5017

Summary of Section VI
Drilling Technology

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INTRODUCTION

Papers in this section deal with various aspects of drilling geothermal wells. Some papers describe current drilling practices (Altseimer, p. 1453; Tan, p. 1523) and improvements in current drilling practice (Jonsson, p. 1501; Dominguez and Vital, p. 1495; Cigni, Fabbri, and Giovannoni, p. 1471; and Maurer, p. 1590); see also Dominguez and Bermejo de la Mora (p. 1619) in Section VII. Other papers describe advanced technology research (Altseimer, p. 1453; Maurer, p. 1509). The magnitude of the drilling program needed to reach 20 000-MW capacity in a 10-year program in the U.S. is estimated to be about 8000 wells using 100 drill rigs (Kennedy and Wolke, p. 1503).

SUMMARY

Kennedy and Wolke (p. 1503) discuss the magnitude of drilling resources needed to develop 20 000 MW of electricity. If the exploratory success ratio is one in six, some 600 wildcat wells would be needed to locate 100 fields of 200-MW capacity. If each production well yields 5 MW, and there is one injection well for each two production wells, then 4000 successful producing wells, 1000 unsuccessful field-development wells, and 2000 injection wells would be drilled, in addition to the 600 wildcat wells—a total of nearly 8000 wells. If these wells were to be drilled in 10 years, 100 drill rigs would be needed. Detailed cost breakdowns for drilling to 10 000 ft for a range of diameters are given.

Altseimer (p. 1453) summarizes data about current drilling experience in the geothermal environment. Histograms of well depth and overall penetration rate are presented for 33 wells in Imperial Valley and 99 wells at The Geysers, California. Plots of overall average penetration rate as a function of depth for The Geysers show that there is little correlation in the depth range between 1 to 2.5 km, where penetration rates vary from about 1 to about 3 m/hr. A 1-km well thus seems to have about as much potential for slow drilling as a 2.5-km well. Altseimer describes the development of rock-melting penetrator equipment (subterrenes), designed to produce self-supporting glass-lined holes by a bit that progressively melts its way into the rock. Various field tests have been run, such as melting a 5-cm hole to a depth of 26 m in a volcanic tuff.

Maurer (p. 1509) summarizes the characteristics of different elements used to drill conventional geothermal wells. These include drill bits, blowout preventers, perforating, and packers. He then goes on to discuss some recent developments in the characteristics of different bits used to drill the Los Alamos Scientific Laboratory's well in New Mexico and to briefly describe some of the novel drilling techniques currently being researched.

Jonsson (p. 1501) describes the use of water in geothermal drilling in Iceland. At the high rates of circulation used, a loss in circulation washes the cuttings into the formation; lost circulation does not seem to be a problem. With only water available, high liquid overpressures can be difficult to control. Water circulation at high rates has permitted journal-bearing tricone bits to be used because the sealing rubber, which is limited to 120 to 150°C, is kept below its failure temperature. Bit life is 200 to 300 hr, and this permits drilling 500 to 1000 m without changing bits. Water is injected after drilling, using a packer to stimulate production by opening up existing fissures.

Cigni, Fabbri, and Giovannoni (p. 1471) discuss advances in techniques for cementing casings. Casing failures are generally produced by temperature cycling, and the coupling near the cementing collar often becomes disconnected. In a good cementing, the casing is uniformly anchored to the surrounding rock and thermally induced stresses can be absorbed. The properties of the cement and the technique used for cementing determine uniformity of filling of the annulus and the quality of the cement bond. Italian experience indicates that good practices are efficient mud removal, precise centering of the casing in the hole, and reciprocating the casing to avoid channeling of the cement. Several cements have been tested for rheological properties, compressive strengths, thickening time, and other properties in order to choose the best mixture for existing conditions.

Dominguez and Vital (p. 1483) discuss problems of casing and cement failure and their repair for wells at Cerro Prieto, Mexico. Failures have occurred at 10 wells, a high frequency caused by reservoir temperatures as great as 344°C. Failures occurred in all wells where a single string of casing was used to serve both as the production casing and to support the borehole walls. In subsequent drilling, the failure rate has been much lower. Repair of the wells has been done using systematic measurements to determine the nature and type of failure and cementing additional casing to cover failures. Only one of the failed wells had to be abandoned; six are currently supplying steam to the power plant. A major blowout in Well M-13 in 1972, caused by casing fracture at 200-m depth, has been controlled by inserting a tube to a depth of 502 m to fill the well with mud and then installing four cement plugs.

In order to lower the failure rate of casings at Cerro Prieto, a procedure described by Dominguez and Bermejo de la Mora (p. 1619, Section VII) has been developed for the slow, controlled, opening of the wells; since sudden starting of a well subjects the casing, cement, and rock formation to large temperature gradients, and gives rise to large stress gradients. If the well is opened slowly, temperatures can equilibrate. Wellhead pressure, temperature logs of the shut-in well after the heating period, amount of casing expansion, percentage of sand produced, and caliper logs are used to check the condition of the well to detect any failures.

Tan (p. 1523) describes the drilling of a 905-m-deep production well for home heating at Afyon, Turkey. Bottom-hole temperature is 107°C, and the well produced 29 l/sec at 86°C wellhead temperature. Temperature and pressure distributions were measured in the well at the end of drilling and again after several days of production.