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HYDRAULIC ANALYSIS OF BRINE REINJECTION PUMP SYSTEMS AT DIENG GEOTHERMAL FIELD, CENTRAL JAVA

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ABSTRACT

The migration from hot brine injection system to cold brine injection system in managing liquid disposal at Dieng geothermal field was adopted to minimize the operational problems due to the presence of solid deposition. However, this attempt seemed not to be effective due to the intensive scale rate deposition.

This study aims to simulate the performance of reinjection pumps due to the scale deposition as one of the major problems in the plant operation. The Pipesim software was utilized to simulate the performance of the reinjection pumps and hydraulic analyses. The required input data for the calculation were pipe routing, bends, valves, pipe elevation, etc. The effects of impeller diameter and pipeline diameter changes due to scale deposition were evaluated. The result of the calculation was in the form of head of the pumping system. The calculated head then was compared with the design head to evaluate the performance of the reinjection pumps.

The simulation results showed that the changes in diameter of impeller and pipeline gave significant effects on the performance of reinjection pumps.

Keywords: Dieng geothermal field, scaling, reinjection pump, Pipesim

INTRODUCTION

The Dieng geothermal field is located in Central Java where most of the wells are drilled in Banjarnegara district while the power plant is built in Wonosobo district. Its elevation is around 2000 m and situated within the cool volcanic highlands of the Dieng Plateau. The field is characterized by intense farming activity and most of the people live within and surroundings the field (Hino et al., 2013).

The installed capacity of the plant is 60 MW and it started operation in 1998. However, at present the plant is operating at 22 MW because of a lack of steam supply.

The initial design of brine injection system at Dieng geothermal field was hot brine injection system where all of them were directed to southern direction (known as southern injection system). However, there was problem in the operation where solid deposition was found in the injection pipelines that have length of around 7 km. The spare pipeline solution for this line was thought not to be feasible. On the other side, it was quite often found the problems in the injection pumps, such as the broken shaft and other damages on parts of pump injection system. Therefore, since 2006 PT Geo Dipa Energi has changed the operation system from hot brine injection system to cold brine injection system for both southern and northern injection wells. By utilizing cooling pond at each PAD, the solids can be deposited there and then the colder brine is transported to reinjection wells in the northern area. The migration of this injection system was done by utilizing the existing equipment in the field, such as injection pumps, line pipes, etc. Even the new system is adopted the scale deposition is still found, and such above problems are still encountered up to present as well. The present northern cold brine injection system is systematically shown in Fig. 1.

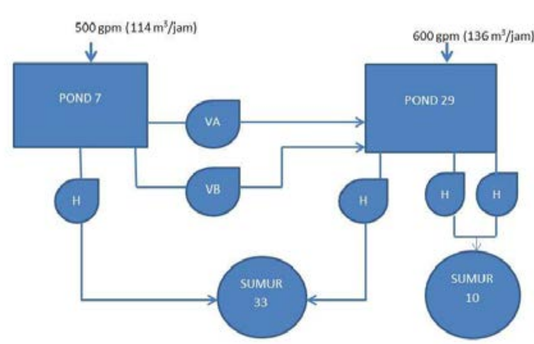

Figure 1: Configuration of northern cold brine injection system.

OBJECTIVES

The management of PT Geo Dipa Energi plans to develop an operation and maintenance management system on the basis of reliability based maintenance on northern brine injection system. The development of this management system is expected to give justification on the attempts of modification, upgrading, and investment to improve the system.

To achieve the above goals, some activities needed to be carried out such as pump performance test, engine performance test, pipe routing, and solid deposition rate test. Prior to pump performance test, it is necessary to conduct hydraulic analysis of brine injection pump system to get idea on the preliminary results of system performance. From this analysis, they will have reasons for making further decision.

METHODOLOGY

The main problem in the brine injection system at Dieng geothermal field is the occurrence of scale deposition in the injection pipelines, shaft, and other parts of injection pumps. Scaling on the injection pipeline causes the reduction of the inner diameter that will further result in the flow restriction then finally increase the pressure drop due to friction. Furthermore, the pressure drop in the suction pipe of the injection pump system can produce cavitation. This can affect the injection pump performance, and further serious effects are the broken parts of the pump such as impeller, casing, seal, shaft, etc. In addition, the decrease in the pump performance and the damages on parts of the pump can be caused by scaling inside the pump.

Pipe Routing

The first step of the activities was pipe routing. The objective of this activity was to route the brine pipelines for collecting coordinate points and important elevation points on the brine pipelines. From the collected data, the alignment sheet of pipelines can be re-drawn.

Figure 2: Routing process for pipelines.

Some equipment and tools required to conduct the activity were measurement tape, handheld GPS, arch, data sheet, camera, and Autodesk and Autocad. Figure 2 shows the existing brine injection pipelines that need to be re-routed. The final result of this work was new Alignment Sheet of the brine pipelines for each pumping system.

Pump Performance

Pumps that are used for reinjection must have good performance in terms of head and capacity. Pump head must overcome the system head, while pump capacity is expected to be able to maintain the flow balance between brine to the pond and one that is injected to underground. The flow balance can be identified from brine level in the pond, and it should be maintained in the safe level.

Due to the intensive scaling in the injection pipelines, the inner diameter of the pipe decreased. As the result, the system head increased significantly due to high friction in the pipe. Another effect was the flow capacity might be reduced. In this situation, the pump was expected to be able to overcome the changes both in head and capacity into certain level. On the other side, the scaling might also occur in the pump. This could cause the reduction in the space between two blades that would in turn lead to head loss where finally could decrease the pump performance. Figure 3 shows one of the pump installations which is needed to be tested.

Figure 3: Pump installation at PAD 29.

RESULTS AND DISCUSSION

The pump hydraulic analyses were conducted for reinjection pumps at PAD 7 and PAD 29. At PAD 7, there were two vertical pumps (VA and VB) and one horizontal pump (Deep Blue), while at PAD 29 three horizontal pumps (SC, DB-1, and DB-2) were analyzed. The three pumps at PAD 7 were used to transfer brine from PAD 7 located at 1921 masl with depth of pond of 6 m. Deep Blue horizontal pump transferred brine directly to reinjection well 33, while pumps VA and VB pumped brine to channel 29 then directed to pond 29 and mixed with brine from PAD 29. The mixed brine is pumped using three horizontal pumps (SC, DB-1, and DB-2) to reinjection wells 33 and 10 as illustrated in Fig. 1.

Pump Performance Analysis

In order to conduct hydraulic analysis, the pump performance data were taken from pump design data, especially the correlation between head and pump capacity. Figure 4 shows design data for horizontal pipe, while Fig. 5 represents design data for vertical pump. For practical consideration, those figures were re-drawn and modified into ones which are shown in Fig. 6 for horizontal pump and Fig. 7 for vertical pump.

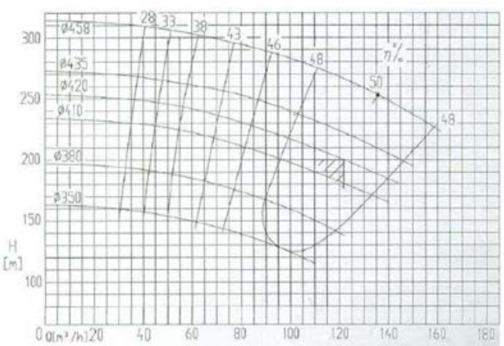

Figure 4: Performance design data for horizontal pump.

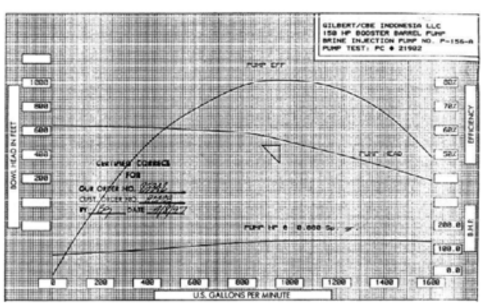

Figure 5: Performance design data for vertical pump.

The hypothesis used in this study is that the pump performance will decrease during the operation due to scaling process in the pump. This process is difficult to predict as well as generated hydraulic losses. However, physically the effects of the scaling can cause damages on the elements in the pump.

One of the important elements in determining pump performance is impeller. Scale deposition which has changed into harder formation can erode the impeller and finally reduce its diameter. If this happens, the pump performance is sensitive to decrease into certain level. The sensitivity of pump performance decrease can be analyzed using the following similarity equations (White, 1986):

Pump capacity:

$$Q_o = Q_p \left(\frac{D_o}{D_p}\right)^3 \left(\frac{N_o}{N_p}\right) \tag{1}$$

Pump head:

$$H_o = H_p \left(\frac{D_o}{D_p}\right)^2 \left(\frac{N_o}{N_p}\right)^2 \tag{2}$$

where,

Q_o = operation capacity
Q_p = design capacity
H_o = operation head
H_p = design head
D_o = operation diameter
D_p = design diameter
N_o = operation rpm
N_p = design rpm

When operation rpm is the same as design rpm, the sensitivity of pump performance decrease for various impeller diameter decrease is illustrated in Figs. 8 and 9.

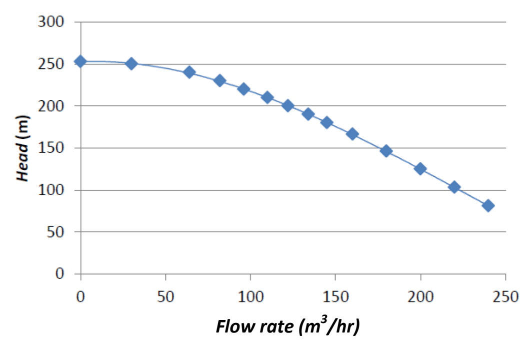

Figure 6: Modified performance design data for horizontal pump.

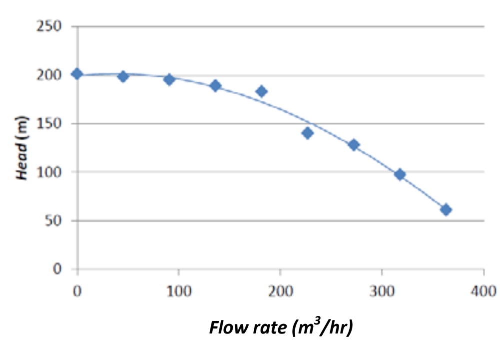

Figure 7: Modified performance design data for vertical pump.

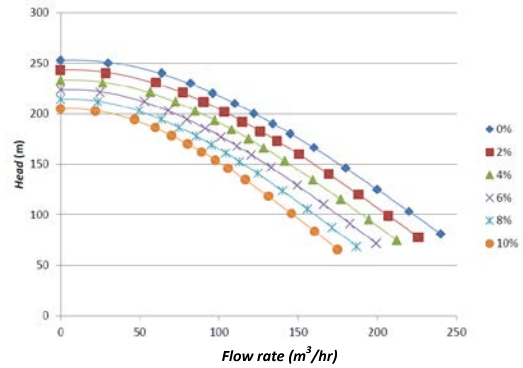

Figure 8: Performance decrease sensitivity due to impeller diameter decrease for horizontal pump.

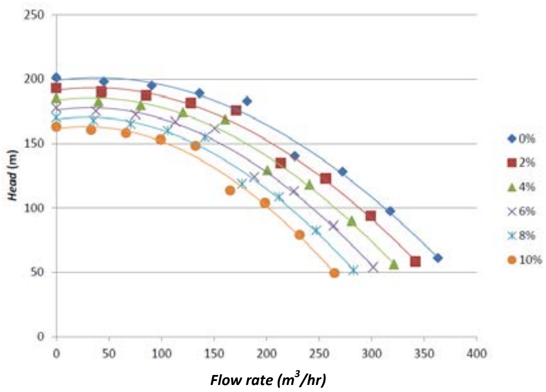

Figure 9: Performance decrease sensitivity due to impeller diameter decrease for vertical pump.

From Figs. 8 and 9, it can be seen that the decrease in the impeller diameter will affect the pump performance. When we maintain the pump operating at the same head, the flow rate will decrease following the equation (1). The decrease rate of impeller diameter about 2% from initial value to 10% decrease results in the similar trend (linear) for both head and flow rate changes. However, for the same flow rate the decrease rate of pump head for higher flow rate is larger than that of lower flow rate.

Hydraulic Analysis

Scaling in the reinjection pipelines caused the decrease in pipe diameter. This can further lead to more restriction for the flow and increase in pressure drop due to major and minor losses in the pipe. The last effect of scaling is the increase in head of pumping system. In this regard, the reinjection pumps are expected to be able to overcome the new head system.

Head system value is determined based on pumping installation which consists of static and dynamic heads. Static head has a constant value, while dynamic head value depends on flow capacity of pumping system. In terms of scale deposition, the increase in head system is mainly contributed by the increase in dynamic head.

The aim of this hydraulic analysis was to evaluate the head system of brine injection system. This analysis was conducted for both with and without scale deposition in pipelines of brine injection system. The calculated head system then was compared with the pump performance used in the system. From this comparison, it can be analyzed whether the pumps can overcome the head system or not.

Hydraulic analysis was conducted by simulating brine pipelines using Pipesim software. Pipe route, bends, valves, elevation, etc. data were obtained from pipe routing work for brine injection pipeline system. The result of the hydraulic analysis was in the form of head of pumping system that would be further compared with pumps performance as mentioned above.

The simulation was carried out by varying the inner pipe diameter to represent the thickness of scale deposition in the pipe which was assumed to form radially. The thicker the scale deposition, the smaller was the inner pipe diameter. The simulation was also conducted for various capacity ranges. Various pipelines routes were simulated, so that which pipeline route produced minimum head system can be selected. Furthermore, it was also simulated the leakage of the pipe, because it was found the leakages in the field. In this paper, only one pump (Deep Blue) which represents horizontal pump is discussed.

Figure 10 shows system head from PAD 7 to the reinjection well 33 with maximum capacity limit in this simulation at 122 m^3/hr. This limit is taken and based on the optimum pump capacity at design condition. The pump head curve is obtained from the design data.

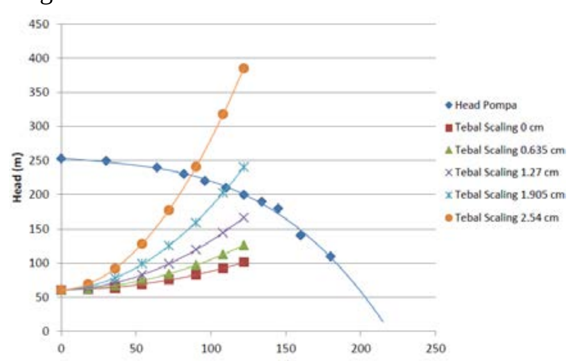

Figure 10: Effect of scale thickness on system head for Deep Blue pipelines system PAD 7 to reinjection well 33 at flow rate of 122 m^3/hr.

From Fig. 10, it can be seen that at the capacity of 122 m^3/hr the pump can overcome the system head with the scale thicknesses of 0 cm, 0.635 cm, and 1.27 cm but are not capable to handle the system head with the scale thicknesses of 1.905 cm and 2.54 cm. In order to able to handle the system head for the cases when the scale thickness of 1.905 cm and 2.54 cm, the pump capacity must be reduced to certain values.

Figure 11 represents the pump power which must be supplied to the fluid at the flow rate of 122 m^3/hr. It can be seen that the thicker the scale deposition formed in the pipe, the supplied power also becomes higher. This becomes the consequence for condition where the system head on the flow rate will increase due to the increase in the scale thickness.

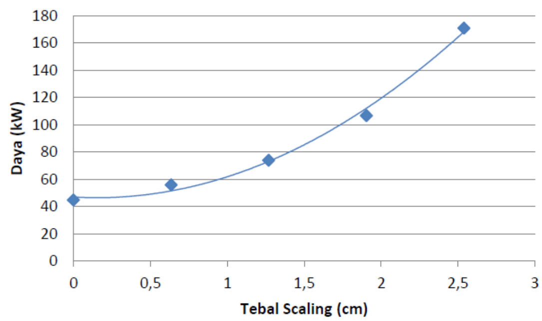

Figure 11: Pump power vs scale thickness for Deep Blue pipelines system PAD 7 to reinjection well 33 at flow rate of 122 m^3/hr.

In order to evaluate and to get the idea of the scaling rate, the field data was used to approximate the scaling rate value. In this study, the time period represented the duration of the scale formed in the pipe. This approximation was based on the field data that for 6" pipe the scale deposition was formed at the thickness of 1.5" in 3.5 months. The thickness conversion to the time period is presented in Table 1 while the system head for different time period is illustrated in Fig. 12.

Table 1: Scale thickness conversion (0-2.54 cm) to time period.

Scale thickness (cm)	Time period scale formation (day)
0	0
0.635	17.5
1.27	35
1.905	52.5
2.54	70

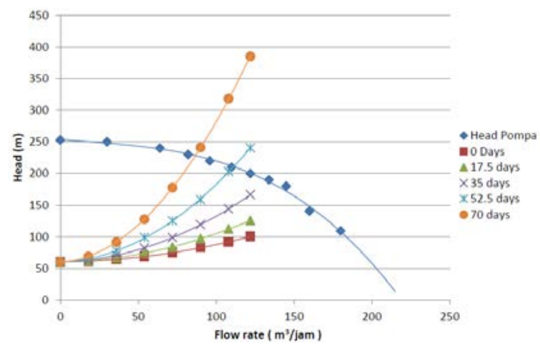

Figure 12: System head at different time period for Deep Blue pipelines system PAD 7 to reinjection well 33 at flow rate of 122 m^3/hr.

The curves in Fig. 12 is important to give information when the necessary action to be taken in terms of plant operation, such as the adjustment of fluid flow rate or scale cleaning job.

Sometimes, it is required to transfer brine at higher flow rate and system head for thicker scale condition as illustrated in Fig. 10. In such condition, the additional pump which is installed in series arrangement (booster pump) can be applied. This installation can make the total pump head can handle the system head for the longer time period in terms of scale formation up to 10%. This addition of the pump which is installed in series is simulated for maximum capacity limit according to the operation needs of northern brine injection system at the value of 200 m^3/hr where Deep Blue pump supplies 114 m^3/hr. The pump performance for series arrangement is presented in Fig. 13.

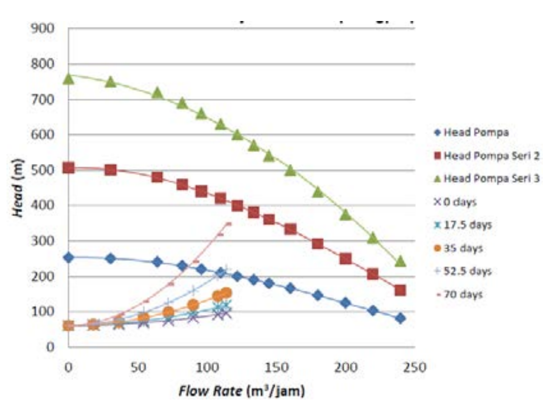

Figure 13: Pump performance in seriesfor Deep Blue pipelines system PAD 7 to reinjection well 33 at flow rate of 114 m^3/hr.

Leakage Simulation

It was found during field survey that there was a pipe leakage which caused air from outside entered into brine flow in the pipe. This leakage was predicted to locate at the route close to the reinjection well which has minus gauge pressure so that air from atmosphere could enter into brine flow in the pipe. The presence of incoming air would affect the brine flow, mainly the dynamic head of the system because at beginning the brine was in single-phase liquid then changed into two-phase gas-liquid flow. Therefore, it is important to simulate the effects of leakage on the brine injection system.

The simulation was carried out by adding a short branch (1 cm) at one pipe segment of the pipelines for Deep Blue pump at PAD 7 to reinjection pump 33 at which the leakage was predicted to occur. Then, the pipe diameter of the short branch as the leakage indicator was varied into 2.5 mm, 5 mm, 7.5 mm, and 10 mm. The pressure of the entering air was adjusted with the pressure at the pipe segment which was affected by static and dynamic system head. Figure 14 shows dynamic head for each diameter leakage.

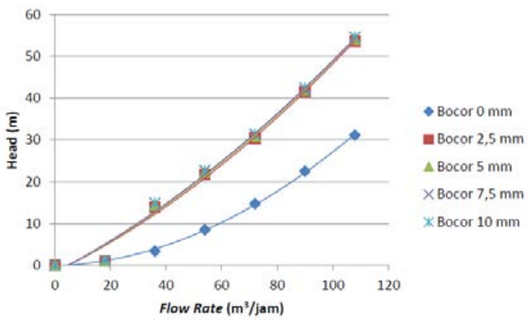

Figure 14: Effect of leakage diameter on dynamic head.

It can be seen that the presence of air (gas phase) in the brine flow causes the increase in dynamic head. This is because the air will accelerate flow rate in pipe in the form of brine and air mixture. This condition will cause Reynolds number to increase and will further enhance the dynamic head as well. It can be obtained that the dynamic head for each diameter leakage gives small different values. This may be caused by the fact that the location of leakage is not too far from the end of pipe or the injection well. In other words, the length of pipeline where the air is flowing is short. This condition may give different results when the location of leakage is changed.

CONCLUSION

From the above discussion and analyses, it can be summarized some important findings as follows:

1. The adopted cold brine injection system at Dieng geothermal field seemed not to be effective due to very intensive scale deposition.
2. It is recommended to have further study various methods to minimize scale deposition into lower level.
3. The intensive scale deposition can cause serious problems such as damages on parts of injection pump system.
4. In terms of fluid mechanics point of view, the intensive scaling can decrease capacity of injected brine as well as to increase head capacity and will further increase the power consumption of the pump.

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