Journal of Energy Technologies and Policy

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Journal of Energy Technologies and Policy

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Gas Accumulator System Design to Prevent Water Hammer Effect on Slop Pump Pipeline Network at Papa Flowstation, PT. Pertamina Hulu Energi ONWJ

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Abstract
Water hammer is pressure fluctuation caused by sudden increase and decrease in flow velocity. At Papa Flow Station, water hammer occurs in the slop-pump pipeline network that use level controller operating system. The pressure fluctuation caused by water hammer can damage pipeline or shorten the life of the components. This research was conducted using AFT Impulse software to simulate the modeling. The results showed the gas accumulator could reduce the pressure oscillations on check valve to 1.5 oscillations. The gas accumulator installation alone did not have a significant effect on reducing the fluctuation from the highest pressure of 70 psi. Adding a check valve on the tie-in header-downstream of the pump combined with the installation of a gas accumulator can reduce pressure fluctuations from a maximum of 70 psi to 15 psi and the pressure oscillation will stabilize after the second second when the pump trips at 11 psi.
Keywords: cavitation, water hammer, pressure oscillation, pressure fluctuation, gas accumulator
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Publication date: September 30th 2020

1. Introduction

PT. Pertamina Hulu Energi ONWJ is an upstream oil and gas company operating in the Java sea area from Cirebon to the Thousand Islands. In supporting exploration, production and delivery, the pipeline network system has a very important role. One of the systems in the oil and gas industry is a slop pump installation network that functions to recycle oil that separated from the water treatment process (depurator and sump caison). The failure in this installation causes the inability to recycle the oil which carried away with the waste water back into the system and will be thrown into the sea and pollute the environment.

The pipeline network experiences several phenomena such as cavitation which causes water hammer. This study focuses on discussing the water hammer phenomenon due to cavitation. Water hammer is a pressure fluctuation caused by a sudden increase and decrease in flow velocity in the pipeline. Water hammer often occurs in the pump discharge area during operation and during pump failure. Pump failure may be caused by a power outage or the pump's operating system itself (Level Control System). Such pressure fluctuations can damage pipeline or shorten the life of the components that receive the impact. This has been proven to have occurred in the pipeline installation at the Papa Flowstation slop pump, based on data from the Maintenance team in the April 2019-December 2019 period, replacing 6 check valves due to this water hammer.

One way to reduce water hammer is by adding a gas accumulator to the pipeline network system. The gas accumulator is generally installed on the discharge pump to reduce sudden pressure fluctuations as a result of pump operation and pump failure. The ability of the gas accumulator to absorb pressure fluctuations depends on the volume of the gas accumulator itself. The excess pressure during the water hammer phenomenon will be discharged into the gas accumulator. On the other hand, when the pressure in the pipe is very low, the gas accumulator will supply pressure so that the pressure in the pipe tends to be stable. Therefore, it is necessary to do research on choosing the right volume of gas accumulator to reduce pressure fluctuations that occur in the pipeline network.

Research in gas accumulator volume selection can be done by using experiments or by using special software to simulate pressure fluctuations in the pipeline network. One of the software commonly used is AFT Impulse. In this software the transition flow phenomenon can be simulated and the effect of installing a gas accumulator with varying volumes can also be simulated. Both of these will be displayed in a graph so that we can analyze the graph.

2. Literature Review

2.1 The Water Hammer Phenomenon

Water Hammer is a pressure fluctuation caused by a sudden change in fluid flow velocity. This pressure fluctuation is the result of the fluid's kinetic energy conversion into pressure energy, which produces a compression wave or result of pressure energy conversion into kinetic energy, which produces rarefaction waves.

Water hammer occurs in the downstream area of the pump or after the valve. When the valve closes rapidly or the pump trips, the downstream pressure may fall below the boiling point pressure of the liquid, creating a vapor cavity. This causes a vacuum in the area of the vapor cavity, causing the liquid to flow backwards and because of the compressible nature of the vapor cavity, the pressure will increase. When colliding with the valve, the impact due to the water hammer occurs with high pressure fluctuation.

Closing the valve suddenly at the end of the pipe that comes from deposit storage causes the fluid flow near the valve to experience a shock and compressed due to changes in kinetic energy to pressure energy. The pressure energy that occurs is absorbed by the liquid fluid and is also absorbed by the pipe wall, resulting in a compression process both longitudinally and tangentially. This process travels as a pressure wave and travels at the speed of the sound wave through the water medium in the pipeline. An imbalance in the pipe end upsteam occurs when a pressure wave arrives. The fluid that is loaded into the expanding pipe begins to flow at the same rate before closing the valve, the pipe wall returns to its original dimension and the fluid acquires a V_0 velocity in the opposite direction. This process is generated at the speed of sound for "a" second passing through the pipe. The process at 2L/a second indicates that the wave has reached the valve and the pressure along the pipe has returned to its normal value. Meanwhile, the liquid velocity along the pipe is equal to V_0 and towards the reservoir.

The condition when the valve is fully closed resulting in no fluid that maintains the wave passes through it and a negative pressure (-H) occurs, so the fluid is slowed back to rest. This low pressure wave flows towards upstream with "a" velocity causing the fluid to slow down to equilibrium. This phenomenon is simultaneously expressed until the pressure is low so that it triggers expansion in the pipe wall. The process at 3L/a second produces a negative wave pressure to the upstream pipe end, the fluid in the pipe is stationary but uniform at smaller loads, one of which is not closed. The imbalance in the reservoir causes the fluid to start moving from the deposit to the pipe and acquire velocity V_0 with the direction to the valve. The condition of the whole system returns to the same as when we closed the valve. The process description is repeated periodically with periods of 4L/a second.

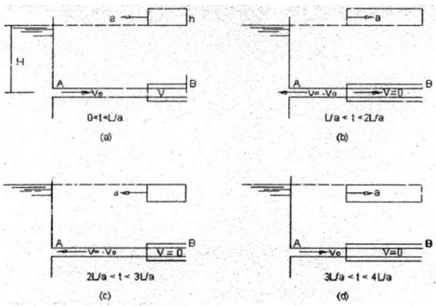

Figure 1. Water hammer scheme phenomenon after closing the valve at a) $0 < t < L/a$; b) $L/a < t < 2L/a$; c) $2L/a < t < 3L/a$; d) $3L/a < t < 4L/a$ *(wylie and streeter, Introduction to Fluid Mechanics I, 1988)*

Moreover, water hammer can occur in the downstream valve area. When the valve is closed suddenly, there will be a separation between one liquid to another which forms an air cavity. This vacuum from the air cavity causes the separated liquid to be drawn back and an impact occurs. This case, it is called as *water hammer with cavitation.*

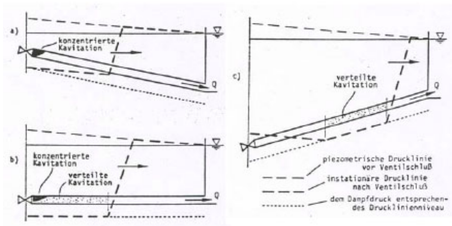

Figure 2. cavitation phenomenon on the fast closing valve *(Zielke and Perko, Water Hammer with Colums Separation, 1985)*

3. Methodology

This research was conducted using AFT Impulse software to simulate the modeling that has been made. In carrying out the analysis, the steps that must be carried out include:

Perform pipe modeling and junction. The pipes and accessories in the slop pump network are modeled in a simple depiction. Do this by going to the windows workpage using the toolsbar on the left to do modeling both for pipes and joints. Make sure all are connected.

Enter pipe, junction and pump data. The actual data input from the pipe, juction and pump is carried out in accordance with the real conditions in the field.

Enter the characteristics of the working fluid. In conducting research, the characteristics of the working fluid are very important to support the accuracy of the calculation / iteration of a water hammer calculation.

Do iteration. Modeling iteration is carried out by clicking the "run program" toolbar.
Presentation through charts. the water hammer pressure fluctuation graph can be obtained by clicking the "graph result" menu bar then clicking "select graph data". Fill in the parameters that will be used as a reference point for water hammer data collection. Then, after clicking the show button, a graphic presentation will appear. From this graphic presentation we can analyze the effect of the water hammer, both pressure fluctuation and pressure oscillation.

4. DATA ANALYSIS AND DISCUSSION

After iterating in a modeling on the AFT Impulse, a graph is drawn with the reference point on the inlet P16. With a sample time of 10 seconds. Then from this data we can analyze the effects that occur. So that it can determine the appropriate gas accumulator volume.

4.1 Without Gas Accumulator

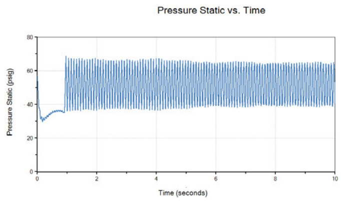

Figure 3. Graph of pressure versus time in an installation without a gas accumulator

Figure 3 shows when the pump suddenly trips, the highest pressure fluctuation value reaches 70 psi and the lowest is 38 psi with lots of oscillation, this pressure oscillation indicates cavitation due to the backflow. Cavitation eroding the internal pipe or check valve that are nearby. If this happens frequently, cavitation erosion will decrease the function of the check valve (passing). In addition, high back pressure fluctuation cause a water hammer when the pump trips, this also decrease the function of the check valve because it resists the impact. Moreover, the vibrations generated can cause the pipe to deform and crack/fracture over time.

4.2 With Gas Accumulator

Gas Accumulator = 10 Liters

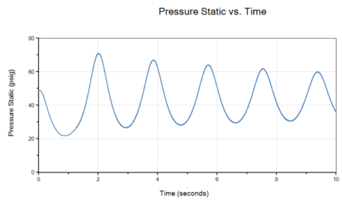

Figure 4. Graph of pressure versus time on installation with a 10 liters of gas accumulator

Figure 4 shows 10 liters of gas accumulator installation decrease the number of pressure oscillations to 5 oscillations in 10 seconds. This affect the cavitation erosion on the check valve or the pipe that drastically reduced. The highest pressure fluctuation value is still at a value of 70 psi and the lowest is at 22 psi which causes the water hammer cannot be reduce yet.

Gas Accumulator = 20 Liters

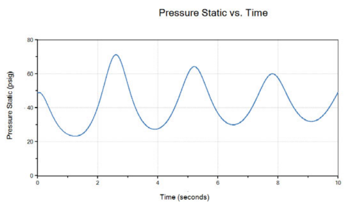

Figure 5. Graph of pressure versus time on installation with a 20 liters of gas accumulator

Figure 5 shows that 20 liters of gas accumulator installation decrease the number of pressure oscillations to 3.5 oscillations in 10 seconds. This will have an effect on the cavitation erosion on the check valve or the pipe that drastically reduced. However, the highest pressure fluctuation is still at a value of 70 psi and the lowest is at 22 psi which causes the water hammer cannot be reduce yet.

Gas Accumulator = 30 Liters

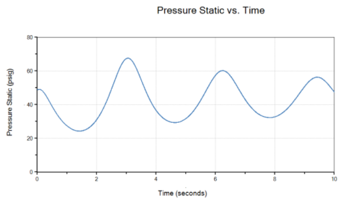

Figure 6. Graph of pressure versus time on installation with 30 liters of gas accumulator

Figure 6 shows that 30 liters of gas accumulator installation decrease the number of pressure oscillations to 3 oscillations in 10 seconds. This affect the cavitation erosion on the check valve or pipe that drastically reduced. The highest pressure fluctuation value fell to 68 psi and the lowest to 24 psi which caused water hammer to decrease but still high.

Gas Accumulator = 40 Liter

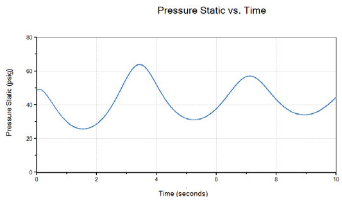

Figure 7. Graph of pressure versus time on installation with a 40 liters of gas accumulator

Figure 7 shows 40 liters of gas accumulator installation decrease the number of pressure oscillations to 2.5 oscillations in 10 seconds. This affect the cavitation erosion on the check valve or pipe that drastically reduced. The highest pressure value fluctuation value fell to 65 psi and the lowest rose to 25 psi which caused the water hammer to decrease but still high.

Gas Accumulator = 50 liters

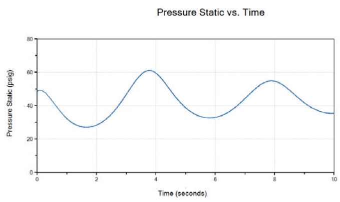

Figure 8. Graph of pressure versus time on installation with a 50 liters of gas accumulator

Figure 8 shows that 50 liters of gas accumulator installation decrease the number of pressure oscillations to 2.25 oscillations in 10 seconds. This affect the cavitation erosion on the check valve or pipe that drastically reduced (almost non-existent). The highest pressure fluctuation fell to 60 psi and the lowest rose to 35 psi which caused water hammer to decrease but still high.

Gas Accumulator = 60 Liters

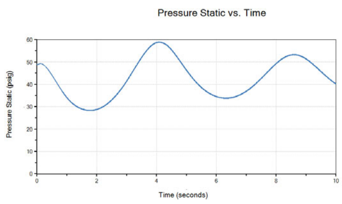

Figure 9. Graph of pressure versus time on installation with 60 liters of gas accumulator

Figure 9 shows that 60 liters of gas accumulator installation decrease the number of pressure oscillations to 2 oscillations in 10 seconds. This affect the cavitation erosion on the check valve or the pipe that almost gone. The highest pressure fluctuation fell to 58 psi and the lowest decrease to 28 psi, which caused the water hammer was reduced but was still high.

Gas Accumulator = 70 Liters

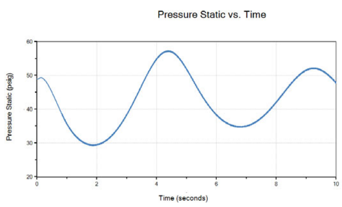

Figure 10. Graph of pressure versus time on installation with a 70 liters of gas accumulator

Figure 10 shows that 70 liters of gas accumulator installation decrease the number of pressure oscillations to 2 oscillations in 10 seconds. This affect the cavitation erosion on the check valve or the pipe that almost gone. The highest pressure fluctuation fell to 57 psi and the lowest increased to 30 psi, which caused the water hammer to decrease but still high.

Gas Accumulator gas = 80 Liters

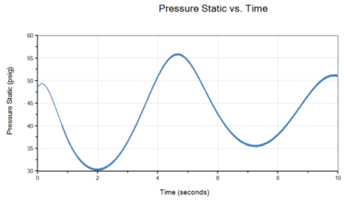

Figure 11. Graph of pressure versus time on installation with an 80 liters of gas accumulator

Figure 11 shows that 80 liters of gas accumulator installation decrease the number of pressure oscillations to 1.75 oscillations in 10 seconds. This affect the cavitation erosion on the check valve or the pipe that almost gone. The highest pressure fluctuation decreased to 56 psi and the lowest increased to 31 psi, which caused the water hammer to decrease but still high.

Gas Accumulator = 90 Liters

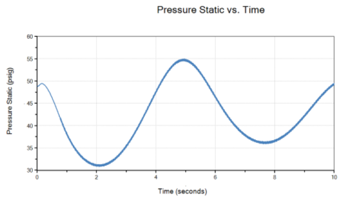

Figure 12. Graph of pressure versus time on installation with a 90 liters of gas accumulator

Figure 12 shows that 90 liters of gas accumulator decrease the number of pressure oscillations to 1.5 oscillations in 10 seconds. This affect the cavitation erosion on the check valve or the pipe that almost gone. The highest pressure fluctuation dropped to 55 psi and the lowest increased to 32 psi, which caused the water hammer to decrease but still high.

Gas Accumulator = 100 Liters

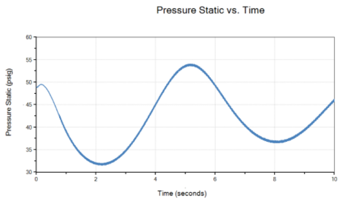

Figure 13. Graph of pressure versus time on installation with a 100 liters of gas accumulator

Figure 13 shows that 100 liters of gas accumulator installation decrease the number of pressure oscillations to 1.5 oscillations in 10 seconds. This affect the cavitation erosion on the check valve or the pipe that almost gone. The highest pressure fluctuation drops to 54 psi and the lowest remains at 32 psi, which causes the water hammer to be reduced but still high.

4.3 With a gas accumulator and a check valve added

Close drain system at Papa Flowstation injects trapped oil from the tank slop to the header with a pressure of 60-70 psi with a header pressure of 40-45 psi. However, there is no check valve in the pipe that enters the header so that there is a potential for back pressure accumulation when the pump trips. If a check valve is installed on the inlet header, the potential for pressure accumulation can be reduced. The following are the graphic result with the installation of a check valve and gas accumulator.

Gas Accumulator = 5 Liters with Check Valve

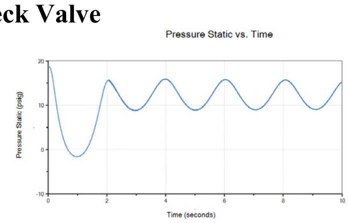

Figure 14. Graph of pressure against time on installation with 5 liter gas accumulator with check valve

Figure 14 shows that there is a drastic decrease in pressure oscillations. This has an impact on the cavitation effect on the check valve and the pump downstram pipe that will decrease. Pressure fluctuation also decrease drastically from 70 psi when without the check valve inlet header to 15 psi (highest) and 10 psi (lowest). This condition makes the impact effect due to the back flow of the fluid (water hammer) will be greatly reduced and vibration or other effects will be reduced for both the pump, check valve, and pipe.

Gas Accumulator = 10 Liters with Check Valve

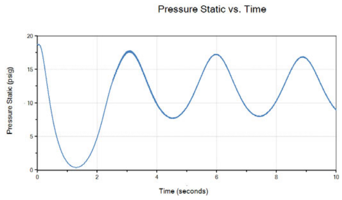

Figure 15. Graph of pressure against time on installation with 10 liter gas accumulator with check valve

Figure 15 shows that there is a drastic decrease in pressure oscillations. This has an impact on the effect of cavitation on the check valve and the pump downstram pipe that will decrease. Pressure fluctuation also decreased drastically from 70 psi when without the check valve inlet header to 18 psi (highest) and 8 psi (lowest). This condition is increased from the condition with 5 liters of gas accumulator so that the impact effect (water hammer) is higher than when using the 5 liters of gas accumulator.

Gas Accumulator = 4 Liters with Check Valve

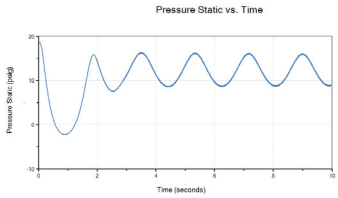

Figure 16. Graph of pressure against time on installation with 4 liters gas accumulator with check valve

Figure 16 shows that there is a drastic reduction in pressure oscillations similar to the system with 5 liters of gas accumulator. Pressure fluctuation also decreased drastically from 70 psi without the check valve inlet header to 15 psi (highest) and 8 psi (lowest).

Gas Accumulator = 3 Liters with Check Valve

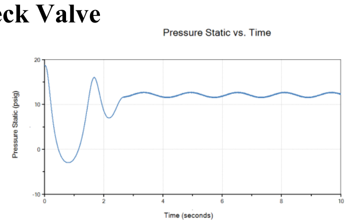

Figure 17. Graph of pressure against time on installation with 3 liter gas accumulator with check valve

Figure 17 shows that the pressure oscillation occurs only up to the 2nd second and for the rest of the time, the pressure is stable at 11 psi. It can be said that the impact effect (water hammer) almost disappeared because the condition was stable after this 2nd second.

Gas Accumulator = 2 Liters with Check Valve

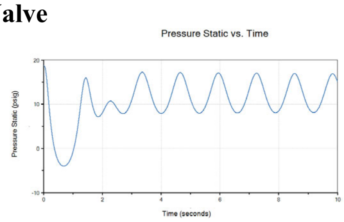

Figure 18. Graph of pressure against time on installation with 2 liter gas accumulator with check valve

Figure 18 shows that the oscillation occurs again when the volume of the gas accumulator is reduced from 3 liters to 2 liters. The highest fluctuation is at a pressure of 15 psi and the lowest is at 8 psi. This is not much different from the system using 5 liters of gas accumulator. with a further decrease in volume which is expected to get smoother results, it turns out that the graph has increased in terms of oscillations and fluctuations.

5. CONCLUSION

From the modeling and analysis, several conclusions can be drawn including:

1. The slop pump pipeline installation has a high maximum pressure fluctuation at 70 psi and the lowest at 38 psi and has a lot of pressure oscillations, which indicates cavitation in the check valve area (J16) where cavity erosion causes the check valve component to erode and finally broken (passing flow).
2. Installing a gas accumulator from a volume of 10 liters to 100 liters has a significant effect on reducing pressure oscillations only. Cavitation erosion is reduced but the decrease in pressure fluctuations is less significant, where the highest decrease in fluctuation is from 70 psi to 54 psi (with a 100 liters gas accumulator volume).
3. An increase in backflow (pressure fluctuation) occurs because the header where the tie-in downstream slop

pump has a pressure of 40-45 psi without a check valve, this results in a high-pressure return flow (water hammer) to the check valve downstream pump.

4. Installing a check valve on the side of tie-in header and downstream of the slop pump line combine with gas accumulator has prove to reduce pressure oscillations and pressure fluctuations. Where the highest pressure fluctuation in the instlation without gas accumulator and check valve is 70 psi, but while using both the fluctuation drops significantly to the highest 15 psi.
5. The installation of an additional check valve and gas accumulator with 3 liters volume has the best graph trend, where the pressure oscillation only occurs until the 2^{nd} second, in the 3^{rd} second and so on the pressure oscillation tends to be stable. This indicates that the effect of cavitation erosion is practically lost so that the potential for the check valve component to be eroded will be small and the check valve life will be longer. In addition, the pressure fluctuation is only 11 psi when conditions are stable, so that the water hammer effect is significantly reduced. Thus, this size of the gas accumulator and pipe engineering is recommended to solve the water hammer effect problem in the Papa Flostation slop pump installation of PT. PHE ONWJ

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Abstract

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Keywords: China insurance industry, Foreign fund, Challenge

1. Heading 1

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Notes

Note 1. This is an example.

Note 2. This is an example for note 2

Table 1. The capitals, assets and revenue in listed banks

	Total capital stock	Income of main business	Total assets
Pudong Development Bank	39.2	214.7	5730.7

Bank of China	459.4	3345.7	59876.9

Description for the above table.

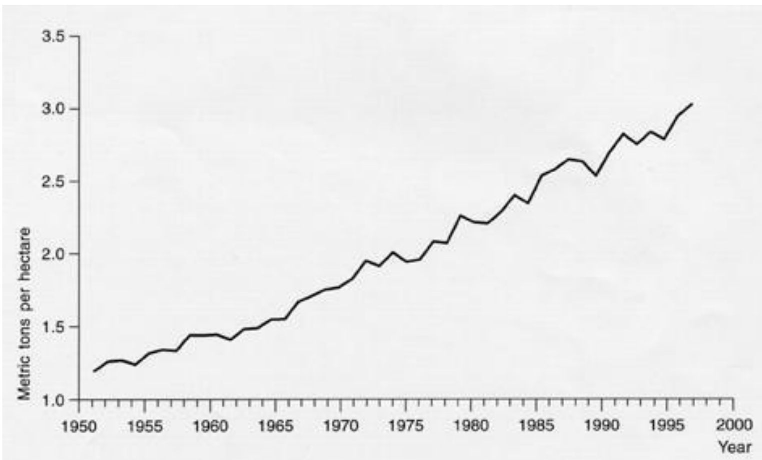

Figure 1. The Trend of Economic Development

Description for the above figure.