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WHAT IF THE WATER ISN'T HOT ENOUGH?

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How much will a kW-hr or a Btu of geothermal energy cost from your promising geothermal lease? The answer to that question is the key to the successful commercial utilization of a geothermal resource.

Despite the widespread surface manifestations of geothermal energy, the cases of significant utilization have been few compared to our total energy consumption. No doubt the oil embargo of 1973 and the resulting rapid inflation of energy costs have made geothermal energy look more attractive, and hopefully will make many more geothermal reservoirs economically competitive.

But just as there are marginal oil wells, marginal coal mines, and marginal nuclear reactors, there are most certainly marginal geothermal reservoirs. We speak of marginal in the sense that the costs of harnessing the energy using available technology are too high to be competitive with other forms of energy. We also anticipate that the marginal fields of yesterday will be the economical reservoirs of tomorrow as technological developments take place. Such rapid changes can be expected in newly developing technologies, such as geothermal.

With our understanding of the nature and extent of the geothermal resources only in rudimentary stages, we can only guess as to what fraction of the hydrothermal resources, for instance, are currently submarginal, let alone guess as to the magnitude these represent in absolute units of energy. Nor can it be anticipated what the marginal limit will be in the future, let alone what it is now.

So many parameters of the reservoir have a significant effect on the economics — temperature, water quality, depth, permeability, recharge rate, hydrostatic head, environment, etc. Let us examine just one such variable, temperature, in some detail.

The technology of power generation and heat utilization that we have developed throughout the years is based largely on high temperature, high pressure steam systems. It is not that we don't know how to utilize the lower temperature geothermal energy. It is, however, a fair statement that we don't yet know all the "tricks" and all the "inventions" that we will develop with time. These technological improvements hopefully will lower the costs and give us substantially cheaper geothermal energy than can now be delivered from a geothermal reservoir of a given temperature.

The "Project Independence" report, issued in the fall of 1974 by the Federal Energy Administration, set a goal that was felt to be realistic: approximately 20,000 MW electric of geothermal energy on the line in the U.S. by 1985. Where will the energy come from? The FEA planners concluded that much of it would need to be developed from reservoirs having lower temperatures than most of the present geothermal power plants. Why? Primarily because there is a limit to the amount of this higher temperature water. But lower temperatures open up a vast additional quantity of geothermal resources.

Nature has characteristic distributions, expressed mathematically as, for instance, the Gaussian Distribution (Figure 1). This distribution shows the deviations about a mean or likely value, where the deviations can extend without interference in both positive and negative directions. If one side is restricted by a physical limit (i.e., absolute temperature cannot be less than zero), then we get a skewed distribution. A Poisson Distribution is one such (Figure 2a). Perhaps it might represent the volume of water below the ground surface vs temperature, as the axes indicate. The peak lies at average ground water temperatures (typically 10 to 15°C).

While the left end of the X-axis (the origin) might be the freezing point, the right end is an asymptote, leading up to higher and higher temperatures, and approaching zero volumes. Let's not assume this is the true curve, it is merely a plausible curve. If we address the question of quantity vs temperature at various depths, we might expect a family of curves. Of the total ground water (say within 2 kilometers of the surface), the most likely temperature may be 30 to 40°C. We will still need to examine the upper end of the curve in considerable detail, since the 20 to 40°C is of no particular interest. A cut-away of such a likely curve is shown in Figure 2.b.

Let's consider where present day technology might be on the curve of Figure 2, regarding geothermal reservoir conditions that we know how to utilize economically. Perhaps it is at line "A," i.e., approximately 180°C (356°F), for a "typical" set of reservoir conditions of depth, permeability, etc. If we acquire technological improvements and can extend the curve down to line "B". 30°C lower, the quantity of useful water available to us expands enormously. But energy content in the water, relative to a base level of

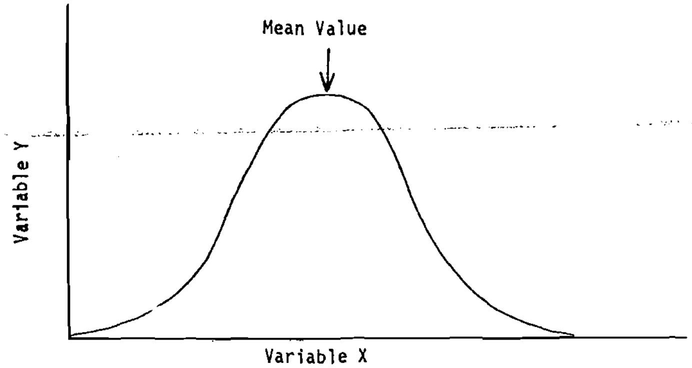

Fig. 1 Typical Gaussian Curve - Nature's "Normal Distribution"

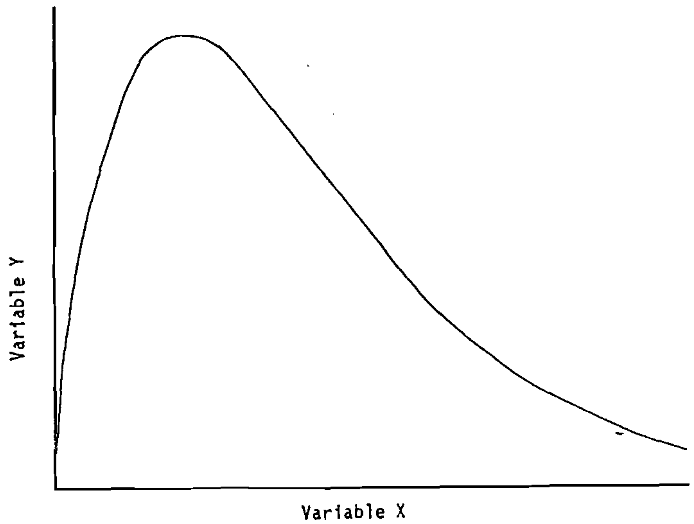

Fig. 2.a The Poisson Distribution

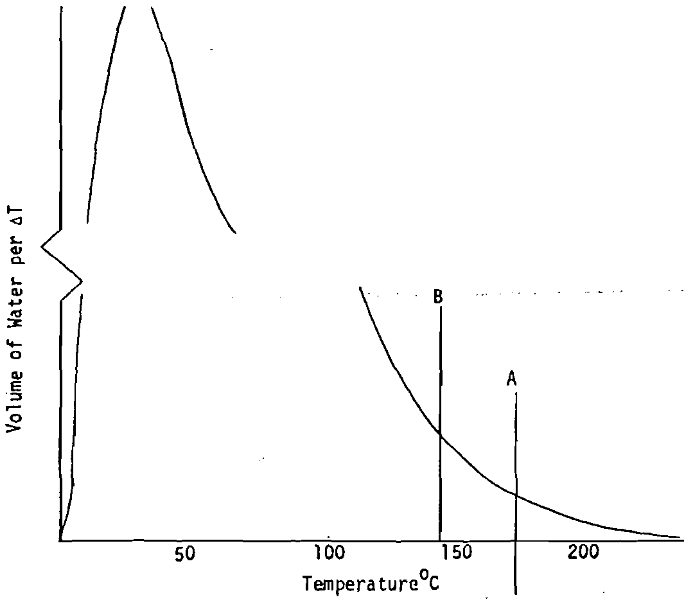

Fig. 2.b Postulated Curve to Represent "Available" Ground Water Volume vs Temperature

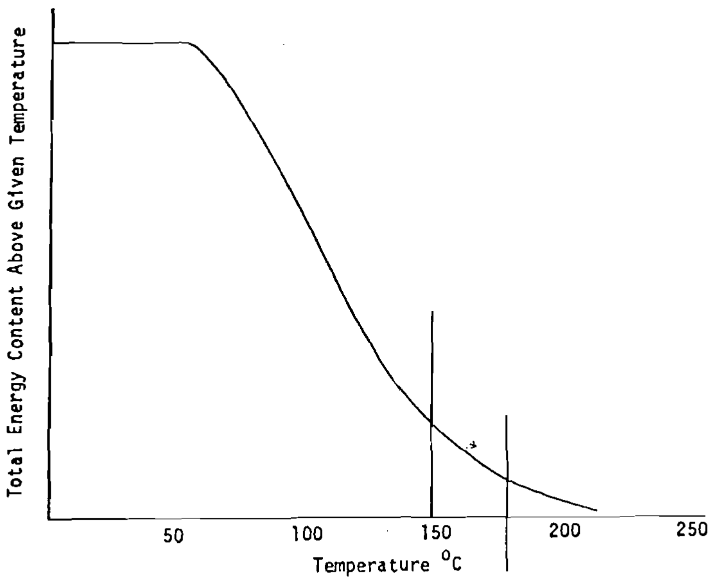

Fig. 3 Energy content (above 45°C) in the "Available" Ground Water

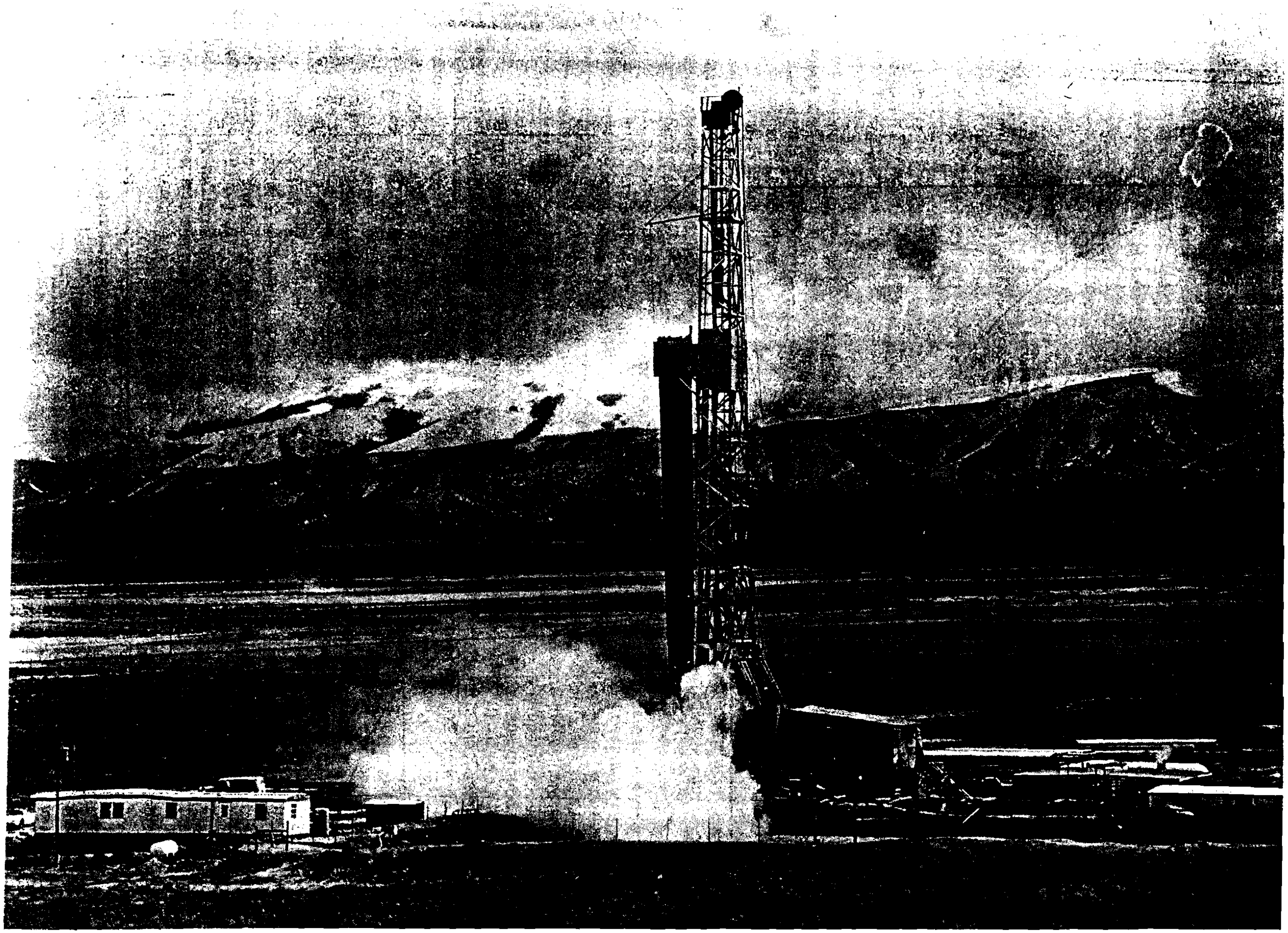

Figure 5 is a photograph of the drill site taken during one of the very brief flow tests conducted later under controlled conditions.

perhaps 45°C (slightly higher than the usual condenser discharge temperatures) gives us a different curve.

The volume of water (Figure 2) multiplied by unit energy content will give us a total available energy content curve (Figure 3). Admittedly we don't truly know the shape of Curve 2, and hence also don't know the true shape of Curve 3. But it is certain that by utilizing only current technology, we will not be able to take advantage of a vast amount of available geothermal energy will be vastly improved if we can find economical methods of utilizing the temperatures below approximately 180°C on a large scale.

The immediate practical concern is not whether we utilize as much of the available quantity of energy, but how much will it cost to harness the energy of a given temperature. Again, this will vary substantially with the given circumstances of depth of resource, permeability, hydrostatic head, etc.

Figure 4 presents the trends of electric energy costs today, from geothermal energy relative to coal and nuclear energy. The costs for geothermal power plants are not well known or understood. (For that matter, one can get widely varying costs for the other forms of energy depending on many factors, such as environment, interest rates, construction time, plant reliability, etc.) The geothermal energy costs for liquid dominated reservoirs are less well known and understood, and technological improvements over the near term are likely to be more prevalent and have a more dramatic effect on costs than for energy from fossil and nuclear sources.

It is to the above considerations that the Idaho National Engineering Laboratory (INEL-) (One of the several national laboratories of the Energy Research and Development Administration) turned its attention.

One of the first concerns was what temperature of reservoir would be the most useful for research and development purposes. Certainly less than the nominal 180°C present economical level. Many reservoirs within 150 miles of the INEL had geochemical indicators no higher than 150°C (302°F).

INEL engineers turned their attention both to ways of reducing the cost of generating electricity from these waters, as well as to better understanding the costs for varying reservoir conditions. For instance, it appears that if the reservoir is extremely good (high well artesian flows), steam power plants using two stages of flash (the last atmospheric pressure) are about as economical as organic (binary) cycle power plants, and probably easier and more reliable to operate using present-day technology. However, for less than ideal reservoir conditions, the organic (binary) cycle has the cost advantage.

Before any such questions can be answered reliably, data must be obtained. A likely site was selected in Southern Idaho, just north of the Utah state line. Known as the Raft River Valley, a number of its irrigation wells had thermal anomalies. Preliminary work by a number of geologists indicated a possible explanation for these anomalies, and the Raft River Rural Electric Cooperative became interested because of the eventual possibility of producing commercial power.

As a result of the preliminary work, the U.S. Geological Survey, in cooperation with the INEL and several universities under contract to INEL undertook a thorough geological-geophysical investigation for geothermal energy in the valley. Though mostly surface measurements (deep resistivity, active seismics, magnetotellurics, magnetics, gravity, self- hydrological wells (typically 100 ft deep) and five slim intermediate depth (1300 ft maximum) cored holes were drilled. Sufficient data was gathered in an attempt to make a geothermal case study, if and when the area would eventually be drilled to greater depth for geothermal energy.

In the fall of 1974, most of the data was available for analysis. The conclusion was simply that the Raft River Valley appeared to be a typical Western valley. Though there was some hot water, the data could not reliably tell how much or where it was coming from, and in any case nothing to indicate reservoir temperatures much exceeding 150°C (302°F). These conclusions made even more pressing the need to explore further. For, if the Raft River Valley was "typical" of many areas in the Western United States, then the information developed would have large scale application.

Shortly after the above information was assembled, the State of Idaho made funding available for about ¼ the cost of a deep exploratory hole. The Energy Research and Development Administration provided the remainder, and the drilling began on January 4, 1975. It was decided to use only water as the drilling fluid in order to maximize the probability of developing geothermal flow and minimize the chance of sealing small fractures with mud.

On January 31, the 4650 ft depth was reached in what appeared, from the cuttings, to be the predicted fracture zone. A core essentially confirmed that conclusion, but still no flow or high temperatures appeared from the 12¼ in. diameter hole (which it later was revealed, by a caliper log, had eroded to 20-inch diameter). A complete set of geophysical logs was felt to be in order before drilling deeper. While logging, on February 2, flow spontaneously developed at 2:00 PM.

By midnight, boiling water was gushing out the top at 800 gal/min (0.051 m3/sec). By 4:00 AM the next morning, as the last of the logging tools was being removed, the flow was well in excess of 1000 gal/min (0.063 m3/sec), and the 10¾ in. mud-line could not carry it without allowing boiling water to spill onto the drilling platform. The well was shut off.

Since that time, the well has been cased with 13-3/8 in. casing to 3700 ft., sealing off some of the cooler producing zones and allowing 136°C (277°F) temperatures to reach the surface during brief flow periods. Peak bottom hole temperature measured to date (April 15, 1975) has been 146°C (294°F). Shut-in pressures are approximately 50 psi after injecting cold water, 165 psi after flowing hot water.

Currently, a second deep hole is being drilled, ¾ mile away, aiming for a different intersection with the apparent main fault. Two wells are needed if either one is to be thoroughly tested. The extensive agricultural activity in the valley makes it environmentally unwise to deposit the geothermal waters on the surface, even though the dissolved solids have been less than the 2000 ppm level.

These initial wells and the data obtained from them will provide additional information to determine if a demonstration electric generating plant should be built. Its aim would be to obtain some of the answers so urgently needed if a significant amount of geothermal energy in water of temperature below nominally 180°C (356°F) is to be utilized for electric power generation. In addition, the Idaho National Engineering Laboratory is turning considerable attention to direct ways of utilizing the geothermal energy, both independently and in combination with an electric power plant.

APPROXIMATE PLANT COSTS

EQUIVALENT 1974 U.S. DOLLARS FOR U.S. MATERIAL AND LABOR