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Modelling of the Separated Geothermal Water Flow between Te Mihi flash plants

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ABSTRACT

The development of the Te Mihi sector of the Wairakei geothermal field includes two large flash/separation plants to supply steam to the Te Mihi and Poihipi power plants. The plants produce large quantities (6500 t/h) of separated water which has to be flowed in a controlled manner to the low pressure flash separators of the Te Mihi power station. The steamfield also has to receive and reinject the water from the Te Mihi station after the second flash stage. Dynamic modelling of the water flows was carried out for operating and upset conditions. It was found that these qualities of fluid had high momentum and this produced oscillations in the water levels between the flash plants during upsets. Operating states with only one plant operating were examined. This included the effects of cooling in dead legs. The reinjection lines were also modelled for water hammer and vapour separation. The modelling showed the two flash plants could be operated effectively as a single plant even with the large geographic separation between the vessels. Operating experience is compared to the modelling.

1 INDRODUCTION

The Te Mihi power station is located in the Te Mihi sector of the Wairakei Geothermal, New Zealand (Harwood 2015). The station has two 83MW dual pressure turbines. The plant is double flash and two steam pressures are designated IP (intermediate pressure) and LP (low pressure). The Steamfield (piping equipment between wells and station boundary) supplies the station with 895/h of IP steam at 4.6 bar.g and 3865t/h of IP separated water (IPSGW). The IPSW is delivered to LP separators with the station compound which produce LP steam and return LP water to the Steamfield for reinjection.

The Te Mihi production wells produce two phase fluid with enthalpy typically 1050 kJ/kg. Some wells produce from a steam cap.

Te Mihi production area also supplies two phase fluid the original Wairakei power station and 375 t/h of IP+ steam to the Poihipi station. The Poihipi station runs with a steam pressure slightly higher that the Te Mihi IP pressure. This steam is designated IP+.

2 FLASH PLANTS FP15 AND FP16

The Te Mihi Steamfield consisted of two main flash/separation plants. FP15 is located north of the Te Mihi station and FP16 south. Production well pads north and south of the station are piped to the closest flash plant. Both plants are located in ridges above the elevation of the station compound. Each plant consists of two large vertical cyclone steam/water separators. 17m tall, 3.6m diameter and the inlet is DN1200 (48”). Water passes from the upper separation section to the lower water tank section via an internal duct.

The Two FP15 vessels operate in parallel to produce IP steam.

FP16 operates as double flash plant. The first separator produces IP+ steam for the Poihipi station. The water from this vessel is flashed to the second IP vessel to produce IP steam for the Te Mihi station. The second vessel also receives two phase fluid direct from production wells. The FP16 vessels can also be operated in parallel to produce only IP steam.

The IP steam mains run south from FP15 and north from FP16 to the Te Mihi station IP manifold. The pressure drops in the steam mains are low and therefore FP15 and FP16 operate at a similar IP steam pressure. Steam vents at the station manifold control the steam pressure.

Figure 1 Te Mihi development viewed from the south during construction. Te Mihi station center. FP15 top right and FP16 center left. Separated Water dump valves bottom. IPSGW IP steam lines as shown.

3 COMMON WATER SYSTEM

The separated water lines between the two phase plants are connected and run next to the steam mains to the Te Mihi station IPSGW manifold.

During startup and when not required by the station the IPSGW is dumped to a large holding pond south of FP16. The layout of the piping means the IPSGW from FP16 flows down slope from the FP to the junction below the plant. From there the water normally flows north and up slope to the station or turns south to the dump silencers and the pond. All water from FP15 flows down slope to the station manifold and when not required, carries on down slope to the FP16 junction and the holding pond, see Figure 2.

The IPSGW piping between the flash plants is operated as a long water tank. The water level in the piping is measured and controlled to a setpoint with the station IP to LP flash valves and the valves at the dump silencers manifold. The level is measured as the pressure difference between the pressure below the water level at the station manifold and the steam pressure above the water level at FP15. Two high level switches located on the piping below FP15 will trip open the IPSGW dump system valves to prevent high water levels in flash plant vessels.

Under normal operation the water level in the leg from FP16 will be slightly higher that the operating set point in the FP15 leg. Steam pressure drops are not equal and the lower FP16 IP steam pressure applies less pressure on the water in the FP16 leg. The level control operating setpoint and the location of high level trip switches are set low to provide capacity to allow the water level to rise during upsets and not reach the separators.

In the event of the station LP flash valves closing the IPSW needs to be dumped to the holding pond. This requires firstly the water level in the leg from FP15 to rise and therefore the Steamfield DCS to open the dump valves. The IPSGW dump valves consist of globe and ball sectors valves that open under level control and will also trip open with a hard wired signal from the level switches.

When the dump valves open the water that was flowing from junction below FP16 to the station needs to reverse direction and flow back towards the dump valves. This DN1050 (42”) pipe leg is 490m long and contains 415 tonnes of water. This mass of water has a large momentum. The driving force to reverse the flow direction is the static head of water in the higher piping legs and lowering of pressure at the dump valves.

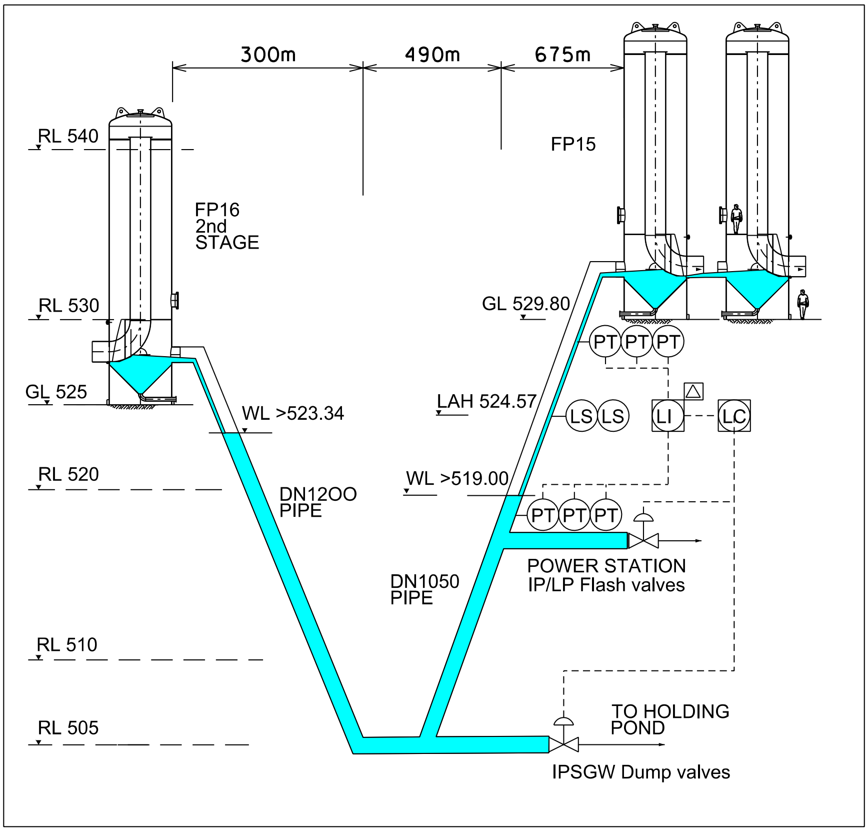

Figure 2 Sematic of FP15 and FP16 IPSGW lines.

4 IPSGW SYSTEM MODELLING

To understand the above dynamics the IPSGW system was modelled using Hytran water hammer software. The scope of the modelling was to look for water hammer (pressure rises) when the LP flash valves close and recommend a maximum closing speed. But, as below, the study also predicted there would be large fluctuations in the FP15 and FP16 water leg levels that need to be addressed.

4.1 Hytran water hammer software

Hytran is a transient software package to simulate the transient flow conditions due to both controlled and uncontrolled operations in a pipe network.

The package is based on the method of characteristics (Wylie 1978), while developed for single phase, has the facilities to model flashing that may occur a geothermal operation. Particular attention was required to obtain correct input information to model the thermal characteristics of the fluid under varying pressure and control levels in the operation of the flash/separation plants FP15 and FP16.

To model saturated hot water at 150 °C (assumed constant in all pipes), the vapour and saturation pressures were both assigned to be 61.55 m (abs). The density of the brine fluid was set at 910.88 kg/m3. If the transient pressures dipped below the vapour pressure, flashing occurs until such time the transient pressures rises above the flash point. Hytran tracks the volume of the column separation during flashing and the time taken for the fluid columns to rejoin and the resulting transient pressures.

A special adaption was required to model the FP15 and FP16 flash/separation tanks characterized by the following:

- 2 sloping pipes set at different angles
- Constant and continuous inflow of IPSGW
- Free water surface
- Over pressures of 4.5 bar (gauge)
- Water level during transient conditions to remain within the maximum and minimum water leg levels.

The Hytran "Standpipe" boundary condition modelled the above requirements by employing a variable area shaft replicating the varying area of the two sloping pipes at different elevations. The brine levels in FP15 and FP16 were recorded at each time step throughout the simulation.

The Te Mihi power station and LP flash valves are represented as a single "Flash Valve" sized to simulate the initial headloss through to the LP System. The first step in the simulation was to close the flash valve.

The opening of the dump valves is delayed to coincide when the trip level of FP15 leg has been reached.

For the steady state scenario, both FP15 and FP16 supply a continuous flow to the Flash Valve which closes in set time to generate transient conditions. Thereafter, the supply flow from FP15 and FP16 are redirected to the opened dump valves to relieve the pressure/level build up. Both the timing to initiate the opening and the time it takes to open the dump valves are important factors to control the level fluctuation in FP15 and FP16 and pressure rise in the pipe network.

4.2 Modelling cases

The Hytran was used to model the flow, pressure and water level transients when the station LP flash valve close and high water level in FP15 leg causes the IPSGW dump valves to open. A number of upset scenarios were modelled.

For the case presented below the parameters where

FP15 IPSGW flow	2900t/h
FP16 IPSGW flow	3500t/h
Normal operating level FP15 leg	522m
Level to open dump valve with level control	523m
Time to close IP/LP flash valve	10 sec
Time to open dump valves (modulating control)	30 sec
Time to open dump valves (high level trip)	30 sec
Capacity of dump valves	7680t/h

4.3 Results- Observations of the System Behavior

After the LP flash valves have closed, there is a dynamic interaction generated by the water mass oscillation between the FP15 and the FL16 with their different respective areas affecting the rates of level rise in the pipe legs. This is further complicated by the activation of the Dump Valve operation. Observation of the system behavior showed that

- On closure of the Flash Valve, the level rises faster in the FP16 leg than the FP15 leg.
- FP16 flow is redirected to the FP15 leg until the dump valve activation level is reached.
- Fully opening the modulating/dump valves drops the pressure at the valves and induces flow initially from the FP16 leg as it is located closer to the DV's and the FP16 level falls. The level in the FP15 continues to rise as it is still receiving residual forward momentum flow from FP16.
- When the FP15 level is at its maximum, the FP16 is nearing its minimum level. Flow from the FP15 reverses and becomes the supplier to the DVs and to FP16 and raises the FP16 level. During this stage, the level in the FP15 drops and eventually empties as more flow is discharging through the DVs than the constant source inflow into the system.

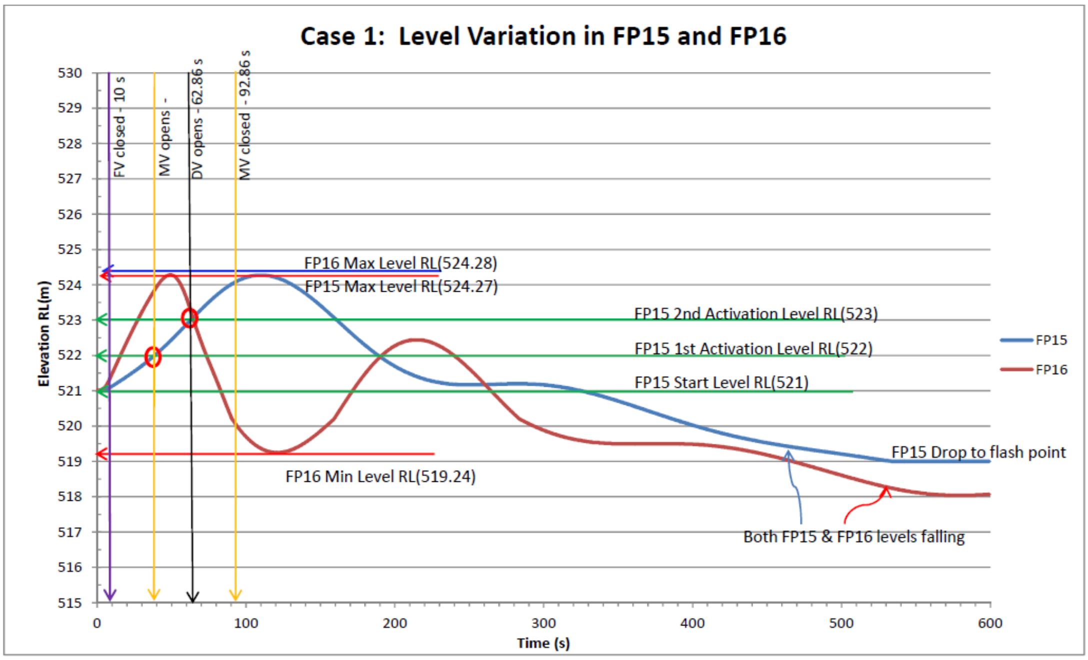

Figure 3 the Water levels in the FP16 and FP15 IPSGW legs after closure of the IP/LP flash valves.

As above when the IP/LP flash valves close the water level in the FP15 leg increases to 524m at 100s even though the dump valves are fully open at this time. The implication is, when the station LP flash valves close, and dumps do not open straight away the water level in the FP15 leg is going to trip the high level switches and fully open the dump valves. On a trip the dump valves do not automatically close so the water level will be lost. The recommendation from this finding was to install a feed forward control signal from a station trip to the dump valves modulating control loop so they would open (but return to level control) and hopefully prevent the water level reaching the high level switches and level control being lost.

The modelling also showed how much overhead is required above the level of the operating set point to prevent vessel flooding. FP16 is the closest to flooding and in the worst case modeled the level reached 526m or 1m meter above the foot of the separator vessels.

The 10sec closing speed of the LP flash valves did not produce water hammer (high line pressure) events above design pressure of the piping.

4.4 FP15 out of services- Dead leg heating

FP15 can be taken out of service. Isolation valves are located at FP15. In this operating mode the FP15 water leg will be a dead leg with no IPSGW inflow and no connection to the IP steam system. Without the inflow of hot water and steam this pipe leg will cool and steam space above the water reduce pressure and eventually collapse. The higher IP Steam pressure above the water level in the FP16 leg will force the water level in the FP16 leg down and eventually so low steam would pass in to the station IP water manifold.

The heat loss from the FP15 water leg was hand calculated. A warming flow of hot water from FP16 was calculated that would maintain a steam space pressure above the FP15 water level. By installing a steam vent at the top of the FP15 leg, warming flow would enter the pipe leg at the bottom, move up the pipe and boil off when it reached the water surface. This water would then be discharged as steam from the top of the FP15 pipe leg.

5 OPERATING EXPERIENCE

The Te Mihi Steamfield was commissioned with IPSGW flows as required for two turbine units. 1500 t/h from FP15 and 2100t/h from FP16, 3600t/h total. The total modelled flow above was 6400t/h for three units. The IP dump valves were the full 3 unit system and were shown to be discharge even more than the design value. The result was lower momentum forces in the piping legs and discharging of water from the pipe legs much quicker than modelled. The commissioning data did show oscillations and out of phase flows in the FP legs. High water levels were not seen in the FP15 leg but at these low flows this was not expected.

The FP15 dead leg warming vent was used but it was found the steam vent at the top of the FP15 leg discharged a two phase mixture of steam and water. It has been postulated, this was due to a layer of boiling water producing a two phase ‘foam’ and the lower density making the actual water level difficult to measure with pressure transmitters or detect with level switches. This was overcome by using a pressure transmitter further downstream (higher static head) and lower level set point.

6 REFERENCES

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