NGAWHA OEC4 GEOTHERMAL FLUID SEPARATION – HORIZONTAL SEPARATOR SELECTION AND PERFORMANCE

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ABSTRACT

New Zealand has a long history of developing higher enthalpy geothermal fields. This has meant that the cyclone type separator design has been preferred. The Ngawha geothermal field has a low enthalpy when compared to all New Zealand's other developed fields. A horizontal separator was selected for Ngawha OEC4, primarily because of low pressure loss when compared with the cyclone type. The separator was easy to commission. The separator performance was tested using sodium as a tracer. Separation efficiency is like what is expected for a cyclone separator. The performance of condensate drop-pots designed for steam scrubbing was also compared to condensate drop-pots intended to capture excess condensate only. The results show that the first condensate drop pot makes a significant difference to the steam purity, but the downstream condensate pots do not irrespective of the steam velocity.

1. INTRODUCTION

Ngawha Geothermal Field is in the far north of New Zealand. It is the only developed geothermal field in New Zealand outside of the Taupo Vulcanic Zone. Ngawha Generation Limited owns and operates three existing geothermal power plants (OEC1, 2, & 3) and the latest addition, OEC4. Ngawha Generation Limited is wholly owned by Top Energy Limited.

The OEC4 plant is supplied by three production wells, NG28, 29, & 30. The average enthalpy of the production fluid is approximately 995kJ/kg. OEC4 was commissioned December 2020 – January 2021.

2. SEPARATOR TYPE SELECTION

In New Zealand cyclone type separators have been used exclusively in geothermal power development. This is likely to be because cyclone separation is appropriate for higher enthalpy fluid which is characteristic of most developments to date. The main advantage for the Ngawha OEC4 development is that a horizontal separator has an insignificant pressure drop whereas cyclone separation can be up to 1 bar if the pressure drop of the inlet piping is included (which is smaller than required for a horizontal separator).

Other potential advantages of a horizontal separator are improved separator performance at low flow (whereas a cyclone separator has limited flow range for maximum performance) and resistance to inlet slug flow.

The separator is located close to the production wells. The primary reason for this was due to the enthalpy of the fluid and long stretch of relatively level pipework upstream of the power plant site. Modelling predicted that unstable two-phase slug would be unavoidable. It is likely that this would make steam separation difficult. Locating the separator close to the production wellhead meant that this risk was eliminated. There were other advantages:

- increased separated brine pressure at the station inlet (due to the elevation change). This means that injection pumping requirements (if required in the future) may be reduced,

- ample pipeline length for effective steam scrubbing,

- reduced pressure drop between the separator and the station.

The above required additional capital cost but decreased net present value.

A diagram of the separator is shown in Figure 1 below.

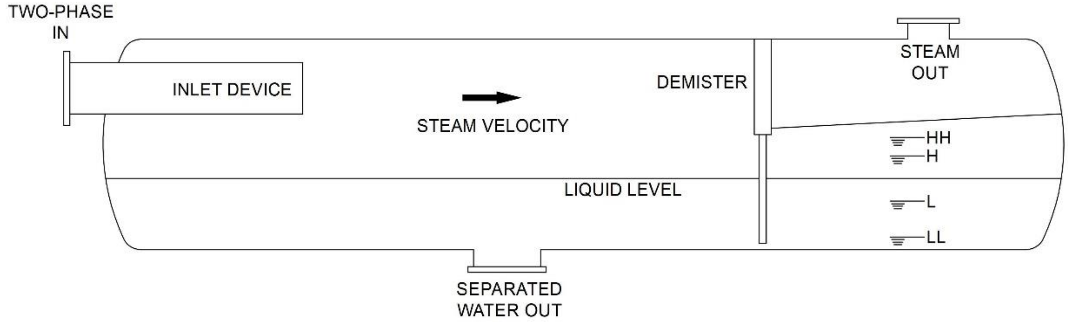

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Figure 1: Separator diagram

3. SEPARATOR COMMISSIONING

Commissioning the separator proved to be uneventful. Other than having to wait for the brine piping to fill, the separator level was stable at any flow and pressure.

4. STEAM SCRUBBING

Ngawha OEC4 is a binary power plant. Separator performance and downstream steam purity is therefore not as important as it would be for a conventional steam turbine. Despite this, Ngawha Generation Limited had no experience with horizontal separators, and therefore passive steam scrubbing was included in the process design to help improve steam purity should the separator performance not be as expected. There is approximately 1300m of piping between the separator and OEC4. Two condensate drop pots designed for steam scrubbing were included in the steam main. These were located about 80m apart. Condensate guide bars were included upstream of each these drop pots. The design of these guide bars was based on expired patent US5740917 - Boundary Layer Condensate Drain Pot (https://patents.google.com/patent/US5740917).

4. PERFORMANCE TESTING

Separation and steam scrubbing was determined by chemical tracer mass balance. The tracer selected was sodium (i.e. naturally occurring in the geothermal fluid). A sample was taken from each flow stream (for example, steam trap) for chemical analysis and the flow rates were measured by either station flow metering or bucket and stopwatch. A simplified schematic of the locations is shown in Figure 2 below.

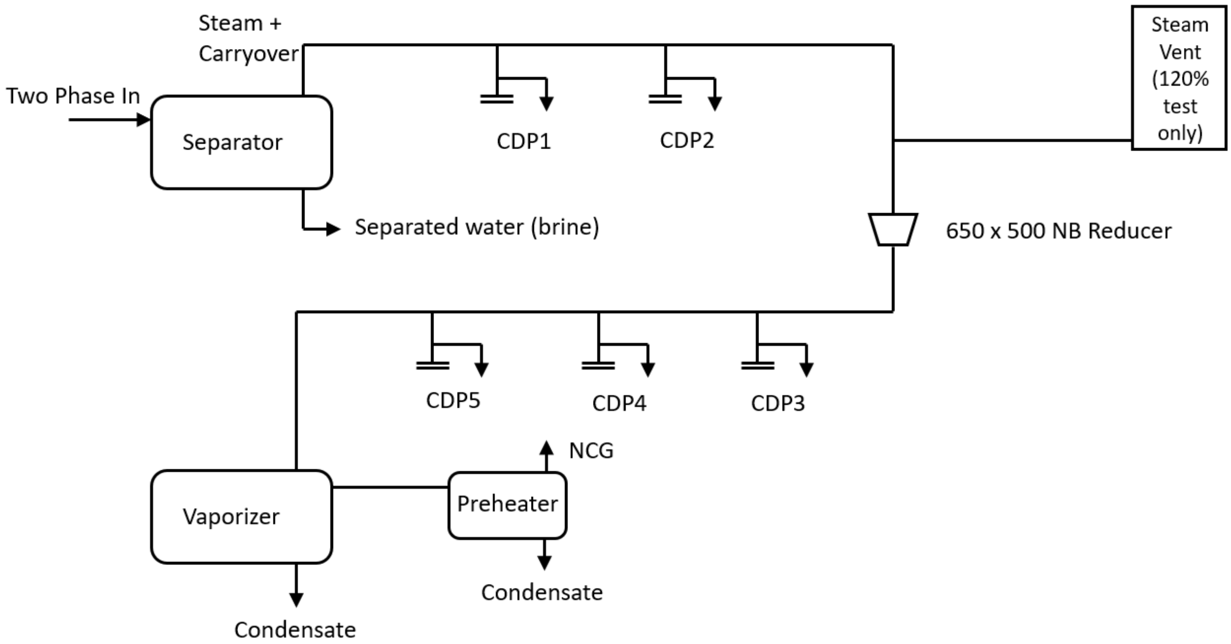

Figure 2: Schematic of test points

Testing was conducted at three nominated mass flow rates: 50%, 100%, and 120% of the guaranteed plant electricity output capacity. The 120% test was to confirm that the separation performance will be adequate at maximum plant output.

Samples were taken from the separated brine, two condensate drop pots (designed for steam scrubbing), three in-plant condensate drop pots, vaporizer condensate, & NCG preheater condensate.

For the nominal 120% test some steam was diverted to the rock muffler (vent). There was no easy or accurate way to measure sodium mass flow in this stream, so it was assumed that the sodium flows were in proportion to the steam flow split.

1.2 Separator efficiency calculation

Separation efficiency is defined as the percentage total steam flow over the total steam flow including carryover.

Carryover (t/hr) = Total sodium flow in steam (t/hr) / sodium concentration in separated water

Separator efficiency (%) = (1-carryover/steam flow)*100

In a similar way the separation efficiency contribution of the condensate drop pots was also calculated.

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5. RESULTS

A summary of the test results and calculations is shown in Table 1. Note that for the 52 t/hr steam flow case the concentration of sodium in the vaporizer and NCG preheater condensate was below the detection limit (therefore the detection limit concentration was assumed). Also note that the sodium flux rates downstream of the vent for the 125 t/hr test were multiplied by 1.2 to allow for the vent flow.

			52 t/hr steam flow @ 12.1 barg				104 t/hr steam flow @ 12.1 barg				125 t/hr steam flow @ 12.5 barg			
	Upstream length	Straight length upstream	Sodium mass flow rate	Condensate flow	Steam velocity	Separation Efficiency	Sodium mass flow rate	Condensate flow	Steam velocity	Separation Efficiency	Sodium mass flow rate	Condensate flow	Steam velocity	Separation Efficiency
	m	m	g/hr	t/hr	m/s	%	g/hr	t/hr	m/s	%	g/hr	t/hr	m/s	%
Separator			0.734		0.3	99.99846	4.295		0.6	99.9955	4.783		0.7	99.9958
CDP1	650	66	0.330	0.379	6.8	99.99915	0.858	0.330	13.8	99.9964	0.822	0.265	16.6	99.9965
CDP2	80	72	0.025	0.050	6.8	99.99920	0.027	0.047	13.8	99.9964	0.029	0.050	16.6	99.9966
CDP3	250	40	0.035	0.130	11.7	99.99928	0.066	0.112	23.7	99.9965	0.096	0.146	28.5	99.9967
CDP4	140	110	0.053	0.073	11.7	99.99939	0.058	0.108	23.7	99.9965	0.058	0.093	28.5	99.9967
CDP5	150	86	0.047	0.079	11.7	99.99949	0.047	0.088	23.7	99.9966	0.044	0.079	28.5	99.9968
Vaporizer			0.224	44.7			2.679	89.3			2.679	89.3		
NCG Preheater			0.020	4.0			0.560	8.0			0.400	8.0		

Table 1: Sodium mass balance and calculated efficiency

6. DISCUSSION

The separator efficiency is as expected providing adequate performance at the tested flow rates and pressures.

Typically, steam purity is not a significant factor in binary units. Despite that, the results of the testing indicated that the first drain pot provided most of the steam scrubbing while the downstream drain pots provided little additional benefit. There was no significant difference in performance between the second condensate drain pot (650NB) and the condensate drain pots downstream (500NB). This is shown in figure 3 below.

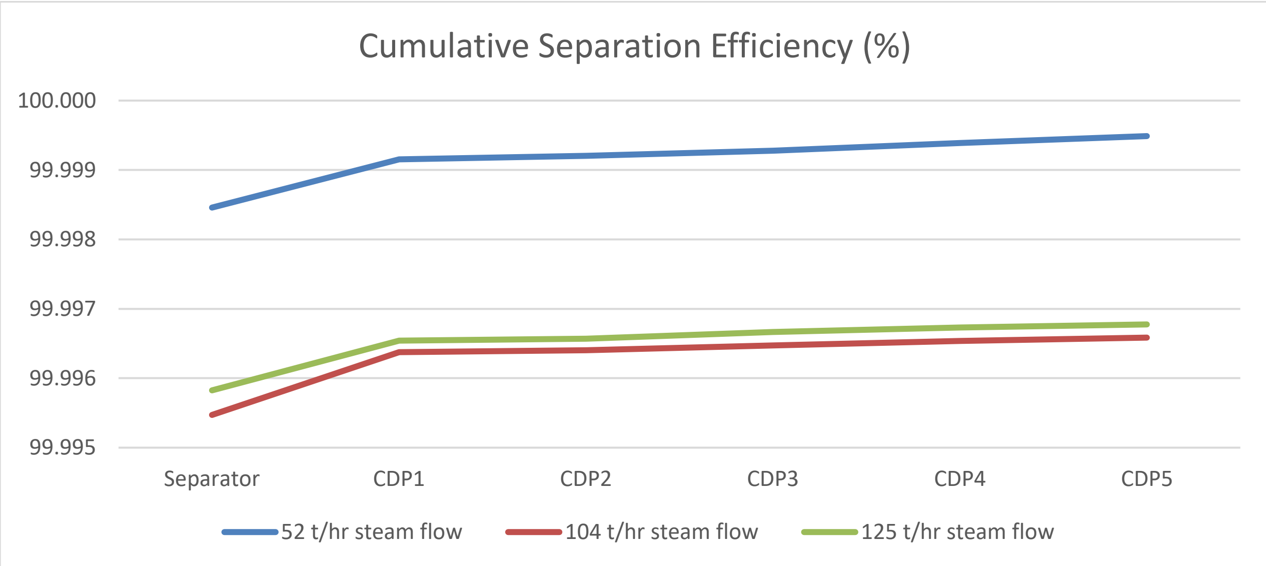

Figure 3: Separation efficiency

It is noted that the efficiency is higher for the 125 t/hr case than for the 104 t/hr case. This could be due to several factors, but due to the limited data set nothing can be inferred without further testing.

There is also insufficient data to determine why CDP2 does not appear to have better performance than the smaller CDP3-5. A factor may be the quantity of upstream exposed pipe wall and therefore condensate captured, but without more testing this could not be confirmed.

7. CONCLUSION

The horizontal separator installed for Ngawha OEC4 provides good separation efficiency at the flows and pressures tested. The first condensate drain pot after the separator improves the steam purity significantly but subsequent condensate drain pots do not make a significant difference.

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