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Proceedings of the

GEOTHERMAL PROGRAM REVIEW VII

"DOE Research and Development

for the

Geothermal Marketplace"

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DISCLAIMER

NEAR-TERM DEVELOPMENTS IN GEOTHERMAL DRILLING

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ABSTRACT

The DOE Hard Rock Penetration program is developing technology to reduce the costs of drilling geothermal wells. Current projects include: R & D in lost circulation control, high temperature instrumentation, underground imaging with a borehole radar insulated drill pipe development for high temperature formations, and new technology for data transmission through drill pipe that can potentially greatly improve data rates for measurement while drilling systems. In addition to this work, projects of the Geothermal Drilling Organization are managed. During 1988, GDO projects include developments in five areas: high temperature acoustic televiewer, pneumatic turbine, urethane foam for lost circulation control, geothermal drill pipe protectors, an improved rotary head seals.

HARD ROCK PENETRATION RESEARCH

- Lost Circulation Control
- Rock Penetration Mechanics
- Instrumentation
- Geothermal Drilling Organization

LOST CIRCULATION TECHNOLOGY DEVELOPMENT PROGRAM

Motivation

- Lost circulation is the most costly problem routinely encountered in geothermal drilling.
- Lost circulation can cause poor casing cement jobs and result in the loss of the well.
- Lost circulation can result in contamination of fresh-water aquifers.

ACTIVITIES

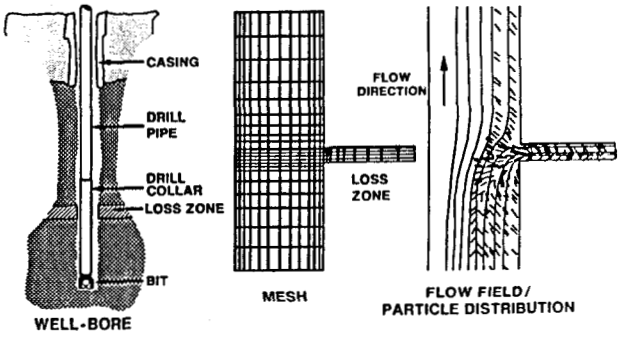
I. Development of high-temperature LCMs for matrix and minor-fracture fluid loss control
II. Development of techniques for major-fracture fluid loss control
III. Development of loss zone characterization techniques

ACTIVITY I
DEVELOPMENT OF HIGH-TEMPERATURE LOST CIRCULATION MATERIALS (LCMs)

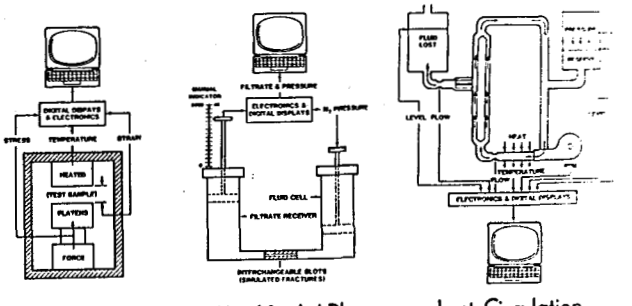
Motivation:
- Fractures smaller than the nozzle diameter can be plugged with solid drilling mud additives (LCMs)
- LCMs used in oil and gas drilling do not survive the high-temperature, high-pressure geothermal environment.

Approach:
- Develop analytical models of fracture plugging mechanisms to quantify material property requirements
- Conduct laboratory tests of potential LCMs to evaluate fracture-plugging capabilities
- Conduct field tests and transfer technology

NUMERICAL MODELING OF PARTICLE-LADEN MUD FLOW

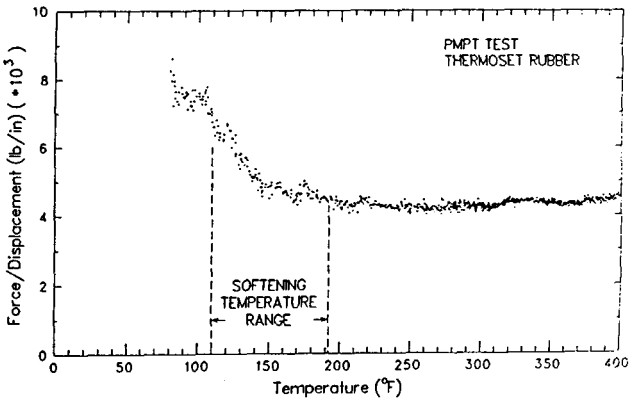


LABORATORY LCM TESTING EQUIPMENT

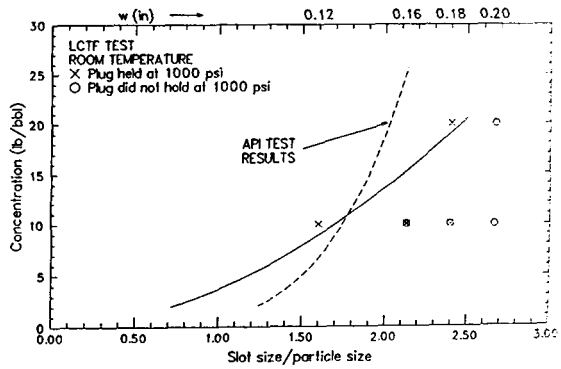


Particle Material Properties Tester | Modified API Tester | Lost Circulation Test Facility

TYPICAL SOFTENING TEMPERATURE RESULTS FOR A PARTICULATE LCM



PLUGGING PERFORMANCE PLOT FOR COMPOSITE THERMOSET RUBBER GRANULES AND THERMOSET PLASTIC FLAKES



ACTIVITY II
DEVELOPMENT OF TECHNIQUES FOR MAJOR-FRACTURE FLUID LOSS CONTROL

Motivation:

- Large fractures, vugs, and caverns are common in geothermal formations
- Pumpable solids are not capable of plugging such loss zones
- Cement is the standard treatment but is costly due to large volume requirements and long waiting period

Approach:

- Conduct laboratory tests of alternative time-and temperature-setting fluids
- Develop emplacement techniques and procedures for such fluids
- Conduct field tests and transfer technology

CURRENT ACTIVITY II PROJECTS

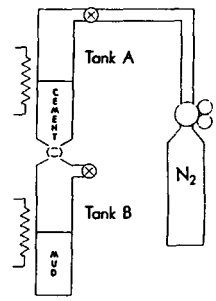
- Polyurethane foam tool testing
- Cementitious mud development (joint project with Brookhaven National Laboratory)
- Evaluation of porous packer concept

DEVELOPMENT OF CEMENTITIOUS MUDS

- Joint development with Brookhaven National Laboratory
- Rapid-setting, temperature-activated cement can be made by mixing:
  bentonite
  ammonium polyphosphate
  borax
  magnesium oxide
- Current study is focusing on encapsulation of the MgO accelerator with a shear-sensitive material that would be removed by fluid action at the bit nozzle

HIGH-DIFFERENTIAL-PRESSURE CEMENT TESTER

- Designed to duplicate cement nozzle velocities encountered in typical field applications
- Tank A represents the drill-pipe; Tank B represents the loss-zone
  - Max. Tank A temperature = 100°C
  - Max. Tank B temperature = 300°C
  - MAWP = 2500 psi
  - Max. ΔP = 1200 psi
- Cement exotherm temperature measured to determine setting time
- 2-hr compressive strength tests conducted on cement samples
- Tester undergoing design and construction by Sandia for use by Brookhaven



ACTIVITY III
DEVELOPMENT OF LOSS ZONE CHARACTERIZATION TECHNIQUES

Motivation:

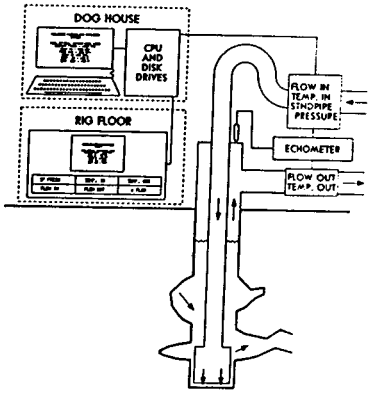
- Techniques are needed for assessing loss zones in order to optimize treatments for specific cases
- Prompt evaluation of treatment effectiveness is needed to help minimize treatment costs

Approach:

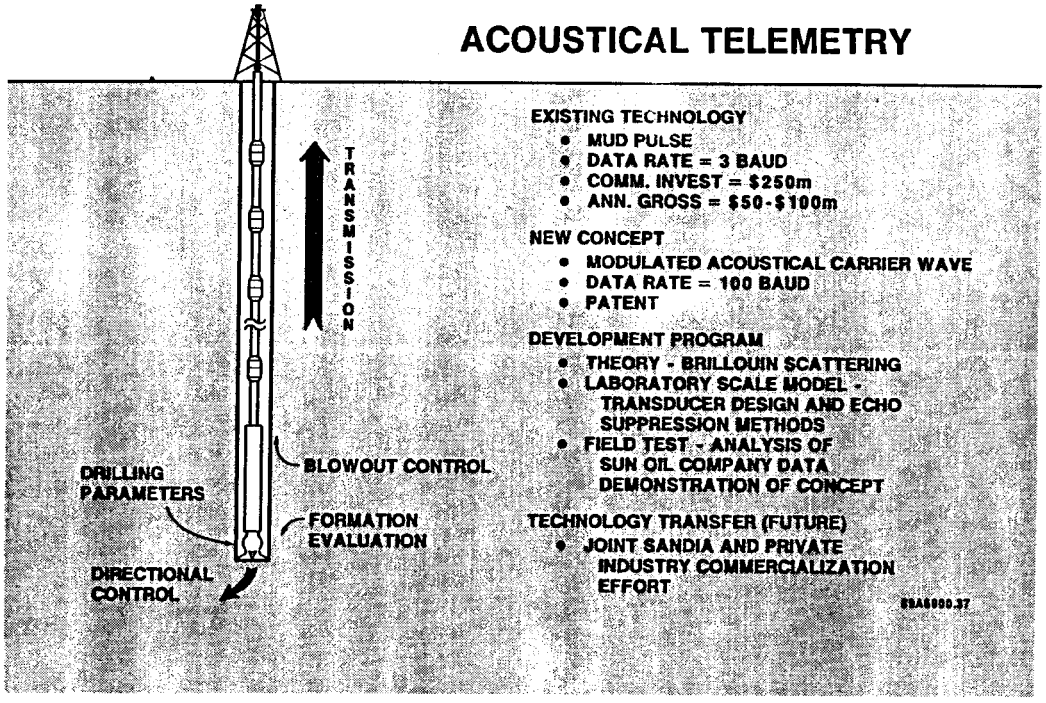
- Develop wellbore hydraulics models for evaluating drilling fluid losses
- Develop hardware/software necessary to acquire and analyze onsite drilling data
- Correlate hydraulics model predictions with physical attributes derived from borehole televiewer logs of actual loss zones
- Conduct field tests and transfer technology

WELLBORE HYDRAULICS ANALYSIS HARDWARE

- Rugged, stand-alone system for acquiring and analyzing wellbore hydraulics data
- Transducers measure :
  - flow rate in
  - flow rate out
  - standpipe pressure
  - temperature in
  - temperature out
  - annulus fluid level
- Central Processing Unit :
  - logs and interprets drilling hydraulics data
  - displays data summary on rig floor
  - alerts driller of fluid loss
  - directs drilling fluid flow tests
  - displays loss zone characteristics
  - recommends type of treatment

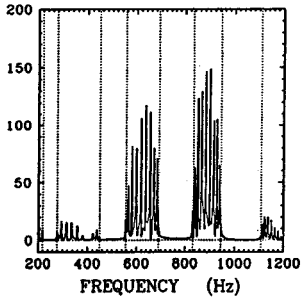


ACOUSTICAL TELEMETRY

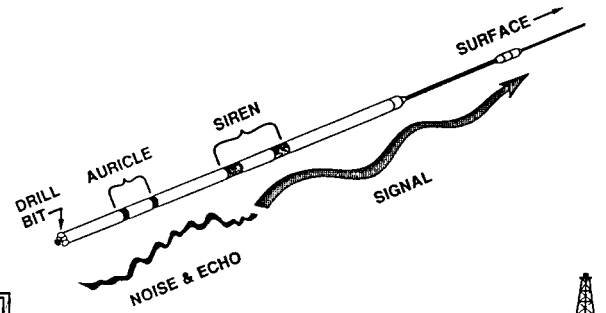


TYPICAL SPECTRAL DENSITY OF AN ACOUSTIC TRANSMISSION

- Tool joints ⇒ blank bands.
- Echos ⇒ spikes.
- Area ⇒ power.
- Amplitude ⇒ detection.
- Tone burst ⇒ diffused power.
- Pure Tone ⇒ concentrated power.



THE DOWNHOLE LINEAR HORN



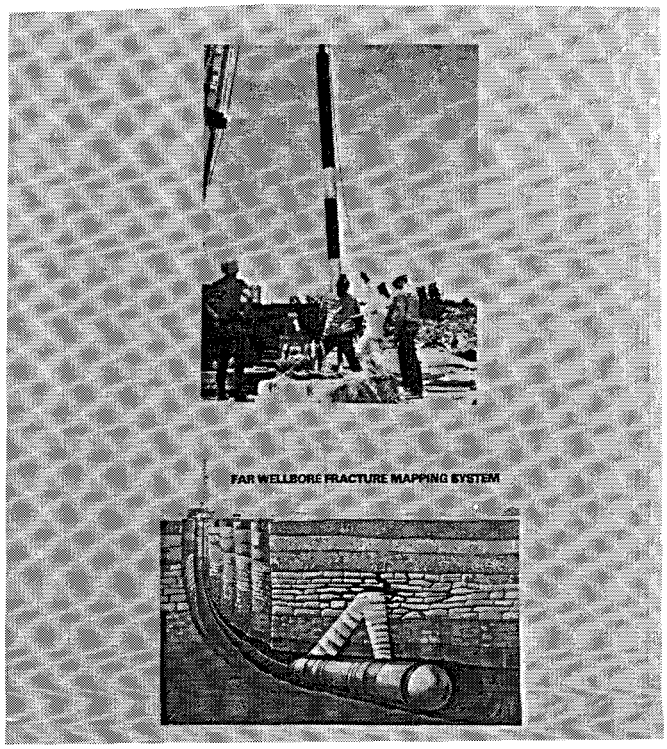
PROGRAM ACCOMPLISHMENTS

☐ THIS YEAR ■ PREVIOUS YEAR

- TRANSMISSION CHARACTERISTICS ■
  - THEORY ■
  - LABORATORY ■
  - FIELD ◪
- LINEAR HORN ☐
  - MODEL ☐
    - ANALYSIS ☐
    - FABRICATION ☐
    - TESTING ☐
  - FULL SCALE ☐
    - MECHANICAL DESIGN ☐
    - CONTRACT ☐
    - ELECTRONICS ☐
- TERMINATION TRANSDUCER
  - ANALYSIS ■
  - CONTRACT, U OF T ■
  - FABRICATION OF MODEL ☐
  - TESTING OF MODEL ☐
- PATENT APPLICATION FILED ☐
- TECHNOLOGY TRANSFER ☐
  - J. ACOUST. SOC. PUBLICATION ☐
  - ACOUST. SOC. CONF. PAPER ☐
  - SPECIAL PRESENTATIONS ☐
    - ARCO ☐
    - EXXON ☐
    - GEARHART ☐

FUTURE

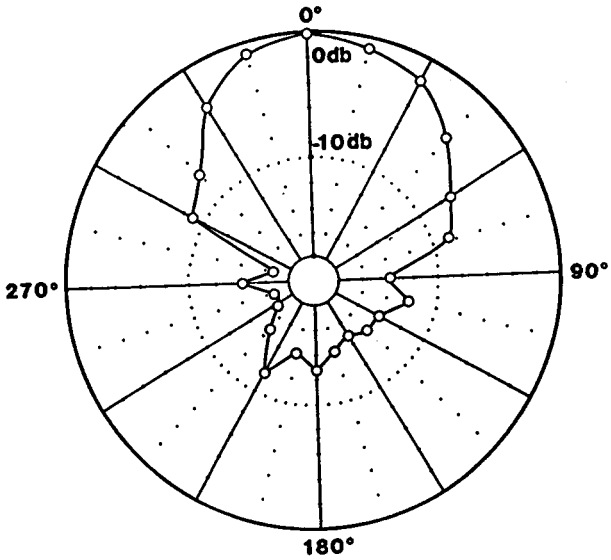
- LINEAR HORN
  - COMPLETE MODEL TESTS
  - PURCHASE FULL-SCALE PROTOTYPES
  - BUILD ELECTRONICS
  - COMPONENT TESTING IN WELLS
  - SCOPE SIGNAL-TO-NOISE RATIO
- TERMINATION TRANSDUCERS
  - COMPLETE TESTING AND EVALUATION OF MODEL
- PATENT
- TECHNOLOGY TRANSFER
  - TECHNICAL PAPERS
    - LINEAR HORN
    - TERMINATION TRANSDUCER
  - INDUSTY CONTACT



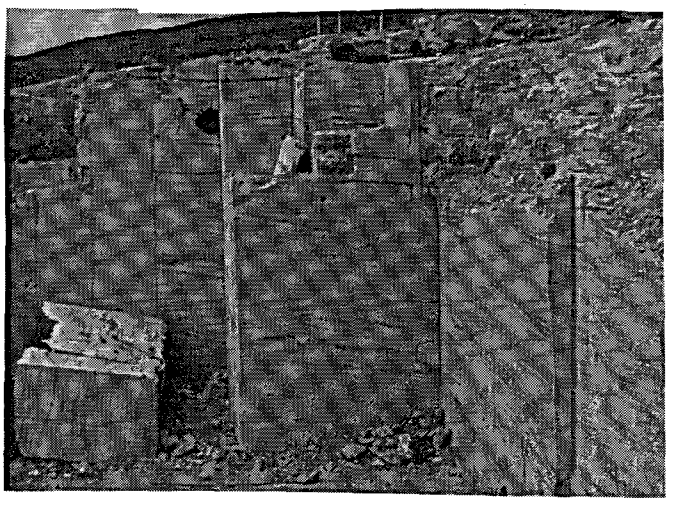
UNIQUE FEATURES OF THE RADAR PROBE

- HIGH RESOLUTION - 1 FOOT ACCURACY
- DIRECTIONAL CAPABILITY
- 50 kW PEAK POWER
- DOWNHOLE SAMPLING - COMPLETE RECOVERY OF RF SIGNALS
- - 100 dBm CAPABILITY - DETECT AS LOW AS 2 MICROVOLTS

RADAR ANTENNA PATTERN
MEASURED IN WATER



ROCK QUARRY TEST SITE



DOWNHOLE RADAR SURVEY SYSTEM

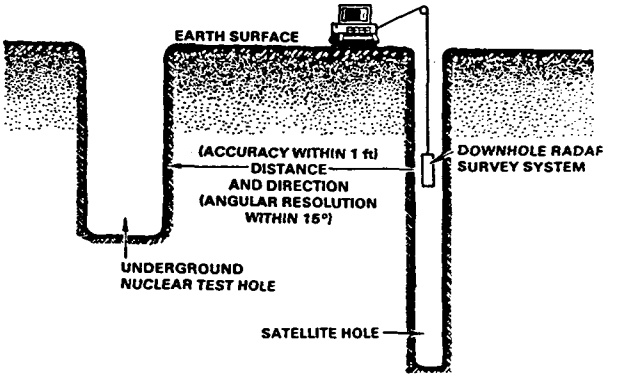
- PROVIDE CORRTEX

A METHOD TO OBTAIN

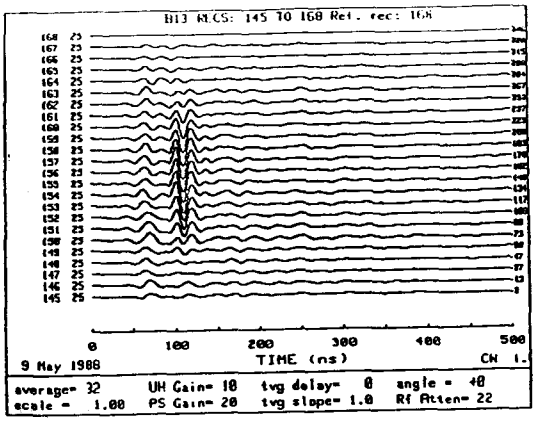
DISTANCE AND DIRECTION

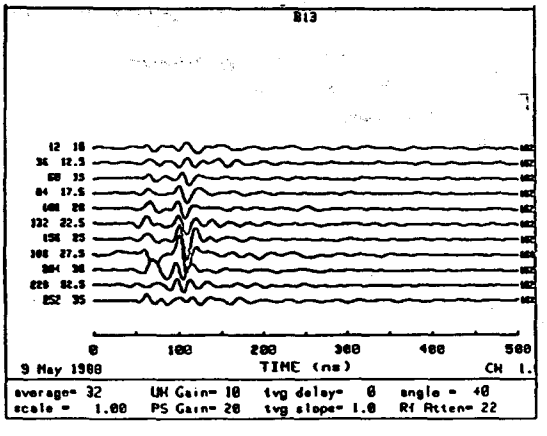
OF THE NUCLEAR TEST SITE

FROM A SATELLITE HOLE



REFLECTION DATA SHOWING CLIFF FACE





SECOND GENERATION RADAR PROTOTYPE

MECHANICAL UPGRADE

- Reduce OD from 7.5" to 5.5"
- Modular housing to facilitate assembly and disassembly
- Variable antenna separation

ELECTRICAL UPGRADE

- Multilayer boards to reduce size
- Improved shielding and ground plane to reduce crosstalk
- Improved sampling circuit
- Improved pulse generator

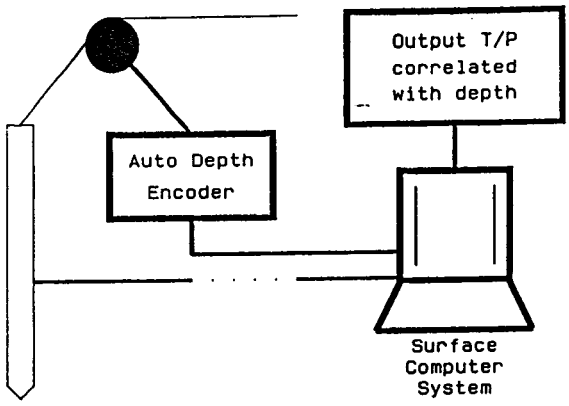
SCHEDULE

• Complete and test 2nd prototype	FY90
• Apply tool to field applications	FY91
• Transfer to industry	FY92

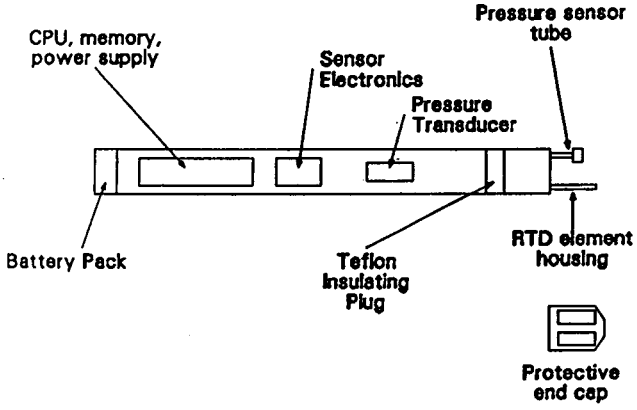
CHARACTERISTICS OF A DOWNHOLE MEMORY TOOL

- Self-contained tool - requires no wireline cable for communication to the surface
- Electronic tool with digital data storage - no mechanical timer or data inscription system
- Use of a heat shield allows the use of standard electronic components at high temperatures (>300°C)

DIGITAL T/P TOOL



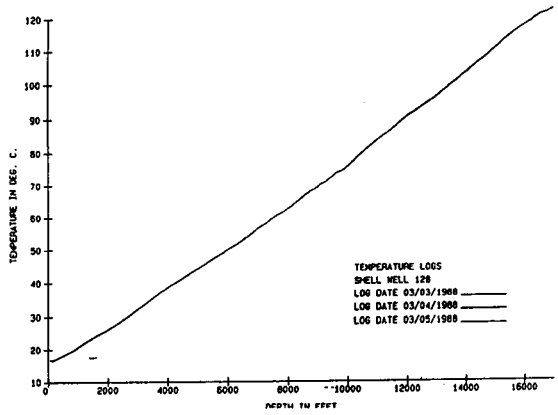
DIGITAL T/P TOOL



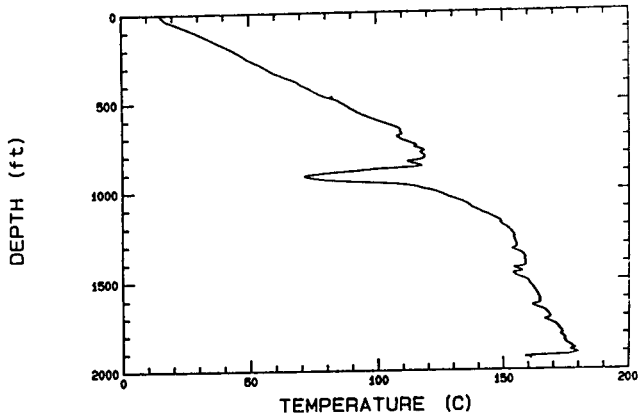
FEATURES OF DIGITAL T/P TOOL

- 3.5-inch diameter, 5 ft long, 100 lbs.
- Dewared to operate for 10 hrs at 400°C
- Programmable time steps
- 1000 T/P data points
- Interfaces with a surface PC
- Temperature - Pt RTD; 0-600°C; .5°C accuracy
- Pressure - quartz crystal; 0-15,000 psi; 3 psi accuracy

TEMPERATURE LOG OF DEEP SHELL WELL



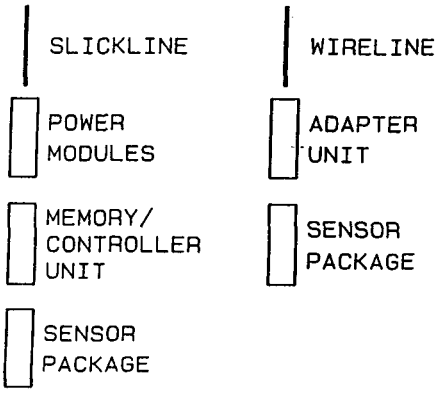
VC-2B TEMPERATURE DATA
(August 30, 1988)



SPECIFICATIONS OF HEAT-SHIELDED GRC TOOL

- Maximum use temperature: 400°C
- External and internal temps. measured
- Outside diameter of tool: 2 in.
- Electronic memory for 10,000 readings
- Able to be used with wireline cable
- Rapid response time of temp. sensor

MODULAR MEMORY/CONTROLLER



HIGH TEMPERATURE MODULAR SYSTEM

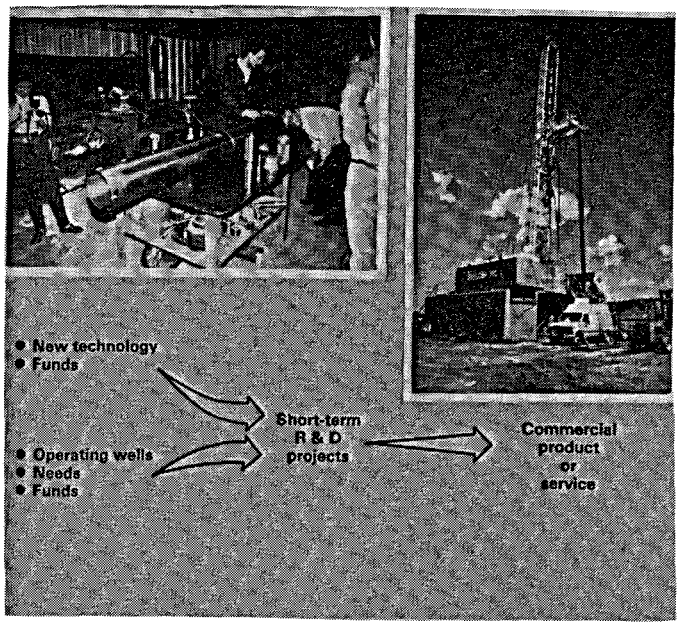
FEATURES

- State-of-the-art microprocessor
- Large memory capacity
- 2 or 3 data channels
- Small diameter

PROBLEMS

- Size of heat shield
- Seals on heat shield
- Power requirements
- Sensor/Controller interconnection

GEOTHERMAL DRILLING ORGANIZATION



GDO PROJECTS	STATUS
1. Borehole Televiewer	Active
2. Air Turbine	Active
3. Foam Lost Circulation Tool	Complete
4. Drill Pipe Protectors	Active
5. Rotating Head Seals	Active

HIGH TEMPERATURE BOREHOLE TELEVIEWER

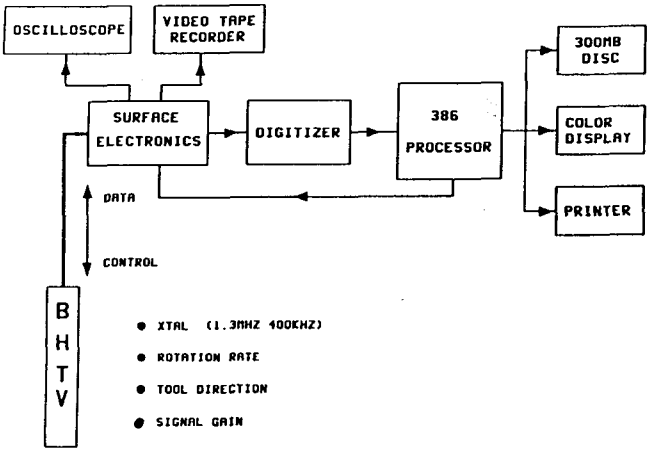
Total Project Cost	$948K
Industry Contribution (cash)	$474K

Participating Members

- Unocal
- Geo Operator

Status

- Contractor Squire Whitehouse declared bankruptcy
- Sandia completed hardware assembly and testing of prototype
- Sandia completing commercial version
- Full system field test - Spring 89
- Follow on contractor will complete field logging phase



PNEUMATIC TURBINE

Total Project Funding	$418K
Industry Contribution (in kind)	$294K

Participating Members
- Rift Engineering
- Geo Operator
- Geysers Geothermal
- Unocal
- Eastman Christensen
- Grace Drilling
- H & H Tool

Status
- First prototype turbine drilled 400 feet of sand and shale sequences at penetration rates up to 180 ft/hr
- Four field tests at the Geysers during 1988
- Several modifications completed
- Third prototype being designed
- Project nearing completion

GEYSERS FIELD TESTING

- Three Unocal wells, one GEO well
- Weakness in gearbox assembly (torque)
- Insufficient lubrication of upper bearings in gearbox
- Turbine motor and thrust assemblies -- no problems
- Fourth field test very successful

DESIGN CHANGES (3rd PROTOTYPE)

- 4-stage turbine motor
- 10,000 rpm output
- Gearbox operated in liquid oil (no spray lubrication)
- 4-stage gearbox 168:1 (drilling)
- 3-stage gearbox 46:1 (course correction)

FOAM FOR LOST CIRCULATION

Total Project Cost	$400K
Industry Contribution (in kind)	$250K

Participating Members
- NL Industries
- Geo Operator
- Unocal
- Grace Drilling
- H & H Tool

Status
- Project complete
- Three downhole tools were built and successfully tested
- Training of field personnel completed at H&H facility
- Field test at Geysers resulted in proper tool operation but insufficient foam expansion
- Extensive laboratory testing of all chemical combinations could not produce expected expansion at elevated T and P
- GDO member interest remains but effective chemical system is needed

HIGH TEMPERATURE DRILL PIPE PROTECTORS

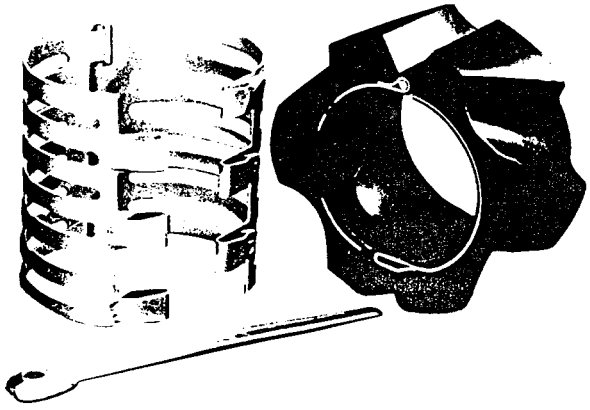
Total Funding $80K

Industry Contribution (cash) $40K

Participating Members
- Geo Operator
- Unocal

Advisor: Larry Kukacka (BNL)

Status
- Thirty-five materials have been screened
- Laboratory testing is complete
- Full scale protectors have been manufactured and successfully tested in air to 550°F
- Problems with elastomer to metal bond at T and P in brine and steam
- Additional testing underway with different base metal



HIGH TEMPERATURE ROTARY HEAD SEAL

Total Funding 440K

Industry Contribution (in-kind + cash) 220K

Participating Members
- Unocal
- Geo Operator

Advisor: Larry Kukacka (BNL)

Status
- Contract placed with Drilex Systems
- Planning complete
- Lab testing continues
- Field test fixture approved and in final design stage

This work was supported by the U. S. Department of Energy at Sandia National Laboratories under Contract DE-AC04-76DP00789.