CONF-790906--1

SANDIA/DOE GEOTHERMAL DRILLING AND COMPLETION TECHNOLOGY DEVELOPMENT PROGRAM*

Jon H. Barnette

Sandia Laboratories
Albuquerque, NM 87185

ABSTRACT

The high cost of drilling and completing geothermal wells is an impediment to the development of geothermal energy resources. Technological deficiencies in rotary drilling techniques are evidenced when drilling geothermal wells. The Division of Geothermal Energy (DGE) of the U. S. Department of Energy (DOE) has initiated a program aimed at developing new drilling and completion techniques for geothermal wells. The goals of this program are to reduce well costs 25% by 1982 and 50% by 1986. Sandia Laboratories has managed this technology development program since October, 1977, and this paper presents an overview of the program. A statement of program goals and structure is given. The content of the FY-79 program is presented and recent results of R&D projects are given. Plans for development of an advanced drilling and completion system are discussed.

INTRODUCTION

In view of the existing technological difficulties associated with drilling and completing geothermal wells, DOE/DGE has initiated a program directed at developing and commercializing the technology required to reduce the cost of geothermal wells. An analysis of existing geothermal well cost data indicates that evolutionary technological developments within the framework of existing drilling practice have the potential for reducing the cost of geothermal wells drilled with conventional rotary technology by approximately 25%. Cost reductions in excess of 25% will require the use of new and advanced drilling and completion techniques, and the successful implementation of these new techniques could possibly reduce well costs by as much as 50%. Based on these facts, goals to develop the technology capable of reducing costs by 25% by 1982 and 50% by 1986 have been set for the DOE/DGE Geothermal Drilling and Completion Technology Program (Polito and Varnado, 1978).

In October of 1977, or the beginning of FY-78, Sandia Laboratories was selected by DOE/DGE to manage the Drilling and Completion Technology Development Program. During FY-78 considerable program planning was conducted, some in-house (Sandia) research conducted, the technical and financial management responsibility for existing contracts was assumed and contracts issued for new externally conducted research. Most research activity was of a type aimed at the 25% cost reduction goal.

Internal research primarily involved the continued development of the Chain Drill, a bit concept providing downhole replaceable cutting surfaces. External contract work on drilling technology fell under three major headings:

1) Bits -- Research in manmade diamond compact bits, fluid jet drilling, and high temperature steels, seals and lubricants

2) Downhole Motors -- Design and testing of high temperature bearings and seals

3) Drilling Fluids -- High temperature and pressure instrumentation was built, a high temperature mud formulated, and drilling foam investigated.

Completion-oriented activity consisted of state-of-the-art studies with emphasis on sand control in geopressured wells and reinjection well analysis in all reservoirs. Included was the demonstration of a cavitating water jet descaling technique.

FY-79 PROGRAM

The majority of the FY-79 program has been aimed at the 25% cost reduction goal, though planning activities and some feasibility studies for an advanced system have been undertaken. Projects not completed in FY-78 were continued, and new research initiated. Highlights are given following the previously used breakdown:

1) Bits -- Laboratory tests were conducted by General Electric on

*This work supported by U. S. Department of Energy.

E&B

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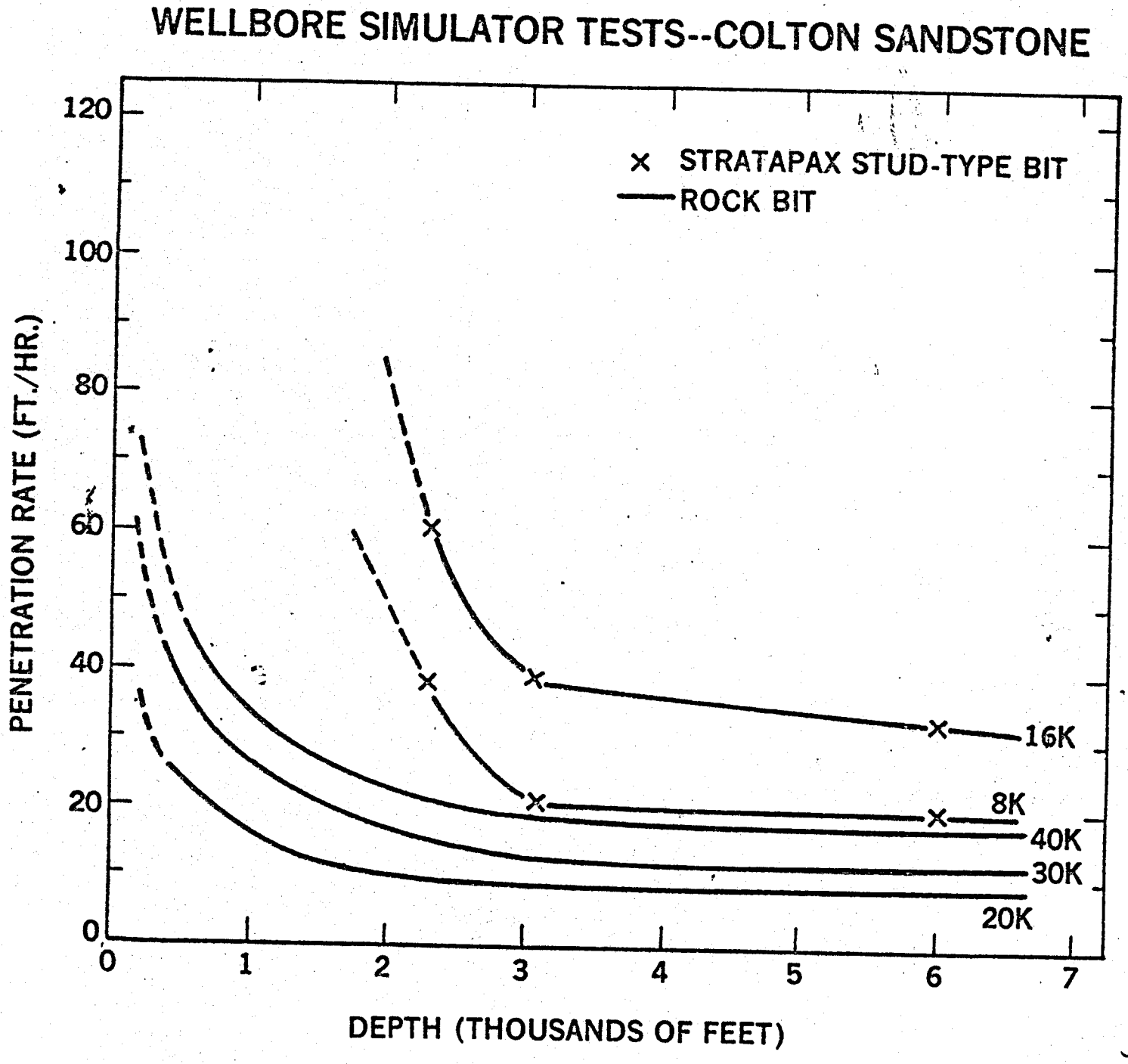
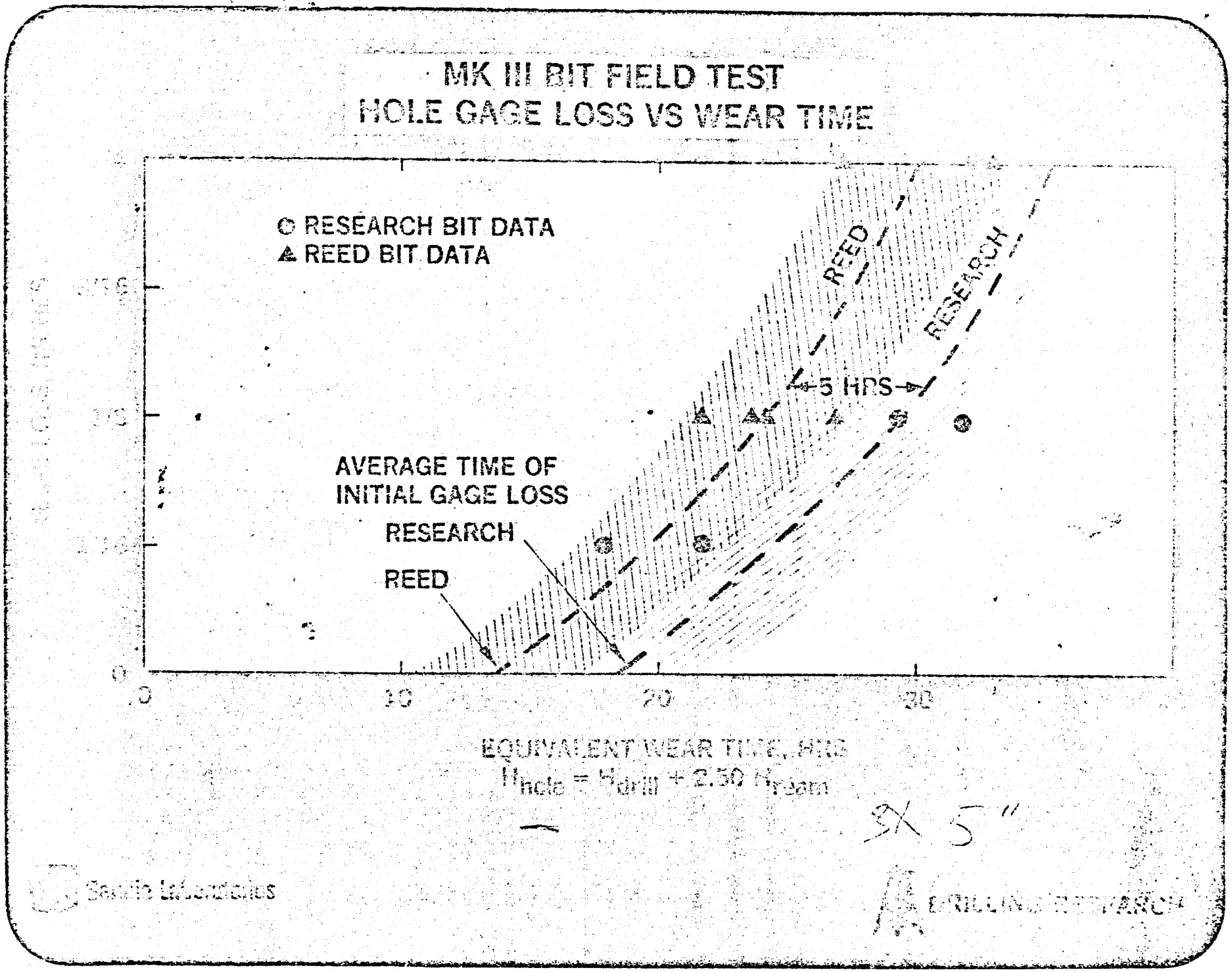
Figure 1. Penetration rate as a function of simulated depth



3"x5"

Figure 2. Gage loss as a function of drilling time



full-scale polycrystalline diamond compact (PDC) bits. Penetration rates to seven times those of roller cone bits were observed (see Figure 1). Field tests of these bits are planned in FY-79 and 80.

Terra Tek conducted field tests of unsealed roller cone bits developed under this program. Research bits using substituted materials with higher hot hardnesses performed noticeably better than control bits using standard materials. Data reduction by A. Maish of Sandia Labs is represented in Figure 2.

The Chain Drill developed by Sandia Laboratories was successfully field tested. Details are presented in a separate paper.

Hydronautics is assessing the performance of cavitating flow nozzles for use in augmenting the cutting performance of conventional bits. This work also provides background information for the possible use of fluid jets in an advanced drilling system.

2) Downhole Motors -- Terra Tek and Maurer Engineering have designed and tested seals utilizing graphite elements which show two to three times the life, at high temperature, of previously tested elastomeric seals. A combined package of similar seals and high load capacity bearings is being tested in a simulated geothermal drilling environment.

3) Fluids -- A 500°F, 3000 psi fluid test flow loop at the University of Oklahoma is operational and design is nearing completion at Baroid on a 700°F, 20,000 psi, autoclave-contained fluid tester.

A state-of-the-art study on foam drilling fluids was completed by Maurer Engineering with a favorable recommendation for further research. The next phase of foaming agent screening tests is being undertaken at Sandia and is detailed in a separate paper by P. Rand.

Feasibility studies have been initiated on the generation of pure nitrogen for drilling fluid use for the purpose of corrosion control. Catalytic treatment of diesel exhaust, cryogenic air separation, and swing pressure adsorption separation are being considered.

Enertech has completed a dynamic wellbore thermal simulator code allowing temperature profile calculations of wellbores during drilling, production and injection.

The Completion Program has continued its state-of-the-art studies, screened completion fluids for high temperature characteristics, investigated high tempera- open hole packers, and initiated studies on fluid-formation interactions. As a follow-on to the previously demonstrated cavitating jet descaling technique by Daedalean Associates, the technique is being extended for borehole workover use. An underreamer using water jets is being developed at the University of Missouri.

Research conducted internally by Sandia has also expanded. A bit hydraulics laboratory is being fabricated. Initial studies will involve polycrystalline diamond compact bits and include the use of aerated fluids. The development of a low-cost steel composition resistant to H_2S is being undertaken beginning with laboratory tests of existing steels.

Rock mechanics studies are being made of the cutting action of drag bits using finite difference computer codes. Results will be used primarily to assist the design of PDC bits.

Some work has been initiated on feasibility studies for possible advanced systems. The work done by Terra Tek on bearings and seals will assist in the downhole motor assessment. The previously mentioned cavitating nozzle work at Hydronautics is being strengthened with basic research into cavitating flow at Hydronautics, the University of Missouri, and the University of San Diego. System studies on the economic feasibility of the overall system needed for fluid jet drilling have begun. The state-of-the-art of percussion drilling is being assessed at Sandia and will include laboratory testing of drills under geothermal conditions.

ADVANCED DRILLING AND COMPLETION SYSTEM

Planning for the advanced system necessary to meet the 1986 cost reduction goal of 50% was begun with a workshop held in New Orleans in January, 1979. Attended by approximately 40 industry representatives, the workshop defined the limitations of present technology and made recommendations for feasible elements of advanced drilling and completion systems capable of development in the required time frame.

Four panels within the workshop investigated 1) Rock Drilling, 2) Borehole Technology, 3) Directional Drilling, and 4) Surface Equipment. Output from these groups has been published and the information utilized as the basis for performing a network analysis of the necessary development programs (Varnado, 1979). Activity networks have been or are being generated in the following major areas:

1) Straight Hole Drilling Systems, with sub-networks for:
   a) Downhole Motors/High Speed Bits,
   b) Fluid Jet Drilling, and
   c) Percussion Drilling

2) Directional Drilling Systems
3) Lost Circulation Control Techniques
4) Completion Systems
5) Supporting Systems and Activities (e.g., corrosion control, computer codes, borehole stability)

Generally, these networks identify the flow of events and their interactions through a state-of-the-art study and data gathering phase, the generation of requirements, hardware design and fabrication or procedures compilation, laboratory testing and field demonstration. Initial time estimates and critical path identification indicate program lengths of seven to eight years. Optimization may shorten these times. Decision points are provided to select the most promising element or systems of those under study in the early program phases for complete development for a field demonstration.

The desired major milestone schedule for the program is:

Advanced System Development Planned	11/79
New Drilling and Completion System Selected	9/81
25% Cost Reduction Technology Developed	12/82
New System Fabricated	10/85
Field Test of New System Complete	12/86

REFERENCES

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