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THE IMPACT OF BIT PERFORMANCE ON GEOTHERMAL WELL COST*

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ABSTRACT

The impacts of technological improvements in drill bits on geothermal well costs are evaluated using a compilation of well costs associated with conventional drilling technology. The compilation centers around well models that have been constructed for the major U.S. geothermal areas. Parametric analyses showing the relative importance of the bit performance parameters in well cost reduction and the results of analyses of specific new bit technologies are presented. These results have been used to evaluate the benefits of new technologies and to direct their development.

INTRODUCTION

The high cost of drilling and completing geothermal wells is an impediment to the timely development of geothermal resources in the U.S. The geothermal technology program managed by Sandia National Laboratories for the Department of Energy has concentrated on reducing well cost through improvement in the technology used to drill and complete geothermal wells.

In its early stages, the program focused on improved drilling hardware that would achieve longer downhole lifetimes and higher rates of penetration. Improvements in hardware included research into new materials, improved designs for existing hardware systems or subsystems, and development and demonstration of new drill bit concepts. Evaluation and comparison of potential technology alternatives were on the basis of their potential impacts on total well cost. This paper summarizes the results of several such evaluations for drill bit technology improvements.

The evaluation of the impact of bit improvements is done in three steps. First, the cost of representative drilling and completing of geothermal wells with conventional bits is analyzed. Then, the bit technologies to be evaluated are characterized and their effects on drilling operations understood. Finally, the changes in well cost that result from the new bits are estimated.

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REPRESENTATIVE WELL MODELS

In order to have sufficiently detailed cost data to evaluate new technologies, it was necessary to construct representative well models for the major U.S. geothermal areas. Several steps are involved in the construction of a representative well. A survey of the drilling and completion history for an area provides data for designing a casing program. A schedule of the necessary drilling and completion operations is then compiled from well records and conversations with producers, operators, and service companies active in the region. This schedule is then filled out with specific times and costs for each portion of each operation. These data are compiled from several sources, including manufacturers' catalogs, actual quotes and invoices, bit records, drilling records, conversations with operators, etc. Finally when this process is completed, the entire well plan with detailed, subtotaled and total costs and times is discussed with producers and operators. These well models, which are described elsewhere (Livesay 1981), are used to evaluate the impacts on well cost of possible new bits and other technologies.

PARAMETRIC ANALYSIS

In many cases, parametric analysis of well cost is sufficient for making decisions about new technologies. Generally, such analyses are much simpler than are detailed characterizations of technologies. The two types of analysis are discussed in this and the next section for bit modifications. Both analyses use the well models to characterize the effects on well cost of modified drilling operations. Parametric results compare well costs associated with various values for rate of penetration (ROP), bit life, and bit cost--the parameters which determine the major impact of bit technology on total well cost.

Tables 1, 2, and 3 present the effects of the bit parameters on the total representative well cost for four geothermal areas. The entries in the tables are percentages of original cost resulting from varying two of the three parameters as indicated. These results indicate the relative importance of the major bit performance parameters in well cost reduction. For example, ROP increases show larger effects than do similar improvements in cost or lifetime. Cost increases show larger effects than do similar improvements in lifetime.

Bit Life Relative to Conventional (%)		Total Well Cost Relative to Conventional (%) — Rate of Penetration Relative To Conventional (%) 50	100	200	300	400
	50	133	108	96	92	90
The	100	125	100	88	84	82
Geysers,	200	120	96	84	79	77
CA	300	119	95	82	78	76
	400	118	94	81	77	75
East	50	121	103	95	92	89
Mesa	100	118	100	93	90	86
Imperial	200	117	99	92	89	85
Valley, CA	300	117	98	91	88	84
	400	116	98	91	88	84
	50	127	106	92	89	87
Baca,	100	121	100	89	86	84
NM	200	118	97	88	85	83
	300	117	96	87	84	82
	400	117	96	87	84	82
Roosevelt	50	134	104	89	84	82
Hot	100	130	100	85	84	78
Springs,	200	128	98	83	78	76
UT	300	127	97	82	77	75
	400	127	97	82	77	75

Table 1. The Effects of Rate of Penetration and Bit Life on the Total Well Cost With Constant Bit Cost.

Bit Cost Relative to Conventional (%)		Total Well Cost Relative to Conventional (%) — Rate of Penetration Relative To Conventional (%) 50	100	200	300	400
	50	121	96	84	80	78
The	100	125	100	88	84	82
Geysers,	200	133	108	86	91	89
CA	300	140	116	104	99	97
	400	148	124	111	107	105
East	50	118	99	92	89	85
Mesa	100	119	100	93	80	86
Imperial	200	121	102	95	92	88
Valley, CA	300	123	104	97	94	90
	400	125	106	99	96	92
	50	118	97	86	83	81
Baca,	100	121	100	89	86	84
NM	200	127	106	95	92	90
	300	133	112	101	98	96
	400	140	118	107	103	102
Roosevelt	50	127	97	82	77	75
Hot	100	130	100	85	80	78
Springs,	200	136	106	91	86	84
UT	300	142	115	97	92	90
	400	148	118	103	98	96

Table 2. The Effects of Bit Cost and Rate of Penetration on the Total Well Cost With Constant Bit Life.

Bit Cost Relative to Conventional (%)		Total Well Cost Relative to Conventional (%) — Bit Life Relative To Conventional (%)				
		50	100	200	300	400
The Geysers, CA	50	104	108	116	124	132
	100	96	100	108	116	124
	200	92	95	103	111	119
	300	91	94	102	110	118
	400	90	94	102	110	118
East Mesa Imperial Valley, CA	50	102	103	105	107	109
	100	99	100	102	104	106
	200	98	99	101	103	105
	300	97	98	100	102	104
	400	97	98	100	102	104
Baca, NM	50	103	106	112	118	124
	100	97	100	106	112	118
	200	94	97	103	109	115
	300	93	96	102	108	114
	400	93	96	102	108	113
Roosevelt Hot Springs, UT	50	99	104	110	116	124
	100	97	100	106	112	118
	200	95	98	104	110	116
	300	94	97	103	109	116
	400	94	97	103	109	115

Table 3. The Effects of Bit Life and Bit Cost on the Total Well Cost with Constant ROP.

The results also indicate for each performance parameter a point beyond which further improvement will have little effect on well cost. For example, increases in ROP beyond three to five times have a much reduced effect. These parametric results allow conclusions to be made about potential bit improvements and have proven useful in focusing bit development activities.

DRILL BIT TECHNOLOGY

Experiments with high-temperature seal designs, materials, and lubricants for sealed bearing bits have identified promising seal/lubricant systems for geothermal use (Hendrickson 1980). The performance of the improved bit seal/lubricant system is estimated to increase bit life 25% relative to that of conventional standard systems without changing ROP and bit cost. Applying this new bit lifetime value to the well models, the impact of the improved bit seal/lubricant system on the total well cost can be calculated. It is seen, however, from Table 4 that such bit seal/lubricant improvements will have little impact on the total well costs.

The unsealed geothermal drill bit development project has identified new materials for use in critical areas of conventional roller-cone bits (Hendrickson 1980). From experiments, it has been estimated that bits with improved materials can drill 30% longer and will cost roughly 20% more than conventional bits. Again, these improvements will have a limited effect on the total well costs as shown in Table 4.

Early characterization of the expected performance of new drilling and bit technologies, such as polycrystalline diamond compact (PDC) drill bits, percussion drilling, and cavitating jet augmented roller cone drill bits, is often difficult and usually inexact. For example, PDC bits tested at the Baca, New Mexico demonstrated on the average a 50% increase in ROP over that of conventional bits. However, subsequent PDC bits tested at The Geysers did not perform as well as conventional bits (Kelsey 1981). Recent laboratory experience with PDC drill bits under high speed and high wear conditions has indicated an improved ROP in sandstone (Hoover 1981). Furthermore, based on limited oil and gas drilling records, PDC bits can demonstrate 2 to 3 times higher ROP, with higher bit cost and longer bit life relative to the standard roller cone bit. By hypothesizing parameter values based upon these performances, the impact of PDC bits on total well cost can be seen from Table 4. As indicated, significant cost reductions are possible.

Laboratory testing of percussion drilling tools for geothermal application has been reported (Finger 1981). Percussion drills with roller bits give rate of penetration increases of 2.5 to 3 times that of the same bit in conventional rotary drilling. The bit costs remain the same, but the bit life may be slightly less. In the testing, a percussion hammer with solid head bits had a ROP increase 2 to 5 fold over the unaided roller bit. Solid head bits cost about one half as much as conventional roller bits, but their bit life is difficult to predict and depends greatly on the formation drilled. Table 4 shows the potential

Bit Technology	Hypothetical Bit Performance and Cost Relative to Conventional (%)			Total Well Cost Relative to Conventional (%)			
	Bit Life	ROP	Bit Cost	The Geysers	East Mesa	Baca	Roosevelt Hot Springs
Improved Bit Seal/Lubricant	125	100	100	97	99	98	98
Improved Bit Materials	130	100	120	98	99	99	99
PDC	100-200	200-300	200-300	103-87	97-89	99-89	97-81
Percussion Roller Bit	90	200-400	100	89-83	93-87	90-85	86-79
Cavitating Jet (Augmented Bit)	100	135-200	100	94-84	95-90	94-86	96-80

Table 4. The impacts of bit technology on the total well cost.

impacts of percussion drilling tools on the total well cost. The results exhibit significant well cost reduction.

Preliminary laboratory tests have been conducted to examine the effect on penetration rates of replacing conventional bit nozzles with cavitating jet nozzles. These tests have shown cavitation to be an effective way to utilize the available hydraulic power to improve the cutting and cleaning action in both roller and diamond bit types (Conn 1979). Field tests of twelve two-cone bits fitted with cavitating jet nozzles have demonstrated ROP increases from 35% to 200% over similar bits run with conventional nozzles (Pratt, 1981). Assuming bit cost and bit life remain unchanged, the impact of a cavitating jet augmented bit on the total well cost is shown in Table 4. A cost reduction of 5% to 20% is expected.

These analyses of specific technologies apply the same hypothesized bit performances to all geothermal areas. While this may not be truly realistic for some of the cases, it does show the general magnitude of the potential well cost reduction for new technologies.

CONCLUSIONS

Analysis of specific bit technologies has been used to evaluate their impact on geothermal well costs. For some technologies, such as PDC bits, (applied to sandstone) and percussion drilling (especially appropriate for hard rocks), the results indicate significant potential reduction of well costs, while for other technology, such as certain improvements in bit materials, little or no impact is predicted. Regardless of the particular conclusions, this analysis of potential well-cost impacts has proven useful in evaluating new geothermal bit technologies.

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