A NEW ADVANCED METHOD FOR TOP-JOB CASING CEMENTING

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ABSTRACT

A new advanced top-job casing cementing method was applied for one geothermal production well in which the primary cementing failed. The cement top depth was about 300m below ground level in the surface to intermediate casing annulus. The basic concept of this newly developed method is to remove the drilling fluids from the annulus, so that the annulus can be filled with cement without leaving water pockets. Steam was circulated in the well to heat and dry the annulus. Then cement slurry, with a specific gravity of 1.90, was pumped through small diameter pipes and filled the annulus to the surface. This top-job operation was successfully conducted and no casing expansion nor casing collapse has occurred during extended well production.

This new method has many advantages compared to the conventional ones.

INTRODUCTION

It is well recognized that casing cementing is one of the most important operations for long life geothermal production wells. However, it has been a very difficult operation to get the cement slurry to return to the surface, especially when the formations have many lost circulation zones. And this is even more true for the deeper geothermal wells that are recently becoming more popular in Japan. Various methods have been developed to fill the cement slurry from bottom to top of the casing strings. But still no guarantee of success can be planned prior to the operation. What often happens is the formation fractures and cement slurry is lost into open thief zones during cementing operations. Finally the top of the cement is found a few hundred meters from the surface within the annulus between the surface and intermediate casing strings. It is not only very difficult to maintain but also dangerous to produce such a well. But if cement slurry is poured into the annulus from the surface, water will be trapped between two cement plugs and when steam production starts, water in the annulus heats up and finally collapses the casing. So, to solve these problems some conventional top casing cementing methods have been devised. However, these methods have major disadvantages.

PURPOSES, METHODS AND DIFFICULTIES OF GEOTHERMAL CASING CEMENTING

Normally, casing strings are run and cemented three or four times until reaching the total depth (Fig.1). The purposes of running casing and cementing are:(1).to prevent formation collapse and to drill deeper formations safely, (2).to install BOP stacks and wellhead equipment on the casing and fasten them to prevent vibrations, (3).to prevent fluid influx into the wells from the shallower formations, (4).to prevent corrosion on the outside of the casing, and (5).to produce geothermal fluids safely. Casing cementing is also performed for oil and gas wells, but it is necessary for geothermal wells to cement all the installed casing length to minimize casing expansion when producing steam. Especially, it is very important to have good cementing for the casing string on to which the master valves and production pipes are installed. Because if the primary cementing job is not done properly, the valves and pipes would expand upwards and also vibrate. It is not only inconvenient to maintain steam production but also very dangerous because the production casing may part and a steam blowout occur.

The standard procedures for casing cementing are that after reaching casing depth, drilling fluids are conditioned and the well is cooled. Then cement slurry is pumped into the casing and displaced with fluids into the annulus from the bottom to the top (Fig.2A). The density of drilling fluids are normally less than 1.20, but the density of standard cement slurries are about 1.80. Therefore even if there is no lost circulation while drilling, what often happens is the formation fractures and cement slurry is lost into open thief zones during the cementing operations. If the well is pressurized at a level equivalent to the cement slurry column pressure at the bottom of the planned casing depth to find out whether the formation can stand the cementing operation or not, consequently applying excess pressure at shallower depths and opening shallower fractures. Ideally it is possible to displace drilling fluids with a dense mud which has an equivalent density to the cement slurry, but it is almost impossible in practice. This is because high density mud tends to gel at high temperatures and also is costly to make and dispose of such fluids after tests. For these reasons there are no testing methods to determine if the cement slurry will return to the surface or not.

Various methods have been developed and adopted to fill the cement slurry from the bottom to top of casing;lowering the cement slurry density with fly ashes and perlits or ultra low density slurry with ceramic microspheres (Fig.1) of which these additives can lower slurry densities to 1.50 and 1.30 respectively. But these methods sacrifice the cement sheath strength (Fig.3). Another solution is multiple stage cementing methods (Fig.2B). This method is applicable for as many stage cementings as desired, but because of more complicated operations with increased stages, two or three stages are popular for geothermal well cementing so far (Fig.1). With these methods, cement returns have improved, but even with this approach no guarantee of success can be given prior to the operation.

If cement slurry is poured into the annulus from the

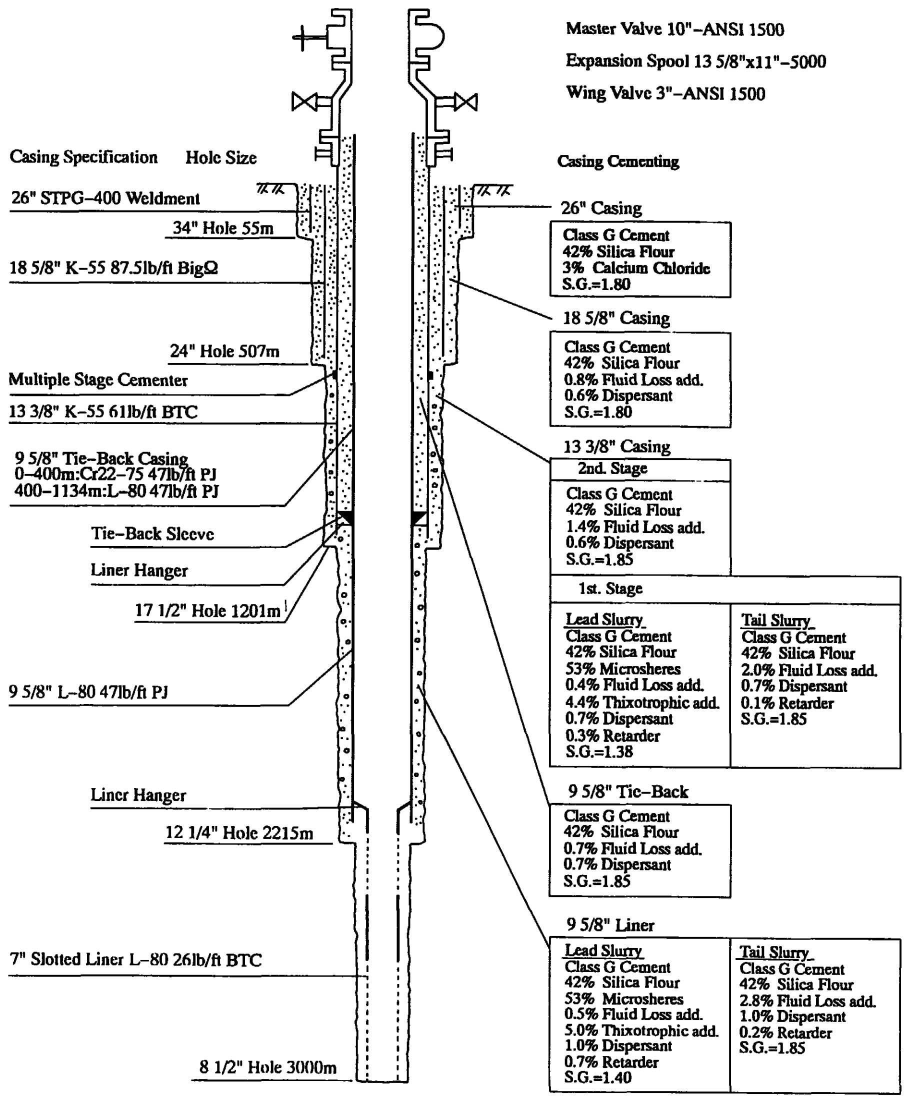


Figure 1. An example of geothermal well primary casing cementing.

A multiple-stage cementing method was used for 13 3/8" casing cementing. Ultra-low density cement was used for 13 3/8" 1st.-stage lead slurry and 9 5/8" liner lead slurry.

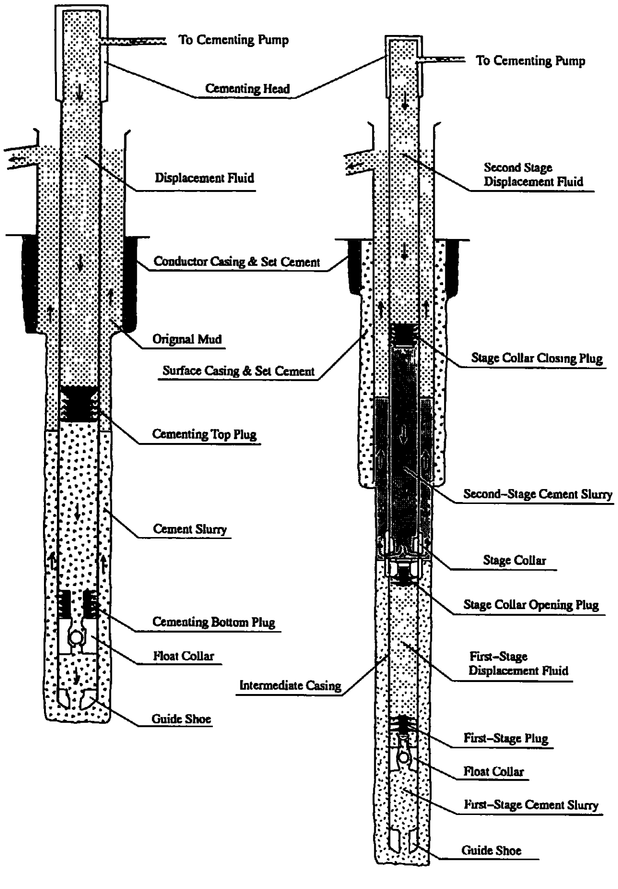
surface, water will be trapped between two cement plugs and when steam production starts, this water in the annulus heats up and pressure increases about 6kg/cm^2 per one degree C temperature rise (Shryock,1982). Therefore, if the temperature rises 50 deg.C, the pressure of the trapped water increases to about 300kg/cm^2 and exceeds the 13 3/8 inch casing collapse pressure. A few examples of collapsed casing have been reported in some areas of Japan.

But without any remedial cementing operations and steam production is started, the casing expands upwards and vibrates. It is not only difficult to maintain steam production but also sometimes dangerous to keep producing such a well, especially if the well has high temperature and pressure.

For these reasons, successful casing cementing remedial jobs are very important but one of the most troublesome operations of all geothermal drilling activities.

CONVENTIONAL TOP-JOB METHODS

Fig.4 shows the conventional top casing cementing methods commonly adopted in Japan. When the cement top is shallow, small diameter pipe strings are run into the annulus to the cement top, and cemented through the strings to the surface (Fig.4A). When the cement top is deep, small diameter pipe strings with ports in the lower section are run. Then the annulus is filled with gravel and sand to some depth, then the upper section of the annulus is cemented through another small diameter short pipe string (Fig.4B). The strings



(A) Single stage cementing (B) Multi stage cementing

Figure 2. Primary casing cementing methods.

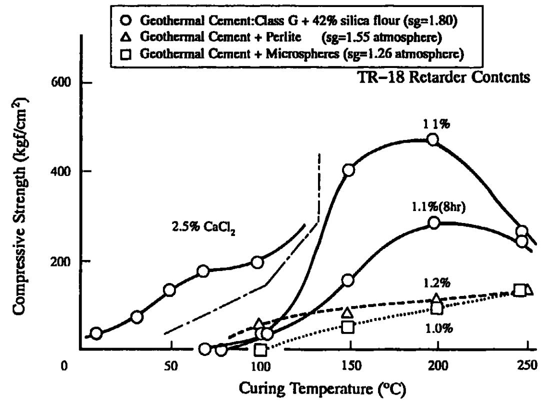


Figure 3. Comparison of slurry density, curing temperature and compressive strength.
Curing time is 24 hours if not specified.
(after Okabayashi,1992)

with ports in the lower section work as pressure relief vents to the surface. Another alternative is to perforate the casing from inside the well and squeeze cement slurry into the annulus. However, this method has the following major disadvantages:(1).it is not certain whether the cement slurry will replace the existing fluids in the annulus,(2).some section of the annulus is not cemented but just filled with gravel and sand,(3).it is almost impossible to find the exact depth and shape of the cement top where perforations are to be placed,(4).it is necessary to perforate the casing.

THE CONDITION OF THE EXAMPLE WELL BEFORE THE TOP-JOB

An 18 5/8 inch casing string was run and cemented at 500m, then drilled ahead with 17 1/2 inch bits to 1,100m casing depth for this production well. Several lost circulation zones were encountered for the 17 1/2 inch hole section, so cement plug treatments were done for each thief zone. No further lost circulation was encountered as the well was drilled to the casing depth. The 13 3/8 inch primary cementing was executed with two stage cementing with specific gravities of cement slurry 1.70 and 1.85 for the lead and tail slurry. But lost circulation occurred during displacing with mud for the second stage cementing operation and the slurry did not return to the surface. After the cement was set, small diameter pipe was lowered into the annulus and found the top of the cement was at about 300 meter depth. Various remedial cementing methods were discussed and finally a new method was adopted because it was thought to be more reliable than any other of the conventional methods. This operation was executed after setting the 9 5/8 inch casing, because it was more convenient to prepare the needed steam line and other surface equipment.

THE NEW ADVANCED TOP-JOB METHOD

To eliminate the disadvantages of conventional top-job methods a new technique was devised. The basic concept of this newly developed method is to remove fluids from the annulus, so that the annulus can be filled with cement without water pockets.

The operation was done using the following procedures (Fig5):

(1).Run 34mm diameter pipe to about 300m and air lift the annulus fluid with compressed air. This was done for safety reason to minimize the amount of boiling water and steam coming out of the annulus when heating up the well.

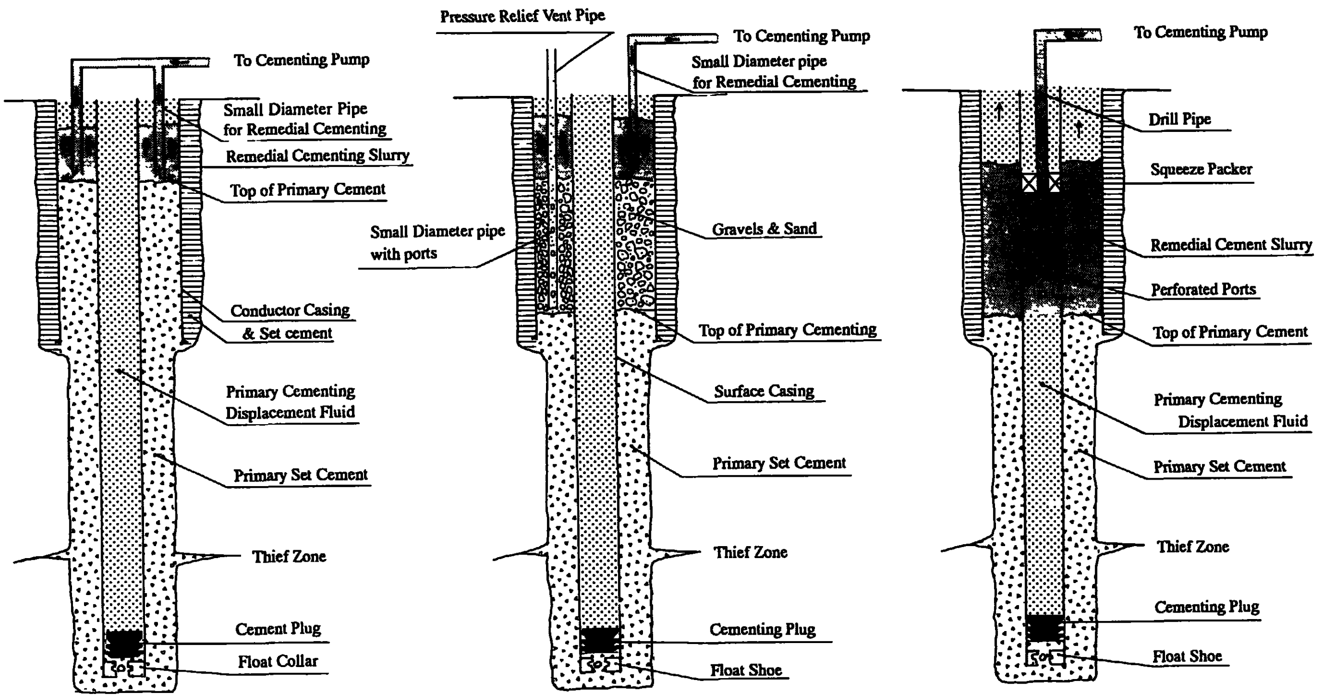
(2).Run 5 inch drill pipe string into the well and air lift until the water level reaches 500m.

(3).Steam was circulated through the 5 inch drill pipe at 400m until the annulus dried up. Since the exact depth and shape of the cement top in the annulus was uncertain, the top 400 to 500m section of the well was heated.

(4).Water was circulated in the well to cool the annulus to prevent flash setting of the slurry while pumping.

(5).The remedial cement slurry with specific gravity of 1.90 was batch mixed and pumped through small diameter pipe into the annulus. A total of 21kl slurry was pumped in 7 stages. For each stage the pipe was pulled to the anticipated cement slurry top depth and finally the entire pipe was pulled out of the annulus when the operation was finished.

The operation was executed as planned.



(A) Cementing through small diameter pipe (B) Cement on top of the gravel and sand (C) Cementing through perforated ports

Figure 4. Conventional remedial top–job casing cementing methods.

THE ADVANTAGES OF THE NEW METHOD

The cement top depths in the annulus are often not determined when the primary cementing fails. The shapes of the set cement are even more difficult to identify. With the new method, neither the depth nor the shape of cement sheath are needed. It is only necessary to run the drill pipe to a depth in the well sufficient to heat and dry up the annulus. Steam was used in this well but hot water is also applicable. With this method, there is no possibility of free water when pumping remedial cement slurry, therefore no collapse casing will occur when steam production starts.
Slurry was pumped through pipes in this case but one could pump into the annulus directly with this method.

Low or ultra low density slurries have often been used to obtain the slurry returns to the surface, even with the sacrifice of the compressive strength. But with this method, high density slurry with higher compressive strength can be placed in the annulus. And also if this new method is adopted at the initial cementing planning stage,the annulus at the shallower depth can be filled with higher density slurry and thus strengthen the shallower part of the well.

One of the major advantages of this method is that no special equipment is required, and therefore operations are straight forward.

Steam has been produced after completion of the well, and no casing expansion nor casing collapse have occurred.

SUMMARY

(1). A new advanced method (JMC Dry–out Method) for top–job casing cementing was created and applied successfully for a geothermal production well.

(2). With this method, the annulus is heated and dried up before the remedial cementing operation. Since there is no possibility of water pockets, there is no possibility of collapse casing.

(3). The remedial cementing slurry with the specific gravity of 1.90 was pumped through 34mm diameter pipe which was run to a depth of 300m depth cement top and filled the annulus to the surface as planned.

(4). This method is applicable even when the primary cement top is a few hundred meters below the surface or even deeper.

(5). One major advantage is that the total length of annulus can be filled with high compressive strength cement slurry.

(6). A new primary cementing method could be created if this method is taken into consideration at the initial cementing planning stage to fill the shallow part of annulus with high strength cement.

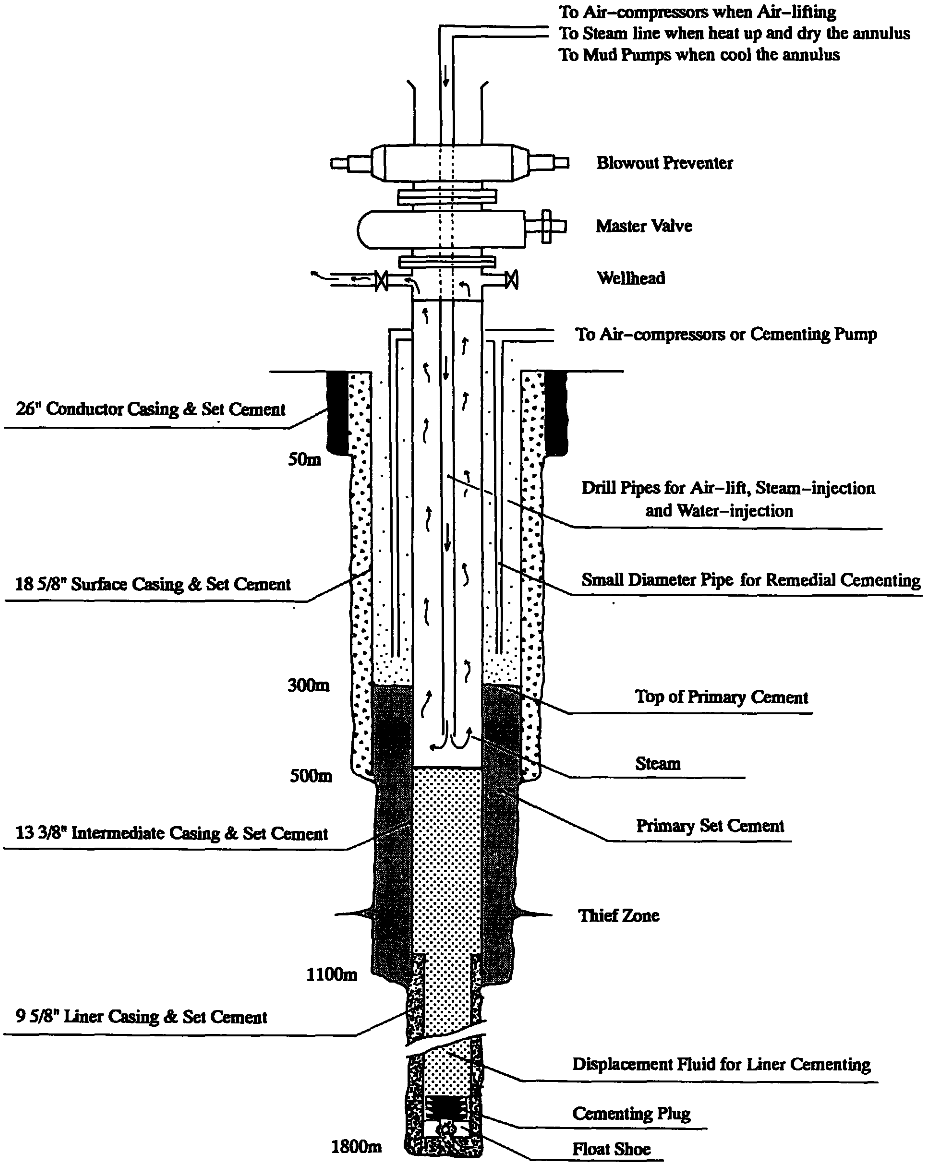


Figure 5. Schematic of a new advanced top-job casing cementing method.

This figure shows how to heat up the annulus by circulating steam in the well. After the annulus is dried up, water is circulated in the well to cool the annulus. Then remedial cement slurry is pumped into the annulus through small diameter pipes and fill to the surface.

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