were several times larger than typical penetration rates for rock bits in similar formations. However, the total footage drilled was limited, and no firm estimates of bit lives can be made at this point. Nevertheless, critical areas for design improvement were identified.

Both experimental geothermal PDC bits were returned to GE(CRD), Schenectady, New York, following the field tests. A detailed wear examination is being carried out to assist in redesign for the two bits to be fabricated and tested in the final phase of this project.

The performance and economic analysis, based primarily on the results of the October field tests, has been started. This analysis should be completed by February 1980. The design modifications for the last two bits have been initiated. Major modifications will probably be confined to changes necessary to reduce gage wear and increase bit life. Arrangements for fabrication of these bits are being made with a bit manufacturer (Smith Tool, Irvine, California).

A field test in the Baca Field, New Mexico, with the Union Geothermal Company of New Mexico has been tentatively scheduled for late April 1980. The other field test will be carried out at the Geysers, California, with Union Oil Company. The date for this test has not been determined, but it is anticipated that this information will be obtained in the near future. If the Geysers field test can be performed before the Baca test, the performance and economic analysis can be completed by the end of May 1980.

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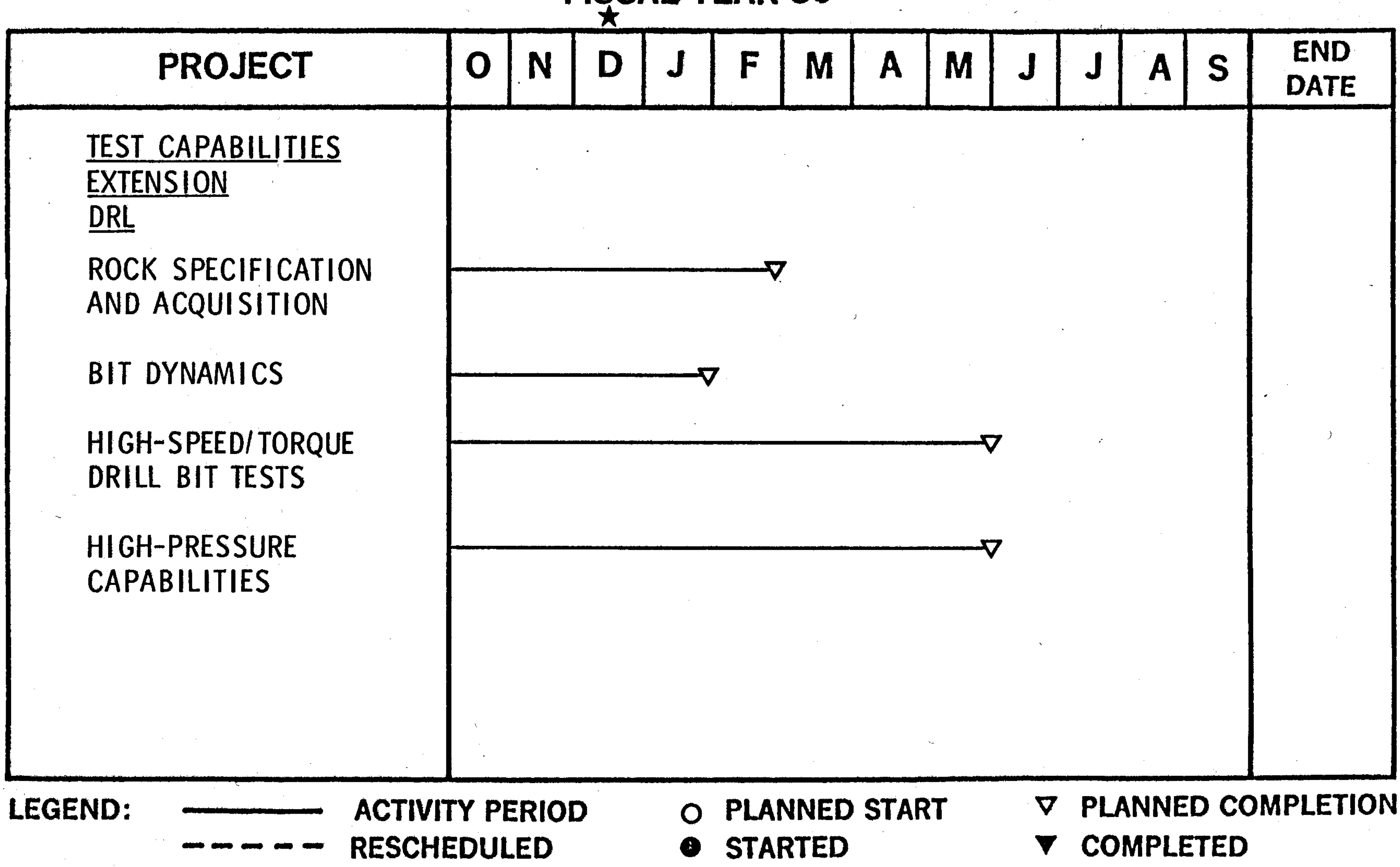


EXTERNAL R&D

Project: Modification and Extension of Testing Capabilities
Contractor: Drilling Research Laboratory, Inc.
Principal Investigator: A. D. Black (801) 582-2220
Contract Period: 12 September 1979 to 12 May 1980
Contract Number: 13-8785 (Sandia)
Technical Consultant: D. Wesenberg (505) 264-0129

Project Objective

The objective of this project is to modify and extend testing capabilities in the following areas:

1. Selection and acquisition of pertinent rock samples and specifications,
2. Torque and rpm availability for testing high-speed/high-torque bits,
3. Bit dynamic data acquisition, and
4. High-pressure/jet-drilling testing capability.

Project Status

All project tasks have been initiated. Rock specification data are being compiled and potential sources of rock specimens identified. Design of the high-speed/high-torque facility is continuing. Some components have been purchased or placed on order. A high-rate data acquisition computer program has been completed, and increased capabilities are under consideration. Conceptual ideas for the high-pressure facility are being evaluated.

Modification and Extension of Testing Capabilities
Quarterly Progress for October-December 1979

Project Planning and Coordination

All project tasks were underway at the start of this reporting period following contract award late in September 1979. A project plan was completed and specific work assignments made. The critical long-lead items were identified to be (1) the high-speed/high-torque devices and (2) the high-pressure capabilities.

Rock Specification and Acquisition

The compilation of rock property data from the major geothermal development sites was continued during the reporting period. Literature on geothermal wells and reservoir rock formations available at Terra Tek's and Drilling Research Laboratory's (DRL's) libraries and files were gathered. A search was started to locate all rock property data on geothermal formations generated on other projects. Outside sources of information were sought and compilation of data started. The rock properties needed for simulation are being defined, and a search for sources of surface rock formations to match these properties has been started.

A decision was made to collect and compile data on the following sites: (1) Geysers, (2) Imperial Valley, (3) Roosevelt Hot Springs, (4) Jemez Hot Dry Rock, (5) Baca, and (6) Coso Hot Springs. Information being compiled includes a brief geological description of each site, mineralogic data, and typical physical and mechanical properties for the predominant rock formations at each site. In addition, core samples are being sought, where possible, to allow physical examination, rock mechanics tests as needed, and display. Emphasis is being placed on determining certain key parameters for each rock type, including density, porosity, strength, and permeability. At this time, these parameters are considered to have a primary effect on rock drillability. A list of potential locations for surface outcroppings of rock that may have similar properties to these sites is also being compiled and will be investigated.

High-Speed/High-Torque Capabilities

The preliminary design of the 0 to 500 rpm high-torque modification was initiated. A suitable transmission was identified, and alternative ways to couple the drive motors, transmission, and turntable were outlined. The transmission was purchased by DRL using their capital funds. Detailed design to mount and couple the components has started.

Due to space limitations on the present DRL drill rig, close examination was given to determine the appropriate layout for the new transmission, two 125-hp d.c. motors, and associated drive trains. The scaled layout selected is shown in Figure 9. The components selected allow installation in the available horizontal space. Data on the transmission

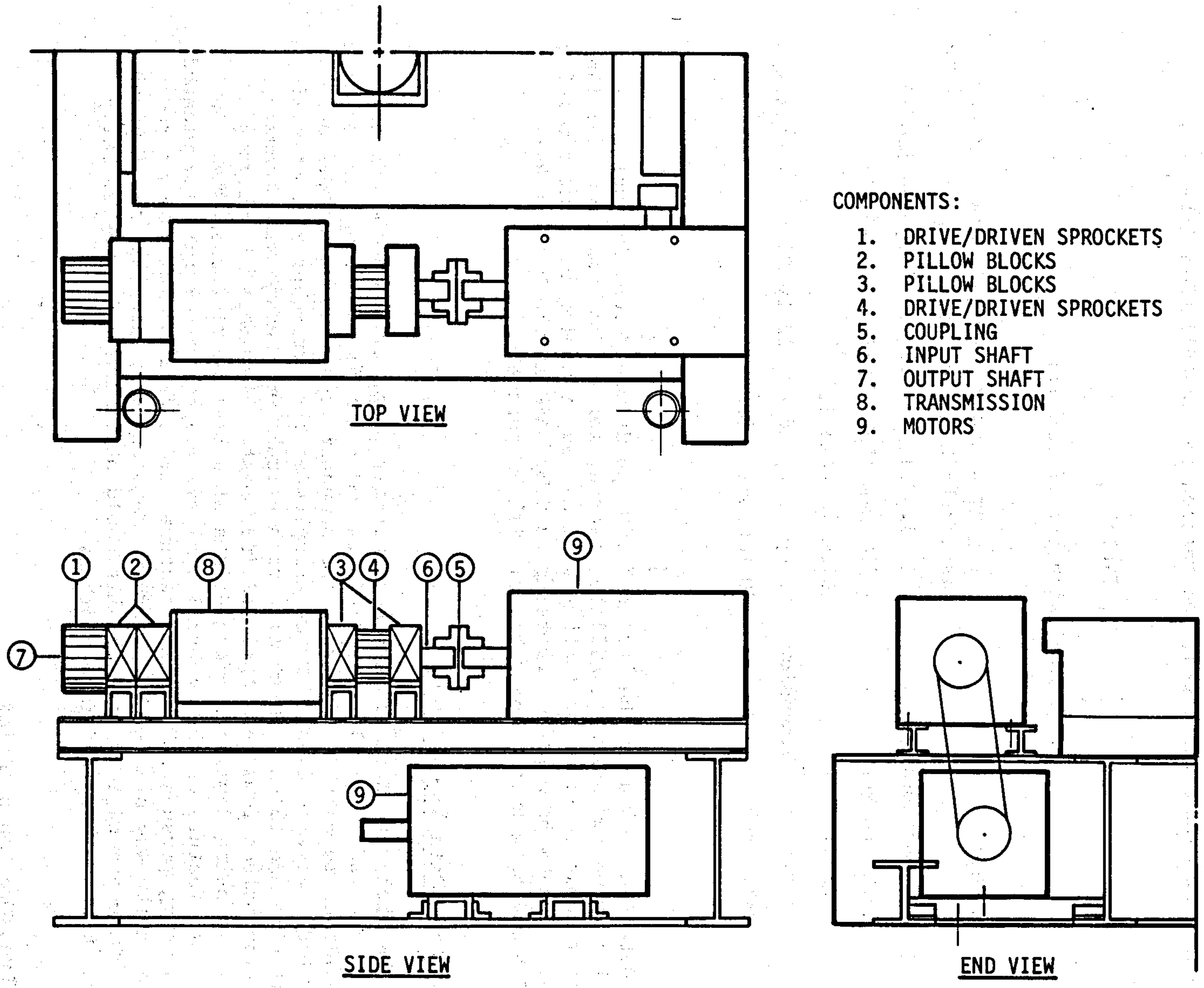


Figure 9. Scaled Layout of Modified Drill Rig

are given in Table 4, and the torque versus speed capabilities of this new drive system is shown in Figure 10. In the next reporting period, the miscellaneous drive components will be ordered and the mounting frame designed. In addition, the second 125-hp d.c. motor will be removed from the small DRL pump, inspected, and readied for installation later on.

Table 4

Transmission Specifications

Model:	Eaton MT - 509 M 5-speed, twin countershaft design manual shift
Gear Ratios:	1:1, 1.32:1, 1.76:1, 2.67:1, and 5.47:1
Input Torque:	1 220 N•m (900 lbf•ft) maximum
Weight:	194.6 kg (429 lb)
Approximate Dimension:	56 by 56 by 36 cm (22 by 22 by 14 inches)
Delivery:	20 February 1980

Detailed design of the 500 to 1 000 rpm drive system, including the reaction frame and bearing, will be started, and a firm commitment for the use of a downhole motor or turbine will be sought during the next reporting period. The turbine presently being used by LASL in the Hot Dry Rock program may be a prime candidate and will be pursued.

Bit Dynamic Data Acquisition

The high-rate data acquisition computer program was completed, debugged, and made operational. The data reduction and plotting routine with capabilities to calculate average and standard deviation values was also completed. Figures 11 and 12 are examples of the hard-copy plot of load versus time and torque versus time with calculated average and standard deviation values from an actual drilling test. The spectral analysis program is being developed and consists of a Fast Fourier analysis. An additional feature of the spectral analysis program not originally planned for is being pursued. With this feature, the difference in dynamic response in the way of magnitude versus frequency response data for a given drill bit compared to a baseline bit could be determined by essentially subtracting one data set from another.

High-Pressure Capabilities

Conceptual ideas for the high-pressure choke system, pulsation dampeners, and high-pressure rotary seal were considered. The pulsation dampening system was identified as beyond the present state of the art and

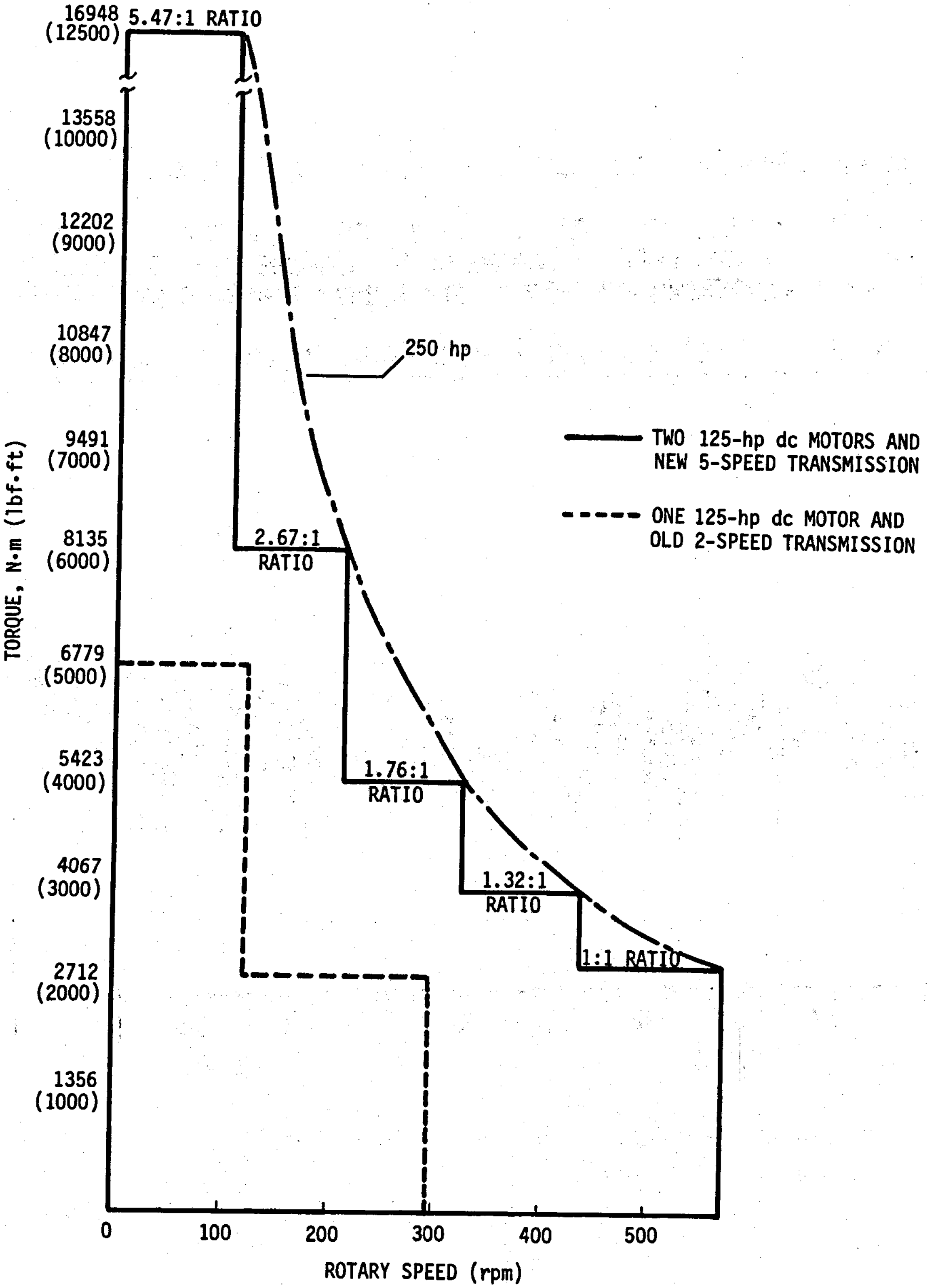
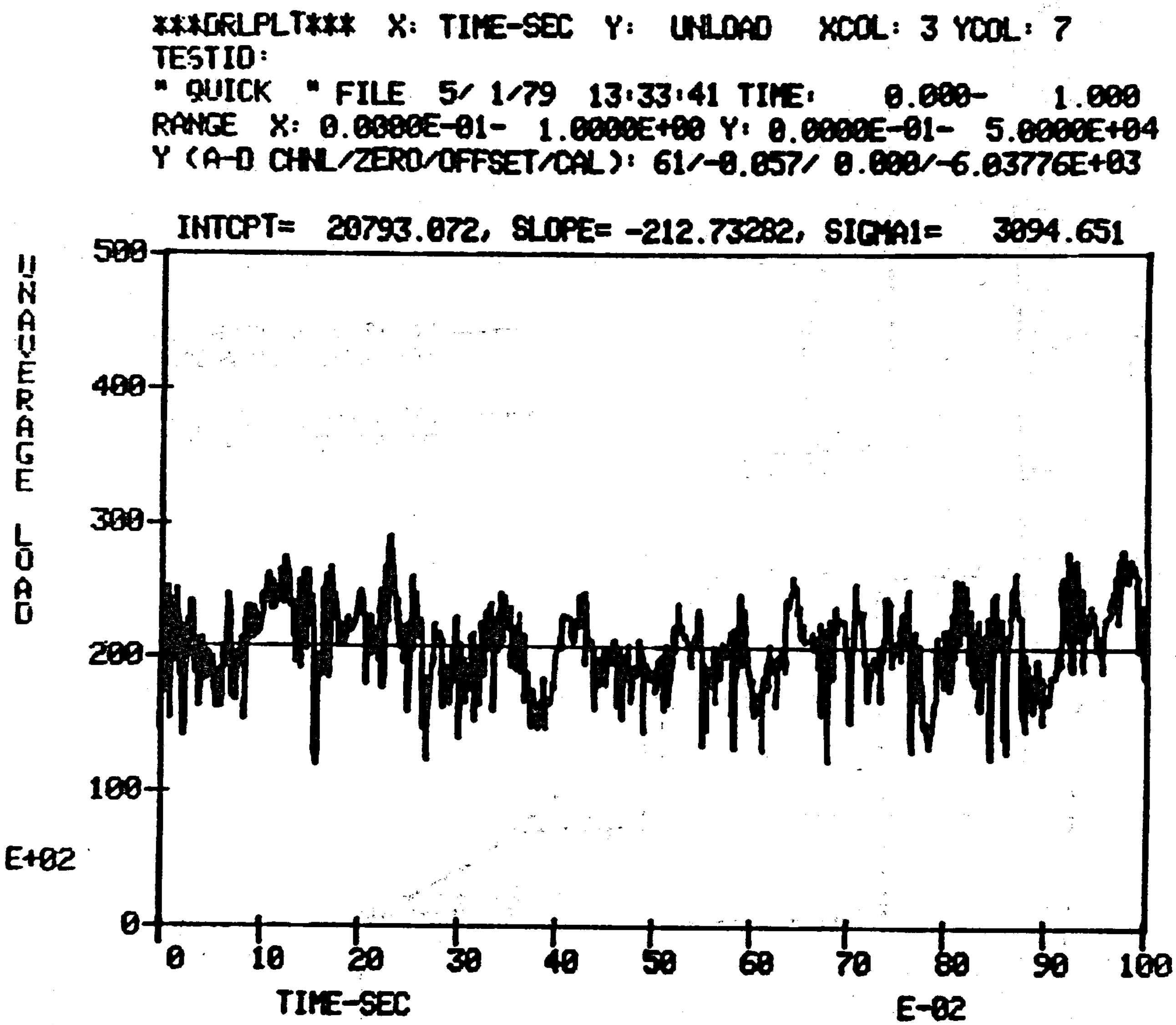


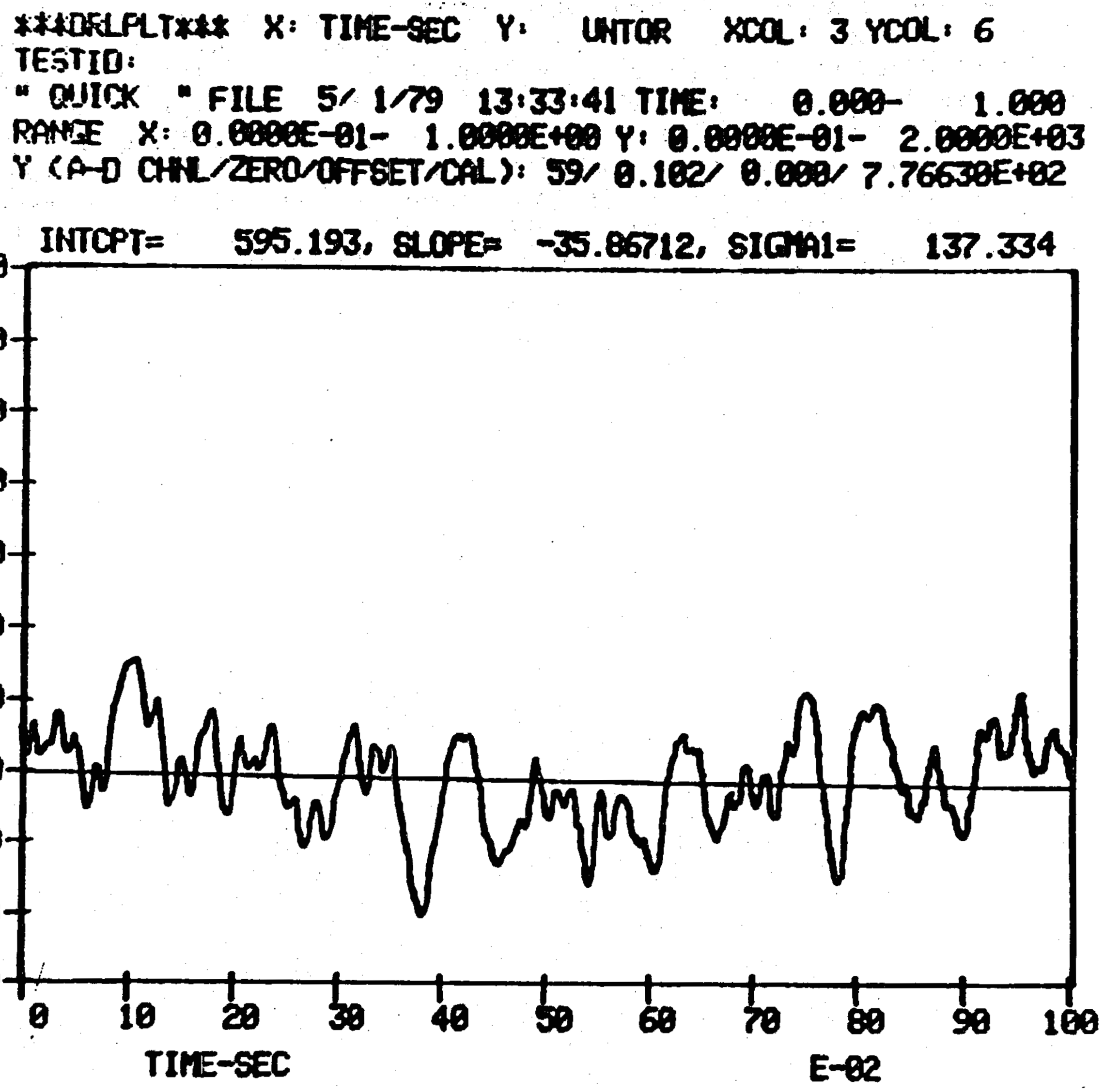
Figure 10. Torque versus Speed of New Drive System



```
***GRLPLT***  X: TIME-SEC  Y:  UNLOAD   XCOL: 3 YCOL: 7
TESTID:
" QUICK  " FILE  5/ 1/79  13:33:41 TIME:     0.000-    1.000
RANGE  X: 0.0000E-01-  1.0000E+00 Y: 0.0000E-01-  5.0000E+04
Y (A-D CHNL/ZERO/OFFSET/CAL): 61/-0.057/ 0.000/-6.03776E+03
```

```
 INTCPT=  20793.072, SLOPE= -212.73282, SIGMA1=   3094.651
```

Figure 11. Example of Load versus Time Plot



```
***DRLPLT*** X: TIME-SEC  Y:   UNTOR   XCOL: 3 YCOL: 6
TESTID:
" QUICK  " FILE  5/ 1/79  13:33:41 TIME:    0.000-    1.000
RANGE  X: 0.0000E-01-  1.0000E+00 Y: 0.0000E-01-  2.0000E+03
Y (A-D CHNL/ZERO/OFFSET/CAL): 59/ 0.102/ 0.000/ 7.76630E+02

  INTCPT=    595.193, SLOPE=  -35.86712, SIGMA1=    137.334
```

Figure 12. Example of Torque versus Time Plot

will probably need some prototype testing of potential concepts before full-scale equipment is fabricated. The conceptual work on this task will continue into the next reporting period.

Plans were made to turn the DRL 1 600-hp Continental Emsco pump 90 degrees, with the fluid ends facing south. With this arrangement, the 3-ton pump fluid end becomes accessible so a fork lift can be used to remove and install it. This option was chosen because it will involve a minimal expense compared with the option of providing a large overhead crane or jib crane. This is the first step in providing quick changeover from the standard to the high-pressure fluid ends. This modification will be completed during the next reporting period. Plans were also made to skid-mount the suction and discharge piping for the high-pressure fluid ends. A preliminary design of a multistage high-pressure seal was also completed. Conceptual ideas for the high-pressure choke and high-pressure pulsation dampener are still under consideration. Selection of the design to be pursued will be made during the next reporting period.

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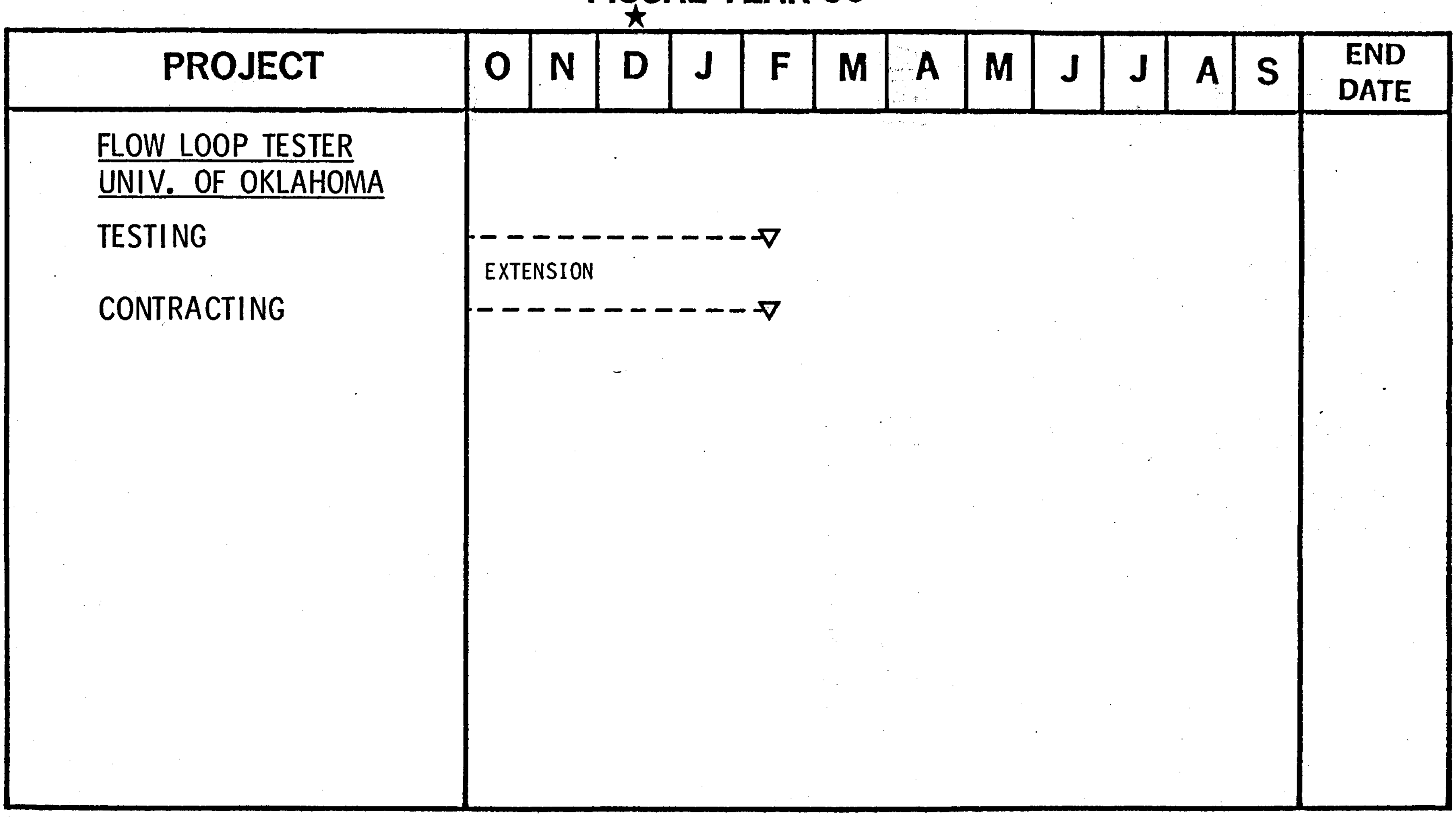
GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80



LEGEND: ———— ACTIVITY PERIOD ○ PLANNED START ▽ PLANNED COMPLETION

- - - - - RESCHEDULED ● STARTED ▼ COMPLETED

Project:	Determining Temperature Limits of Drilling Fluids (Flow Loop Tester)
Contractor:	University of Oklahoma
Principal Investigator:	E. F. Blick (405) 325-5011
Contract Period:	1 August 1978 to 15 February 1980
Contract Number:	13-0346 (Sandia)
Technical Consultant:	A. Maish (505) 264-3601

Project Objective

The objective of this project is to evaluate the high-temperature properties of available drilling-fluid additives in a dynamic flow loop. This contract provides for the establishment of a mud test laboratory, for the design and fabrication of a 288°C (550°F) flow loop, and for a moderate amount of drilling-fluids testing.

Project Status

Sufficient testing has been accomplished using a modified flow loop at Magcobar to demonstrate the existence of a large discrepancy between ambient data as normally taken in mud laboratories and the actual characteristics of the fluid under dynamic simulated downhole conditions. A new flow loop has been fabricated at the University of Oklahoma, and testing of muds has begun. Repetitive malfunctions of the test equipment have delayed the test program. However, correction of all problem areas was accomplished in September 1979. The contract was extended to permit the completion of scheduled mud tests.

Temperature Limits of Drilling Fluid
Quarterly Progress for October-December 1979

Reports of progress for October-December were not received. These activities will be consolidated with the final project report in the next quarterly report.

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GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80

PROJECT	O	N	★ D	J	F	M	A	M	J	J	A	S	END DATE
<u>HT/HP MUD TESTER</u> <u>NL/BAROID</u>													
INSTRUMENTATION													
1. FILTER	---												
2. FILTER MEDIUM	COMPLETE												
3. DENSITOMETER	---												
4. CORROSIVITY	---									NEW SCHEDULE UNDER DEVELOPMENT			
5. RHEOLOGICAL	---												
INTEGRATE INSTRUMENTATION	---												
HIGH-PRESSURE GAS SYSTEM	---												
INTEGRATED SYSTEM	---												
TEST TWO FLUIDS	---												
CONTRACTING (DOE)	────	────	────	────	────	────▽							

LEGEND: ──── ACTIVITY PERIOD ○ PLANNED START ▽ PLANNED COMPLETION

- - - - - RESCHEDULED ● STARTED ▼ COMPLETED

EXTERNAL R&D

Project: Development of High-Temperature/High-Pressure Drilling Mud Research Instrumentation
Contractor: NL/Baroid
Principal Investigator: K. L. Walter (713) 527-1100
Contract Period: 1 April 1978 to 31 March 1980
Contract Number: DE-AC04-77ET27144
Technical Consultant: A. Maish (505) 264-3601

Project Objective

This project will result in the fabrication of a drilling-mud testing instrument capable of measuring fluid properties under dynamic flow conditions of up to 371°C (700°F) and 138 MPa (20 000 psi). This is an extension of the 288°C (550°F) capability provided by the University of Oklahoma project.

Project Status

State-of-the-art studies have been conducted. Three fabrication bids for the pressure vessel were received, and a design was chosen for testing. Design work on the system instrumentation is continuing. A time schedule has been determined for the Microcomputer Development System software development. The installation site for the geothermal drilling fluid test system has been tentatively selected. A contract extension is under consideration, and a new schedule is being developed.

Development of High-Temperature/High-Pressure Drilling Mud Research Instrumentation
Quarterly Progress for October-December 1979

Review of the preliminary design to house the high-pressure equipment has still not been completed. Sandia may assist in this review, but arrangements are pending. E. Ripperger of the Engineering Mechanics Department of the University of Texas has agreed to analyze the consequences of a vessel failure inside the pit. His study will estimate static overpressure, shock wave pressure, and projectile energy to be withstood by the pit, its cover, and vents. Review of architectural drawings of the rest of the building has been completed, but a cost estimate is not yet available.

National Forge notified NL/Baroid that the main pressure vessel assembly delivery date has been moved back to the week of 14 April 1980. This is beyond NL/Baroid's current contract period, which ends 31 March 1980. This delay is due in major part to National Forge's design for the vessel cooling jacket. This design is a great improvement over Baroid's initial design, but also requires vessel modification. The cooling jacket quotation price is $17,500.

Approval drawings for the pressure vessel, as modified to accept a cooling jacket, were received from National Forge. Some modifications will be required, which may further delay delivery by 1 or 2 weeks. The order for the cooling jacket designed by National Forge was placed in December.

In view of the above development, an extension of the contract period will be proposed. The full-scale monthly report called for by the most recent amendment to the prime contract will be issued when this new schedule is completed. Systran Corporation has been hired to do a study on the best way to implement software control and data logging for the Geothermal Drilling Fluid Test System (GDFTS). Based on this study, Systran and other companies will bid on a contract to supply assistance to NL/Baroid in software development. When these proposals are received, a new estimated time and cost schedule for NL/Baroid's main contract with DOE can be completed. This schedule will also reflect the late delivery of the pressure vessel and will be the basis for a request to extend the contract beyond the current completion date of 31 March 1980. The need for this extension was reviewed with Sandia on 12 November 1979.

During the initial stage of this planning, it became evident that the control system hardware and software would require considerably more effort than estimated initially. The stepper motor controller operation has been faulty. A number of problems have been solved, but more remain.

Quotations have been received on a liquid argon storage system and 6 000-psi gas reservoir. Machining of rheometer parts and their minor modification have been completed. Assembly requires receipt of a chemically etched spring for the torque transducer. Testing of the rheometer was expected to begin at the close of this reporting period. Fabrication of the filter has begun.

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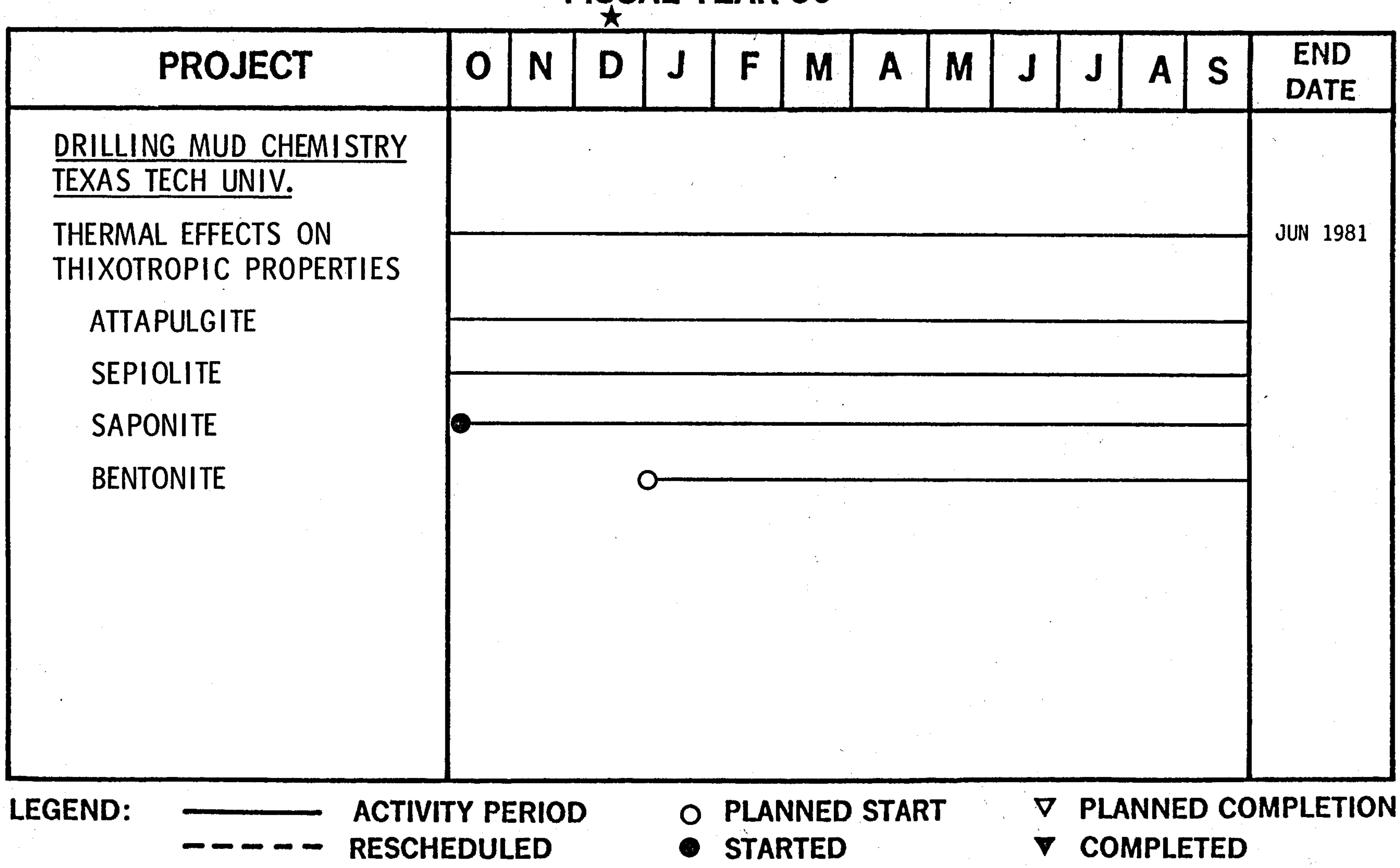
GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80



EXTERNAL R&D

Project:	Basic Understanding of Chemical and Elevated Temperature Effects on Clay-Based Drilling Fluids
Contractor:	Texas Tech University
Principal Investigator:	N. Güven (806) 742-3110
Contract Period:	15 July 1979 to 15 July 1981
Contract Number:	13-5104 (Sandia)
Technical Consultant:	B. Kenna (505) 264-1565

Project Objective

This project will result in a fundamental understanding of clay particle interactions under the influence both of various chemical species and elevated temperatures similar to the conditions encountered during geothermal drilling activities. On the basis of this understanding, clay-based geothermal drilling fluid systems, complete with the additives dictated by downhole conditions, will be designed for use in geothermal drilling.

Project Status

The Texas Tech University Clay and Drilling Fluids Laboratories were remodeled to accommodate the project. The project investigations were initiated in July 1979. X-ray and microscopic studies of the effects of various salts and elevated temperatures on attapulgite have been conducted. Studies of saponite fluids have begun.

Chemical and Temperature Effects
on Clay-Based Drilling Fluids
Quarterly Progress for October-December 1979

Experiments with saponite were started during this reporting period. Saponite is a trioctahedral smectite with the formal composition

$$[(Si_{3.67}Al_{.33})\ (Mg_3)\ O_{10}\ (OH_2)]\ M^+_{.33}$$

It is the magnesian analog of the montmorillonite (commercially known as bentonite) with the formal composition

$$[(Si_{3.67}Al_{.33})\ (Al_2)\ O_{10}\ (OH_2)]\ M^+_{.33}$$

Large amounts of saponite occur in the Amargosa Valley in Nevada, and it is mined there by Industrial Mineral Ventures (IMV), Inc., of Colorado. The saponite sample for the experiments was obtained from this deposit through IMV. Fluids containing 4% saponite were prepared in distilled and deionized water. Salts of NaCl, KCl, and $CaCl_2$ were added to these fluids at 1% concentrations. These fluids, with and without addition of salts, were subjected to hydrothermal treatments within the temperature range of 93.3 to 371.1°C (200 to 700°F). The original samples contained impurities of mica, feldspar, calcite, and dolomite. These impurities make up about 10% of the samples, the rest being saponite. The products of hydrothermal runs in saponite/water and in saponite/NaCl have been examined with X-ray diffraction. The results are tabulated in Table 5. These data suggest that

1. Saponite does not lose its swelling capability within the temperature range of 93.3 to 371.1°C (200 to 700°F) and
2. Saponite does not undergo any structural or chemical changes during the above experimental conditions.

Saponite-based fluids were prepared with and without the addition of salts of NaCl, KCl, and $CaCl_2$ as described above. The run products in the saponite/water and saponite/NaCl systems have been examined, and the results are described below.

Saponite/H_2O Systems

The typical morphological features of the saponite particles after the runs at 93.3 through 371.1°C (200 through 700°F) are shown in Figures 13 through 18. No changes in morphological features of saponites are observed up to 260°C (500°F) runs (Figures 13 and 14). The saponite particles seem to be well dispersed and separated into individual flexible and curled layers during the hydrothermal run at 315.6°C (600°F) (Figures 15 and 16). Morphological features of saponite display again some changes after the hydrothermal run at 371.1°C (700°F). As seen in Figures 17 and 18, saponite seems to develop thick aggregates of platy particles.

Table 5

X-Ray Diffraction Data on the Products of the Hydrothermal Runs in Saponite/Water and Saponite/NaCl Systems

			Saponite before and after Glycolation		Major Observed Reflections			
Systems	Hydrothermal Conditions °C (°F)	Run Time Hours	Before Å	After Å	Mica Å	Feldspar Å	Calcite Å	Dolomite Å
Saponite and Water	93.3 (200)	24	14.3	17.5	9.98	3.23	-	-
	148.9 (300)	24	14.3	17.4	9.94	3.22	-	2.885
	204.4 (400)	24	14.3	17.8	9.98	3.23	-	-
	260.0 (500)	24	13.4	17.4	9.94	3.23	-	-
	315.6 (600)	16	13.3	17.5	9.98	3.23	-	-
	371.1 (700)	16	14.3	17.1	9.98	3.23	-	-
Saponite and NaCl	93.3 (200)	24	14.1	17.3	9.96	3.23	-	-
	148.9 (300)	24	14.6	17.2	10.00	3.23	-	-
	204.4 (400)	24	14.4	17.5	9.91	3.23	-	-
	260.0 (500)	24	13.4	17.5	9.95	3.23	3.03	-
	315.6 (600)	16	13.2	17.3	9.98	3.23	-	-
	317.1 (700)	16	14.1	17.1	9.96	3.23	3.03	-

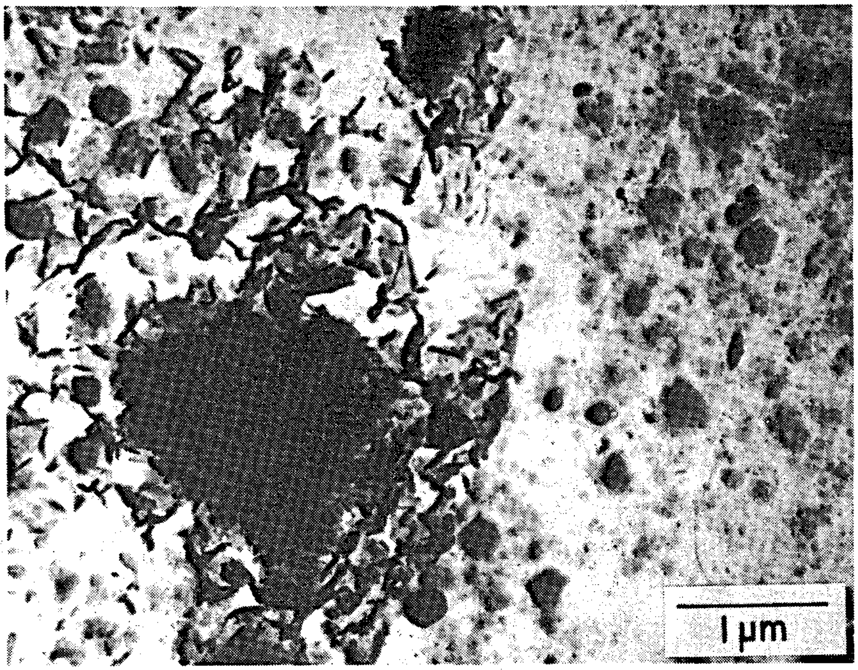


Figure 13. Typical Saponite Particles after the Hydrothermal Run at 93.3°C (200°F) in Saponite/Water Systems

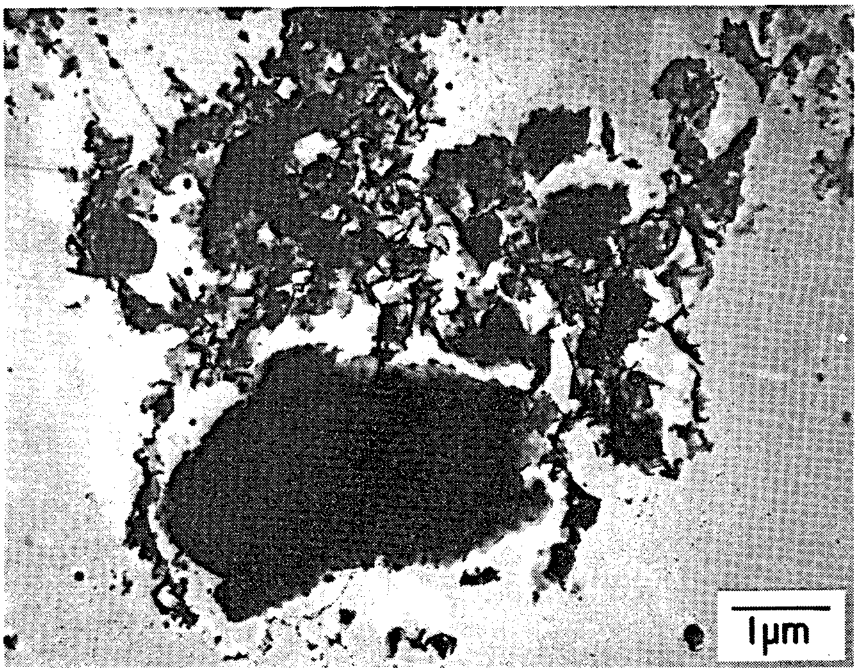


Figure 14. Saponite Particles after the Run at 260°C (500°F) in Saponite/Water System

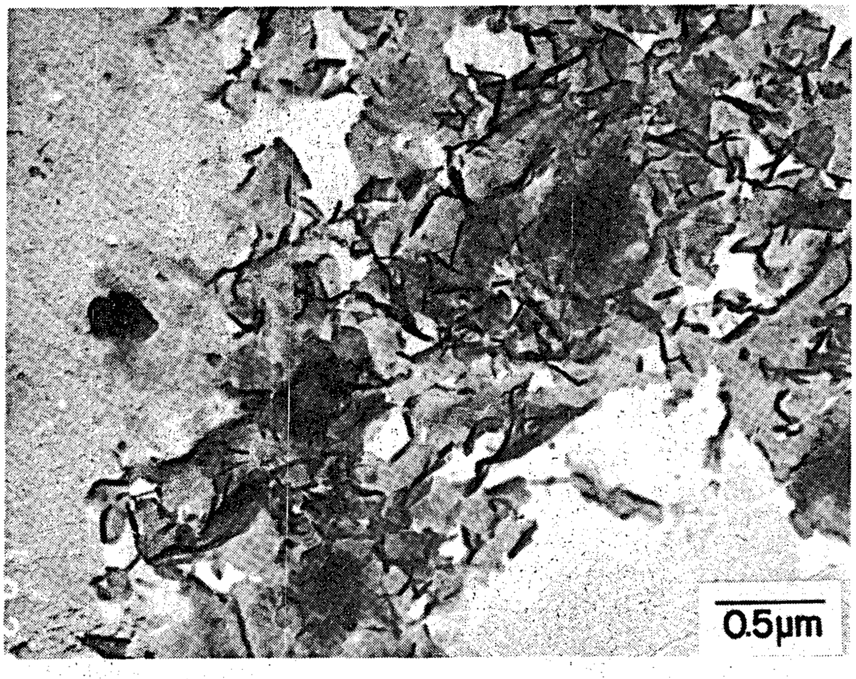


Figure 15. Saponite Particles after the Run at 315.6°C (600°F) in Saponite/Water System

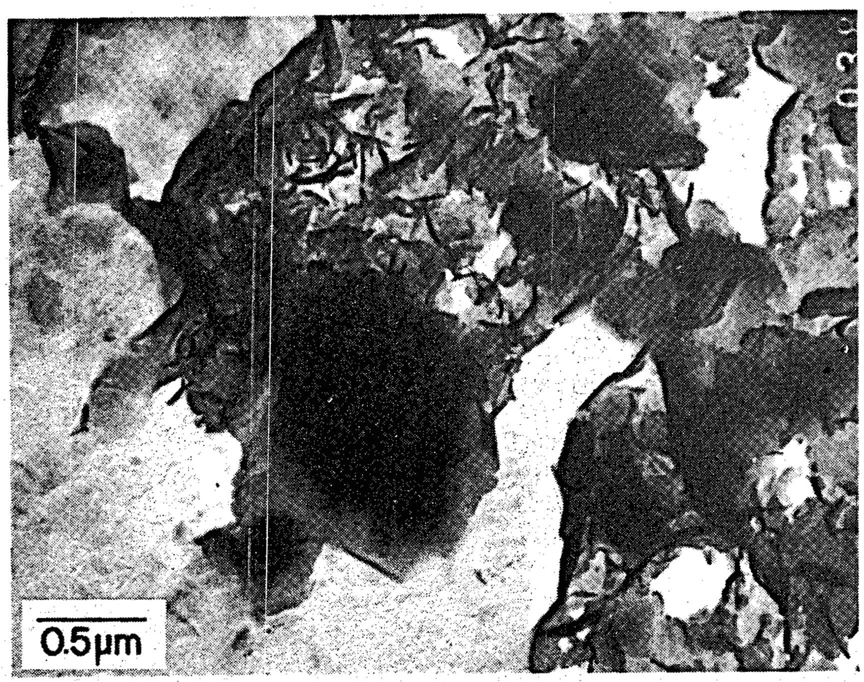


Figure 16. Saponite Particles after the Run at 315.6°C (600°F) in Saponite/Water System

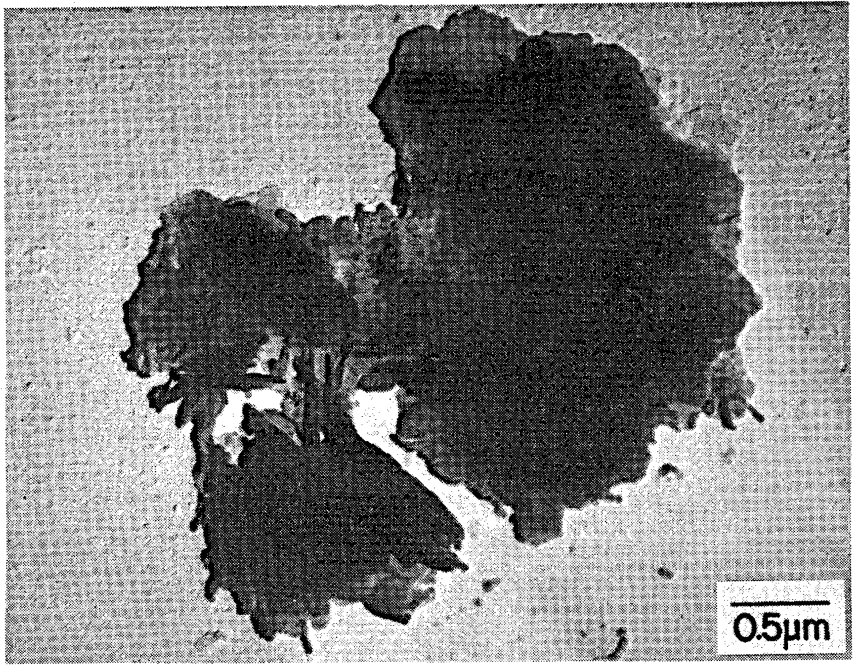


Figure 17. Saponite Lamellar Aggregates after the Run at 371.1°C (700°F) in Saponite/Water System

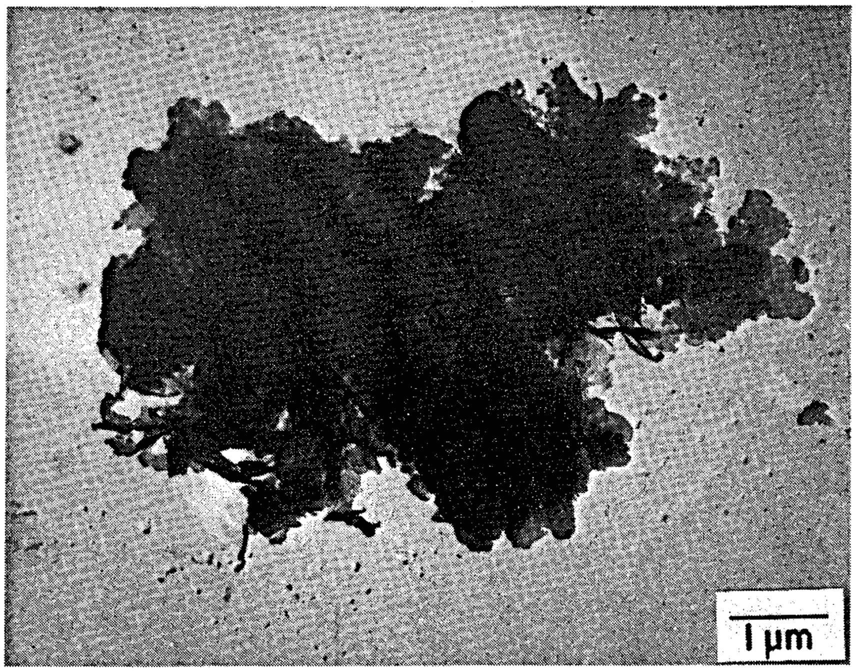


Figure 18. Other Saponite Aggregates after the Run at 371.1°C (700°F) in Saponite/Water System

Saponite/NaCl Systems

Typical saponite particles in this system are shown in Figures 19 through 22 after the runs from 93.3 to 260°C (200 to 500°F). Very little change was observed in this temperature range, except thin and curled layers of saponite seem to develop as a result of dispersion of aggregates with increasing temperatures.

X-ray diffraction and electron microscopic examination and rheological measurements are continuing for other saponite-based fluids.

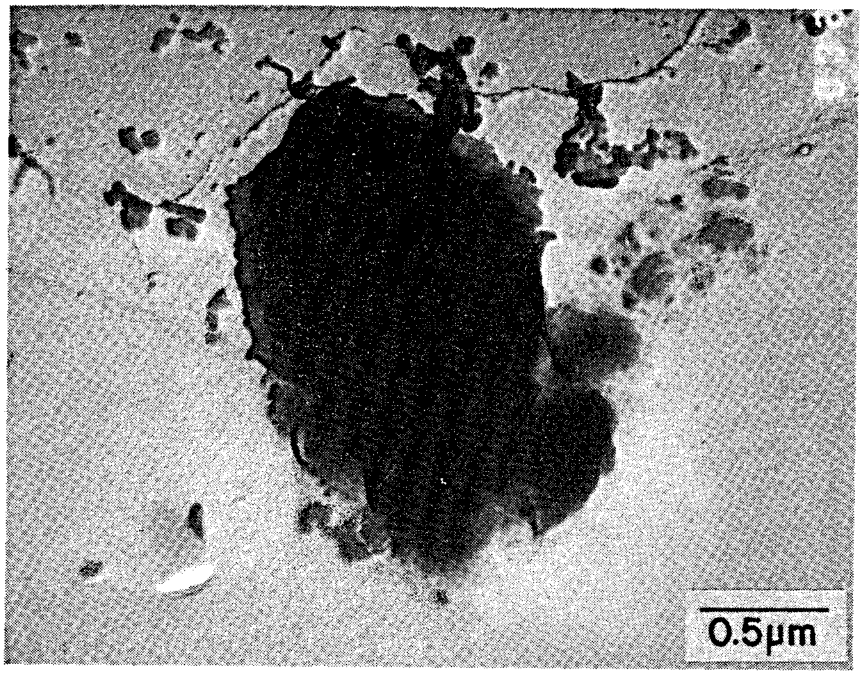


Figure 19. A Thick Saponite Aggregate after the Run at 93.3°C (200°F) in Saponite/NaCl System

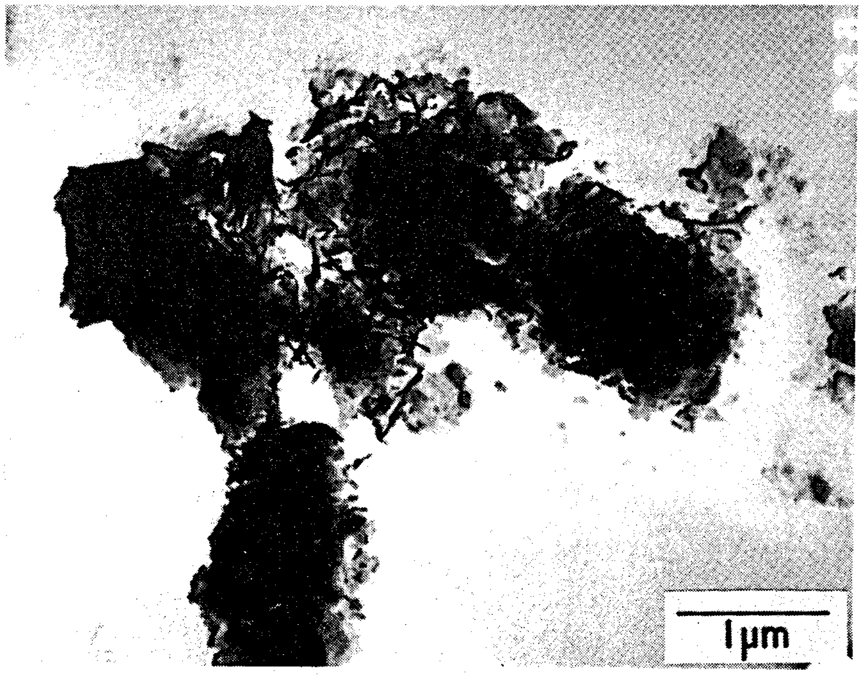


Figure 20. Typical Saponite Aggregates after the Run at 148.9°C (300°F) in Saponite/NaCl System

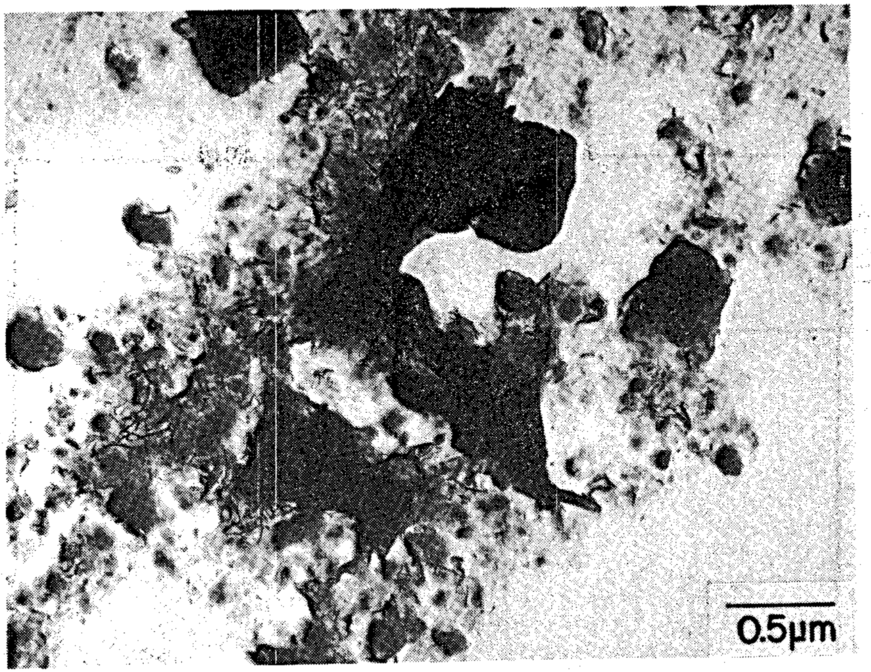


Figure 21. Typical Saponite Aggregates after the Run at 204.4°C (400°F) in Saponite/NaCl System

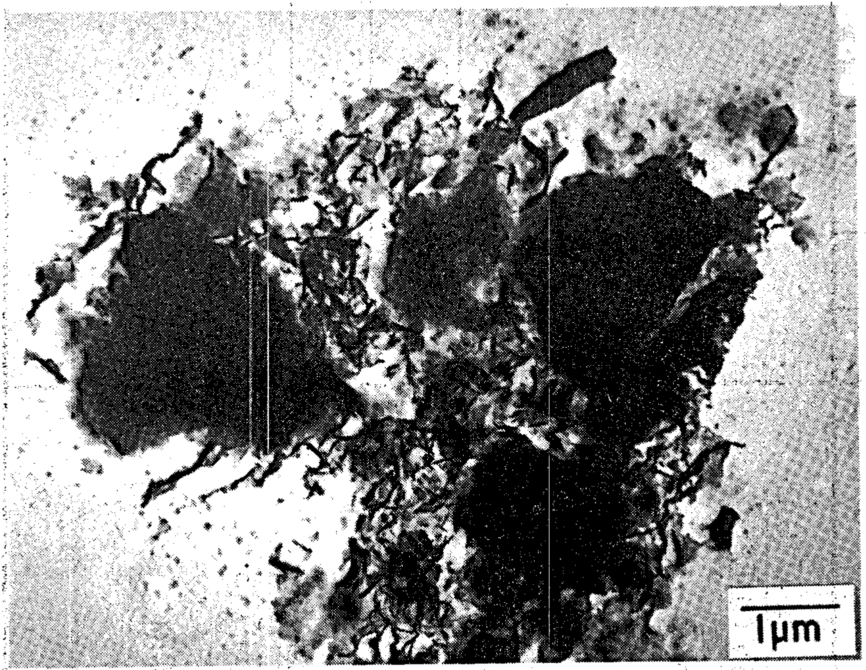
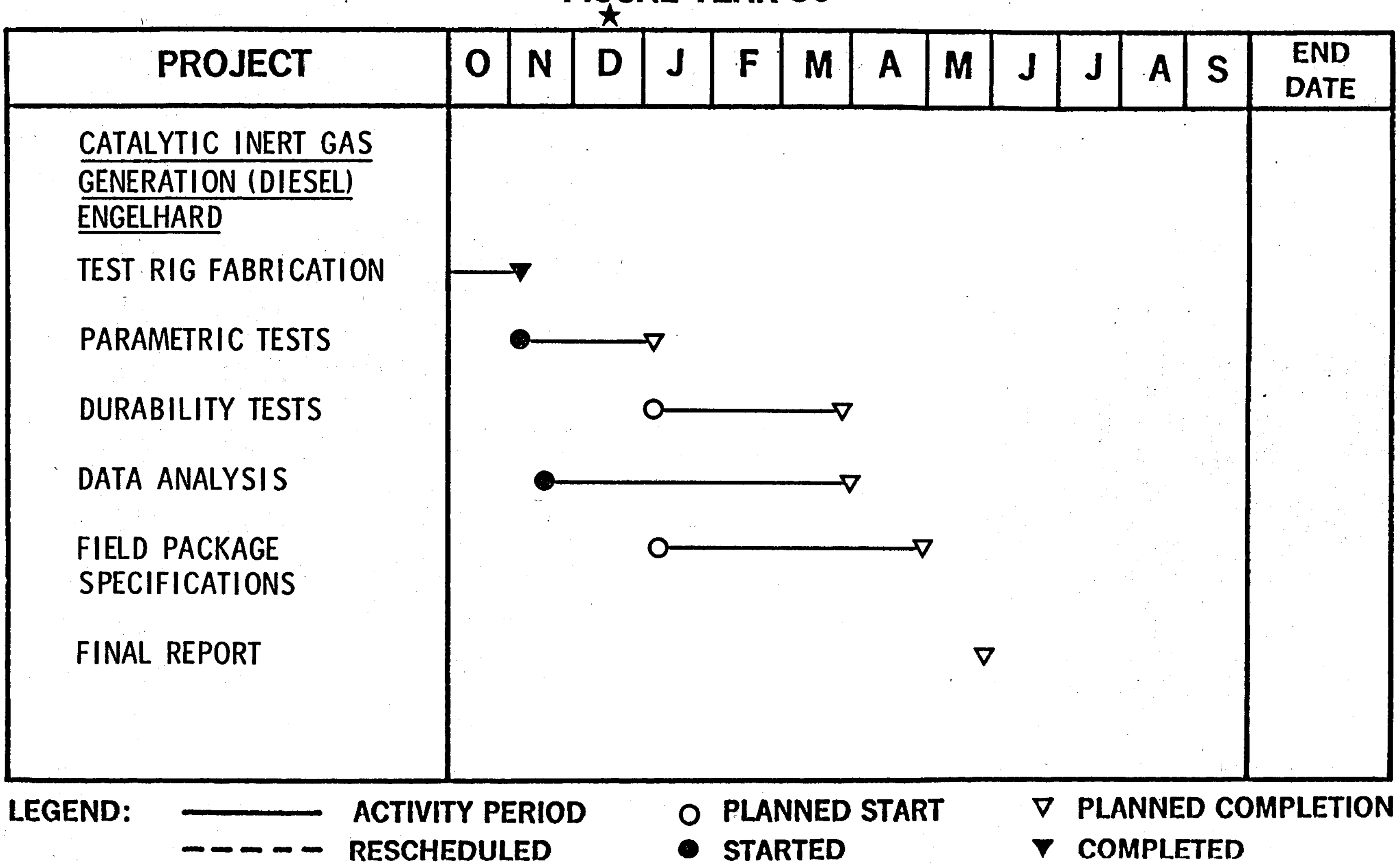


Figure 22. Typical Saponite Aggregates after the Run at 260°C (500°F) in Saponite/NaCl System

GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80



Project:	Inert Gas Generation from Diesel Exhaust Using a Catalyst System
Contractor:	Englehard Minerals & Chemicals Corporation
Principal Investigator:	I. T. Osgerby (201) 321-5230
Contract Period:	1 August 1979 to 30 April 1980
Contract Number:	13-5071 (Sandia)
Technical Consultant:	B. Kenna (505) 264-1565

Project Objective

The objective of this project is to demonstrate catalytically supported thermal combustion as a means of generating an inert gas from the exhaust stream of a commercially available diesel engine. An existing, proprietary catalyst will be used with supplemental No. 2 fuel over the load range of the diesel engine to achieve this objective. This performance objective will be evaluated over an extended period of time to verify that the catalyst activity can be retained under operating conditions consistent with the intended field application.

Project Status

The project was initiated in August 1979. The test rig design and fabrication have been completed and the facility debugged. The parametric test program has been initiated.

Inert Gas Generation from Diesel Exhaust
Using a Catalyst System
Quarterly Progress for October-December 1979

A major contributor to the high costs associated with geothermal wells is the extensive corrosion of the drill pipe by oxygen present in the drilling fluid. The importance of controlling the corrosive attack of oxygen in the drilling operation is evident when the cost and availability of drill pipe is considered.

A possible method for reducing the corrosive attack of oxygen is the utilization of an inert drilling fluid such as nitrogen. Nitrogen could replace air in foam drilling, air drilling, and for the aeration of drilling muds. The volume of nitrogen required for geothermal drilling ranges from 2.2×10^3 to 8.4×10^3 standard m^3 (8×10^3 to 3×10^3 standard ft^3) per day, making the transportation of liquid nitrogen to a drilling site prohibitively expensive. Therefore the major problem with using nitrogen containing less than 5 ppm of oxygen is to economically produce sufficient quantities at the drilling site. One of the methods being studied for producing nitrogen on site is catalytic conversion of diesel exhaust.

The catalytic conversion of diesel exhaust (nominal composition shown in Table 6) involves the combustion of diesel exhaust-fuel mixtures slightly rich in fuel (i.e., above stoichiometric proportions) over a noble metal catalyst. A schematic of the process is shown in Figure 23. The main reaction products are N_2, H_2O, and CO_2, with some NO_x and O_2.

Areas to be studied include the qualitative and quantitative analysis of product gases from the catalytic converter, fuel consumption, and catalyst life studies. A diesel generator unit will be employed, utilizing the generator as a dynamometer, and will pass the engine exhaust through a catalytic converter. The condition of the catalyst will be monitored throughout these studies. Variables will be (1) engine air/fuel ratio to cover altitudes from sea level to 2 438 metres (8 000 feet), (2) engine loading of 25%, 50%, 75%, and 100%, (3) exhaust temperature, and (4) amount of fuel doping applied prior to entry into the converter. Expected results will be (1) the quantitative and qualitative analysis of exhaust products as a function of operating conditions, (2) catalyst life, (3) input information for design of downstream treatment processes, and (4) identification of criteria for scale-up from the laboratory apparatus to a field test unit capable of producing 3 682 standard m^3 (130 000 standard ft^3) per hour of nitrogen.

During the first month of the project, the overall project planning, the test rig design, instrumentation systems specifications, and the catalytic reactor fabrication were completed. A schematic of the facility is shown in Figure 24.

Fabrication of the test facility and its analytical instrumentation were completed this quarter. The exhaust analysis equipment and necessary calibration gases are listed in Table 7. Commissioning tests of the facility were also completed during this reporting period. Difficulties experienced with the engine/generator/load set and the analytical train were

Table 6

Typical Composition of Exhaust From 1 100-hp
Diesel Running at 1 200 rpm (No. 2 Diesel Fuel)

Exhaust Constituent	Flow Rate[a]		% by Volume[a]
	g/h	(lb/h)	
N_2	$3.8x10^6$	$(8.6x10^3)$	76.1
CO_2	$6.0x10^5$	$(13.2x10^2)$	7.7
O_2	$4.9x10^5$	$(10.8x10^2)$	8.6
H_2O	$2.4x10^5$	$(5.3x10^2)$	7.5
CO	900	(1.98)	0.02
NO	5 000	(11.03)	0.1
NO_x	7 700	(16.98)	0.0
Hydrocarbons	53	(0.12)	0.0
SO_2[b]	760	(1.68)	0.01

Flow Rates kg/s (lb/h)

Fuel Rate	0.05 (421.3)
Inlet Air Flow	1.36 (10 800.0)
Exhaust Flow Rate	1.41 (11 221.0)

[a] These data based on steady-state engine operating conditions of 29.4°C (85°F) and 99.2 kPa (29.38 in. Hg).

[b] SO_2 is based on a fuel sulfur content of 0.2 weight percent.

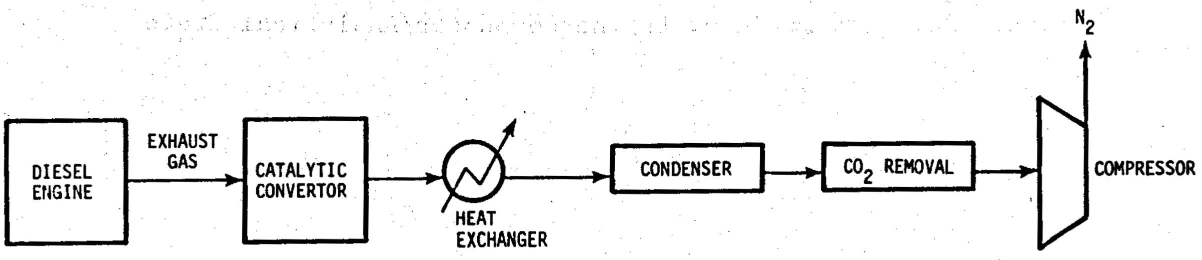


Figure 23. Catalytic Conversion of Diesel Exhaust Gas

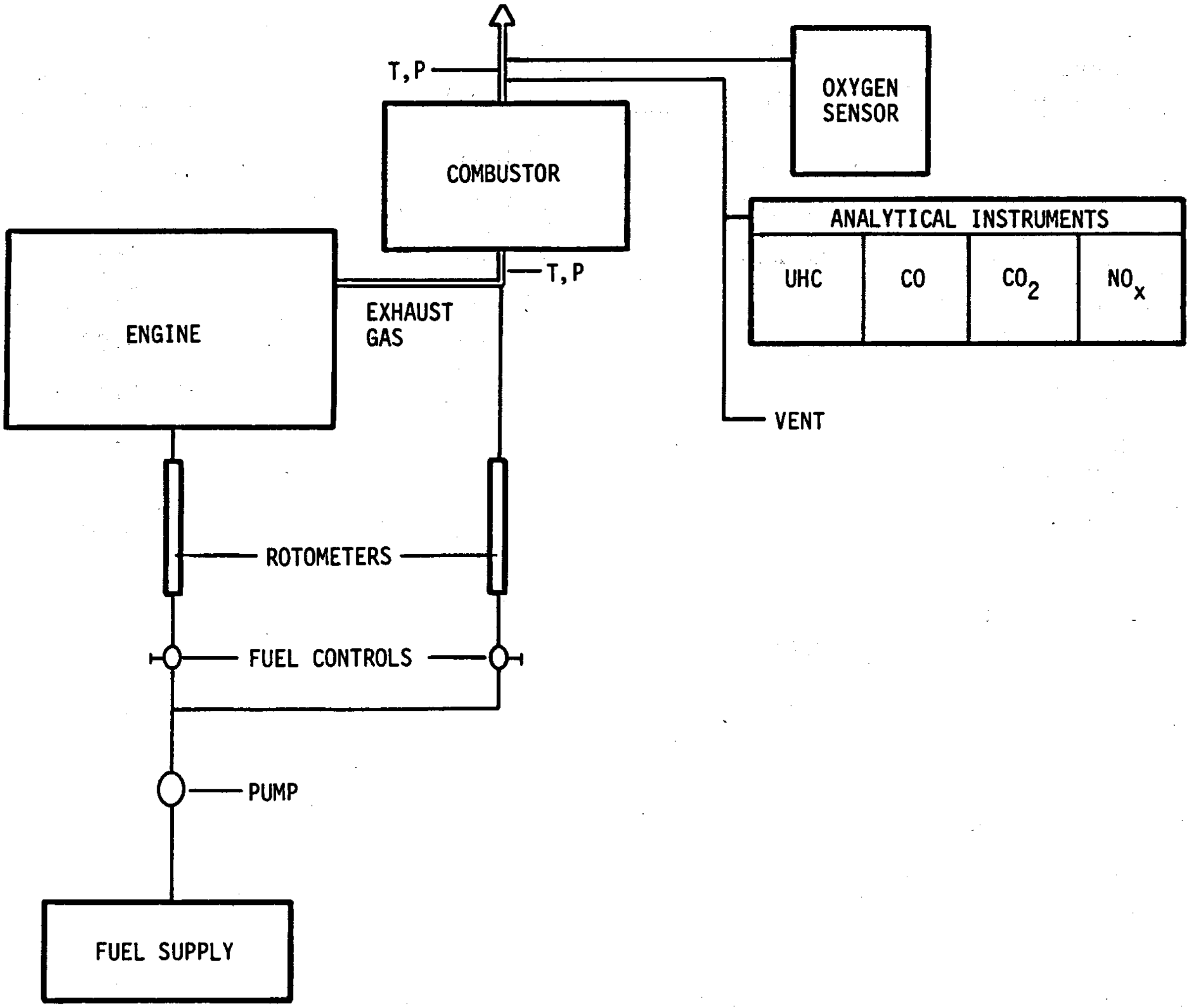


Figure 24. Schematic of Engine/Combustor/Analytical Train

Table 7

Exhaust Analysis Equipment and Calibration Gases

Exhaust Analysis Equipment

1. Beckman Model 402 Hydrocarbon Analyzer (flame ionization)
2. Horiba Model AIA-21 CO_2 Nondispersive Infrared Gas Analyzer
3. Horiba Model AIA-21 AS CO Nondispersive Infrared Gas Analyzer
4. Infrared Industries Model IR-703 CO-05 01-FI-RI Nondispersive Infrared CO Gas Analyzer
5. AeroChem Chemiluminescence NO_x Monitor Model AA-3
6. Teledyne Model 311 Portable Trace Oxygen Analyzer

Calibration Gas Cylinders

1. Fuel Gas - 40% H_2/60% N2
2. Propane in N_2 - 93 ppm C_3H_8
3. Low CO_2 in N_2 - 4.28% CO_2
4. High CO_2 in N_2 - 8.27% CO_2
5. Low ppm CO in N_2 - 10.2 ppm CO
6. High ppm CO in N_2 - 200 ppm CO
7. Low % CO in N_2 - 2% CO
8. High % CO in N_2 - 6% CO
9. Low NO_x in N_2 - 10.2 ppm NO_x
10. High NO_x in N_2 - 205 ppm NO_x
11. Zero gas - N_2

resolved. Engine valve failure resulted in the replacement of the original Allis-Chalmers DES-60 diesel engine. The exhaust characterization of the replacement engine at loads in the range of 0 to 60 kV is similar to that of the original engine and is shown in Figures 25, 26, and 27. Additional problems with setting engine load were caused by malfunctioning of the electrical load dissipation equipment. These problems were corrected by the rental contractor. Some minor adjustments were required to obtain a good reference zero for the oxygen analyzer train. The demonstration of the unit planned for November 1979 was tentatively rescheduled for mid-January 1980.

The parametric test program was initiated in the latter part of this reporting period. An outline of the program test conditions and test variables is shown in Table 8.

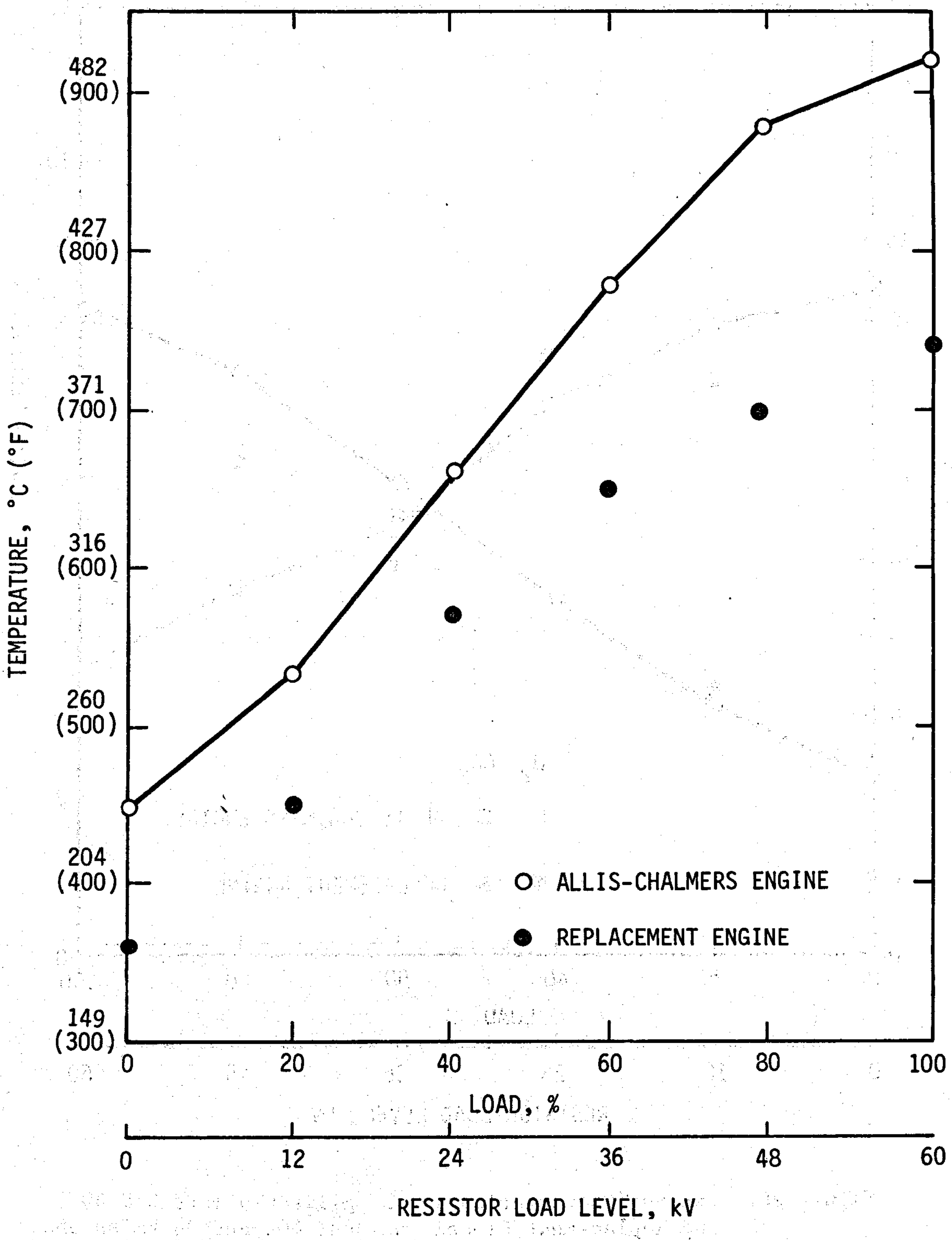


Figure 25. Exhaust Characterization of Allis-Chalmers DES-60 and Replacement Diesel Engines; Temperature

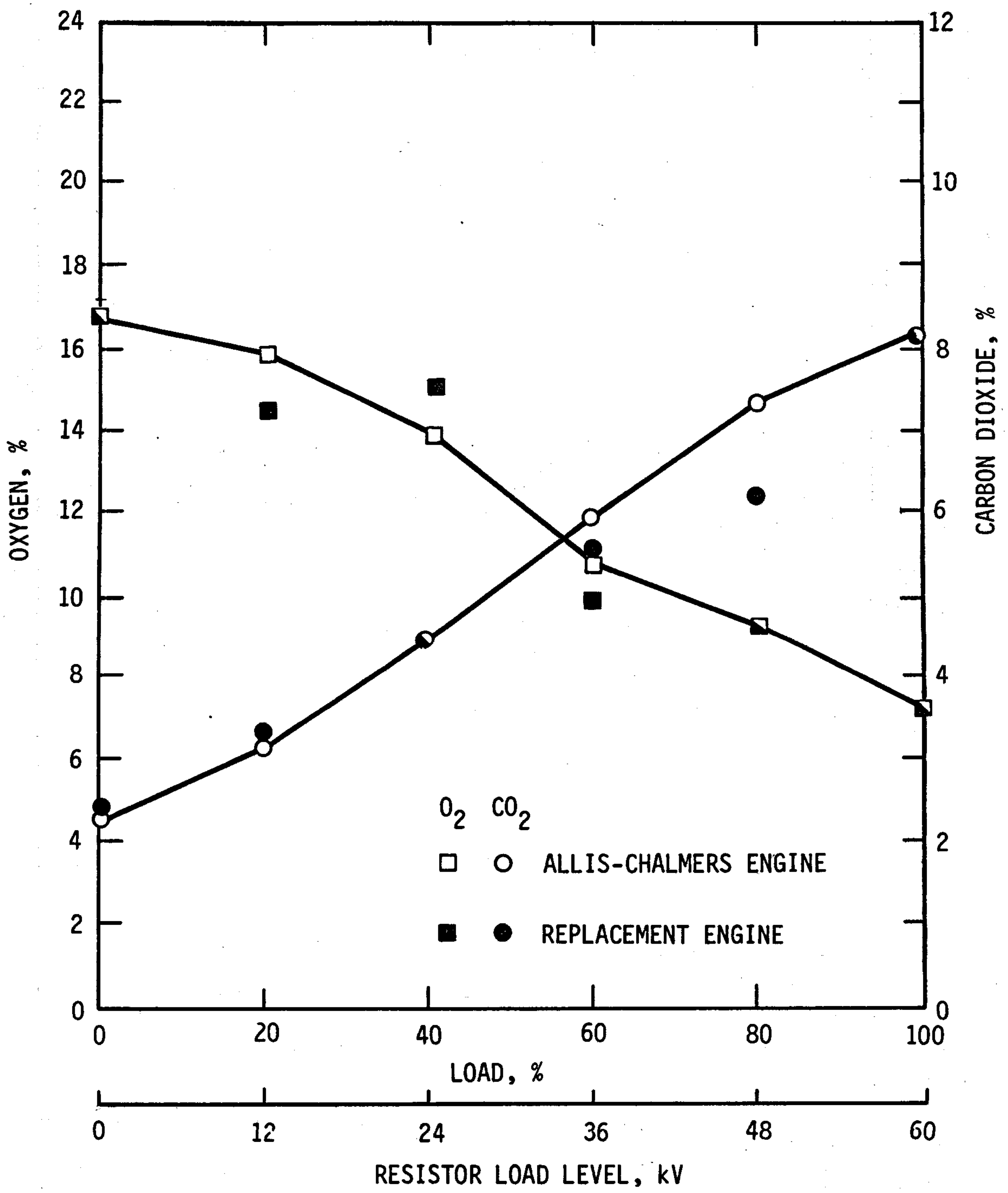


Figure 26. Exhaust Characterization of Allis-Chalmers DES-60 and Replacement Diesel Engines; CO_2 and O_2 Emissions

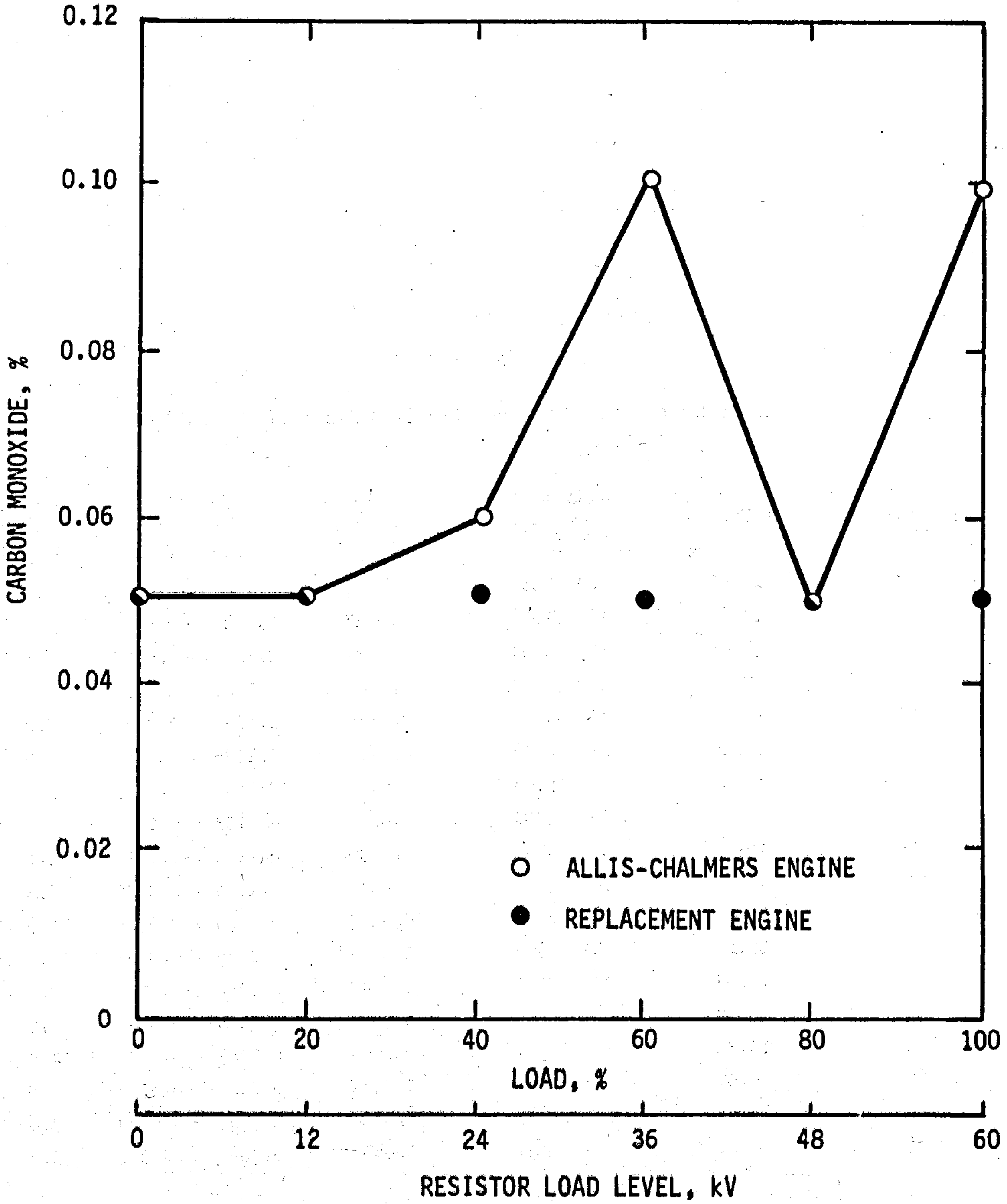


Figure 27. Exhaust Characterization of Allis-Chalmers DES-60 and Replacement Diesel Engines; CO Emission

Table 8

Parametric Test Program Conditions and Variables

Generator Load Bank Setting kW	O_2 Content of Exhaust Wt %	Catalyst Inlet Temperature °C (°F)	Engine F/A Ratio lb/lb	Overall F/A Ratio lb/lb	Reference Velocity m/s (ft/s)
0	18.66	182 (360)	0.0137	0.1285→0.071	5.2 (17)
0	18.66	182 (360)	0.0137	0.1285→0.071	6.1 (20)
0	18.66	182 (360)	0.0137	0.1285→0.071	6.7 (22)
12	17.65	232 (450)	0.0168	0.1225→0.072	5.8 (19)
12	17.65	232 (450)	0.0168	0.1225→0.072	7.0 (23)
12	17.65	232 (450)	0.0168	0.1225→0.072	7.9 (26)
24	15.37	299 (570)	0.0239	0.1193→0.0723	6.4 (21)
24	15.37	299 (570)	0.0239	0.1193→0.0723	7.9 (26)
24	15.37	299 (570)	0.0239	0.1193→0.0723	9.1 (30)
36	12.09	343 (650)	0.0372	0.1129→0.0725	7.3 (24)
36	12.09	343 (650)	0.0372	0.1129→0.0725	8.8 (29)
36	12.09	343 (650)	0.0372	0.1125→0.0725	10.0 (33)
48	10.33	371 (700)	0.0399	0.1064→0.073	7.9 (26)
48	10.33	371 (700)	0.0399	0.1064→0.073	9.7 (32)
48	10.33	371 (700)	0.0399	0.1064→0.073	11.2 (37)
60	8.01	393 (740)	0.0474	0.0983→0.0732	8.5 (28)
60	8.01	393 (740)	0.0474	0.0983→0.0732	10.6 (35)
60	8.01	393 (740)	0.0474	0.0983→0.0732	12.5 (41)

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GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80

PROJECT	O	N	★ D	J	F	M	A	M	J	J	A	S	END DATE
COMPLETIONS STUDY COMPLETION TECHNOLOGY COMPANY													
LONG-RANGE GEOTHERMAL WELL TECHNOLOGY PROGRAM FORMULATION	———	———▼											
NIELAND INJECTION STUDY	COMPLETED												
CASING/LINER DESIGN STUDY	COMPLETED												
SPE AND GRC PAPERS PACK/PERF™	COMPLETED												
INSTALLATION IN HDR WELL	COMPLETED												
CONTRACTING TASKING UNDER CONTRACT NO. 13-2297	———	———▼											

LEGEND:

———— ACTIVITY PERIOD

– – – – – RESCHEDULED

○ PLANNED START

● STARTED

▽ PLANNED COMPLETION

▼ COMPLETED

Project:	Completion Technology Consultation
Contractor:	Completion Technology Company
Principal Investigator:	R. E. Snyder (713) 961-5011
Contract Period:	1 December 1978 to 30 November 1979
Contract Number:	13-2297 (Sandia)
Technical Consultant:	T. Hinkebein (505) 264-5202

Project Objective

The project objective is to provide consulting services and assistance to the geothermal drilling and completion technology effort in the formulation and implementation of the long-range DOE/Sandia Geothermal Well Technology Development Program. Specific objectives of the project include (1) assistance in the definition and review of current completion technology programs, (2) evaluation of field millipore injectivity tests, (3) completion of a state-of-the-art study of casing/liner design and cementing technology relating to geothermal/geopressured environments, (4) assistance on a study of high-temperature properties of casing and casing joints, and (5) evaluation of cement-inflatable packers in hot dry rock (HDR) and fluid-dominated geothermal systems.

Project Status

All work under this contract was completed this quarter. A new contract, No. 46-0173, was being finalized during the last part of this reporting period.

Completion Technology Consultation
Quarterly Progress for October-December 1979

The preliminary draft of the American Society of Mechanical Engineers (ASME) Paper "Geothermal Well Casing Failure Modes" was returned, with reviewer suggestions, by the chairman of the Emerging Energy Technologies Committee of the ASME Conference scheduled in New Orleans for 3-7 February 1980.

The draft was expanded to incorporate the reviewers' suggestion, art work was finalized, and the paper was retyped on camera-ready mats for ASME Headquarter preparation. The content of the paper is similar to presentations made at the Las Vegas Society of Petroleum Engineers (SPE) and Reno Geothermal Resources Council (GRC) meetings, with greater emphasis on casing string problems.

All work was completed under this contract. A new contract, No. 46-0173, to continue Completion Technology Company's consulting and engineering services, was being processed near the end of this reporting period.

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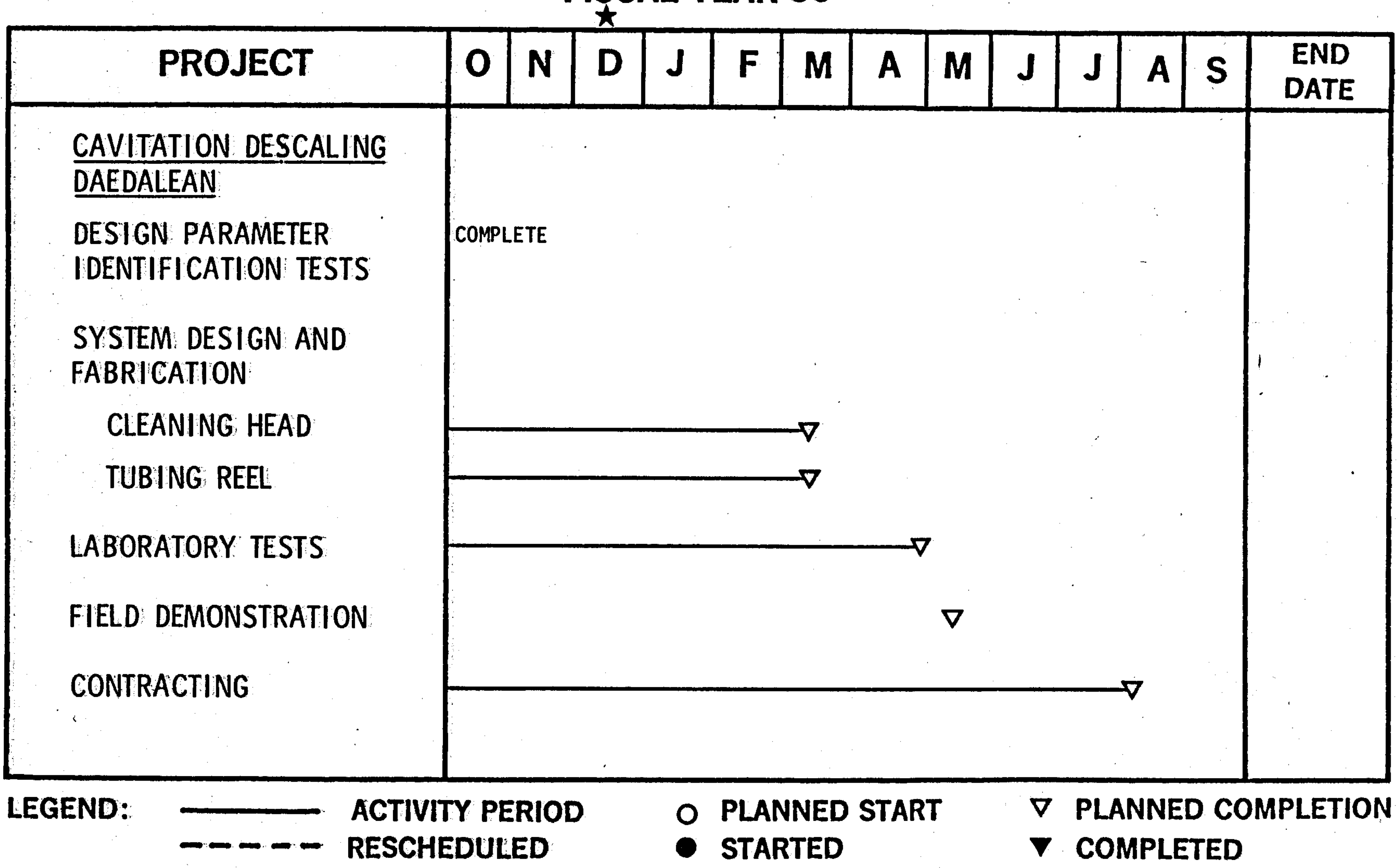
GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80



EXTERNAL R&D

Project:	Cavitation Descaling Technique for Downhole Geothermal Well Cleaning
Contractor:	Daedalean Associates, Inc.
Principal Investigators:	Dr. A. P. Thiruvengadam Dr. A. A. Hochrein, Jr. } (301) 442-2620
Contract Duration:	14 February 1979 to 15 August 1980
Contract Number:	13-2361 (Sandia)
Technical Consultant:	T. Hinkebein (505) 264-5202

Project Objective

The objective of this project is to develop and apply a controlled cavitation technique for downhole geothermal well cleaning and scale removal.

Work in this program is expected to build on technology acquired under a previous DOE contract for the development of a cavitation descaling technique for pipes and tubes in geothermal power plants (EG-76-001-2289).

Project Status

The design parameters were identified on 29 and 30 March 1979 at the East Mesa (California) geothermal test facility. The design process is now proceeding as a result of the data obtained from this test.

Development of a Cavitation Descaling Technique for Downhole Geothermal Well Cleaning and Scale Removal
Quarterly Progress for October-December 1979

Work is continuing on the design of the downwell cleaning head. Several hydraulic motor manufacturers have made recommendations for the drive motor that will rotate the nozzle head. Centering device configurations are being analyzed. The main design thrust at this time is on a workable rotating seal assembly for sealing the multinozzle head and the rotator device at the high working pressures that will be encountered.

Nozzle design and evaluation is an ongoing effort. Current efforts are concentrating on evaluating the performance of the nozzle designs at the elevated ambient pressures that will be encountered downwell. The major effort has been on evaluating conical spray pattern nozzles. The next series of tests will be conducted on fan nozzles and on nozzles that incorporate a swirl-inducing device.

A commercially available rotating seal is being evaluated in the laboratory. This seal is being utilized in conjunction with one of the dual-nozzle cleaning head designs. The reliability of the seal under the flow and pressure conditions that will be necessary to remove the scale from the well is being determined. Several sizes of nozzles are being tested with this cleaning head. The effectiveness of these nozzles in removing the geothermal scale from the scaled pipe specimens received from East Mesa will be evaluated during the next reporting period.

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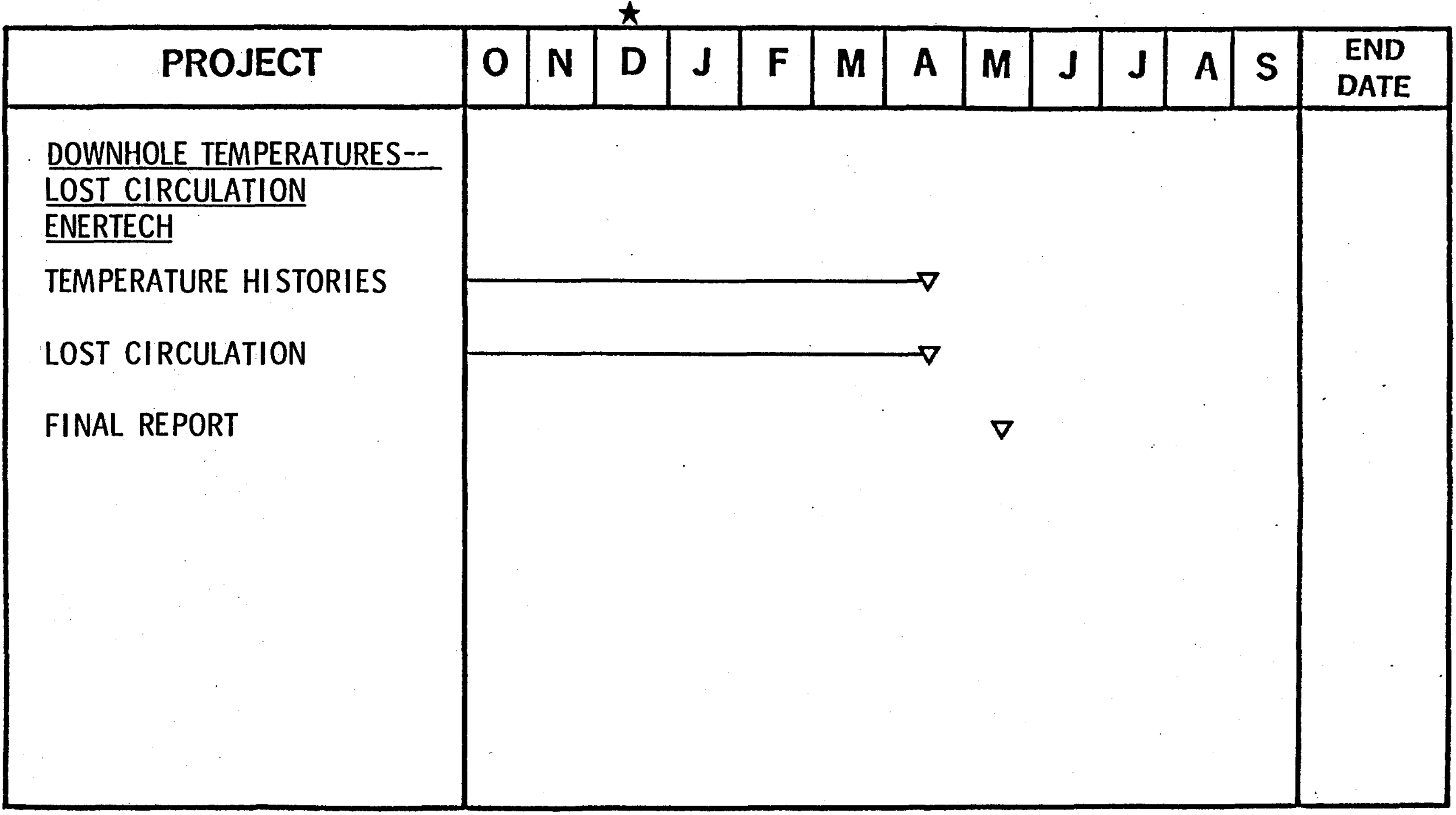
GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80



PROJECT	O	N	★ D	J	F	M	A	M	J	J	A	S	END DATE
DOWNHOLE TEMPERATURES-- LOST CIRCULATION ENERTECH													
TEMPERATURE HISTORIES	———	———	———	———	———	———	——▽						
LOST CIRCULATION	———	———	———	———	———	———	——▽						
FINAL REPORT								▽					

LEGEND:

———	ACTIVITY PERIOD	○	PLANNED START	▽	PLANNED COMPLETION
– – – – –	RESCHEDULED	●	STARTED	▼	COMPLETED

EXTERNAL R&D

Project: Temperature History and Lost Circulation Experience in Geothermal Wells
Contractor: Enertech Engineering and Research Co.
Principal Investigator: G. Wooley (713) 521-9294
Contract Period: 29 August 1979 to 29 April 1980
Contract Number: 13-8769 (Sandia)
Technical Consultant: T. Hinkebein (505) 264-5202

Project Objective

The objective of this project is to provide temperature histories required for geothermal well casing design and to provide a synopsis of causes and preventions of, and remedies to, lost circulation in geothermal environments.

Project Status

Project work was initiated in September 1979. An information survey plan has been developed to acquire and organize the required well thermal history and lost circulation experience data. The review of pertinent literature and the interview of selected companies with appropriate experience is progressing.

Temperature History and Lost Circulation Experience in Geothermal Wells
Quarterly Progress for October-December 1979

Activities in this quarter were directed at acquiring useful literature, identifying companies with valuable experience, and initiating of the interview phase of the project.

Literature on lost circulation is extensive. Several activities were selected for their practical value from the literature acquired so far. The following are representative of the articles being reviewed:

1. J. U. Messenger, "How to Combat Lost Circulation," Oil and Gas Journal;
2. J. U. Messenger, "How to Remedy Lost Circulation," Oil and Gas Journal;
3. Bill Rehm, "Lost Circulation Complicates Well Killing Operations," Oil and Gas Journal;
4. J. U. Messenger, "Barite Plugs Can Effectively Seal Off Active Gas Zones," Oil and Gas Journal;
5. J. U. Messenger, "Common Rig Materials Combat Severe Lost Circulation," Oil and Gas Journal;
6. J. L. Lummus, "A New Look at Lost Circulation," Petroleum Engineer, November, 1967; and
7. P. P. Scott, Jr., J. L. Lummus, and G. C. Howard, "Method for Sealing Vugular and Cavernous Formations," Drilling Contractor.

Although there has been much work in the field, new approaches for dealing with lost circulation have not been developed for many years.

A list of companies to be interviewed was compiled. These companies were selected from those with extensive lost circulation experience and included the following:

Geothermal Operators:

1. Union
2. Chevron
3. Republic Geothermal
4. Los Alamos Scientific Laboratories
5. Phillips
6. Mexico

Petroleum Operators:

1. Exxon
2. ARCO
3. Gulf
4. Shell
5. Mobil

Drilling Mud Companies:

1. Magcobar
2. Milchem
3. IMCO
4. Baroid
5. Oil Base

Consultants:

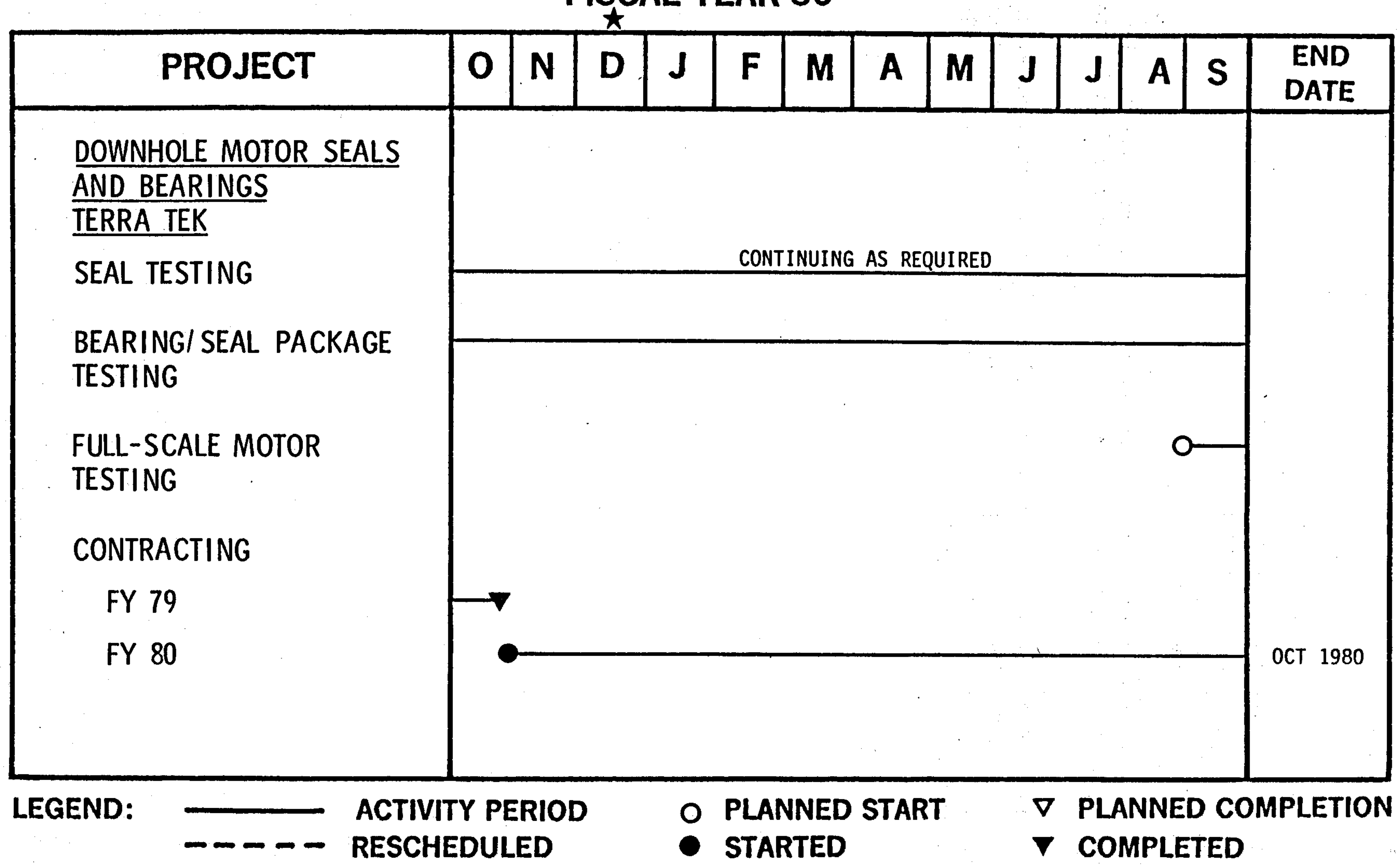
1. Chenevert Engineering
2. Nicholson and Associates
3. Completion Technology
4. Maurer Engineering

From this list of companies, approximately 10 will be selected for interview in accordance with the information survey plan developed in September 1979.

Thermal history data will be solicited from the same geothermal operators selected from the above list. From the thermal data obtained during interviews, typical and atypical histories will be constructed, and downhole temperatures will be computed with GEOTEMP.

GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80



Project:	Improvement of Downhole Drilling-Motor Bearings and Seals
Contractor:	Terra Tek, Inc.
Principal Investigator:	G. Tibbitts (801) 582-2220, ext. 187
Contract Period:	1 November 1979 to 31 October 1980
Contract Number:	46-3053 (Sandia)
Technical Consultant:	J. Finger (505) 264-8089

Project Objective

The application of downhole motors to geothermal drilling has been limited because of short bearing and seal life in the high-temperature geothermal environment. The specific objective of this project is the development of a 200-hour-life bearing and seal package adaptable to most types of downhole motors that operate at a 121°C (250°F) circulation temperature.

Project Status

Facilities have been developed to test seals and bearing/seal packages at geothermal downhole conditions: 300°C (572°F) and 34.5 MPa (5 000 psi). Some standard seals have been tested to determine baseline performance. New seals have been designed in cooperation with the seal industry and have been tested in the laboratory. New bearing seals for downhole motors have been designed and will be laboratory tested in the bearing/seal package test facility. The bearing/seal test facility is now completed, and full-scale testing has begun. The present lubricant screening program test results have been completed and published. The lubricant test facility remains available for check-testing as required. Seal testing and debugging of the bearing/seal package test facility is continuing.

Improvement of Downhole Drilling-Motor Bearings and Seals
Quarterly Progress for October-December 1979

During this reporting period, the contractual actions required to continue the project were accomplished. The contract provides for the required testing activities through October 1980. Certain design and fabrication support activities, previously provided under subcontract to Terra Tek, will be furnished by Maurer Engineering under a separate Sandia contract. These support activities will be reported separately in this Quarterly Progress Report. A final report of previous work, Phase III - Part 2, was completed and ready for distribution at the close of this quarterly reporting period.

Seal Testing and Evaluation

Tests DMT-029 through DMT-033 were completed during the reporting period. Table 9 summarizes these seal test results.

Table 9

Seal Test Results

Test No.	Seal Type	No. of Pressure Rings	Backup Rings	ΔP MPa (psi)	Rpm	Duration (hours)	Chrome Shaft Coating Finish (rms)	Diametral Clearance Shaft to Backup Rings mm (inch)
028	II GRAFOIL^R-Bronze	3	SAE 660 Bronze	10.3 (1500)	412	2.92	4 - 8 μin	0.025 (0.001)
029	II GRAFOIL^R-Bronze	3	SAE 660 Bronze	10.3 (1500)	412	3.17	4 - 8 μin	0.025 (0.001)
030	Canted -- 31A Material	2	9C Aluminum Bronze	10.3 (1500)	412	0	4 - 8 μin	0.020 (0.008)
031	Canted -- 42DR Material	2	9C Aluminum Bronze	10.3 (1500)	412	0	4 - 8 μin	0.20 (0.008)
032	RD-199 Graphite-Metal Matrix	3	SAE 660 Bronze	10.3 (1500)	412	8.57	4 - 8 μin	0.025 (0.001)
033	Canted -- 42DR Material	2	9C Aluminum Bronze	10.3 (1500)	412	0.72	4 - 8 μin	0.20 (0.008)

Test DMT-029 was a repeat of test DMT-028. The seal tested was GRAFOIL® with 0.76-mm (0.030-inch) preformed rings of yellow brass. The total running time was 3.17 hours. The test ended abruptly when the spline at the bottom of the shaft, which was worn, disengaged from the torque cell. The shaft was removed and the spline was repaired.

Test DMT-032 tested the RD-199 graphite-metal matrix (soft copper) seal. The total running time was 8.57 hours. The backup system used was the same system used in test DMT-024--the bronze backup ring with flexing lip. The seal did not start leaking until the end of the test, and the seal failure was catastrophic. Examination of the seals after the test showed a loss of some of the graphite from the matrix.

Tests DMT-030, DMT-031, and DMT-033 tested the first generation 127 by 152 mm (5 by 6 inch) canted seal. The canted seal assembly consists of two seal rings held in place by a three-piece backup system made of 9C aluminum bronze. The three parts of the backup system are pinned together. The seal material in DMT-030 was 31A (Buna-N and cotton duck), and the seal material in DMT-031 and DMT-033 was 42DR (lubricated Buna-N and cotton and nylon).

Two important findings concerning the canted seal installation resulting from these tests were

1. The loading of canted seals is very difficult. A new method of loading the seals will be developed. One solution would be to preload the canted seal assembly before installation and then install the assembly as a cartridge unit in the seal tester.
2. A modification to the seal tester is needed to prevent damage to the lip of the canted seal during installation of the shaft. A solution to this problem is to put a small taper of approximately 0.51 mm (0.020 inch) on each end of the shaft sleeve.

In tests DMT-030 and DMT-031, the canted seals and spacers were installed in the seal tester. The seals were preloaded, and finally the shaft was installed. The test was started, and the seals in both tests leaked immediately. The seal tester was disassembled, and the seals were inspected. Scratches on the outside of the canted seal backup system showed that the seals had rotated in the seal tester.

F. Pippert from Utex Industries, the manufacturer of the canted seal, visited Terra Tek on 25 October 1979. He supervised the installation of the canted seals for DMT-033. The seals were installed in the same manner as in DMT-030 and DMT-031, except that the canted seal backup systems and the spacers were all pinned together inside the seal tester.

On Pippert's recommendation, the test was run without heating the vessel. A reverse differential pressure was put across the seals to shock the lip on the lower seal pack into place. The seals held a differential pressure for approximately 45 minutes before they started leaking.

Ten of the 127 by 152 by 0.38 mm (5 by 6 by 0.015 inch) phosphor bronze backup rings and 10 of the 127 by 152 by 0.76 mm (5 by 6 by 0.030 inch) phosphor-bronze backup rings were received from Maurer Engineering.

A new torque cell preamp was fabricated. The new preamp offers greater sensitivity.

A couple of minor changes were made to the seal tester shaft drawing. Minor changes were incorporated into the new seal tester shaft. The shaft was being manufactured with delivery expected near the end of this reporting period.

A preliminary design was completed to modify the ends of the seal tester shaft sleeve to make the installation of the shaft easier. The need for this design change came from earlier work on testing the first generation canted seals. At that time, the seals were found to be difficult to install in their present configuration.

Bearing/Seal Package Testing and Evaluation

The cartridge heaters with insulated leads have been installed in the geothermal vessel, and the vessel has been reinstalled in the pit.

Quotations have been obtained for the interconnecting parts between the bearing/seal package and the DynaDrill and Eastman Whipstock motors.

New load and torque cells were installed on the dynamic actuator shaft. A preamp was constructed for the load and torque cells that will give greater sensitivity to the cells.

The electronic cables were inspected and overhauled. The purpose of overhauling the cables was to facilitate the hookup of the electronic instrumentation console to the bearing/seal package test facility when it is moved from the downhole motor (DHM) seal tester.

The final draft of the report "Bending Stress and Frequency Calculations for the Bearing-Pack Shaft," by J. Barnwell and D. Dareing (Terra Tek Technical Report No. 79-26), was received at Terra Tek and was being printed at the end of this quarterly reporting period.

Lubricant Testing and Evaluation

Two lubricant tests, Tests 162 and 163, were completed during this reporting period using the same procedure as in previous lubricant tests. These two tests were performed on Pacer PLX-014 mixed with a small amount of water to check for water effects on lubricant performance. The tests were run at 204°C (400°F) so that comparisons could be made with the previous tests on Pacer PLX-014. The test results were as follows:

Test No.	Average Wear Scar Width
162	4.42 mm (0.174 inch)
163	2.74 mm (0.108 inch)

Previous Pacer PLX-014 tests, Nos. 103 and 104, at the same temperature showed wear scar widths of 1.78 mm (0.070 inch) and 2.21 mm (0.087 inch), respectively.

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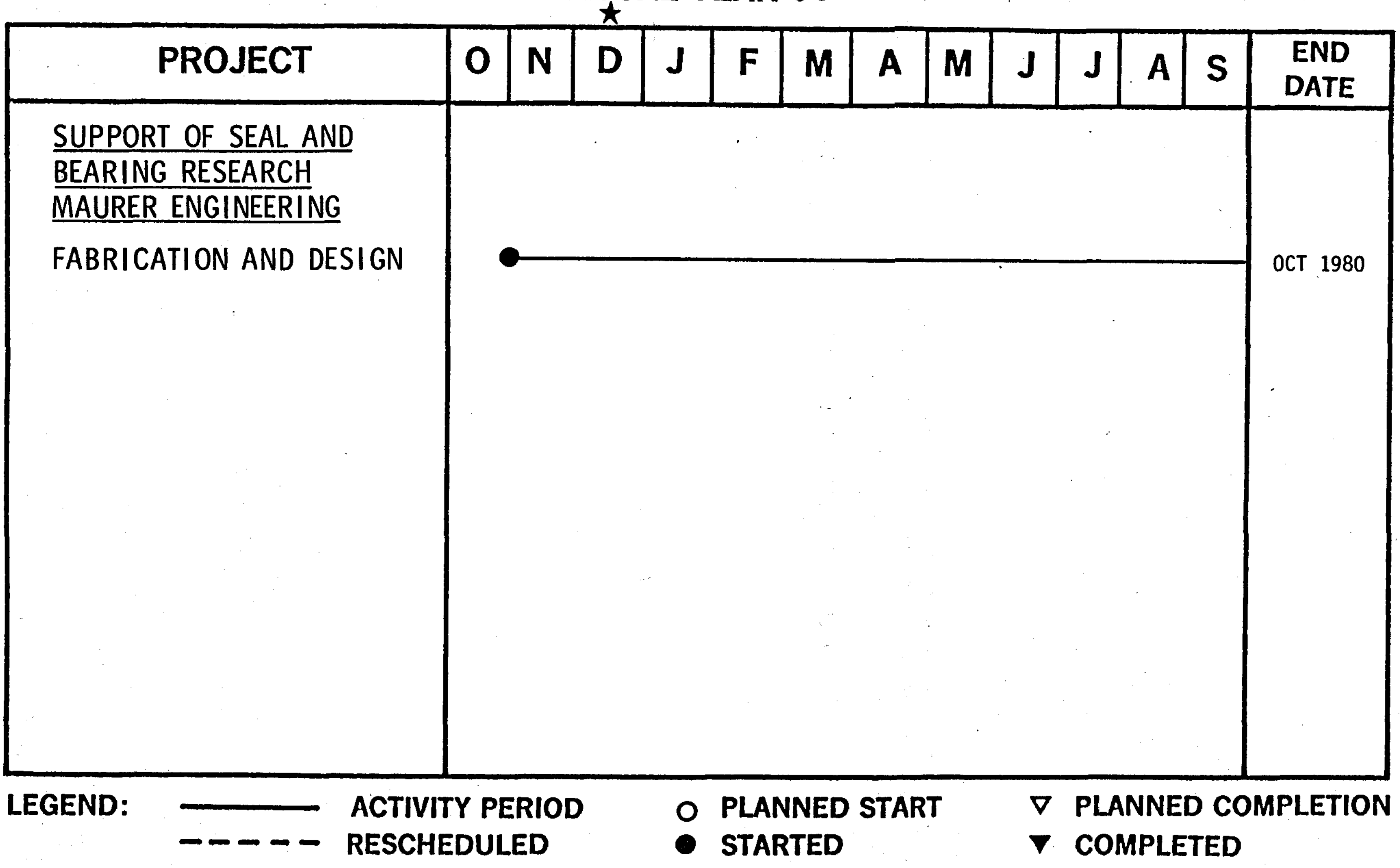
GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80



EXTERNAL R&D

Project: Design and Fabrication Support of Bearing/Seal Research
Contractor: Maurer Engineering, Inc.
Principal Investigator: J. Barnwell (713) 683-8227
Contract Period: 1 November 1979 to 31 October 1980
Contract Number: 46-3054 (Sandia)
Technical Consultant: J. Finger (505) 264-8089

Project Objective

The objective of this project is to provide the required design, manufacturing, and post-test component analysis support for the development of downhole drilling-motor bearings and seals.

Project Status

Maurer Engineering has been providing support services to the bearing/seal research under a subcontract with Terra Tek, Inc. Beginning in November 1979, the required support services are being furnished under a separate contract with Sandia. Design of redundant seals and the interface areas with the bearing/seal package are continuing.

Design and Fabrication Support of Bearing/Seal Research
Quarterly Progress for October-December 1979

During this reporting period, the following design activities were accomplished:

1. A layout drawing of the redundant seals which utilize a check valve to activate the spare seals was completed.
2. Machine drawings of the redundant seal assembly parts were completed. One set of these parts was manufactured by Maurer Engineering and delivered to Terra Tek in December 1979. Terra Tek will manufacture the expendable parts after those initial parts are used up. Terra Tek will also provide the GRAFOIL® seals used in these tests.
3. Drawings which show two additional types of redundant seals have also been completed. One design utilizes a porous filter to activate the spare packing, whereas the second design utilizes a floating piston containing small flow ports. With these designs, the spare packing is activated when the porous filter or floating piston parts are plugged by GRAFOIL® particles or solids in the drilling mud.
4. A drawing which shows the modifications to be made to the existing bearing pack seal nut was completed. These modifications, which will allow the redundant seals to be used in this bearing pack, will be made by Terra Tek.

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GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80

PROJECT	O	N	★ D	J	F	M	A	M	J	J	A	S	END DATE
<u>WATER-JET DRILLING</u> <u>UNIV. OF MO-ROLLA</u>													
HYDRO MECHANICAL BIT (18 000 psi TEST)	- - ▼												
UNDER-REAMER	———	———	———	———	▽								
CAVITATION TEST STANDARD IN ROCK	———	———	———	———	▽								
CONTRACTING	———	———	———	———	▽								

LEGEND:
——— ACTIVITY PERIOD
- - - - - RESCHEDULED
○ PLANNED START
● STARTED
▽ PLANNED COMPLETION
▼ COMPLETED

Project:	Development of Geothermal Erosion Drilling Hardware
Contractor:	University of Missouri-Rolla
Principal Investigator:	D. A. Summers (314) 341-4365
Contract Period:	6 February 1979 to 5 February 1980
Contract Number:	13-2346 (Sandia)
Technical Consultant:	D. Glowka (505) 264-3601

Project Objective

The objective of this project is to continue work in erosion drilling for geothermal applications through investigations into the design, fabrication, and demonstration of hardware useful for geothermal well drilling and completion. There are three primary objectives of this project:

1. Development and demonstration of an erosion drilling under-reamer for use in geothermal injection wells,
2. Field testing of a hybrid water jet/roller cone bit, and
3. Development of a cavitation damage test standard for rock.

Project Status

Modifications to the triaxial test chamber have been made. The test chamber is being used to demonstrate the capability of a water jet under-reamer to cut rock at the ambient and confining pressures specified.

Initial results of field tests of the hydromechanical drill in drilling dolomite indicated that a jet pressure of 68.9 MPa (10 000 psi) must be exceeded before a jet assist improves performance. Above 82.7 MPa (12 000 psi), improvements of approximately 100% or better in drilling rate can be achieved using a single jet directed axially along the drill. Other jet orientations have achieved even higher rates. The field tests were concluded during October 1979. While an improvement in drilling rate was achieved where high-pressure water jets were directed across a quadracone bit (the hydromechanical bit), the practical problems of running the present bit design in a hole were such that it was recommended that this particular design not be further developed.

Work is continuing on evaluating the cavitation resistance of various rock types. The stationary specimen tests have been completed. The cavitation test system has been modified by fabrication of a larger Lichtarowicz cell to allow continuation of development of a cavitation damage test standard for rock. Progress has been made in the test program to evaluate the Lichtarowicz cell as a means of testing rock resistance to cavitation. Analysis of the data is proceeding.

Erosion Drilling Hardware
Quarterly Progress for October-December 1979

The field test program examining field performance of the hydromechanical drill bit was completed. In comparison to an air-cleaned tricone bit of equivalent size, the hydromechanical bit was able to penetrate at approximately twice the rate, under similar loading conditions. However, a comparison made with the performance of a conventional tricone bit, to which a high-pressure jet was added, indicated that, when the jet was directed at the hole gage, the latter system was superior.

More critical to the evaluation of the hydromechanical bit was a problem encountered in drilling the relatively hard dolomite at the test site. The leading water jet nozzle, which drills the access for the lateral jets, does not drill a "tight" circular hole but rather an irregular hole somewhat larger than the nozzle body. Chipping of the surrounding hole by the drilling cones and the flow of fluid in the current design has the potential for feeding debris into this hole. These rock fragments generate a high degree of wear on the leading nozzle body and could result in premature failure.

At the present time, it is difficult to foresee a simple, practical solution to this problem. Taken with the other test data cited above, it is therefore, concluded that no further testing of this concept can, at this stage, be recommended.

The third phase of the current test program to evaluate the cavitation erosion resistance of rock has been completed. Based upon the use of a modified Lichtarowicz cell, and using transmission fluid as the cutting medium, a standardized test method was devised. A suite of rocks has been tested, following this procedure, and three measures of resistance have been developed. Current detailed analysis of the data is proceeding. Only one rock from the suite of rocks which has been tested is normally erodible at the jet stagnation pressures under which the tests have been carried out.

The work will be reviewed with two members of the American Society for Testing Materials (ASTM) Subgroup on Cavitation Testing prior to submission of a report. A report on the cavitation studies, and on the hydromechanical bit field tests, was in preparation in the latter part of the reporting period.

The cavitation test program will be continued using water as the cutting fluid and extending the test range to include a wider suite of rocks. A second pump is being relocated to allow the tests to be repeated, using water rather than transmission fluid as the cutting medium.

Parts have been ordered for a conceptual prototype reamer unit to be run to verify the cutting patterns. A test matrix is under development for these initial tests in the development of the erosion drilling underreamer.

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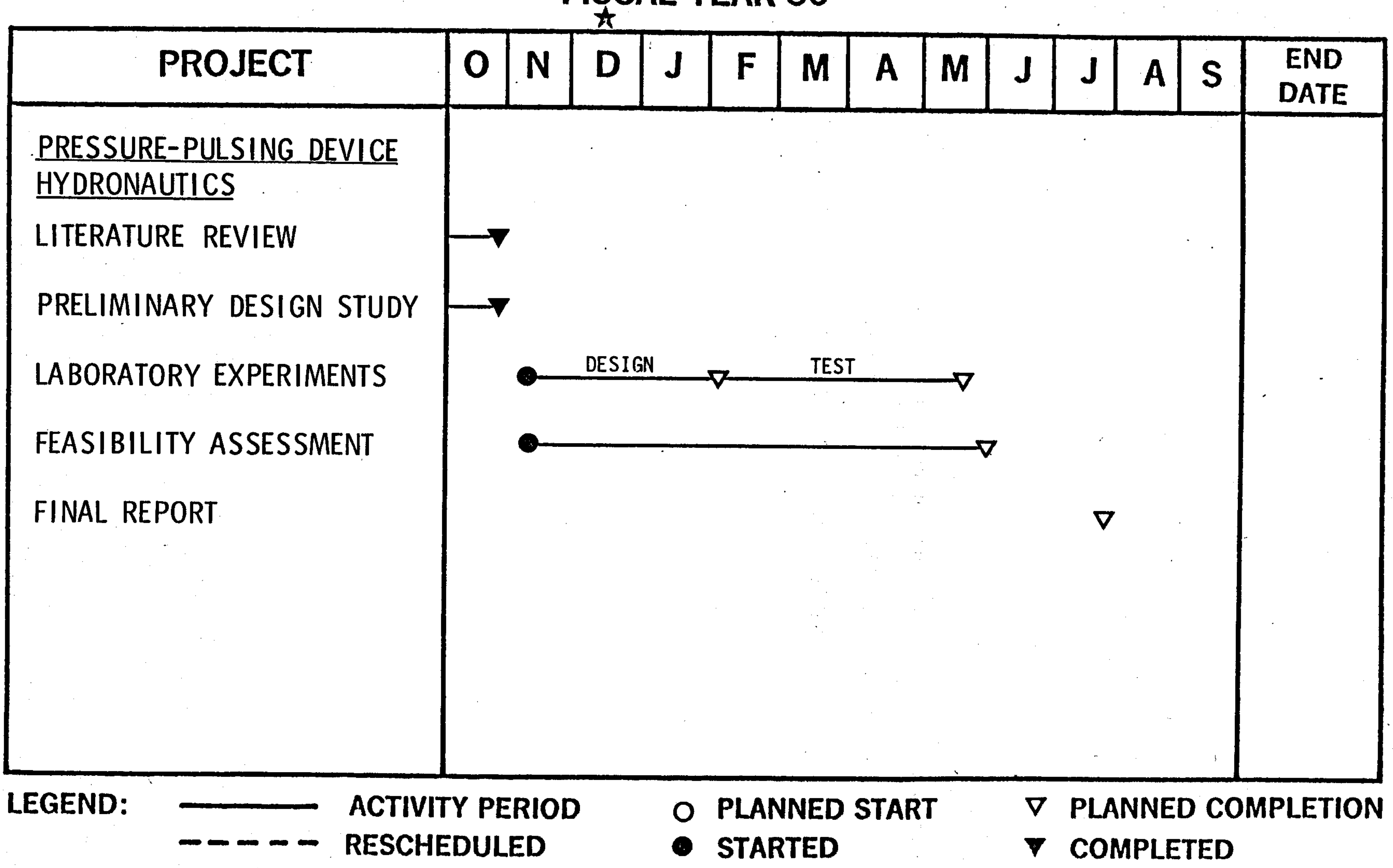
GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM
FISCAL YEAR 80



EXTERNAL R&D

Project:	Feasibility and Design Study of a Downhole Pressure-Pulsing Device
Contractor:	Hydronautics, Inc.
Principal Investigator:	V. Johnson, Jr. (301) 776-7454
Contract Period:	1 August 1979 to 31 July 1980
Contract Number:	13-5111 (Sandia)
Technical Consultant:	D. Glowka (505) 264-3601

Project Objective

The objective of this project is to conduct a feasibility and preliminary design study of a downhole pressure-pulsing device for use with cavitating jets. This device would convert steady pressures supplied by the pump into pulsing nozzle pressures, thereby supplying higher than average pressures over one-half the cycle. This should greatly increase the effectiveness of cavitation erosion, since tests have shown that rock cutting rates with Hydronautics' CAVIJET™ nozzles increase as the third power of nozzle pressure drops.

The design of this device will take into account an interesting characteristic of CAVIJET™-induced cavitation. The shedding of toroidal vortices and the subsequent formation of cavities in the jet shear zone have been shown to occur with a high degree of periodicity. The pressure-pulsing device will essentially consist of a flow passage immediately upstream of the nozzle, the passage sized so as to resonate at the vortex-shedding frequency, thereby amplifying the small pressure pulses created by the vortex-shedding phenomenon.

Project Status

Preliminary design studies have been completed along with a review of past research and literature on shear and oscillatory flows. Three nozzle concepts have been selected for design, fabrication, and laboratory test.

Feasibility and Design Study of
A Downhole Pressure-Pulsing Device
Quarterly Progress for October-December 1979

A meeting was held at the University of California at San Diego with A. Ellis on 3 October 1979. At this meeting, various conceptual schemes were discussed, with particular attention directed toward selecting promising simple systems that might be checked out in a relatively short time using available equipment in Professor Ellis' laboratory. The following program was initiated:

- Design of a 5.5 MPa (800 psi), 0.0013 m^3/s (20 gpm) recirculating water system using available equipment. This system will be provided with an auxiliary piston modulating oscillator with variable frequency up to 5 000 Hz. The concept of the experimental apparatus will be similar to that used in the jet noise experiments described in Reference 1.
- The incipient cavitation number of various nozzles, having variable length supply passages will be determined as a function of the modulating frequency.
- The first nozzle tested will be a plain CAVIJET™. Additional nozzles with flat-plate orifice exits having a mechanical natural frequency near the jet vortex preferred frequency are planned.

On 5 October, a meeting was held with R. Arndt at the Saint Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis. Dr. Arndt, who has been active in cavitation research for most of his career, has recently been studying the mechanics of noise created by jets, with particular interest in the effects of structured eddies in the jet. He confirmed Hydronautics' belief that the incipient cavitation number of a submerged water jet could probably be increased by controlled low-energy excitation near its exit at a frequency corresponding to the preferred Strouhal number of 0.3. Dr. Arndt suggested some recent literature describing studies of air jet noise that might be pertinent to devising an improved cavitating jet.

The following concepts were selected for preliminary design:

- Nozzle with flat-plate orifice whose thickness is selected so as to have a natural frequency near the preferred jet-vortex-shedding frequency. The nozzle supply passage length will be variable so that acoustic resonance can be achieved.
- A nozzle will be designed with a thin annular slit surrounding the exit. This annular slit will be connected to a larger surrounding annular volume so as to act as a Helmholtz resonator tuned to the jet-vortex-shedding frequency. If possible, a piezoelectric crystal will be installed in the large section of the Helmholtz resonator so that active excitation may be studied. The planned experiment will be similar to the air jet noise experiments described in Reference 2, except that the annular nozzle supply volume will be selected to act as a resonator.

- A series of two nozzles feeding and exiting from a chamber sized to oscillate as a Helmholtz resonator will be designed for future testing. This experiment will be similar to the experiment carried out in air and described in Reference 3. Although this type of nozzle may not be directly applicable to the drilling problem because of possible cavitation within the chamber, the remarkably high pressure oscillations reported in Reference 3 should be investigated. If the discharge from such a resonator is not directly applicable, the device might be incorporated as a substitute for the crystal drive in the annular modulator device described in the previous paragraph.

Several recirculating systems capable of testing the various resonator nozzle designs in the Hydronautics laboratory were studied. However, the final system selection has been postponed in order to gain some experience from the test apparatus which has been assembled at the University of California at San Diego by A. Ellis.

Studies of the details of structured ring vortex flows from nozzles, with particular attention to understanding the preferred frequency of shedding and of the theoretical incipient cavitation number for such flows, were also carried out.

The test apparatus at the University of California at San Diego for studying resonator nozzles was completed and testing initiated.

References

[1] S. C. Crow and F. H. Champagne, "Orderly Structure in Jet Turbulence," Journal of Fluid Mechanics, 48:547-91, 1971.

[2] V. Kikens, Discrete Noise Spectrum Generated by an Acoustically Excited Jet, AIAA Paper No. 79-0592, 1979.

[3] T. Morel, "Experimental Study of a Jet-Driven Helmholtz Oscillator," ASME Journal of Fluids Engineering, 101:383-90, September 1979.

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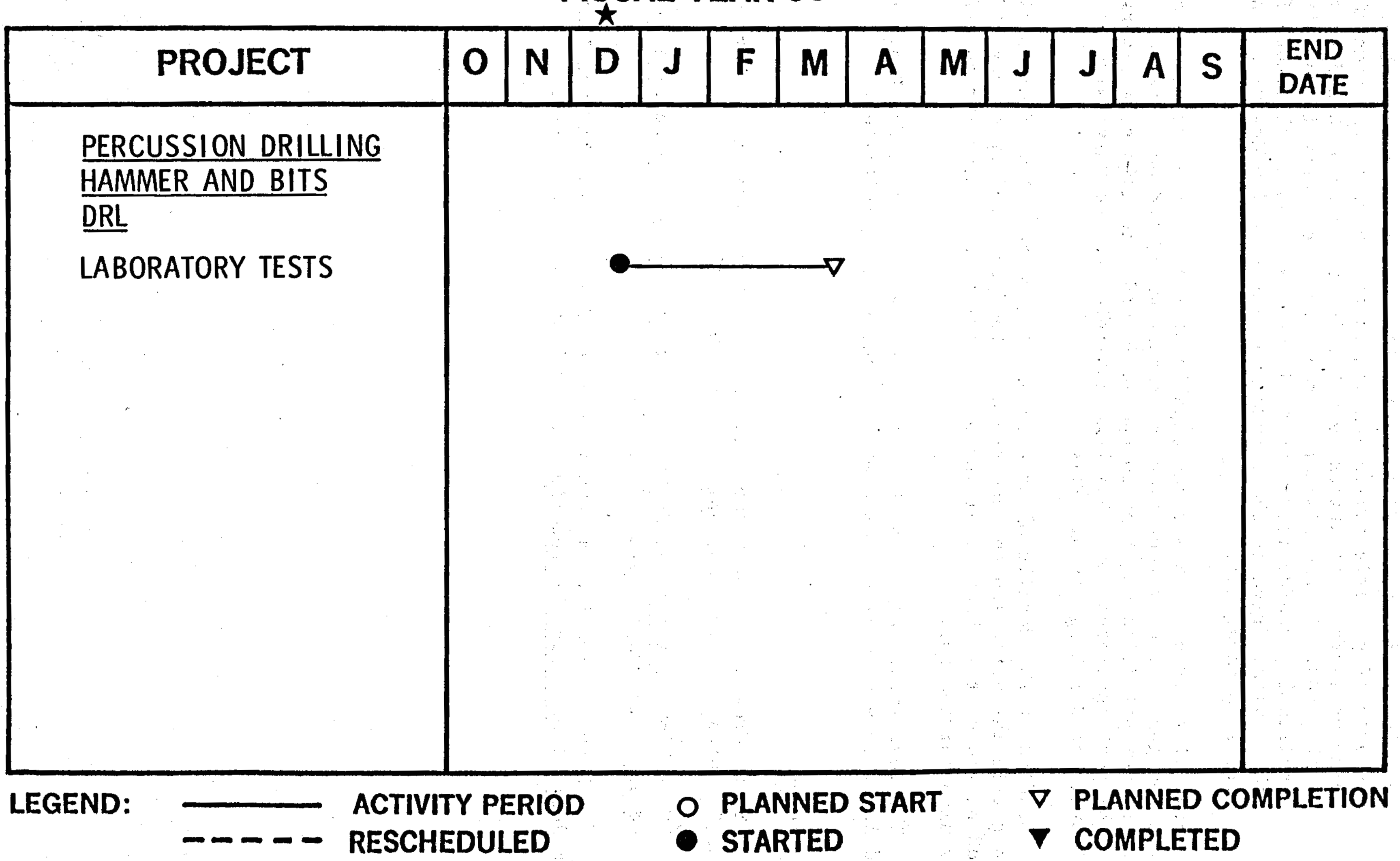

EXTERNAL R&D

Project:	Testing of Percussion Drilling Hammers and Bits
Contractor:	Drilling Research Laboratory, Inc.
Principal Investigator:	G. Tibbitts (801) 582-2220
Contract Period:	15 December 1979 to 31 March 1980
Contract Number:	46-3173 (Sandia)
Technical Consultant:	J. Finger (505) 264-8089

Project Objective

The objective of this project is to evaluate percussion drilling devices which offer the potential advantages of high penetration rate and achievement of straight holes when drilling with low-density fluids in brittle rock.

Project Status

The project was initiated at the close of the reporting period.

Testing of Percussion Drilling Hammers and Bits
Quarterly Progress for October-December 1979

Evaluation of percussion drilling devices will include data collecting, laboratory testing, and, if warranted by the findings, field testing. However, the current project will be limited to laboratory testing of penetration rate and high-temperature hammer performance.

After obtaining general information and specific data on high-temperature testing of hammers from manufacturers, Sandia purchased three hammers with bits for testing at Drilling Research Laboratory (DRL). These hammers, all with solid head bits, will be tested in comparison with a conventional roller bit and a conventional roller bit and hammer. Relative penetration rates over a range of drilling parameters such as weight-on-bit, air supply pressure and flow rate will be determined. The hammers will then be run against a load cell to establish baseline performance data while varying air supply pressure.

High-temperature performance and endurance of the hammers will be investigated using a heated air supply and an insulated shroud to provide a hot test environment. The load-cell test will be repeated to collect data under ambient temperatures for comparison purposes. The hammers will also undergo a 50-hour endurance test while hammering against a cast iron target. During the endurance test, the temperature will be cycled between hot and ambient at 10-hour intervals. The endurance test is expected to provide any indications of shortened hammer life or unexpected failure modes.

After completion of the tests, the results will be used to quantify the potential economic benefits of percussion drilling operations.

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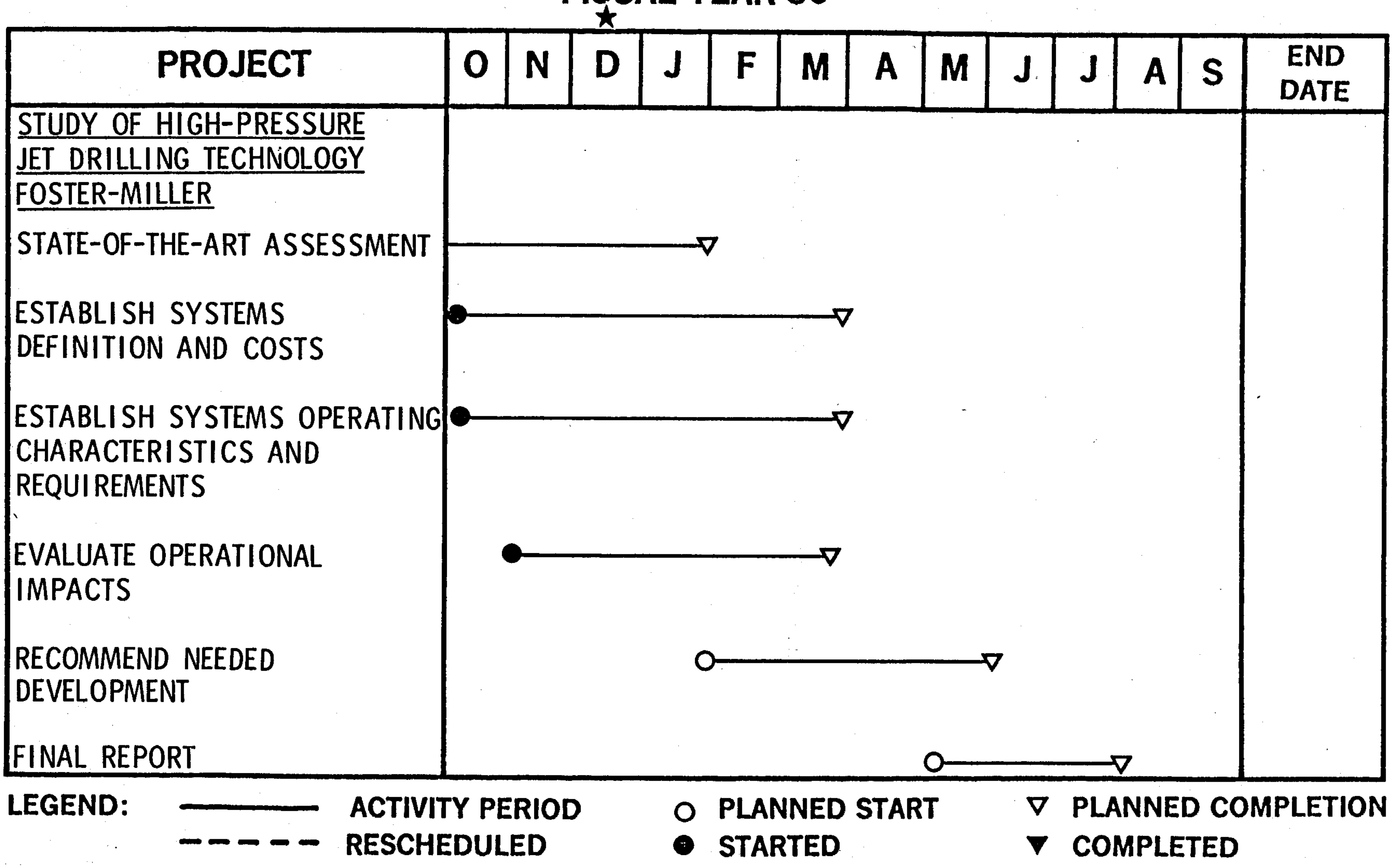
GEOTHERMAL WELL TECHNOLOGY-DRILLING AND COMPLETIONS PROGRAM

FISCAL YEAR 80



EXTERNAL R&D

Project:	Characterization of High-Pressure Jet Drilling Systems
Contractor:	Foster-Miller Associates, Inc.
Principal Investigator:	J. Harding (617) 890-3200
Contract Period:	1 August 1979 to 31 July 1980
Contract Number:	13-8728 (Sandia)
Technical Consultant:	D. Glowka (505) 264-3601

Project Objective

Sandia personnel are conducting a study to assess the performance potential and economics of erosion drilling systems for geothermal resource recovery. Data characterizing the performance of erosion drilling systems investigated in the past are needed as input to this study. The objective of this project is to gather, analyze, and present these data. In particular, this project will supply data for the various systems relating to

1. System hardware requirements and costs,
2. Penetration rates,
3. Bit lifetime,
4. Operating and rig costs,
5. Downtime,
6. Maintenance requirements,
7. Operational characteristics,
8. Time requirements for necessary operations, and
9. Impacts on other drilling and completion operations.

In addition, areas of potential system improvements and increased efficiency, required technology and hardware development, and additional analytical, experimental, and field work requirements will be identified.

Project Status

Project activities were initiated in August 1979. The state-of-the-art assessment is continuing. Coordination has been made to assure a proper interface between the study output and the Sandia Wellbore Simulation Model. An erosion drilling information computer search has been made and data on the Gulf Oil Company abrasive jet drilling program obtained. Assessment of the data is progressing.

Characterization of High-Pressure Jet Drilling Systems
Quarterly Progress for October-December 1979

The state-of-the-art study of erosion drilling continued during the reporting period. The computer search at the University of Tulsa of the recent literature concerning erosion drilling showed that little relevant information exists.

A subcontract was issued to drilling consultant J. Cobbs. Cobbs will provide a variety of services to Foster-Miller Associates (FMA) on this project. He has extensive background in all phases of drilling technology.

A meeting with J. Fair of Gulf Research and Development was held. The purpose of the meeting was to get an in-depth view of the Gulf abrasive jet drilling system and obtain Gulf reports covering the work. The meeting was successful on both of these items.

Fair made a 3-hour presentation covering the following key items:

1. History of the Gulf abrasive jet drilling program,
2. Equipment specifics,
3. Potential market for abrasive jet drilling,
4. Economics of abrasive jet drilling, and
5. Major problem areas still existing at the completion of the Gulf problem.

The meeting provided insight into the Gulf work and initiated a dialogue between FMA and Gulf on this subject. Gulf made available to FMA many of their internal reports for assessment of their system. These reports are company confidential and must be returned.

The assessment of the Gulf abrasive jet drilling program has been initiated. The amount of information that Gulf provided is quite large, and the assessment process is expected to require a significant amount of effort. The initial appraisal of the information is that

1. It is very thorough,
2. It is well organized,
3. It contains most of the information needed to input to the Sandia computer program,
4. The costs are 7 years out of date, and
5. The technique is still in the developmental stage.

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Geothermal Drilling and Completion Program Overview, by S. Varnado, to Geothermal Drilling and Completion Advisory Panel Meeting, Washington, D. C., 11-13 December 1979.

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