Modelling a Reinjection Network

Kevin Koorey[1]

[1]MB Century. 166 Karetoto Rd , Taupo, New Zealand

kkoorey@mbcentury.com

Keywords: *piping, reinjection, water hammer, pumping*

ABSTRACT

A case study is presented of a geothermal reinjection piping network model from the power station through to the reinjection wells. Commercial piping network modelling software has been used to model the static and dynamic response of the system and options for increasing capacity. The model includes a number of reinjection well analogues for modelling well behavior, including a well with the piping/casing modelled to the loss zone. The terrain includes elevation changes and the model needed to account for cavitation and column separation

1. GENERAL

Geothermal power plants require spent separated geothermal water and steam condensate to be reinjected, usually, into the resource with separation form the production wells.

A network of piping runs from the power plant to the reinjection wells. Piping friction losses, elevation changes and varying well injectivity characteristics means the pressures in the network and distribution of flow is difficult to model.

For the case presented in this paper, commercial network modeling software (AFT Impulse 8) was applied to a existing reinjection distribution network covering more than 6 km of piping, two wellhead pump stations and 6 reinjection wells. AFT applies the method of characteristics for solving the flow and pressure distribution.

2. MODELING COMPONENTS

The software includes standard inputs for pipes, fittings and valves. Each pipe segment was modelled between changes in elevation (nodes) and valves as required. The software has a graphical interface for ease of data input, Figure 1.

Detailed information and the operating characteristics are required for valves and pumps. This is important for the modelling of transients when pumps and valves stop/close.

3. MODELING REINJECTION WELLS

The modelled network is an operating plant. Where well flow and wellhead pressure have been measured, injectivity curves for wells that operate flooded (water level above the wellhead (WH)) can be plotted from the operating data. The data points for wellhead pressure (WHP) and flow was then entered into the model.

One of the wells has a maximum flow restraint. The field operators fix this flow with a valve on the wellhead under steady operating conditions. This valve was modelled with an opening for the required flow under steady state conditions. During modelling of transients, the flow past the valve will change with the pressure variations.

Two of the reinjection wells have field pumps operating upstream of the wellhead. The pump's pressure/flow curves and the well injectivity are modeled in series.

One well operates with the water level below the wellhead. The piping model was extended down the well to the loss zone where the pressure and injection flow has been measured with downhole logging. When the flows in the model were increased, the friction losses in the well casing were then included. When modelling high flow cases, the water level in this well reached the surface.

3. COLUMN SEPARATION

If the water pressure drops below saturation pressure, it will boil/flash and form vapor. For example, 85°C water flowing along a horizontal pipe starting from 1 bar.a will reach saturation pressure when the pressure drop in the pipe is 0.42 bar.

In the reinjection network, there are high points where flashing occurs and the flow transitions to channel flow down the pipe slope or down the reinjection well. To model this, it must first be determined where the flashing occurs. A first iteration of the model showed where the pressure drops below saturation pressure. The line is then manually broken at the high point where flashing occurs. Then this node is modelled with a reservoir and setting the vapor pressure over the fluid at saturation pressure. The model is run again with the reservoir. This modelling approach calculates the flow rates and pressure just before the flashing point.

4. GAS

The model does not consider the effects of non-condensable gas release (exsolving) when water pressure drops. Gas will change the water vapor partial pressure and may also cause gas locks. Gas in the flashed water vapor may soften the pressure spikes from vapor void collapse

5. STEADY STATE

The model is run to generate steady state flows. The model was validated using operational data provided by the station operator.

The steady state model and actual system flows were in good agreement, less than 5% variation on total flow but higher variations of pressures. The good agreement with flow rates could be expected since some wells had fixed flow and others operated with no WHP (water level below the master valve). The later well's flow was dependent on reinjection water temperature and vapor pressure rather than system pressure drops.

The higher than expected pressure drops in the model may be due to pipe scaling and could be corrected with higher a friction factor.

ISSN 2703-4275

6. SYSTEM DEMAND CURVE

The model was used to calculate the effect of increasing the pressure at the start of the network. For each step increase in station pressure a higher steady state flow was calculated. (Figure 1) These figures would be used to size station reinjection pumps for higher reinjection flows.

Higher flows through the station also increases pressure drop in the station. To achieve the higher reinjection flows, pumps are required with head to compensate for reinjection network pressure increase and higher pressure losses in the power plant piping.

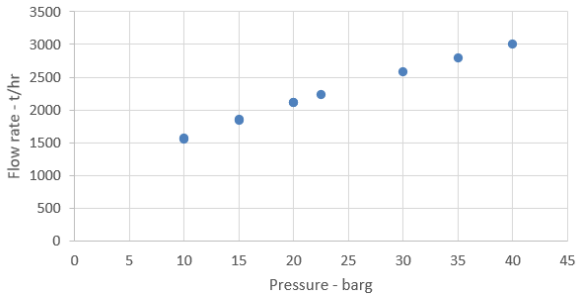

Figure 1 Reinjection System Demand curve. Station pressure required for higher reinjection flows.

7. NETWORK OPTIONS

The model was used to explore options to increase injection flows. Pumps at the station, as above, field pumps and decreasing the network friction losses with twining some piping branch lines were among the options investigated.

One well with high injectivity was flow limited by the size of the branch line to the well. The pressure drop in this line clauses flashing upstream of the well. Twining the line was modelled and showed much greater flow down this well.

8. TRANSIENTS

The software used for the model was developed to analyze transient pressure rises (water hammer) from disruptions in the flow. For example, pump trips and valve closures. These events send pressure waves through incompressible water. These pressure increases need to remain below the piping code allowances (B31.1 clause 102.2.4) and the class rating of the system components.

The network options modeled include increases in water flow and velocity. The higher the velocity the higher the momentum change, and transient pressure rises during upsets.

Amongst another results the model predicted for transients were pressure spikes from cavitation and void collapse at the far ends of the network where steady state pressures were low and could fall below saturation pressure. Figure 2.

9. CONCLUSION

As expected, the commercial network modeling software was able to model the above ground reinjection piping. Reinjection wells of various configurations were successfully modelled including down to reinjection well loss zones.

The requirements for higher total reinjection flows were established and options for pumping and increased pipe capacity explored.

This study showed the problems with modelling and operating a reinjection network with under sized lines, high velocities and pressure drops and water close to saturation pressure. Modelling iterations are required to account for flashing in the steady state and flow transients cause high pressures when vapor voids form and collapse.

REFERENCES

Koorey, K., Harwood, K., & Lawgun, N. (n.d.). Modelling of the Separated Geothermal Water Flow between Te Mihi flash plants. *Proceedings World Geothermal Congress 2015.* Melbourne.

Walters, T., Marroquin, A., & Smith, F. (2019). Understanding Waterhammer in Pumping Systems and Surge Suppression Options. *48th Turbomachinery & 35th International Pump Users Symposia.* Houston. Retrieved from www.aft.com.

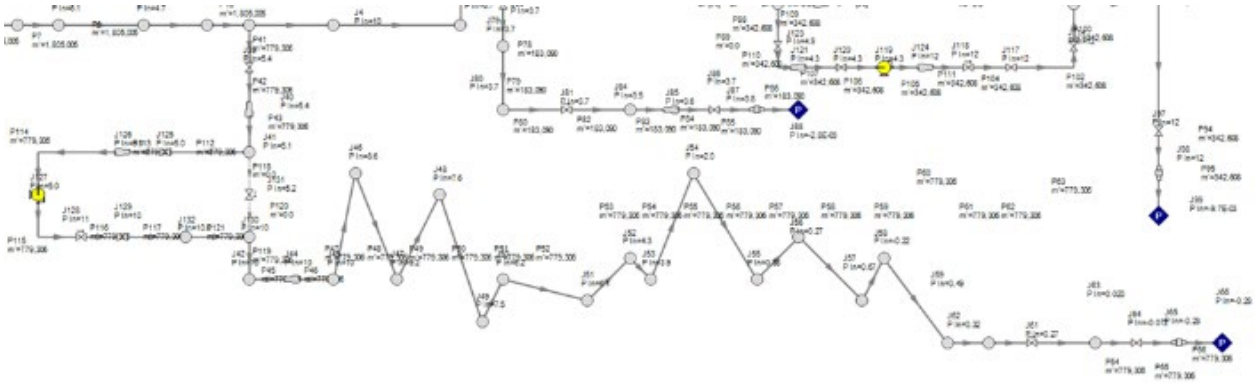

Figure 2 Screen shot of part of the network model with piping nodes and components. Nodes are manually located with relative elevations for clarity. The graphical interface allows easy input and editing of the nodes.

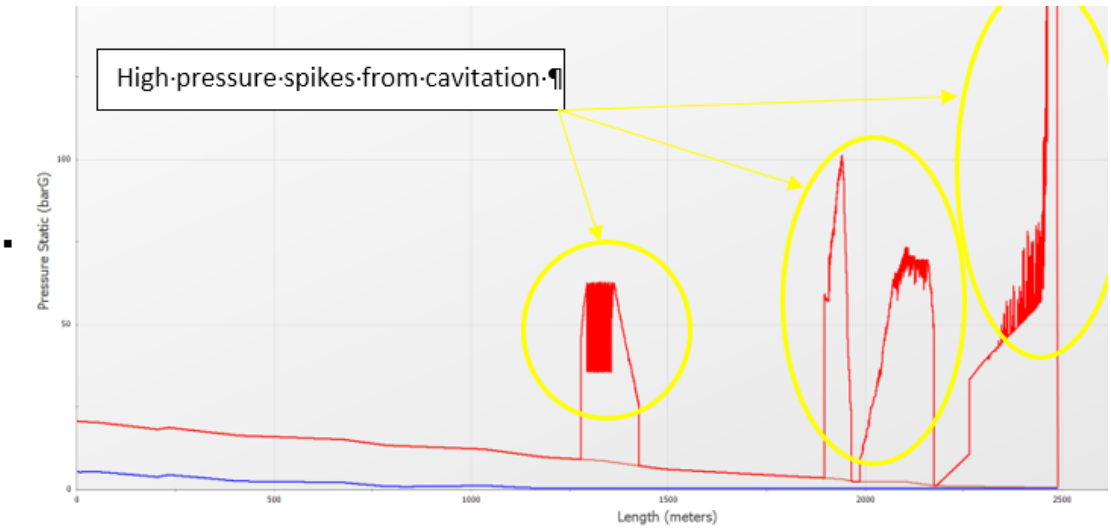

Figure 3 Cavitation occurs at the high point on a branch line and generates high pressures from the steam space collapse