GEOTHERMAL WELL CONTROL EQUIPMENT APPLICATION FOR MINING DRILLING IN GEOTHERMAL ENVIRONMENT

Didin Chaerudin Irwansyah[1*], Gilang Rifki[1], Vicki Agustino[1], Daniel Adityatama[1] and Hafni Wahyu Wiharlan[1]

[1] PT Rigsis Energi Indonesia, Equity Tower 49th floor, Sudirman Rd. 52-53, South Jakarta, Jakarta, Indonesia

didin.irwansyah@rigsis.com

Keywords: *Well Control, Well Control Equipment, BOP, Kick, Geothermal Drilling, Mining Drilling.*

ABSTRACT

One of the considerations during the planning of geothermal drilling is the selection of the well control equipment or Blowout Preventer (BOP). The BOP is used to shut in the well when the first barrier of the drilling operation, drilling mud, cannot withstand the well pressure. The pressure of the well itself originates from the Boiling Pressure Depth (BPD) profile which is controlled by the well temperature. Thus, all drilling operations inside the geothermal environment, including mining drilling, have the same risk on the well control side. Normally, well control equipment is not required in mineral/mining drilling exploration. But for some mineral coring operation that intersect a geothermal area, high temperature of water/steam and/or gases could be encountered during the drilling operation. In order to safely conduct drilling, we need to consider the use of well control equipment for mineral/mining drilling operations in geothermal areas. This paper will describe the assessment of well control equipment that is commonly used in geothermal drilling for mining drilling operations in a geothermal environment. The assessment will discuss the well design configuration, BOP stack configuration and BOP operation appropriate for the mining drilling equipment (drilling rig and BHA).

1. INTRODUCTION

Drilling is an activity to safely make a hole from the surface down to the targeted depth. During the operation, drilling may encounter various hole problems that may prolong the drilling time (further raise the drilling cost) or even result in a disastrous event. Kick is a process of unexpected formation fluid invasion into the wellbore. If the kick is not well handled, it will cause further serious problems. These problems include a fractured formation and the most dangerous one for the surrounding environment is the blowout. Thus, it is important to apply a well control method. A well control method is designed to control the kick, so that it will not cause further problems.

A well control method is operated sequentially in order to handle the kick, and is usually called a well control barrier. The well control barrier is classified into 3 types: First, Second and Third Barrier. Simply, if the first barrier fails, the second barrier will be applied and so on. The first barrier is the first well control component to prevent the occurrence of kick. The hydrostatic column of a drilling mud is applied to cool down the formation and prevent the formation water from flashing during the drilling operation. A cement bond in the annulus between the casing and formation provides permanent zonal isolation that prevent the flow of formation fluid from its original location to the surface. If the first barrier method fails to prevent the kick, then the second barrier is activated in order to shut in the well (handle the kick). The well control equipment is used in this case. A BOP (Blow Out Preventer) is the main well control equipment used to prevent high pressure and/or temperature formation fluid from entering the wellbore. A BOP stack consists of an annular preventer and various rams with customized combinations for each drilling section and operation. If a blowout happens (the second barrier failed), the third barrier should be activated to protect the drilling operation and secure the well and surrounding environment.

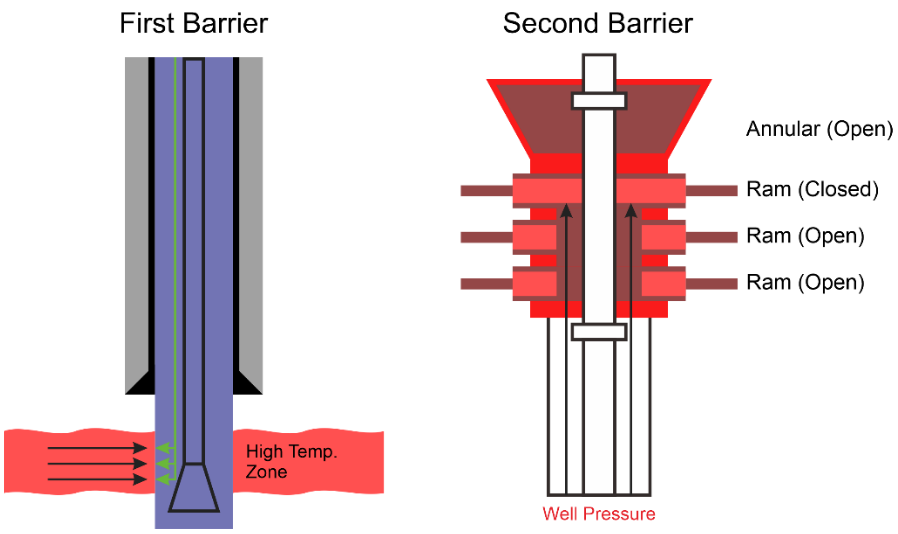

Figure 1: First, Second, and Third Barrier Illustration.

ISSN 2703-4275

A mining well is usually constructed with coring to a certain depth and in this case there is no well control method that can be applied to prevent, handle, or remedy the occurrence of kick. Therefore, a disastrous event can easily happen in certain areas including a mining field that intersects a geothermal prospect area. The water fluid inside a high temperature zone will easily flash since there is not enough material to cool down the formation and there is no equipment to secure the well. A good well control method should be applied to prevent the unwanted formation fluid flow from creating a disastrous event.

2. BASIC THEORY

2.1 Geothermal Drilling Hazard: Kick Definition and Causes

If the borehole advances into a fractured or permeable stratum where the pore pressure is higher than the static head of the drilling fluid, the formation fluid will flow into the wellbore—this is called a "kick"—and that flow must be controlled. If control of that flow is lost, then the resulting disaster is a "blowout" which, at the least will be very expensive and, at worst, can result in loss of life, equipment, and the drill rig, as well as damage to the environment. In most cases in geothermal, a kick results from insufficient cooling of the reservoir/productive zone with drilling fluid/fresh water. This process will increase the temperature of the fluid in the reservoir. When the temperature reaches the boiling point it creates an increasing Flowing Bottom Hole Pressure (FBHP) and the steam slowly migrate upwards by buoyancy driving forces and pushes to the surface or wellhead. The pressure in the well will transmit from bottom hole static to static well head pressure and the well may contain fully or partially static steam pressure (top to bottom).

There are two cases that may cause geothermal well kick:

- Circulating hot fluids from deeper depths to the surface, resulting in the fluids flashing to steam, which causes a loss in hydrostatic pressure, and further flashing or a boil down effect
- Lost circulation causes the fluid level, and thus the pressure, in the wellbore to suddenly fall far enough for the same thing to happen.

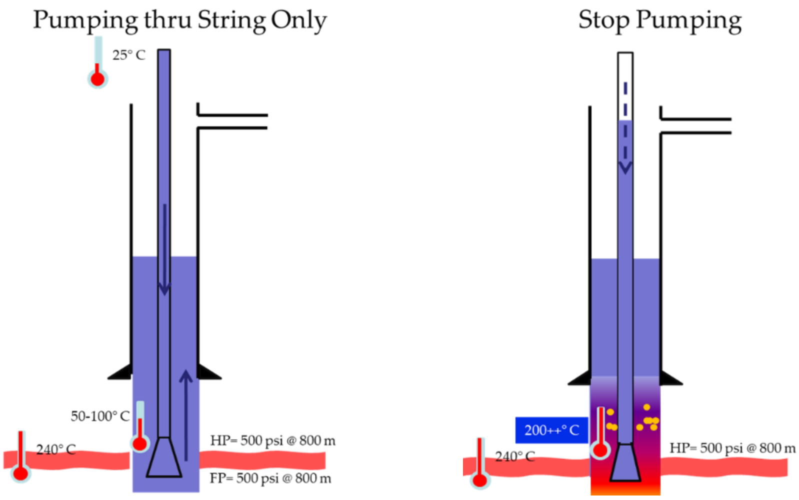

Figure 2: Well Kick Caused by Insufficiently Cooled Hot Formation.

2.2 Well Control in Geothermal Drilling

Well control, in general, has to do with preventing the flow of formation fluids into the wellbore and safely removing them if they get into the wellbore, ensuring safety of the drilling operation. The well control measures must be taken quickly in the event of a kick. If control is lost, a large amount of high-temperature drilling fluid, formation fluid and gas (sometimes contains toxic gases) will flow into the wellbore then blow out from the wellhead. The resulting disaster is called a "blowout".

As mentioned in the introduction, there are three types of well barrier: First, Second, and Third Barrier. The first barrier of well control is aimed to prevent the flow of formation fluid into the wellbore. During the drilling operation, drilling mud is circulated from surface to surface, resulting in a column of hydrostatic fluid that will balance the pore pressure of the formation. The hydrostatic pressure of the drilling fluid should be set below the weakest fracture point at the well by adjusting the fluid density to prevent uncontrolled loss of circulation that may initiate kick. When total loss of circulation occurs but the drilling operation is continued (blind drilling), drilling mud/freshwater should be continuously pumped both from the annulus and drill string in order to keep cooling the formation. After the drilling operation of a section is completed, cement slurry will then be pumped down to the annulus between the casing and formation. The set cement will isolate each formation zone from the surface environment and replace the drilling fluid as the first barrier.

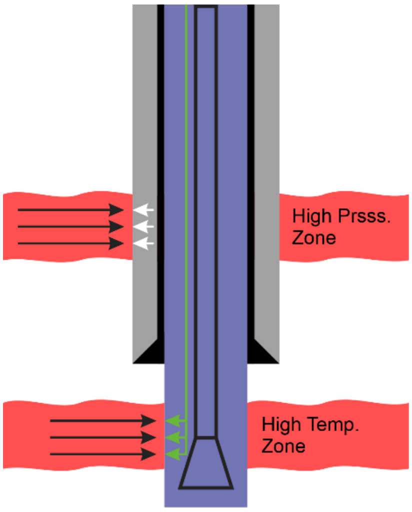

Figure 3: Cement and Mud Hydrostatic Pressure Scheme as First Barrier.

The second barrier of well control will be conducted by shutting in the well with well control equipment, usually called a Blowout Preventer (BOP) stack, if the first barrier cannot prevent the invasion of formation fluid into the wellbore. The BOP stack has to be arranged and sized to meet the well requirement: casing size, well integrity, well pressure and temperature. The BOP size should be selected based on the well schematic plan since it will attach on to the top of the casing. A reverse approach can be adopted by listing the availability of BOP size then modifying the well construction. The number of rams is determined based on the well integrity and API 53 standard. While the rating or working pressure and material of BOP and/or ram should be sized and selected based on the maximum well pressure and temperature that may be encountered during the drilling operation.

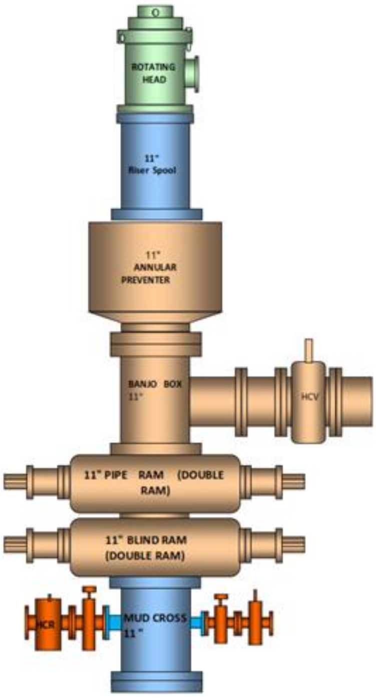

Figure 4: Typical BOP Stack for 8-1/2" Hole Drilling.

3. GEOTHERMAL WELL CONTROL APPLICATION FOR MINING DRILLING

The information shown below is obtained from a mining field in Eastern Indonesia that intersect a geothermal prospect area.

3.1 Current General Mining Well Construction

Since a mining well is drilled with a continuous coring operation using a coring rig, the well size is quite different from that used in geothermal. Typically each mining well section is not completed with a cementing operation. The coring rod is left in the wellbore after reaching the TD then a smaller hole will be drilled, maintaining the communication of each formation zone to the surface. The depth of each section in a mining well is usually determined by the capability of the rig to run the coring rod to a maximum depth. Figure 5 shows a typical mining well construction.

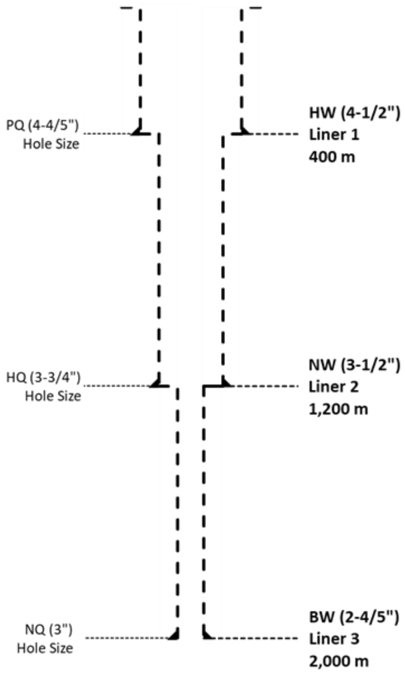

Figure 5: Typical Mining Well Schematic.

3.2 Standard Well Construction for Geothermal Drilling

A typical geothermal well schematic, classified into Big, Normal and Slimhole based on the last section size, is shown in Figure 8. The difference between each last section size is determined by the production rate requirement or well purpose (exploration or development). The use of well control equipment will be different for each well type according to the casing size to which the BOP is to be attached.

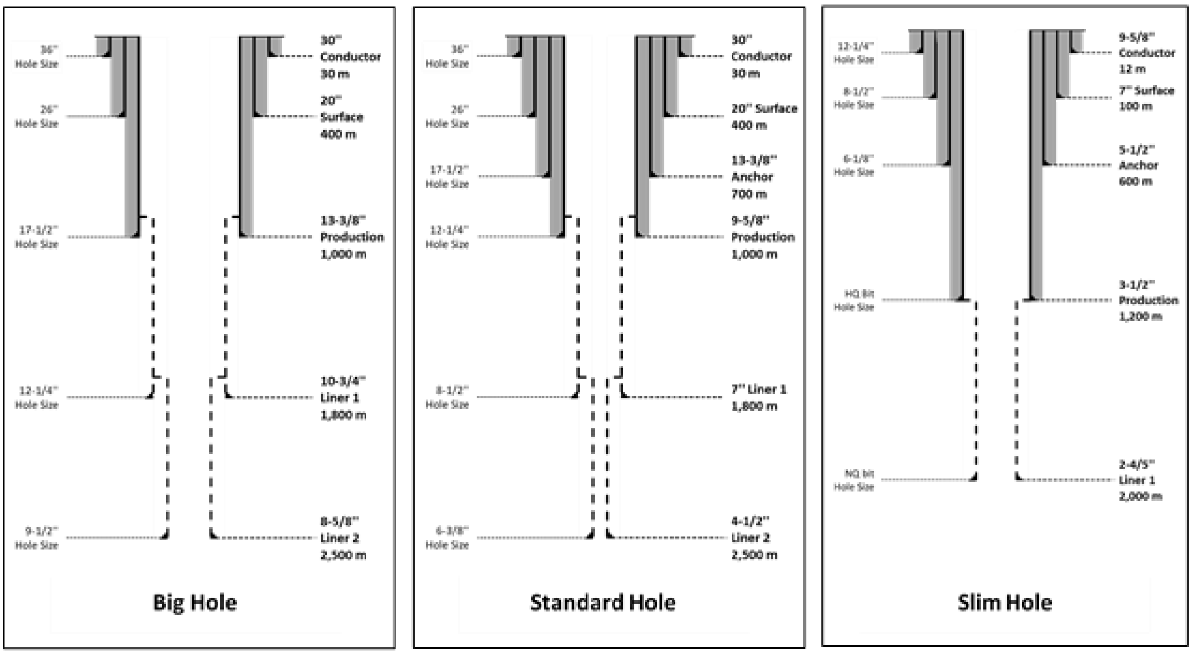

Figure 6: Big, Standard and Slimhole Geothermal Well.

3.3 Geothermal Well Construction Implementation to Mining Well

Since the geothermal well control equipment is planned to be installed for mining drilling, a modification of the mining well schematic has to be made to accommodate the diverter or BOP stack installation. A combination of coring rod size for common mining well and API bit and casing size for geothermal well has been proposed as shown in Figure 7.

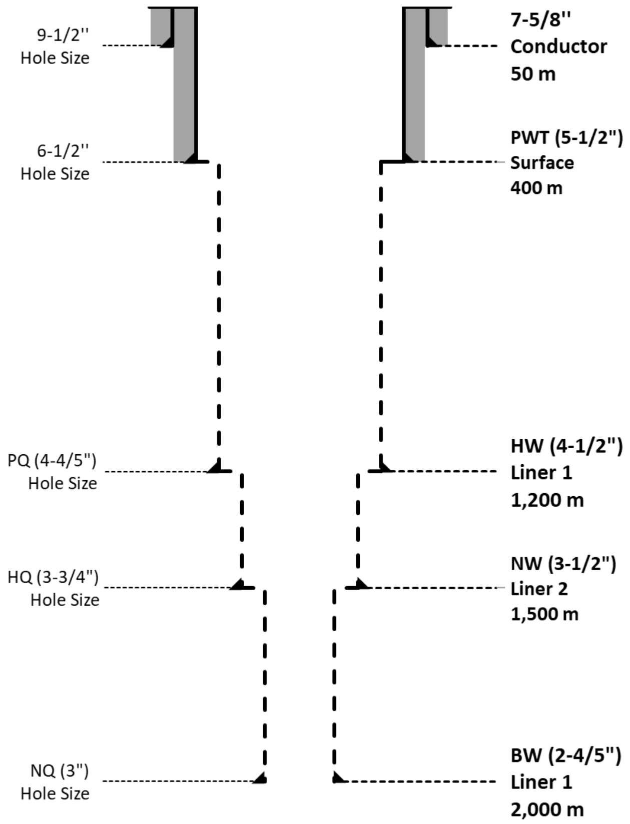

Figure 7: Modified Mining Well Schematic.

3.4 Geothermal Well Control Equipment Application for Mining Drilling

Figure 10 shows the well control equipment for each section of modified mining well schematic. The first section of the well can be installed by augering or other related civil works to install a shallow casing string. The last option is to install the first casing string by conducting conventional method with a coring rig: coring a hole, ream to bigger size hole and run the casing. Since there is no installed casing yet during the drilling of this section, well control equipment cannot be used, but PQ coring practice before the reaming operation may also be considered as a pilot hole to reduce the risk of kick.

After the first casing has been installed, a well control equipment called an annular diverter can be installed during the deepening of the 6-1/2" hole. A diverter will divert the kick into surface and will not shut in the well since if the weakest point at the first casing shoe is fractured, it may communicate up to the surface environment. The next section of the well will be secured by installing Inflatable Packers (IPI) until the final depth. IPI is a tool to contain pressure from the well that is commonly used in mining drilling. But since they are limited to PWT casing, the first 2 sections have to be drilled to safely conduct the drilling operation. The 7-1/16" BOP will be a good option for well control equipment for the next section, but due to the requirement for additional rams the height of the BOP stack will exceed the mining rig substructure. To prevent the flow of formation fluid inside the drillstring, a downhole float valve and an Inside BOP (IBOP) at surface should be installed during the drilling of each section of the well.

ISSN 2703-4275

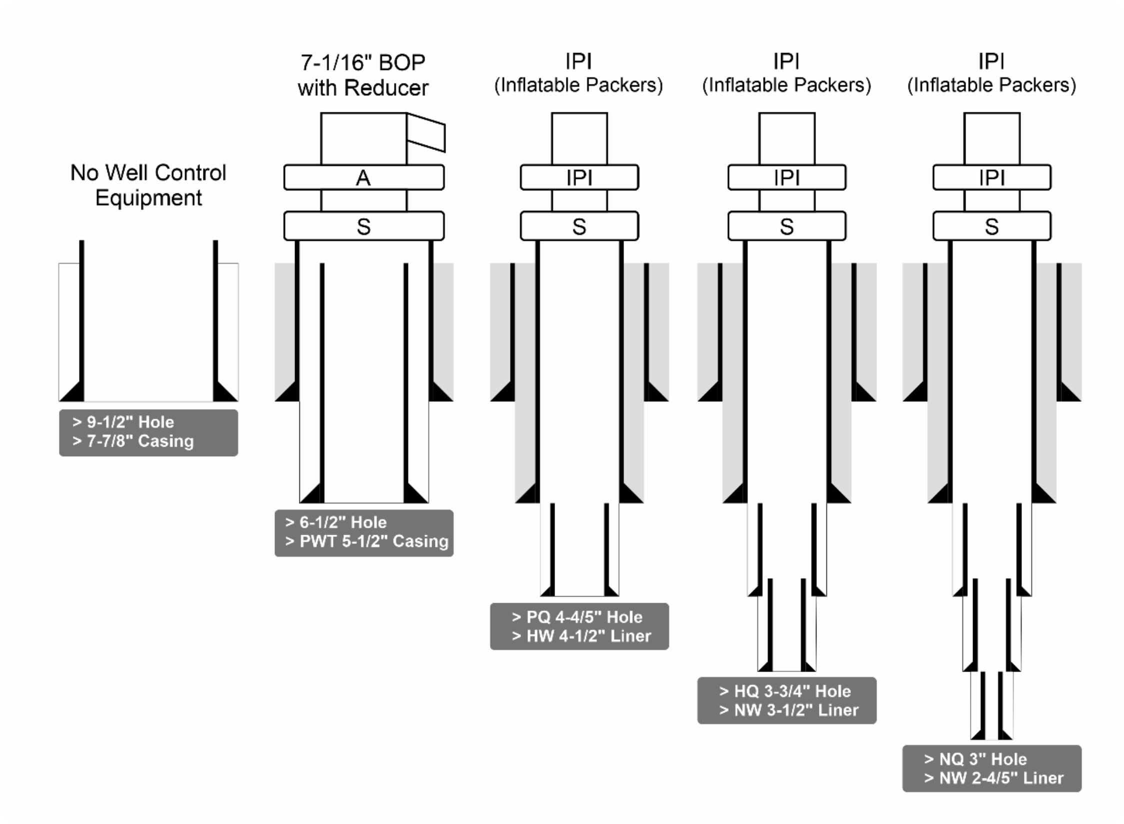

Figure 8: Well Control Equipment for Each Mining Well Section.

4. CONCLUSION

A mining drilling operation in a mining area that intersects a geothermal prospect area has the same risk with respect to kick and a further blowout accident. Thus, well control practices should be applied during the drilling of the whole section of the well. For the application of the geothermal well control to mining drilling operations, the mining well schematic should be modified. There are two additional sections that have to be drilled with 9-1/2" and 6-1/2" IADC bit. Those additional sections will support the installation of a 7-1/16" diverter, thus ensuring the safety of the mining drilling operation. Then the mining drilling can be continued for the rest of the section by installing IPI (inflatable packer).

REFERENCES

Bayutika, I.G.: Geothermal Well Control & Momentum Kill Equation for Surface Bullheading. (2019).

Boart Longyear. (2020). GLOBAL PRODUCT CATALOGUE: CORING RODS AND CASING. Boart Longyear. Retrieved from http://app.boartlongyear.com/brochures/CoringRodsCasingCatalog_2020_797.pdf

Delong, Z.: *Study on Well Control Technology of High Temperature Geothermal Drilling*. Geological Engineering Drilling Technology Conference (IGEDTC). Chengdu, China. (2014).

Finger, J and Blankenship, D.: *Handbook of Best Practices for Geothermal Drilling.* Sandia National Laboratories. (2010).

Purba, D., Adityatama, D., Umam, M., & Muhammad, F. (2019). Key Considerations in Developing Strategy for Geothermal Exploration Drilling Project in Indonesia. *PROCEEDINGS, 44th Workshop on Geothermal Reservoir Engineering.* Stanford: Stanford University.