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GEOTHERMAL DRILLING: THE PRICE OF REACHING THE RESOURCE

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ABSTRACT

Geothermal projects typically have high initial investment costs due to drilling needs, power plants built and the relatively low operating costs. The replacement cost of steam for a 75 MW project represents 25% of the cost in a period of 30 years. Operating costs vary depending on the plant capacity, thermodynamic and reservoir transmissibility chich directly affects the numbers of the replacement wells (new wells to recover lost production or injection capacity).

The costs of the steam supply not only include drilling or workovering wells, also have to consider the exploration and resource confirmation, surface facilities and infrastructure costs. The costs of the components and factors influencing them are usually independent of each other, and each component is described in the following text, including its impact on total investment costs.

The first components includes acquisition or lease land in order to do a geological and geophysics prospection, wells location, roads as well as building the drilling pad.

The second component is the drilling of production or injection wells which have a success rate range from 60 to 90% percents, the cost of this factor include the depth of the wells, rig availability, well design (vertical or directional), special fluid circulation, drilling times, wells number and financial considerations in drilling contracts. (Hance de 2005;. Tester et al, 2006).

The third component is well equipment to obtain steam and to handle brien, such as separators, valves, pumps, pipes and roads access. If the brine handling is not necessary the installations to obtain steam has the lower costs. Factors than incises in this cost are related to the chemical composition of the fluids, prices of raw materials (steel, cement), topography, accessibility, slope stability, the well average productivity and its location regarding to the power plant (pipes, diameters and length), and fluid parameters as pressure, temperature or chemicals characteristics (Hance, 2005).

1. INTRODUCTION

Geothermal field location depends among others factors on the natural process that lead to the geothermal reservoirs formation, for which several studies are performed, with different objectives, some conducted to evaluate the geothermal reservoir potential, others to describe physical and environmental conditions, and others more in order to define the commercial exploitation feasibility of the geothermal resource.

Once defined the geothermal reservoir, begins the development of geological, geochemical and geophysical studies, involving the collection of ground surface level data, without the intervention of the environmental setting. These studies allow creating a Conceptual Model, which give future scenarios for development, (Hiriart-LeBert, 2011).

The next stages mainly consist of drilling wells at variable depth, depending on reservoir local conditions. The main objective is to prove the existence of the adequate conditions of a geothermal fluid for exploitation and subsequent electricity generation. Deeper exploration consists of several types of drilling with different targets, from gradient shallow thermal wells (300-100m small diameter) to exploration wells typically completed with large diameters and deeper (1000-3000 meters).

The wells depth in Mexico varies between 600 and 3500m, depending of the region and the zone of the permeable geological structure. The appropriated drilling equipment is selected according to the depth of the projected well, the formations to be drilled and the specific reservoir conditions. The drilling time depend of the programmed depth and the geological subsoil conditions. According to Mexico´s experiences, the perforation time of a typical well varies from 45 days to 180 days, noteworthy that for the latter case, external factors influenced in the prolongation of drilling times.

Within of the costs structure is necessary differentiating the two main items: the operation and maintenance costs (labor and equipment) and the steam supply and replacement costs. In order to exploit a steam ton, addition to the investments involved in the productive well, have to incur in operation costs and contribute to the maintenance of the structure costs (indirect costs).The operations costs varies depending of the power plant capacity, the reposition wells (new wells to recover lost production or injection capacity).The construction of wells to steam replacement as well as to repair production or injection wells during the lifetime of a project (30 years) in a 75MWpower plant represents 25% of the total costs, (CFE 2011).

The costs of the steam replacement not only include drilling or repairing wells, also have to consider the exploration and resource confirmation, surface facilities and infrastructure costs. The costs of the components and factors influencing them are usually independent of each other, and each component is described in the following text, including its impact on total investment costs.

2. PREPARATION OF THE DRILLING PAD

The first component of the cost includes acquisition or lease land roads as well as building the drilling pad, once selected the new well location (Figure 1). In existing drilling pads as well in new ones is necessary weed, clean, race, even the well and conditioning the drilling pad. In this step the costs will depend of the road length. In Mexico the usually the dimensions of the drilling pad are 40 x 80m. The length of the access roads is 6 m wide. The cost of building a standard drilling pad of 40 x 80 m is USD 75,000.

FIGURE 1: Drilling pad and roads access

3. DRILLING PRODUCTION AND INJECTION WELLS

The second component is the drilling of production or injection wells which could have from 60 to 90% percentage of success (Hance, 2005; GTP, 2008) The cost of drilling a well depends on different factors such as the wells depth, rigs availability, well design (vertical or directional), special fluid for circulation, number of wells to be drill and the financial considerations in drilling contracts (Hance de 2005;. Tester et al, 2006).

Once building the roads access, drilling pads and mud dam, but before installing drilling equipment proceeds to waterproof the new drilling pad, to avoid spillage of fuels and lubricants on the ground, also mud dams are waterproofed to place and crop waste material generated during drilling (Figure 2). At the end of this activity, these residues are stored, removed and sent to authorize landfills. Subsequently, begins with the assembly of the drilling equipment and its installation on the drilling pad.

FIGURE 2: Site selected for the mud dam and waterproofed

The drilling time depends, firstly, of the well length, due to the deeper formations are harder to drill and for the other hand and secondly, due to the "reposition time" which increases with depth whenever of the string drilling has to be replenished. As well as the drilling time depends also of the each lithological formations that are drilling, for example if we found limestone or sandstone or shale the advance of drilling time decrease or even can be adjourned. In other case if there high probabilities of unexpected pressures, it is needed to prepare a program of special coating, which will take more time to install, (Jennejohn, 2009).

However, this time can vary from 45 days to a well 1,800 m deep to 150 days for one whose depth reaches 3500 m.

In Mexico the geothermal drilling steps have been standardized and only, depends on the depth of the well varies the area where the different pipes are cemented. The drill hole is started with a depth of 5 m and 1 m (40 inch) diameter, in which the annular conductive tube is installed. This tube has an inner diameter of 0.762 m (30 inch).

The following activity is drilling up to 50 m deep to install the TR of 508 mm (20 inch) Diameter pipe called surface pipe. This hole drilling is carried out first, using auger 311 mm (12 ¼ inch) diameter, extending later, at 508 mm, and finally to 660 mm (26 inch).

The next step is to drill the hole to 500 m depth using auger 311 mm in diameter and its extension to 444 mm (17 ½ inch) . The procedure to install the anchor pipe 340 mm (13 ⅜ inch). In the next stage the well is drilled up to 1200 m deep well with 311mm diameter auger. In this section will be installed and cemented the production tubing of 244 mm (9 ⅝ -in), from the surface to a few meters (5 m) above the bottom of the hole. In the last phase, was directionally drilled with auger 216 mm (8 ½ inch) in order to locate producing area to find attractive or sooner if conditions of pressure and temperature are localized before. At this stage pipe (liner) of 178 mm (7 inch) diameter is installed. This is characterized by vertical slots along its length to allow access of the geothermal fluid. Table 1 shows in summary the types of pipes and setting depth of these and in Figure 3 a typical layout of the pipe configuration of a well in Mexico.

TABLE 1: Pipe diagram configuration and settlement depth

Diameter of bit	Diameter of pipe	Tube type	Setting depth
40”	30”	Conductor	5 m
26”	20”	Superficial	50 m
17 ½”	13 3/8”	Anclaje	500 m
12 ¼”	9 5/8”	Conductora	1200 m
8 ½”	7”	Producción	2000 m

The total wells cost tends to increase exponentially with depth (Shevenell, 2012), (Table 2). In special areas, the mobilization costs and demobilization of drilling equipment must be taken into account, as they can reach several hundred thousand dollars. This will significantly increase the drilling cost. For example, in Mexico typical well of 2200 meters depth cost about $ 5.5 million. Figure 4 shows a graph of the cost of drilling well with depth and time.

TABLE 2: Approximate costs according to well depth

Depth	Costs
1500 m	USD 4,500,000
2200 m	USD 5,500,000
2500 m	USD 6,300,000

In Figure 5, the graph shows the percentage that each item in the total cost of the well. Well casing costs represent 18% of the well drilling cost, while cementing represents 14% of total cost. 38% of the total cost represents the actual operation of drilling the well.

The fixes costs can vary greatly from one well to another, even within the same general area. These costs relate to the administration, data interpretation, decision making, etc. and, usually expressed as a percentage of the costs of geophysical studies and drilling exploration. In areas well known and developed the fixed costs can be low and represent 15% of the geophysical costs and 10% of drilling costs, while new areas, fixed costs are generally high: about 25% of the first and 20% of the latter.

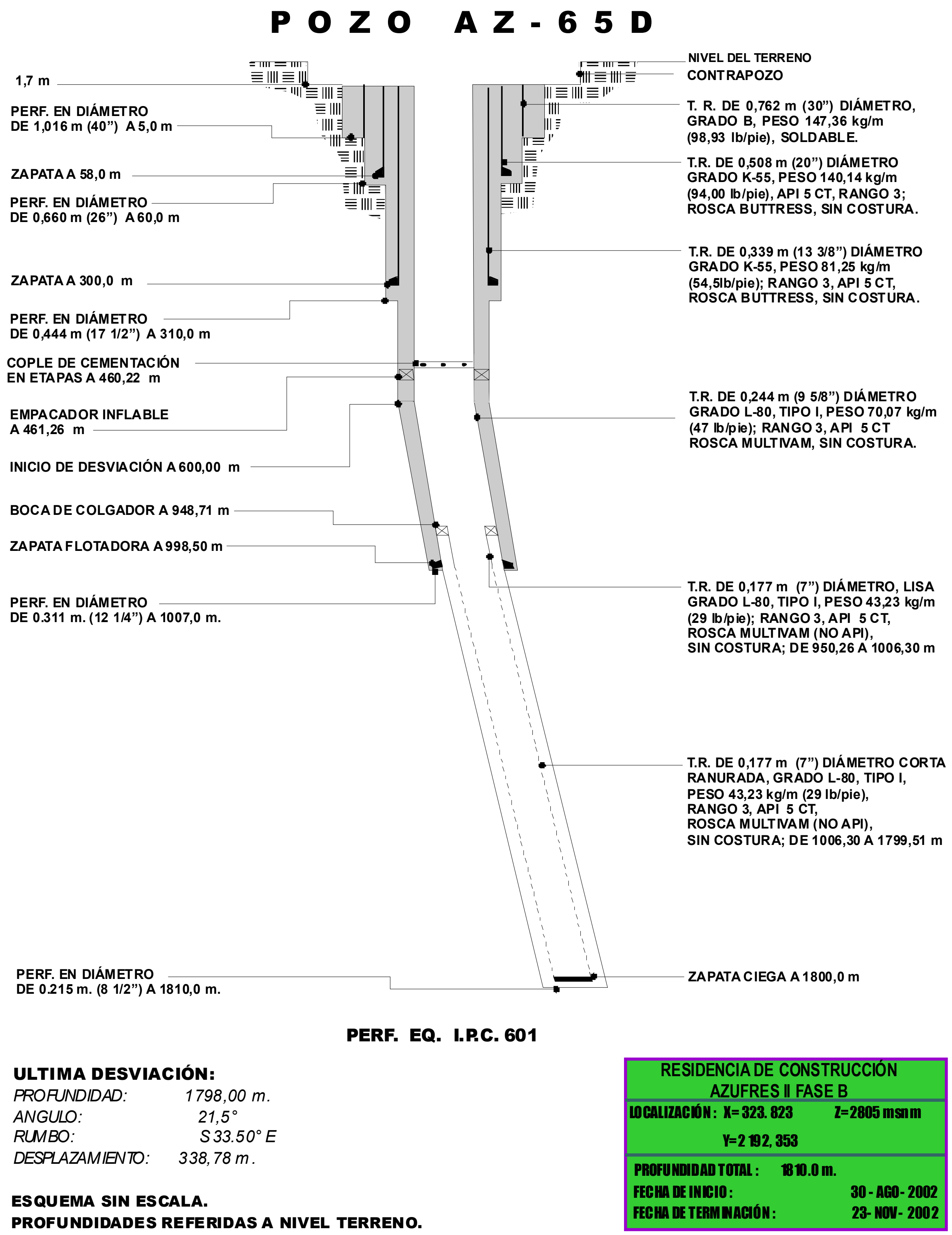

FIGURE 3: Pipe diagram configuration of a typical well in Mexico

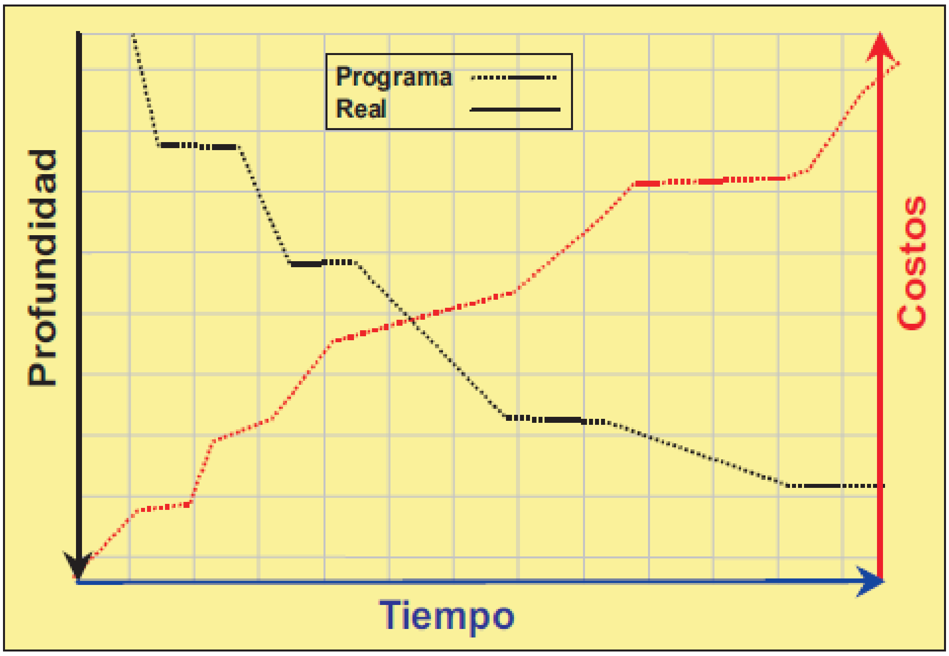

FIGURE 4: Drilling cost with respect to well depth and time

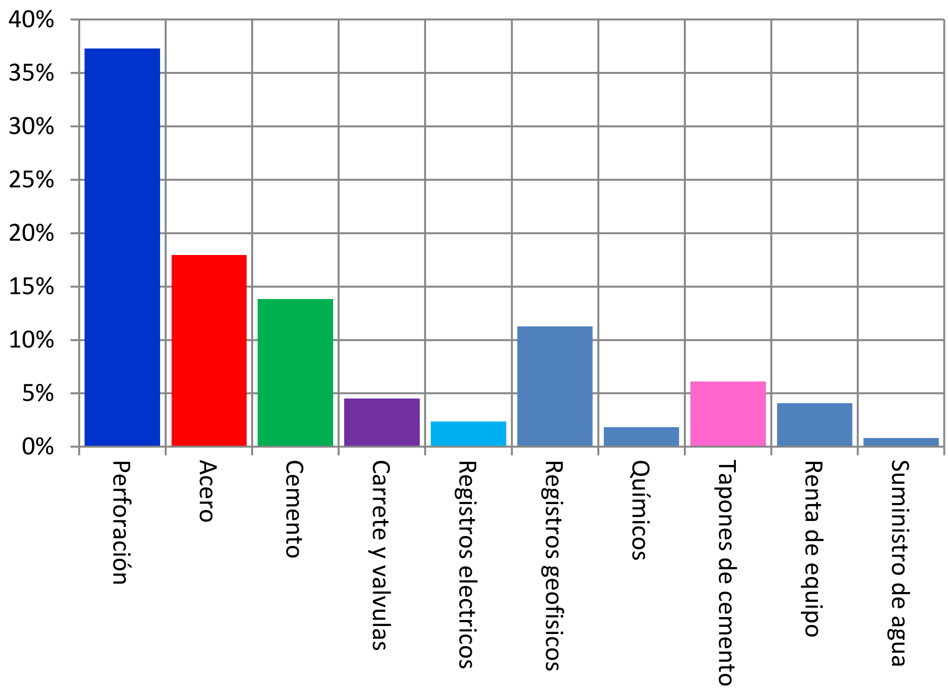

FIGURE 5: Distribution of well costs

4. INFRASTRUCTURE FOR THE EXTRACTION OF STEAM

A third component is the neede installation to obtain steam and to handle the separated brine; separators, pumps, pipes and roads access. If the brine handling is not necessary the installations to obtain steam has the lower costs. Some of the factors are; chemical fluids compositions, prices of raw materials (steel, cement), topography, accessibility, slope stability, the well average productivity and its distribution (pipes, diameters and length), and fluid parameters as pressure, temperature or chemicals characteristics (Hance, 2005).

Once drilled the well to produce steam, it is required to perform the necessary infrastructure for evaluation, development and integration of the well to the steam supply system. The mixture of water and steam flowing in each well is sent to a separator where the water is separated from the steam, each separator is installed in the well drilling pad, but in some cases several wells production is sent to a separation island, the mixture enters the separator tangentially with respect to the equipment body, inducing a centrifugal force separating the phases, because of the higher density of water related to steam, it acquires greater inertia than steam, will stick to the wall of the separator and by gravity falls to the bottom of the device. The separated steam flows the top through the central pipe, to be sent to the turbines by means of a steam pipe designed and built with carbon steel materials and thermally isolated to ensure efficiency.

The cost of the equipment of each well to supply the steam to the power plants varies depending on the distance between the well and the interconnection point with existing steam pipe. In addition to the steel pipe, valves are required as well as centrifugal separators, silencers and pipelines to transport the flash brine to the injector wells. A standard cost for this concept oscillates around USD 640,000 thousand

5. CONCLUSIONS

Within of the costs structure it is necessary to differentiate the two main items: the operation and maintenance costs (labor and equipment) and the steam production and replacement costs.

The construction of wells to produce steam as well as work overs in production or injection wells during the lifetime of a project (30 years) in a 75MWpower plant represents 25% of the total costs.

The costs of the steam not only include the drilling or workovering g wells, also have to consider the exploration and resource confirmation, surface facilities and infrastructure costs. The costs of the components and factors influencing them are usually independent of each other.

The total well cost tends to crease exponentially with the well depth. This will increase significantly the cost of drilling. In special areas the mobilization and demobilization of drilling equipment must be taken into account, as they can reach several hundred thousand dollars. For example, in Mexico 2200 meters typical well costs about USD 5.5 million. Well casing costs represent 18% of the well drilling cost, while cementing represents 14% of total cost. 38% of the total cost represents the actual operation of drilling the well.

The cost of equipping wells for steam supply system varies depending on the distance between the well and the interconnection point with existing steam pipe. In addition to the steel pipe required the installation of valves, centrifugal separator, silencer and works to transport the flash brine to the injector well.

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