ABSTRACT

This is an overview of the design and development of steamfield plant and pipework. The production system comprises 5 separation plants each fed by a group of production wells. Initially supplying HP and IP steam, the plants are designed for eventual derating to IP. Production wellheads feed individual two phase pipelines. Detailed study of pipeline supports achieved a reduction in pipeline costs. Two phase silencers have been developed to meet noise limits. The separated water is reinjected using a pumped system to wells near the boundary of the field.

INTRODUCTION

The Electricity Corporation of New Zealand has recently commissioned the Ohaaki Power Station.

Design of the geothermal wellheads, two phase pipelines, separation plants, reinjection pipelines, two phase silencers and station steam vent silencers was carried out by Works & Development Services Corporation (NZ) Ltd for Design Power.

The overall program for the project allowed for the development and field testing of plant improvements which have been successfully incorporated in the final design.

SEPARATION PLANTS

The concept of centralised separation plants was chosen, each plant fed by a group of wells. The number and location of separation plants was the subject of a detailed study of alternatives, the criteria being the capital cost of plant and pipework and the best balance of steam and water production from each plant. Three separation plants were selected for the West Bank, two for the East. See Figures 1 and 2.

The separation plants are designed around a standard configuration of one 1500mm diameter HP separator and one 1800mm diameter IP separator. The separators are a development of the conventional cyclone separator used extensively in the Wairakei field. Each separator is skirt mounted, bolted directly onto a R.C. pedestal, from which cantilever arms support the water vessel.

The water vessels are of vertical configuration to provide sufficient range for control purposes. Their capacity will accommodate fluctuations in water flow within the sensitivity of the automatic water control system. Each water vessel is coupled to one separator; a modular configuration which allows variation as in SP5, which comprises two HP separators and one IP separator. This variation is more suited to the higher enthalpy East Bank wells.

LEGEND

STEAM MAINS
TWO PHASE PIPELINES

SCALE: 0 100 200 300 metres
The HP stage is designed to accommodate the rundown in the HP system pressure commensurate with maintaining the IP turbines on full load. Eventually the field is expected to be fully derated to IP. The HP and IP stages, initially connected in series, will finally run in parallel. The separation plants have the necessary flanged branches, now blanked off, for eventual conversion to IP. The basic design criteria for SP1 to SP4 are given in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>HP STAGE</th>
<th>IP STAGE</th>
<th>DERATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRESSURES:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design barg</td>
<td>17 0</td>
<td>8.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Operating barg</td>
<td>13 5</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>FLOWS:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam tonne/hr</td>
<td>135</td>
<td>100</td>
<td>183</td>
</tr>
<tr>
<td>Water tonne/hr</td>
<td>735</td>
<td>673</td>
<td>755</td>
</tr>
</tbody>
</table>

There is provision on each separator inlet manifold for the connection of additional wells. Each HP well connection is arranged such that it can be transferred to the IP manifold should the well be derated ahead of the system derating. Water from the HP stage is flashed down to IP through a locally designed and manufactured angle valve feeding the IP inlet manifold.

Water flows from the IP stage at or near the silica saturation temperature to the reinjection pumps. These are located in a 2m deep pump pit, to provide sufficient NPSH on the pumps. There is provision for bypassing the flow into a two phase silencer adjacent to the separation plant. This facility is used during start up, under manual control and during automatic shut down.
Each production wellhead is designed to facilitate rig workovers with minimal dismantling, as well cleanouts may be required annually.

Design pressure up to the first isolating valve is 69 bar g, the maximum shut-in pressure recorded for these wells. Downstream of this valve the design pressure is derived from the safety valve set pressure at the separation plant plus an allowance for the maximum head loss in any two phase pipeline.

As a large proportion of the wells had twin cyclone silencers at the wellheads, built during the field investigation stage, it was decided to incorporate a bypass and silencer as a standard feature on all production wellheads. A few wells without silencers were provided with the later design single cyclone silencer.

A design point flow rating was derived for each production well, being the estimated output allowing for two years production rundown. Flow ratings varied widely, from 7 tonne/hr to 76 tonne/hr HP steam.

Production from each well is limited by a back pressure plate, which can only be changed during a separation plant shutdown. One well for each separation plant is fitted with a flow control valve at the wellhead, useful during startup and for trimming the steam production from the plant.

Each production well feeds an individual line to the separation plant, as a general rule, allowing future selective derating of wells to IP. Isolating valves are not fitted at the connection to the separation plant manifolds, resulting in savings in capital and maintenance costs. This also avoids designing for the substantially higher pressure rating of the production wellhead.

All the two phase lines are designed for slugging flow conditions using design procedures and concepts established in the Wairakei and Kawerau geothermal fields. Thermal expansion is allowed for using horizontal offsets and the natural flexibility of the pipework. Expansion compensators are not used.

Ideally each two phase pipeline will have a continuous fall from wellhead to separation plant allowing drainage when the well is off production. These lines require venting at the highest point when not on production. Similarly each low point in a two phase pipeline must be drained when the well is off production.

A detailed study was made of pipeline support systems with the objective of minimising costs. Field trials were conducted on cast in situ concrete piles and these were then adopted as standard for all pipelines. The optimum spacing of supports was derived for each pipeline size, wall thickness and for each of the different duties (two phase, steam, water). This was assisted by finite element analysis of the pipe attachment in the vicinity of the support. Optimum support spacing has achieved a significant reduction in the total pipeline cost.

Properly designed and sized cycle silencers have been shown to be an effective method of noise reduction. The single cyclone silencer was selected as the basis for further development. Attenuation requirements were then determined for the two production wells which would produce the highest noise levels at the Maraew. To satisfy the intermittent day time noise criteria at the Maraew of 40 dB(A) at the Marae, the maximum permissible sound power level (Lw) from each wellhead silencer was derived. (see table 2).

Tests with the conventional twin cyclone silencers on BR20 and BR22 wellheads gave sound power levels of about 126 dB(A) . As the separation plant silencers are likely to be in more frequent operation and possibly for extended periods, eg following a trip of the reinjection pumps, they are required to meet the semi continuous night time noise criteria at the Marae of 40 dB(A) for the IP discharge.

Measurement of noise levels from a single cyclone silencer on the Kawerau separation plant fed by wells KA21, KA27 produced a sound power level of 108 dB(A).

Noise emission sources from a single cyclone silencer was identified and a development program agreed. (Refer Fig 3).
a) Modifications to the inlet duct including elimination of the joint gap between the back-pressure pipe and the silencer inlet duct.

b) Insertion of an acoustic pack in the steam discharge path.

c) Eliminate swirl at the silencer outlet, increasing vertical velocity of steam discharge to the atmosphere.

The test program was conducted on a single cyclone silencer which was installed on BR45, the largest production well, having a mass flowrate of 270 tonne/hr, enthalpy 130 0 kJ/kg.

The results of the testing are given in Table 3. The measurements on BR45 site were affected by flanking noise emitted from the wellhead pipework and valves, accounting for the apparent higher sound power levels obtained from the 30m readings. (Test results for the unmodified silencer were obtained on BR19 well).

From these results it is evident that a modified single cyclone silencer would meet the noise criteria for BR20 wellhead. For BR22, a modified silencer plus acoustic pack in the steam path would be required. For SP2, a modified silencer, without acoustic pack, proved adequate in meeting the noise criteria.

<table>
<thead>
<tr>
<th>Distance from</th>
<th>30m</th>
<th>200m</th>
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<tbody>
<tr>
<td>Single cyclone silencer</td>
<td>LP dB(A)</td>
<td>Lw dB(A)</td>
</tr>
<tr>
<td>Unmodified</td>
<td>84</td>
<td>121</td>
</tr>
<tr>
<td>Modified inlet duct</td>
<td>76</td>
<td>113</td>
</tr>
<tr>
<td>Ditto plus acoustic pack</td>
<td>69</td>
<td>106</td>
</tr>
</tbody>
</table>

Table 3: Two Phase Silencer Test Results

REINJECTION SYSTEM

Background

'Reinjection from a User's Point of View' a paper by JPF Robinson at the 1979 NZ Geothermal Workshops, provides a useful insight into the client's initial thoughts and objectives for reinjection. It includes a summary of reinjection tests carried out in the Broadlands geothermal field and outlines tests which were then being prepared.

These early tests were fraught with pump problems, particularly in the gland area. These problems were identified and solved. Technical specifications for pumps are now based on API 610 'Centrifugal Pumps for General Refinery Services' with specific design features and materials of construction. Glands are fitted with a cartridge mounted metal bellows carbide face mechanical seal, flushed with cold pressurised water. Design Power incorporated these features in the specifications for supply of the reinjection pumps.
System Design

The reinjection system is designed for approximately 1800 tonne/hr of separated geothermal water. The surplus condensate is reinjected independently, a decision made following a study by DSIR Chemistry Division on the corrosivity of mixed fluids.

Water Rights define the allowable discharge of geothermal water to the Waikato River, the principal WR is for 3500 m³ per day at times of flow measurement, maintenance and development work.

The preferred location for reinjection wells, based on studies by DSIR and WORKS is at the boundary of the reservoir. A limited flow is permitted into the Ohaaki rhyolite, via the Ohaaki pool. Additional reinjection capacity is obtained by the use of booster pumps on selected wells, a lower cost option to drilling additional wells.

Reinjection capacity was determined for each reinjection well by cold water injection tests; the results corrected for reinjection of 150°C separated water. One well was allocated to condensate reinjection with one standby.

Separated water flows under normal plant operating conditions are:

<table>
<thead>
<tr>
<th>Well</th>
<th>Flow (tonnes/hr)</th>
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<tbody>
<tr>
<td>SP1</td>
<td>416</td>
</tr>
<tr>
<td>SP2</td>
<td>237</td>
</tr>
<tr>
<td>SP3</td>
<td>388</td>
</tr>
<tr>
<td>Total West</td>
<td>1042</td>
</tr>
<tr>
<td>SP4</td>
<td>366</td>
</tr>
<tr>
<td>SP5</td>
<td>376</td>
</tr>
<tr>
<td>Total East</td>
<td>742</td>
</tr>
</tbody>
</table>

The overall layout of the reinjection system is shown in figure 4. Design pressure of 38 bar g applies to each pipeline from the reinjection pump at the separation plant to the non return valve at each reinjection wellhead and to the booster pumps. Downstream of the booster pumps to the non return valves at BR29 and BR30 wellheads the design pressure is 50 bar g. Pipeline sizes were derived from an economic evaluation of pumping costs, with an allowance made for silica deposition derived from the earlier reinjection field tests.

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GAS EXHAUSTER UNITS UNDER CONSTRUCTION

HP STEAM LINES EXIT RIGHT FROM BYPASS AREA

STEAMFIELD PIPEWORK UNDER CONSTRUCTION

Photos: DesignPower