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THE ECONOMICS OF DRILLING FOR DIRECT HEAT

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ABSTRACT

The drilling for direct heat applications involves techniques which are more like those of the water well drilling industry than of the oil and gas industry. The earnings capability of each geothermal well is much less than for oil or gas wells. Yet the drilling depths to tap the hot water are usually such that oil and gas drilling rigs are needed. This paper discusses this paradox, and the approaches needed to drill the well adequately and yet keep costs within the necessary bounds.

RESOURCES TYPE AND ABUNDANCE

Direct heat applications can be for space heating, for which minimum well-head temperatures of 100°F (120°F is usually quoted) are required, or for process heat. The latter applications are primarily in the food processing and related industries, where minimum temperature requirements are about 200°F.

The lower temperature waters will be more abundant, and will generally be found at shallower depths. Compared to gas or oil, or high temperature geothermal for generating electricity, these low-to-moderate temperature resources are much more abundant. If one uses the normal temperature gradient as a guide, 100°F can be expected at 2000 ft, 150°F at 4500 ft, and 200°F at 7000 ft. But often one drills for these fluids in known hot spring areas. where 200°F might be found at depths of a few hundred feet. Water at temperatures of 200°F or above is dangerous. Below 120°F the fluid can be safely handled. Some of these resources will be under artesian pressure, others won't. Any artesian pressure is a nuisance when one is trying to keep the well under control, but a benefit if one is trying to determine if the resource has been encountered during the drilling.

EARNINGS POTENTIAL

A very good geothermal well, one which can easily have 60°F stripped from its fluid and which can produce 1000 gallons per minute (GPM), can earn $2100 per day if the heat content is sold at the rate of $3 per million Btu. But if the application is for space heating, the well may only be used 25% to a maximum of 50% of its full capacity all year, reducing the earningsaccordingly. On the other hand, a good oil well producing a mere 500 barrels per day will earn $12,500 per day, every day, or over $400,000 per year. If the well costs$500,000 to drill, the return on investment is obviously very attractive. The geothermal well may cost the same or less, but there are additional geothermal expenses before the energy can be used - pipelines, pumps, disposal facilities, etc. Qualitatively, the return on investment for a geothermal well would not seem nearly as attractive as in the oil and gas business, and quantitively this is generally true. Therefore, it is so much more important in the geothermal business to find methods of reducing costs.

Drilling the wells probably represents the greatest expense and the greatest risk in geothermal energy utilization. Fortunately geothermal water is much more abundant than oil and gas, and hence the success of either wildcatting or of drilling new wells in proven geothermal fields is likely to be much greater than in the case of oil and gas exploration. Nevertheless, geothermal energy demands very strict attention to costs of drilling, to reduce these to the bare minimum.

WELL DIAMETER AND DEPTH

Casing size, particularly at the bottum of the string, and the diameter of the hole in the producing section need to be established before the size of the well at the surface can be determined. Also, the drilling equipment may well determine the minimum diameter of the hole. As a general rule, a 9-5/8" diameter casing is plenty large to conduct flows of as large as 1000 GPM (for which the pressure loss is about 5 psi per 1000 ft.). Well bore diameters larger than this in the producing section generally will have little additional benefit to the productivity of the well, unless is is in a very productive and high permeability formation.

The number of steps in the casing string will in part depend on the depth of the well. If the casing is to be cemented, a string longer than 3000 ft needs to be cemented in two or more stages, in general, and this adds complications and risks. In formations where there is much fracturing, cementing casing strings of more than 500 ft length may present problems. It is for this reason that the well design, and contingency plans for that design, are so important a consideration prior to the start of drilling of the well.

Figure 1 shows a typical well design for a relatively deep well for direct heat applications - such as 2000 to 5000 ft deep.

SAFETY

Drilling with safety is one of the major considerations. The concerns are the temperature and pressure which are likely to be encountered. A further concern is the casing expansion that may repeatedly occur in the completed well as it is started and stopped, allowing the well to cool. For this reason, it is generally good practice to never completely shut off a producing geothermal well.

Environmental as well as personnel safety considerations require that the drilling fluids and the geothermal reservoir fluids be able to be contained during the entire drilling operation. This may require the installation of expensive blow-out-preventors on the well head during the drilling operation. On the otherhand, if there is logically no such danger, than it is appropriate to save the expense of using these expensive devices. Close cooperation with the state and federal regulators on this matter is required if unnecessary costs are not to be incurred.

COSTS OF DRILLING

The drilling rig represents the major cost in drilling the well. Generally the rig and crew are contracted for on an hourly or daily fixed charge rate. Occasionally a drilling contractor will agree to drill a well on a footage rate basis, but usually only in areas where the formations are known from prior drilling experience.

The following lists the typical costs for drilling rigs of various types:

1. Truck-mounted rotary
   a) depth capability 1000 to 2000 ft
      $80 to $120 per hour
   b) depth capability to 4000 ft
      $3000 to $4000 per 24 hour day
2. Medium-sized rotary, depth capability to 15,000 ft.
   $5000 to $7000 per 24 hour day
3. Cable-tool rigs, nominal depth capability 1500 ft
   $50 to $100 per hour

Casing is generally the next most expensive item:

13-3/8 inch threaded oil field casing
$22 per foot

12-inch water well casing
$13 per foot
(this is assembled by welding the joints together, which is a time consuming job).

DRILLING APPROACH

There are three types of "experts" that are needed to economically find and produce direct heat geothermal fluids:

1. The geologist/geophysicist, who targets the location for the drilling, based on the surface information, analysis of it, and some experience and intuition.
2. The drilling engineer who plans and designs the well, specifies the type of drilling equipment, supervises the drilling operation, and develops the well with pumps and other devices.
3. The drilling contractor who operates the drill rig in a competent, safe, and cost effective manner.

All are needed to accomplish the task of harnessing low-to-moderate temperature geothermal fluids economically

The following table summarizes the results of drilling direct-heat application wells at a number of projects. All resulted in successful or moderately successful wells on the first try. Boise, Cedar City, and Raft River involve more than one successful well.

EXPERIENCE IN THE DRILLING OF SEVERAL "DIRECT-APPLICATION" PROSPECTS

Location	Type of Resource: Fault or reservoir	Temp. °F	Depth of resource	Total depth drilled	Type of rig	Drilling time	Cost of well
Boise (city, NE)	Fault	170	1000 ft.	1200 ft	Water-well rotary	10 days	$80,000
Raft River (deep)	Fault	300	4500	5000	Oil-field rotary	40	800,000
Raft River (intermed.)	Reserv.	220	1500	2500	Truck-mounted oil-filed rotary	20	250,000
Cedar City (Newcastle)	Reserv.	220	300	500	Water-well rotary	5	25,000
Salt Lake City	Fault	140	3500	5000	Oil-field rotary	15	330,000
Salt Lake (prison)	Fault	200	300	400	Water-well rotary	3	25.000

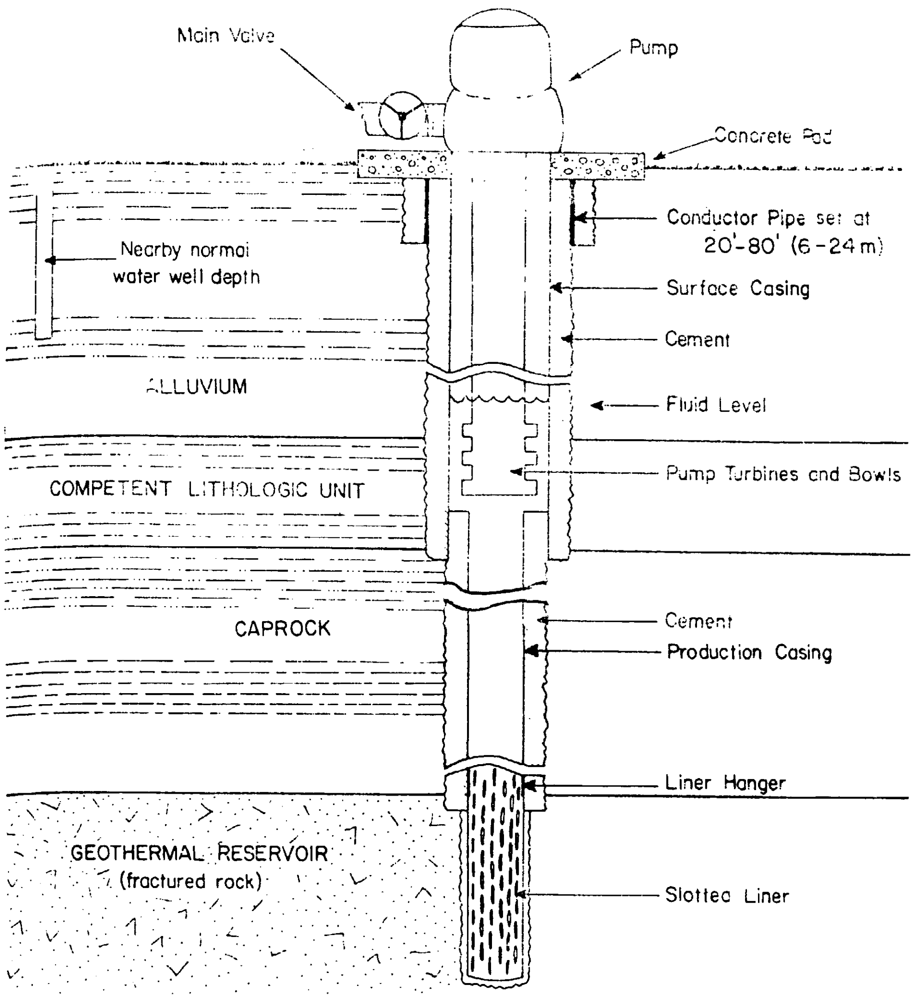

Figure 1 - Typical well design for 2000 to 5000 ft deep direct-applications well.