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LaGeo S.A. de C.V.

OPERATION AND MAINTENANCE OF HIGH-TEMPERATURE GEOTHERMAL WELLS

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ABSTRACT

The use of geothermal energy has been progressively spreading around the globe. Many countries have adopted the drilling of geothermal wells for resource search and use for different applications: producing steam to generate electricity and hot water for direct use. Since a geothermal field enters the operational phase, it is necessary to adopt a program for operation and maintenance of wells that comprise it. Most of the descriptions considered in this report are based primarily on the experiences gained during the operation of the Berlin geothermal field where 34 wells have been drilled. This number involves production, reinjection and monitoring wells with depths ranging between 750 and 3450 meters. It is important to have the equipment, tools and staff to deal with tasks that demand specialized discipline.

1. INTRODUCTION

The search for renewable natural resources to generate electricity is one of the biggest challenges at present, before the uncontrollable increase in oil prices. One of these resources is geothermal, which is being widely exploited for the development of some countries. More and more fields and geothermal wells are drilled around the world looking for the resources for the use of each country.

The exploitation and operation of a geothermal field have involved a number of wells for steam and one for the reinjection of geothermal water coming from the phase separation in cyclone separators. In addition, it is necessary to have wells that are used to monitor reservoir conditions both in the areas of production and reinjection.

The important part is the handling of the geothermal fluid that is extracted from the reservoir, through the wellhead arrangement, separation equipment, and carrying-fluid lines until their final disposal. Steam must be directed to the power plant for its conversion into electricity and geothermal water to be reinjected into wells.

The steam produced from the geothermal wells is an essential part of the operation of the generating station. It is for this reason that the operation and maintenance of these wells play an important role to achieve continuous electrical generation of the power plant. Therefore, it is necessary to have an adequate maintenance program, both in the wells as well as all piping and equipment involved in the supply of steam.

2. INITIAL ISSUES

After a geothermal well is drilled, it is subjected to several activities prior to its connection. Most of these activities are directed specifically to the assessment of the production or absorption of the well. Others focus on adapting the conditions of the well for its use. Some of them are:

1. Early chemical stimulation is being used in most recent wells drilled in El Salvador. It is carried out immediately after the well has been drilled. Basically, it consists of injecting a mixture of chemical products in order to eliminate possible damage to the area of production or reinjection well, or even to improve the conditions of the well.

2. Thermal recovery is used to keep the well under static conditions for an estimated period of two to three months, which depends on the results of static surveys undertaken at the well while at rest.

3. Static P and T surveys are made periodically to the well at standby, and whose objective is to evaluate the thermodynamic conditions.

4. Well pressurization is used as that the well, due to its conditions, will not flow by itself. For this reason, various methods to induce its discharge are used. One of these is to connect a compressor to a side valve of the wellhead and inject air in order to descend and warm the water column.

5. Well discharge is carried out through a controlled process of gradual opening of the valve head, which also induces a gradual warming of the well production tubing. This ensures a uniform heating of the inner pipe and the cement casing. The well is then discharged to a portable muffler. With this initial discharge, initial conditions of the well are defined, and its electric potential is estimated by calculating the fraction of steam present in the geothermal fluid.

3. WELL OPERATION

After the initial testing of the well, different surveys, controlled openings, productive assessment, and final connections are made. The well is pressurized again and an initial discharge is scheduled to integrate it to the power plant for generation.

The well is discharged through the pipe into the muffler, as shown in Figure 1. After waiting for several minutes to acquire the well stabilization conditions, which are observed in its pressure head, it is directed to the cyclone separator. It is in this device where the two-phase fluids are separated: steam to power plant and water directed to reinjection. The diagram of the process is presented in Figure 2.

The steam is transported to the power plant through a pipeline system, called the carrying-fluid line, previously designed. Several conditions are considered to design the pipe: flow rate and steam velocity, pressure drops, diameter of pipe, anchors, supports and a trap system installed along

FIGURE 1: Well TR-18 discharged to the mufflers system before being derived into separation station, Berlin geothermal field

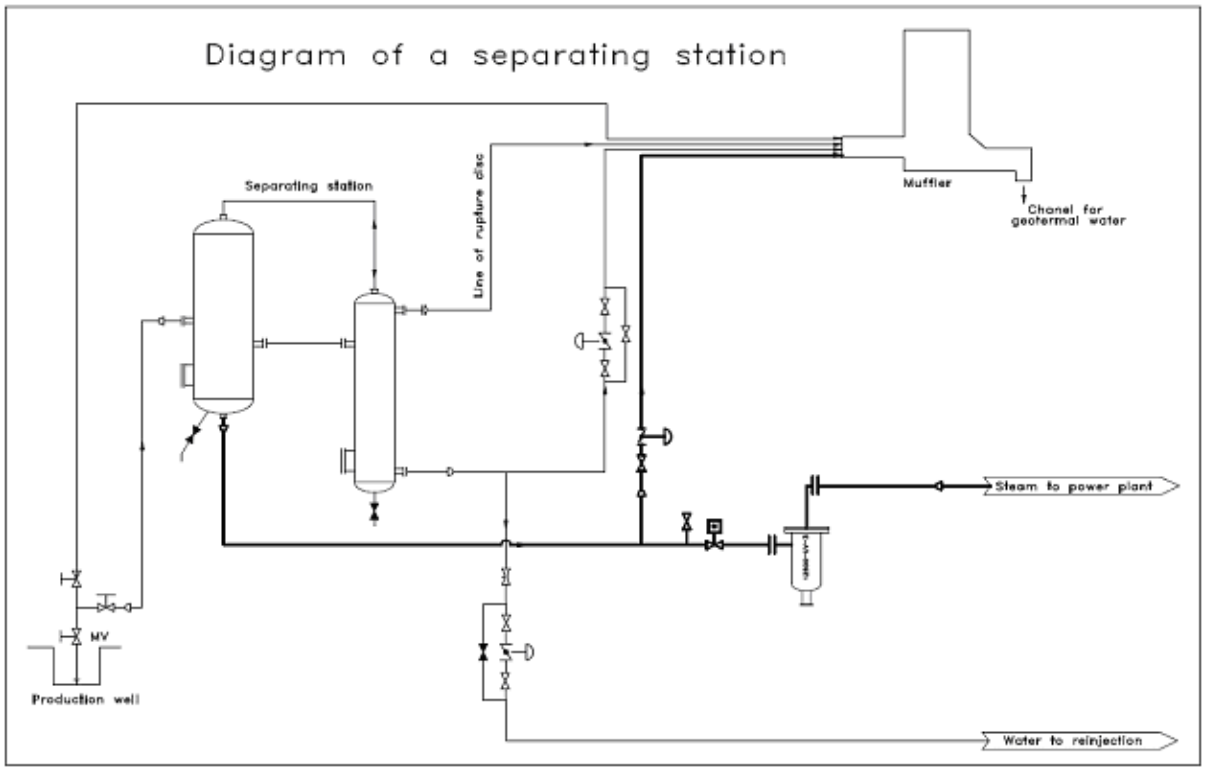

FIGURE 2: Schematic diagram showing the separation of the two-phase flow extracted from a producing well, Berlin geothermal field

the haul line to remove the condensate from the steam generated inside the pipe.

Also, the water line consists of a piping system designed to transport water into injection wells. Along this line of carrying water a drainage system is installed in order to empty the pipeline when it is indisposed for maintenance. These drains are periodically operated to prevent the silica content of the water form deposits and clogging.

It should be noted that vertical discharge of the wells is not carried out anymore in geothermal fields of El Salvador. This is with the objective of protecting the environment.

3.1 Reinjection

As a result of the phase separation in the separation station, geothermal water is transported through pipes at temperatures around 180°C to the injection wells. All the pipes for geothermal fluid transportation are properly insulated to prevent environmental and human problems.

3.2 Monitoring conditions

From the commercial exploitation of a geothermal field, it is necessary to implement a monitoring system that allows the monitoring of the reservoir conditions and the production and reinjection parameters of each well. It is necessary to define a baseline of untapped geothermal field in order to observe its behavior during their development. The physical, chemical, thermodynamic and geological changes reveal important information that serves to take action on the operation of the geothermal field.

The most important conditions or parameters to monitor during the development of geothermal wells are described below.

3.2.1 Production well

1. Wellhead pressure monitoring and recording are done continuously, because reading is obtained directly from a pressure gauge or transmitter located in a side valve of the wellhead arrangement.

2. Opening of sacrifice valve is located immediately after the master valve of the well. The operation of this valve regulates the degree of opening of the well.

3. Separation pressure is also monitored continuously in the cyclone separator.

4. Steam and water flow rates use measuring equipment installed at the exit of the separation equipment.

5. Calibration, pressure and temperature surveys: the calibration survey is use to obtain important information regarding the status of the interior of the production casing and slotted liner (scale, possible collapses, etc.), and possible settlement of solids in the bottom of the well. This survey is done with weight bars and spheres of different diameters ("go-devils"). It can also use a Multi-Finger Caliper (MFC) to detect corrosion damage or irregularities in the casing. Charts and profiles are obtained from the pressure and temperature surveys, which indicate the behavior of these parameters throughout the well using an electronic tool for high temperatures. Figure 3 shows the equipment used for carrying out the surveys into the wells.

FIGURE 3: Surveys run into a production well, TR-4C, Berlin geothermal field

6. Output test is carried at least once a year to verify or define the conditions of the well. From this test, a curve is obtained that indicates the conditions to different degrees of opening of the sacrifice valve, and calculates the average enthalpy of mixing. It is performed each year in order to update the conditions and thermodynamic changes over time.

7. Steam and water samples are carried out in the two-phase line on the well or before entering the cyclone separator in order to define conditions or chemical species present in the fluid.

8. Steam samples are used to obtain the amount of non-condensable gases and other minerals in the steam and define the degree of purity of steam. They are collected at the cyclone separator.

9. Opening and closing operations of the well is necessary to record all the field operations as they are important in order to define the life of a well. It is not appropriate to make such operations

often as it might cause problems with the casings and well head due to contraction and expansion to which they are subjected.

10. Performance of elements of the wellhead is necessary to check the status of valves, abnormal movements of the well, leaks, etc.

11. Behaviour of the physical conditions of cellar is likely that over time, damage is observed in the cellars or mild manifestations of steam around the well pipe. This continuous monitoring allows taking prompt action to repair.

3.2.2 Reinjection wells

1. Wellhead pressure is a parameter recorded daily and continuously.

2. Reinjection temperature and flow rate: flow measurement is recorded by a Venturi or Annubar, and temperature is recorded using an RTD installed in the reinjection line. Figure 4 shows a Venturi element installed for monitoring the flow reinjected into the well.

FIGURE 4: Measurement element installed in the pipe for reinjection (Venturi)

3. Chemical conditions for water reinjection;

4. Scale and/or corrosion in pipes that reach the well should be regularly checked inside the pipes of the wells to verify the degree of product embedding (scale) the silica contained in the water. It is necessary to use easily removable flanged reels. Figure 5 shows scaling found inside the pipe to reinjection wells.

FIGURE 5: Silica deposition found inside the pipe to reinjection well

5. Calibration, temperature and pressure surveys are monitoring and reporting similar to that performed for the production wells.

3.2.3 Monitoring wells

The geothermal monitoring wells are designed to continuously record the temperature and pressure conditions in the reservoir, both in the production and reinjection areas. This is undertaken to provide data that indicates the behaviour or tendency of any anomalous condition, especially pressure which requires some action in resource management.

3.2.4 Separation stations

The separation stations are used for making the separation of the two-phase fluid coming from the production wells. They consist of a cyclone separator, water tank and ball valve. The separation station in TR-17 wellpad is showed in Figure 6.

FIGURE 6: Separation stations in the same pad of TR-17 wells, Berlin geothermal field

The main function of the cyclone separator is to separate liquid and vapour phases. The water tank is responsible for capturing the separated water and sends it to the injection wells. Because the pressure separation is very close to the wellhead pressure, the steam and water are conducted with that initial pressure value. The main function of the ball valve is to act as a security device to possible presence of excess water into steam.

4. MAINTENANCE OF GEOTHERMAL FIELD

Maintenance activities of a geothermal field are one of the most important works for the exploitation of the geothermal resource. An adequate maintenance is important for the steam being supplied in a continuous and reliable way to the power station. In addition to the wellhead, it is important to provide adequate maintenance of the surface facilities of each wellpad and the fluid-carrying lines, with special consideration to the valves and other accessories installed from the wellhead to the power station.

The main function of the valve arrangement of a production well is to control the flow which is extracted from it. The high pressure and temperature values and chemical elements present in the fluid can affect the mass flow resulting in leakage, erosion, fouling, valve corrosion or entrapment causing difficulty of operation, hence it is necessary to have a maintenance program designed to prevent the above situations.

Basically, the maintenance to take into account is described below:

1. Wells and surface facilities maintenance
2. Well intervention
3. Well stimulations
4. Fluid-carrying line maintenance

4.1 Maintenance of wells

4.1.1 Maintenance of wellheads

This activity consists in removing the whole bolts of flanges and valve arrangement of the wellhead valves for cleaning, oiling and painting to withstand environmental conditions and temperature at which they will be operated. Flange bolts and valves are lubricated with a mixture of high temperature grease and graphite, and then subjected to a complete coating of aluminium paint for high temperatures. This activity is a minor maintenance to fix the wellhead and is held once a year.

Besides this activity, a major maintenance to the valve arrangement of the wellhead is also carried out to change gaskets, interior cleaning and lubrication seats gates and master valve. This activity is held every two years and valid for head arrangements of production wells and reinjection. Figure 7 shows disassembly of a production well wellhead valves for maintenance.

FIGURE 7: Disassembly of a production well wellhead valves for maintenance

4.1.2 Maintenance of surface facilities

Because of the environment surroundings the surface facilities of a separate wellpad is necessary to perform a complete service to all flange bolts, valves, steam traps, drains, separation stations, measurement elements for water and steam flow, motor valves, etc., so they will always be under operational conditions and be able to support environmental and temperature conditions to be subjected during normal operation.

Also it constitutes important parts: mufflers, pipes installed in the wellpads, dumps and channels to transport geothermal water. The main problems associated with these equipments are scaling, corrosion and erosion; therefore require a periodic revision of all the equipment in order to avoid serious consequences for the field staff and for the mentioned equipments. This activity also takes place once a year.

Likewise, a major maintenance is performed on all the valves in surface facilities, consisting of removal of caps and dampers for inspection and cleaning, replacement of gaskets and internal cleaning of the whole valve body. A revision and cleaning of separation equipment, and measuring the thickness of the central tube of the cyclone separator are done. The major maintenance is performed every two years.

4.2 Intervention in wells

Depending on the destination of a geothermal well, either for production or for reinjection, so are the problems they may encounter during its lifetime.

The production wells are those that feed steam to the power station. It is common to observe declines or significant drawdowns in the production of the wells due to possible scaling in production casings, changes in the thermodynamic conditions and chemical composition of the fluids, carry-over solids, etc., which leads to necessary interventions to conserve or restore their productive capacities and thus prolong its life. However, before proceeding to any well intervention, it is necessary to run surveys to determine the cause of the problem to define the program according to the situation found.

The injection wells have similar problems of decline in absorptive capacity. Generally, these problems are associated with deposits on the walls of the well casing or in the surroundings of the formation.

Depending on the characteristics of each geothermal field, location in particular or well, so is the intervention program. The most common alternatives are:

1. Intervention for descaling well.
Once it has been defined that the problem of declining on the productive or absorption capacity of the well is because of scaling either in casings or in the formation, it proceeds to develop an intervention program to remove the scale. This can be done either with the well in a static condition or with the well flowing. Generally, for this type of intervention, a rotary rig to ream the scale is used.

When the procedure is performed with the well in a stationary condition, it is convenient to remove the wellhead arrangement from the master valve, or substitute it by a used one, in order to prevent that the rotation of the drill pipe may cause damage. The connections of the pumping system of the rig are made on the side valves of the wellhead in order to inject water, slowly and in stages, to ensure effective control of the well. This operation is done carefully because any sudden change in temperature inside the well could generate cracks by contraction of the casings.

Following this, it is convenient to perform calibration surveys into the well in order to check on their condition. With the well under control it is necessary to go down the bottom with of the rotating drill string to remove scale. It is advisable to use water at ambient temperature (27 to 30 degrees Celsius) to prevent further damage to formation. Under this procedure, it has the disadvantage that the cuttings of scaling do not go to surface, and the well is cleaned longer unavailable to the plant, due to the removal of the valve wellhead arrangement.

Removing scaling with the well flowing is also advisable using a drilling rig, and a blowout preventer system installed on the wellhead to operate the well under controlled conditions. The same well flow allows obtaining the scaling cuttings on surface through a tubing installed. Although operations can be quite risky, it is more convenient to use this alternative, as the operation is carried out in a controlled and coordinated way and can result in an almost immediate availability of the well to the power plant.

2. Intervention for repairing a well.
It is possible that since its drilling, or during operation, a well may present some kind of mechanical damage that ca be manifested in loss of production or absorption capacity. This problem may be associated with corrosion damage, breakage due to contraction and expansion of the casings, collapses associated with poor cementing, erosion, degradation of cement and decoupling of the production casing. If any of these problems appears, it is necessary to act quickly as the situation can be handled. Each of these situations requires a special procedure for its solution.

In the Berlin geothermal field, it had experiences with collapsed casings, poor cementing and leak in the production casing in different wells. In the first case of collapse casing, the repair was made using a conventional drilling rig. The bottom string arrangement, to repair the collapse, consisted of a conical cutter and mill type "watermelon" in order to overcome the damaged casing section. The collapsed area was approximately 3.6 meters. Once repaired and surveys for recognizing the whole well were done, it was decided to install a new production casing, smaller diameter inside the old one, to put the well back into service.

The case of poor cementing in the production casing was very special because in addition to that problem it also found that there was leak in the same casing that did not allow pressurizing the well to flow. After running a dynamic survey with spinner, it was determined that possibly the casing had holes that depressurized the well. In order to overcome this situation, a packer was installed below the

damaged area and blow-out preventers were closed. Then cement was injected by squeezing to force it to enter into the spaces of poor cementing. Later, a CBL survey was ran and observed that the operation had been successful.

4.3 Stimulation in wells

It is common that along time and with continuous operation of a geothermal field, some changes in both production and reinjection wells are observed. Decline in production or absorption capacity is present in wells. When these problems are related to deposit in slotted liner or feeding areas, it is convenient to carry out chemical stimulations down the well. This is carried out to eliminate the scaling problems and to recover, or improve, the production or absorption capacity of the damaged wells. Chemical stimulation works are done either using "coil tubing" down to the feeding area, pressure pumping from the wellhead or rig. The first two have been the most used.

4.4 Maintenance in fluid-carrying lines

The fluid-carrying lines, made of pipes of different diameters, are in charge of transporting the steam to the power plant, and water into injection wells. They are sustained by supports of different kinds. It is necessary to inspect these lines at least once a week to check the status of skids in order to lubricate if required. A steam trap system to remove condensate generated within the pipes is installed along the pipes that carry steam to power plant for removing condensate generated within the pipe. Similarly, a drainage system to drain the pipe is installed along the pipes in charge of carrying geothermal water to injection wells, when required.

During the field inspection to the pipelines and drain system in order to keep them in operating condition. These routines are part of the maintenance that is performed to accessories and equipment installed along the fluid-carrying lines.

5. CONCLUSIONS

It is important to keep in mind that there must be an adequate maintenance program in order to keep the wells, and the geothermal field, in efficient conditions for supplying continuously the steam to the power plant.

Valves, bolts, surface equipments, traps system, drains, facilities, etc., should be subjected to rigorous maintenance activities. The first sign of trouble in a well should be treated immediately and with responsibility. It must not lose sight that steam is the raw material to maintain continuity of generation in the power plant along the time. Since the well is drilled, there must be a data register which controls the main parameters and check their productive or absorption conditions to take action against any problem.

A hard problem to face is the scale into the pipes, mainly in lines that transport geothermal water. Long lengths of pipes combined with low temperature in geothermal water cause increase in the rate of deposition. Hence, it is convenient to design an inhibition program for geothermal water in order to avoid, or delay the rate of deposition.

Calibration, temperature, and pressure surveys of all the geothermal wells are necessary in order to have excellent criteria for operation of the wells, mainly for field management.

Monitoring wells plays an important role for the operation in geothermal field. Reservoir pressure is monitored in these kinds of wells. This is one of the most important parameters for deciding what to do when this pressure is going down.

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