SAN099-1750C

A PROPOSAL FOR AN ADVANCED DRILLING SYSTEM WITH REAL-TIME DIAGNOSTICS
(Diagnostics-While-Drilling)

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ABSTRACT

In this paper, we summarize the rationale for an advanced system called Diagnostics-While-Drilling (DWD) and describe its benefits, preliminary configuration, and essential characteristics. The central concept is a closed data circuit in which downhole sensors collect information and send it to the surface via a high-speed data link, where it is combined with surface measurements and processed through drilling advisory software. The driller then uses this information to adjust the drilling process, sending control signals back downhole with real-time knowledge of their effects on performance. We outline a Program Plan for DOE, university, and industry to cooperate in the development of DWD technology.

OVERVIEW

Drilling is an essential, ubiquitous, and expensive part of the oil, gas, geothermal, water-well, and mining industries. Improving the drilling process carries great interest, but research targets are not obvious because the technology is very mature. Drilling technology improvements can fall in one of two categories: reducing the cost of conventional drilling, where "conventional" includes even high-risk, high-cost operations such as off-shore horizontal drilling; or providing a beneficial new capability that did not exist before, regardless of cost.

Consequences of reducing cost can be impressive. U. S. oil and gas drilling expenditures exceed $10 billion per year (Oil & Gas Journal, 1/98), while drilling and well completion can account for up to 50% of the capital cost for a geothermal power project. Because of the industry's size, reducing total drilling expenditure by a small fraction pays off with a large amount of dollars. Cost reduction can take many forms – faster drilling rates, increased bit or tool life, less trouble (twist-offs, stuck pipe, etc.), lower completion cost through multi-laterals, and others – but the key to any of these improvements is better knowledge at the surface, in real time, of what is happening downhole.

In this proposal, we describe a new technology called **Diagnostics-While-Drilling** (DWD) that will address both kinds of drilling improvement. The central concept of DWD is a closed information loop, carrying data up and control signals down, between the driller and tools at the bottom of the hole. Up-coming data will give a real-time report on drilling conditions, bit and tool performance, and imminent problems. The driller can use this information to either change surface parameters (e.g. weight-on-bit, rotary speed, mud flow rate) with immediate knowledge of their effect, or to return control signals to active downhole components. DWD will reduce costs, even in the short-term, by improving drilling performance, increasing tool life, and avoiding trouble. Its longer-term potential includes variable-damping shock subs for smoother drilling, self-steering directional drilling, and autonomous "smart" drilling systems that analyze data and make drilling decisions downhole, without the driller's direct control.

DISCLAIMER

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The cost reductions mentioned above and their magnitude can be realized in the following ways:

- Improved penetration rate – If operating the bit under optimum conditions will increase its performance, this translates directly into more footage per day or lower cost per foot.
- Increased bit life – Perhaps even more important than penetration rate, increased bit life will mean less time tripping, especially important as depths increase, and lower expenses for bit purchase. Taken together, doubling penetration rate and bit life have been estimated with Sandia's well-cost model to lower total well costs by about 15%.
- Diminished tool failures – In addition to bits, other downhole tools, especially more vulnerable and expensive ones such as motors and directional drilling hardware, fail regularly. Reducing the number of failures, through real-time knowledge of the tool's operating environment and condition, will cut operating time (tripping) and will reduce service and repair charges for this costly equipment. This saving could be as much as 10% of well cost in expensive, directional wells, but because those are not universal, we assume a 4% average.
- Reduced completion cost – If more accurate knowledge of the reservoir (especially geothermal) can assure the operator that multi-leg completions will be effective, he can plan a larger casing program at the top of the hole. This will cost more per well, but production per well will increase at a greater ratio, thus saving on casing and cement costs in a given reservoir. Because completion costs can exceed 40% of total well cost, the potential saving from multi-lateral completions is taken to be an average of 6%.

Thus, the sum of the projected near-term savings listed above is 25%, but advanced technology, which is only dimly visualized now, has the potential to drive the savings even higher. Some examples of indirect, or long-term, improvements are better drilling simulators for training; improved learning-curve analysis for multi-well drilling programs; ability to incorporate more detail and variables in drilling optimization studies; and surface-controllable downhole tools.

SYSTEM DESCRIPTION

Specifications for a DWD system are driven by four functional requirements:

1. Identify the information that is useful to the driller.
2. Process surface and downhole measurements to provide that information.
3. Collect downhole data with appropriate sensors.
4. Use telemetry to bring downhole data to the surface and return control signals downhole.

These four requirements translate into hardware and software needs, as shown by the schematic of a DWD system in Figure 1. Data from all parts of the drilling system, both downhole and on the surface, will be acquired, analyzed, and displayed for the driller at a rate fast enough to provide him with a feeling of response.

> **Example:** *The driller will be able to watch a trace of weight-on-bit, measured at the bit. If the bit is bouncing, which is often the case, the driller would try to attenuate this by adjusting rotary speed and/or weight-on-bit at the surface. Research has shown that it is possible to eliminate bit bounce by adjusting these parameters (Heisig et al, 1998.).*

The following components make up the DWD system:

- *DWD Tool* acquires data from downhole sensors, conditions it for transmission, and delivers it to the high-speed data link;

- *High-Speed Data Link* carries downhole information to the surface and carries surface control signals back downhole;

- *Drilling Advisory Software* acquires, analyzes, and displays downhole and surface data in real time to provide the driller with a complete and accurate status of drilling conditions and system performance;

- *Driller* uses traditional methods as well as the Drilling Advisory Software to direct the drilling process;

- *Drill Rig/Drill Pipe* is the primary mechanism through which the drilling process is controlled (e.g., weight-on-bit, rotary speed, and mud flow);

- *Surface-Controllable Downhole Tools* permit the driller to actively control downhole tools with real-time knowledge of the effect of his actions.

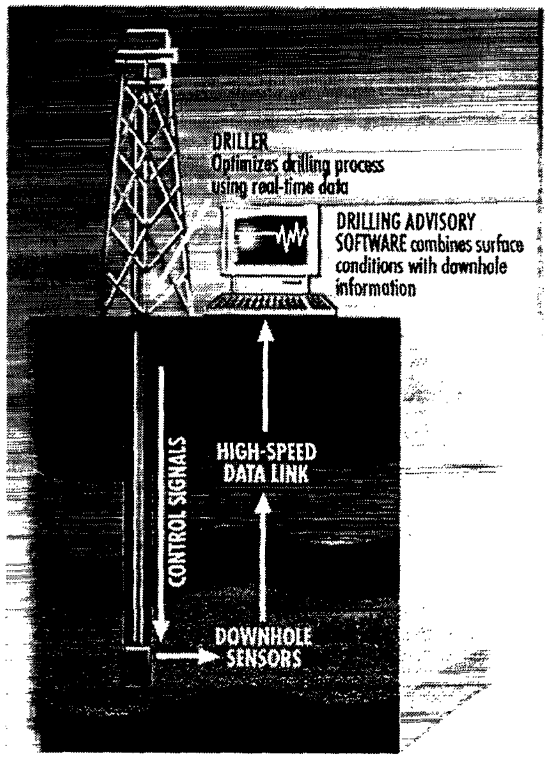

Figure 1 - Schematic representation of the Diagnostics-While-Drilling System

TECHNICAL CHALLENGES

Considering the six components listed in the previous section, development of a DWD system appears to face four major technical challenges: the high-speed data link; the drilling advisory software; surface-controllable downhole tools; and advanced downhole sensors.

- The principal technical challenge is the high-speed data link. To minimize downhole signal processing, the data link should have a minimum transmission rate of 100kbits/sec, which is four orders of magnitude above the data rate of mud-pulse telemetry used in conventional MWD systems.
- Of the critical elements shown in Figure 1, the only one for which prototypes do not currently exist is software for the driller's console. Raw data is of little value to the driller, so a major task in this program is to work with the driller and determine the best way of processing and presenting the data.
- With an economical high-speed data link to transmit control signals downhole and transmit sensor data back uphole, a wide range of downhole tools that have not been feasible to date will become practical.
- Development of advanced downhole sensors with high-temperature, high-shock capability may be evolutionary from existing devices, but may require significant innovation. This will become clearer after the proof-of-concept tests help to refine a list of measurements to be taken and conditions under which the sensors will have to operate.

PROGRAM PLAN

The program to develop an advanced DWD system will have four phases:

- Phase 1 – Project planning and consortium development,
- Phase 2 – Proof-of-Concept testing – assembly of a prototype DWD system, using modified existing downhole components and a hardwired data link, and demonstration of its benefits through field tests,
- Phase 3 – Development of systems needed for cost-effective, commercialized DWD for the geothermal and oil and gas industries, and
- Phase 4 – Research, development and field-testing of enhanced (primarily surface-controllable) tools for DWD applications.

We will depend on industry to contribute to the cost of Phases 2 and 3 by providing cash, measurement-while-drilling tools, and field testing opportunities and facilities. The entire program will be a joint endeavor with industry, universities, including the recently created Well Construction Technology Center, and DOE. It is expected to require $60M over six years.

RATIONALE

Without this aggressive approach to lower drilling costs, geothermal energy will not capture a significant portion of the world's growing demand for electricity. DOE and Sandia have worked for more than 20 years to reduce drilling cost through a combination of incremental and revolutionary improvements in drilling technology, and are well positioned to lead this activity. Coupling geothermal drilling expertise to the vast technology resources that support the DOE weapons program, Sandia is in an unparalleled position to lead the DWD Program. DOE/OGT funding will catalyze the program and assure that the technology is available to enhance worldwide development of geothermal energy, but the geothermal, oil, and gas industries also have crucial roles, through their contributions, in making DWD technically viable and marketable.

SUMMARY

A Diagnostics-While-Drilling system, either as a stand-alone tool or as a precursor to a smart, semi-autonomous drilling method, has been industry's goal for years, if not decades. An explanation for their marginal success to date lies more in the cyclic nature of drilling R&D, which rises and falls with the oil market and has been notably volatile for almost twenty years, than in any lack of talent or motivation. Many of the issues that we propose to address in this program can also be attacked more effectively now because of advances in associated technologies such as computing power, information processing, expert systems, and improved materials.

We view this program as a necessary step in a revolutionary approach to drilling. It will show value in a systems approach that leads to both near-term drilling improvements and long-term enabling of new technologies that may be only dimly visualized now. The proposed work is ambitious, yet realistic, and could have an enormous payoff; we should start now to realize this potential.

REFERENCES

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ACKNOWLEDGEMENT

This work was supported by Sandia National Laboratories, which is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DO-AC04-94AL85000.