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GEOTHERMAL WELL DRILLING COSTING – A CASE STUDY OF MENENGAI GEOTHERMAL FIELD

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ABSTRACT

The cost of drilling geothermal wells forms an important component of any geothermal project. It accounts for 40% of the total investment cost for a new high temperature geothermal project (Kipsang, 2013). Proper well costing is paramount as it will have a direct bearing on the costing of steam and subsequently cost of electricity. Well costing therefore is important in future planning and budgeting for geothermal projects. It can also help in drilling economics such analysis of drilling cost per meter or foot which will in turn help in drilling optimization studies.

Statistical analyses of historical drilling costs data show that the depth of the well is the major parameter explaining its overall cost. It is estimated that 56 percent of cost variability of geothermal wells is linked to depth (Cedric, 2010).

It has also been shown that besides depth, other factors such as total drilling duration and well configuration influence costs of geothermal wells.

The Scope of this paper will dwell on major cost components of a geothermal well.

1. INTRODUCTION

Geothermal well drilling costs vary from one well to another. The main cost components of a geothermal well include the following:

1. Drilling consumables;
2. Drilling hardware;
3. Well head equipment and accessories;
4. Specialized drilling services;
5. Rig move (mobilization); and
6. Personnel and consultancy.

Drilling consumables include: diesel, bentonite, cement and cement additives, drilling detergent and lubricants, and drilling water. Diesel forms the bulk of drilling consumables cost.

Drilling hardware include: casing joints, casing shoes, float collars, top plugs, rock bits, non-return valves etc. For this component casing joint form the bulk of the cost.

Personnel costs are costs incurred in emoluments of the drilling crew.

Specialized services include: directional drilling and fishing services.

Well head costs include costs for master valves side valves, adaptor flanges, ring joints and other accessories.

Rig move (mobilization) costs are costs incurred in transportation of the rig from one site to another.

Costing for wells drilled in Menengai does not include cost of rigs since GDC uses own rigs.

2. COST COMPONENTS

2.1 Drilling consumables

Drilling consumables include diesel, bentonite, cement and cement aditives, drilling detergent, lubricants, tool joint compounds and loss circulation materials (LCM).

2.1.1 Diesel

Diesel is used to run engines that power electricity generators and air compressors (Figure 1). Electricity from generators is used to power the rig equipment and for lighting. On the other hand air compressors provide compressed air which is used with water and drilling detergent to form a drilling fluid mainly used in drilling the 8½" hole.

Diesel has been noted to constitute the biggest portion of drilling consumables cost at 77% .

FIGURE 1: Diesel tanks and power generating unit

2.1.2 Bentonite (Drilling mud)

Bentonite is impure clay consisting mostly of montmorrilonite. It is used with water and other chemicals to lift out rock cuttings during the drilling process. In Menenagi geothermal field bentonite is used mainly in 26 inch and 17½ inch sections. Bentonite accounts for about 2% of the drilling consumables cost.

2.1.3 Cement and cement additives

In geothermal well drilling, cement is used to cement casing and for plug jobs to either heal losses or consolidate unconsolidated formation (Figure 2). Casing cementing is done for 20 inch, 13⅜ and 9⅝ inch casings in 26, 17½ and 12¼ inch holes respectively. Cement plug jobs are common in 26 and 17½ inch sections. Cement and cement additives accounts for about 10% of the drilling consumables costs.

FIGURE 2: Cement silos

2.1.4 Drilling detergent

Drilling detergent is mainly used in aerated drilling to aid in removal of cuttings (Figure 3). It is mainly used in the production section. The foam formed by the drilling detergent helps to suspend and lift cuttings while drilling on bottom. Besides lifting cuttings and hole cleaning, the foam also acts as a lubricant which helps in reducing rotary torque and drag. Drilling detergent accounts for about 5% of the drilling consumables costs.

2.1.5 Lubricants

Lubricants are used in maintenance of various rig equipment. They include engine oils, hydraulic oils, compressor oils and lubricating grease. Lubricants account for about 3.7% of drilling consumables costs.

FIGURE 3: Drilling detergent

2.1.6 Thread compounds

These include casing, drill pipe and drill collar thread compounds. Thread compounds seal tool joint connections during make up to provide protection under the most severe drilling conditions while ensuring low break out torques. Casing thread compounds are high pressure thread compounds that provide high pressure sealing on the casing thread connections. Thread compounds account for about 0.2% of drilling consumable costs.

2.1.7 Loss circulation materials

These are materials used to heal circulation losses. They include conventional loss circulation materials such as walnut shells, mica flakes and locally available loss circulation materials such as saw dust and bagasse. These account for 0.2% of the drilling consumable costs.

2.2 Drilling hardware

Drilling hardware include rock bits, casing and casing accessories.

2.2.1 Rock bits

Rock bits are used to cut the rock while drilling on bottom (Figure 4). There are four common sizes of bits used to drill a standard geothermal well, namely 26", 17½", 12¼" and 8½" bits. On average 17½" section uses one new bit, 12¼" section four new bits and 8½" four new bits. Old bits are mostly used to drill 26 inch section and drilling out cement. Rock bits account for about 36% of drilling hardware costs

FIGURE 4: Rock bit

2.2.1 Casing

Casing of geothermal wells is done for the following reasons:

- To prevent contamination of fresh water well zones;
- To prevent unstable upper formations from caving in and sticking the drill string or forming large caverns;
- To isolate different zones, that may have different pressures or fluids - known as zonal isolation, in the drilled formations from one another;

- Provision of anchorage or support for drilling and the final wellhead;
- Containment of well fluids and pressures;
- To counter losses of drilling fluid circulation during drilling;
- Protection of the well and formation against erosion, corrosion, fracturing and breakdown; and
- To provide a conduit for geothermal resource to flow to the surface.

There are four different sizes of casing string based on different hole sections. These include:

- 20 inch casing for 26 inch hole section;
- 13⅜ inch casing for 17½ inch section;
- 9⅝ casing for 12¼ inch section; and
- 7½ inch casing (liner) for 8½ inch section.

Twenty (20) inch casing string lengths ranges from 40 to 70 m; 13⅜ casing strings from 300 to 500 m; 9⅝ inch casing from 800 to 1300 m while 7½ inch ranges from 800m to 1650 m. Casing string lengths vary from well to well depending on the drilling programs for each well.

The cost of casing for each well therefore varies from well to well. The casing cost for a typical well for Menengai field is about 64% of the total hardware costs (Figure 5).

FIGURE 5: Drilling rig with casing joints on the rack

2.3 Wellhead equipment and accessories

Well equipment and accessories include a 10" master valve, double studded adapter flange, 13⅝" casing head flange and $^{2}/_{16}$"-5000 psi side valves R57, R53 and R24 ring gaskets 53 and R24 ring gaskets.

2.3.1 Master valve

This equipment is used for capping a well after completion of the well. The master valve contains the resource within the well until such a time need arises for the resource to be discharged either for production or discharge tests. Master valves are available in three classes namely; class 600, class 900 and class 1500. The most common master valves used in Menengai are however class 600 and 900. The master valve accounts for 70.5% of the total well head costs.

2.3.2 13⅝ inch casing head flange

A 13⅝ casing flange is made up on a 13⅜ casing. It bears the blowout preventer (BOP) stack during drilling operations and the well head assembly after well completion. We have two types of casing head flanges i.e the weld on type and the screw or threaded type. The most commonly used casing head flange in Menengai is the threaded type. A 13⅝ inch casing head flange accounts for 9.8% of the total hardware costs.

2.3.3 Double studded adapter flange

A double studded adapter flange is used to connect flanges with different nominal sizes, pressure ratings and configurations. It acts as an interface between a 13⅝ inch casing head flange and the master valve. It accounts for 8.8% of the total well head costs.

2.3.4 2/16 inch-5000 psi side outlet valves

These are valves fixed on the sides of a casing head flange. They provide a means of connecting water pipes to the well when need arises. Pressure gauges are fitted on these during well discharge tests. These valves account for about 10.4% of the total well head costs.

2.3.5 Ring joint gaskets

Ring joint gaskets are metallic sealing rings suitable for high pressure and high temperature applications and are fitted in ring groove type flanges (Figure 6)**.** We have three sizes commonly used in Menengai field namely, R57, R53 and R24. One of each is used for R53 and R57 while two R24 are used. Ring joint gaskets account for 0.5% of total well head costs.

FIGURE 6: Well head assembly

2.4 Specialized drilling service costs

These are costs incurred for directional drilling and fishing services. Directional drilling services are offered by directional drilling contractors for directional wells. They include costs for personnel and tools. Directional tools include mud motors, Non-magnetic drill collars (NMDC), universal bottom hole orientation subs (UBHO), stabilizers and directional survey tools. Fishing services are also specialized services offered by contractors. Fishing costs include tools and personnel.

Directional drilling costs account for about 12% of the total costs of the well for directional wells.

2.5. Rig move costs

These are costs incurred in moving rig equipment from one site to another after completion of a well. It can either be done by a contractor or with own equipment. The rig move considered for well costing is the one from previous well to the well in question. Rig move costs account for about 2.6%of the total well costs.

2.6. Personnel and consultancy costs

Personnel costs are cost incurred in remuneration of the drilling crew drawn from GDC and expatriate consultants. The costs are estimated as it is a bit difficult to get the exact personnel costs. These costs account for about 23% of the total well costs.

2.7 Administrative costs

These are not directly tied to drilling of a well. They are related to the organization as a hole as opposed to an individual department. They account for about 10% of total costs.

3. SAMPLE WELL COSTS FOR A VERTICAL AND DIRECTIONAL WELL

Table 1 below shows typical well costs for a vertical and directional well in Menengai.

It is important to note that rig costs are not included in the table above since GDC drills using own rigs. It would be prudent to cost the rigs in terms of depreciation costs. However this has not been put into practice.

It is worth noting that directional wells cost more to drill than vertical wells. However several other factors determine the well costs. Such factors include:

- Total duration spent in drilling a well which is dependent on many other variables such as procurement processes, non-productive time etc.;
- Geological characteristics of the formation which determines the drilling speed;
- Well design whether large bore or standard bore well;
- Depth of the resource which determines the number of casing strings needed and time required in drilling the well; and
- Chemistry of the resource which determines the grade of casing to use.

4. CHALLENGES IN WELL COSTING

Well costing challenges in Menengai geothermal field include:

- Difficulty in factoring rig costs;
- Lack of a proper system to capture usage of drilling materials;

- Difficulty in capturing the cost of personnel and other hidden costs such as administrative costs; and
- It is difficult to capture the cost of well pad preparation as the figures are not readily available.

TABLE 1: Typical well costs for vertical and directional wells in Menengai

	VERTICAL WELL			**DIRECTIONAL WELL**		
	Description	Cost ($)	% of total cost	Description	Cost ($)	% of total cost
01	Drilling Consumables	626,198.21	26.8	Drilling Consumables	928,116.91	30.9
02	Drilling Hardware	383,983.07	16.5	Drilling hardware	332,770.88	11.1
03	Wellhead Equipment	78,087.00	3.3	Wellhead Equipment	61,830.99	2.1
	-	-	-	Specialized services	507,350.89	16.9
04	Rig Move Services	502,894.12	21.5	Rig Move Services	508,880.95	16.9
05	Personnel and Consultancy Costs	530,690.87	22.7	Personnel and Consultancy	440,957.73	14.7
06	Administrative Costs	212,185.32	9.2	Adminitrative Costs	227,255.67	7.4
	TOTAL	**2,334,038.57**	**100.0**		**3,007,164.02**	**100.0**

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From this study, it can be concluded that drilling consumables take the biggest portion of a geothermal well drilling cost accounting for 20 to 30 percent of the total costs.

The cost of drilling directional wells is higher than that of a vertical well of the same depth.

5.2 Recommendations

Ways should be found to cost rigs in an arrangement where a drilling company uses its own rigs as is the case in Menengai geothermal Field. The cost could be in terms of depreciation of the rig equipment. Effort should be made to capture all drilling costs.

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