PERFORMANCE TESTS OF THE CONDENSATE DRAIN POTS AT WAIRAKEI

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ABSTRACT

As part of the investigation for a solution to the corrosion problem of the steam mains at Wairakei, the performance of the condensate drain pots was tested. Air-water model tests suggested that the typical shallow drain pots at Wairakei were not very efficient and that the efficiency could be improved by increasing the depth of the drain pot or by installing a baffle in the drain pot to destroy the vortex that caused the inefficiency.

Deepening a shallow drain pot at Wairakei confirmed the finding of the model tests. Installing a baffle plate in each of two consecutive drain pots of a steam main enabled the efficiencies of the drain pots to be quantified and improvements in the efficiencies were clearly demonstrated.

No significant effect by the baffle plate on the drain **pot** pressure drop was detected, however the pressure drop coefficient of a drain pot having the same diameter as the steam main was approximately twice that of a drain pot of two-thirds the pipe diameter.

INTRODUCTION

Wairakei Geothermal Power Station commenced generation in November 1958. At present there are ten main steam transmission pipelines supplying steam to thirteen turbine-generator sets. The nominal bores of the pipes range from 430 mm to 1220 mm, the steam pressures in the pipes range from 1.2 to 8 bar gauge and the steam velocities range from 25 to 60 m/s. The distance from the centre of the steamfield to the power station is approximately 3 km.

Corrosion of the two 760 mm NB pipes carrying HP steam at 8 bg was first discovered durinq the station shutdown in November 1977. All the ten pipes are now known to be corroding. The condensate, that is causing the corrosion, is the result of the heat loss of the saturated steam being conveyed and is collected at regular intervals, of approximately 140 m, by drain pots before being discharged to the surroundings via thermodynamic steam traps. A typical drain pot has a diameter of 51 cm and a depth of 29 cm from the bottom of the pipe. It was thought that the drain pots allowed excessive carry-over of the condensate to the downstream pipes, hence improving the condensate collection efficiency of the drain pots (defined as condensate discharge rate/rate of condensate accumulated) was seen as possibly beneficial to the corrosion problem.

Air-water model tests of Freeston and Rentzios (1980) showed that the efficiency was dependant on the physical configuration and dimensions of the drain pots, and wasapproximately constant at 85% when $h/d \geqq 0.6$ for $D/d = 1.5$, where h is the depth, d is the pot diameter and D is the pipe diameter. $h = 0.6$ d was defined as the critical depth below which there was no significant change in efficiency due to small changes in water flow. However, above the critical depth, a 10% decrease in water flow resulted in about 10% improvement in the collection efficiency. The efficiency reduced significantly when the wetness was increased from 1% to 4%. For $D/d = 1.0$ a very strong pair of vortices were observed when $h/d = 0.5$. Insertion of a baffle in the drain pot destroyed the vortices and improved the efficiency to over 95% for all cases.

Pressure drop coefficients (drain pot pressure drop/dynamic head) of 1 to 2% were reported for h/d up to 0.4. For $D/d = 1.5$ and $h/d = 0.5$ a 10% pressure drop coefficient had been reported, and 13% for $D/d = 1.0$ and $h/d = 0.52$.

Experiments were conducted principally on the HP steam lines at Wairakei to test the findings of the air-water model. These tests essentially compared the performances between modified and unmodified drain pots, and concentrated on the effect of the baffle plates because there is generally insufficient space beneath the pipes for the deepening of the drain pots to be a viable modification.

EXPERIMENT

The condensate discharged from a drain pot was measured by connecting the outlet from the thermodynamic steam traps to a 200-litre drum. The water level in the drum was measured on a sightglass which had been calibrated using known weights of water. By timing the filling of the drum, the condensate discharge rate could be determined and an allowance made for the portion of the total discharge flashed to steam as follows:

$$W = Ch/(h' - h'')$$

where W = Actual condensate discharge rate, kg/hr;
C = Condensate discharge rate in the drum, kg/hr;
h = Specific latent heat of vaporization of water at atmospheric pressure, kJ/kg;
h' = Specific steam enthalpy at atmospheric pressure, kJ/kg;
h" = Specific water enthalpy at drain pot steam pressure, kJ/kg.

Figure 1 is a sketch of the main steam transmission pipelines showing the locations of the drain pots.

The shallow drain pot on L line at A1 was deepened from 29 cm to 63 cm, and its condensate discharge rates before and after the modification were measured.

Two consecutive drain pots also on L line at A4/5 and A5 were each fitted with a baffle plate designed according to the recommendation of Freeston and Rentzios. The upper edge of the baffle plate was approximated to the intersection of the pipe and the drain pot and small gaps were provided around the edge and in the centre of the baffle plate as shown in Figure 2. Condensate discharge rates were measured before and after the modification. Also measured was the condensate discharge rate from the next downstream drain pot at A4 which remained unmodified throughout.

Three drain pots were chosen for pressure drop analysis, the first a baffled drain pot on L line at A5, the second an equivalent unbaffled drain pot on J line at A5, and the third an unbaffled shallow drain pot on a 508 mm pipe (B line) also at A5. Three pressure tapping points were installed, two upstream at 5D and 25D and one downstream at 35D from each drain pot. Pressure drops were measured using inverted water manometers.

RESULTS AND DISCUSSION

An assessment of the heat loss from the pipes was made to quantify the condensation rates of the steam for comparison with the condensate discharges measured. The heat loss was based on an annual mean air temperature of 12.4°C and a mean wind factor of 1.4. The rate of condensation for the HP steam pipes was estimated at 0.924 kg/mhr.

The measurements of the condensate discharge rates before and after the pot depth modification showed a sustained increase in discharge from a mean value of 62 to 133 kg/hr. The upstream drain pots showed no significant changes in their discharges. This gave a ratio of the efficiency of the deep drain pot (h/d = 1.24) to that of a shallow one (h/d = 0.57) approximately equal to 2.1.

The model tests of Freeston and Rentzios showed that a drain pot with a depth greater than the critical depth of h = 0.6 d had an approximately constant efficiency of 85%. The shallow drain pot would therefore have a collection efficiency of around 40%.

The model tests also demonstrated that a drain pot installed with a baffle had an efficiency over 95%. This would mean that when A4/5 and A5 drain pots were installed with baffles, the A4/5 drain pot should discharge approximately at the rate of condensate formation in the pipe section between A4/5 and A5; and that the A4 drain pot having an efficiency of 40% should discharge at 40% the rate of condensate formation in the pipe between A4 and A4/5. Table 1 shows the predicted condensate discharges from the drain pots of L line before and after the installation of baffle plates at A4/5 and A5 drain pots.

The predicted and measured condensate discharges, which are compared in Table 2, agreed well except for that of the A4 drain pot which was believed to be due to blocked drain pipes, the maximum discharge through which was 63 kg/hr.

The pressure drop data and results across the three drain pots at A5 are shown in Table 3. The pressure drop coefficient across a shallow drain pot (h/d = 0.57, D/d = 1.5) is about 10%, with or without a baffle plate. The pressure drop coefficient for a shallow drain pot with D/d = 1.0 is about twice that for D/d = 1.5.

CONCLUSIONS

1. The shallow drain pots (h/d = 0.57) at Wairakei have an efficiency in the order of 40%.

2. The deep drain pots (h/d ≥ 1.24) have an efficiency of 85%.

3. A drain pot installed with a baffle plate has a 95% efficiency.

4. The pressure drop coefficient across a shallow drain pot with D/d = 1.5 is approximately 10%.

5. The pressure drop coefficient across a shallow drian pot with D/d = 1.0 is about twice that for D/d = 1.5.

6. The baffle plate appears to have no significant effect on the pressure drop across the drain pot.

7. The mean condensation rate for the HP lines is 0.924 kg/mhr.

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REFERENCE

Freeston, D.H. and Rentzios, E., 1980: "Performance of Condensate Catchpots, Model.Tests". Proc. N.Z. Geothermal Workshop, University of Auckland, p 149-151.

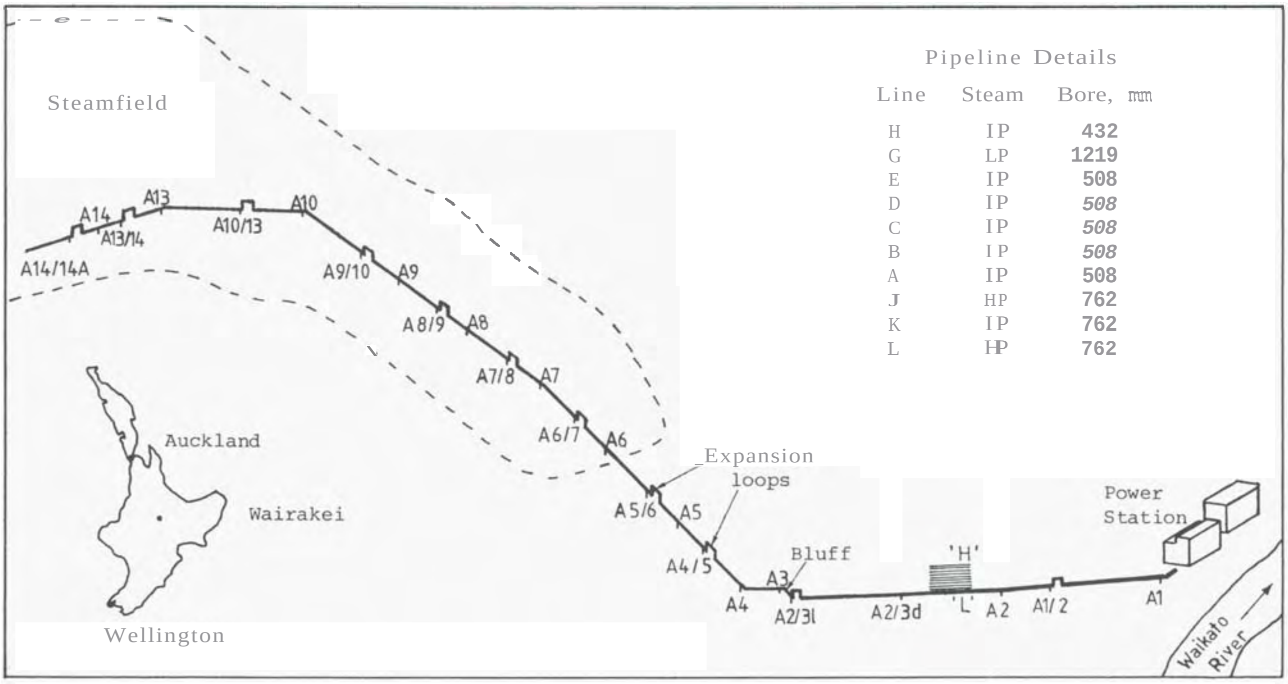

Figure 1: A sketch of 'L' line showing the locations of the drain pots.

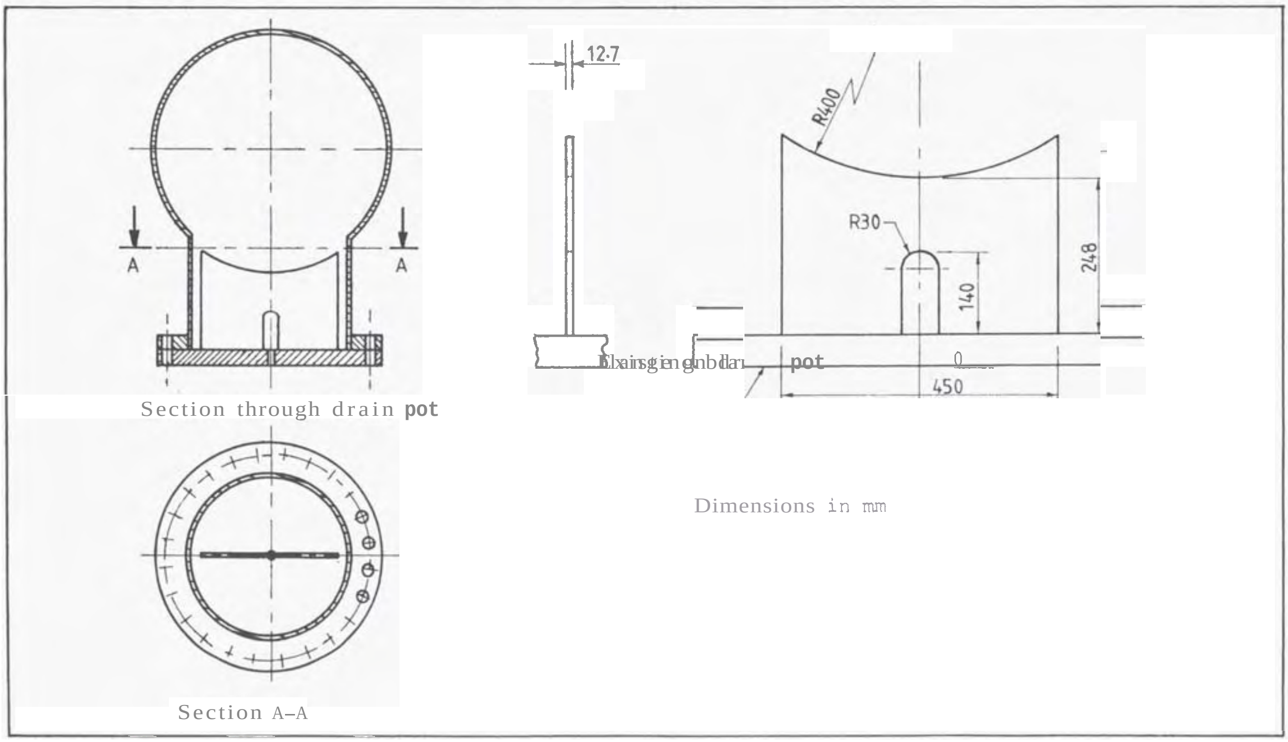

Figure 2: The baffle plate design.

Drain pots	Upstream pipe length m	Condensate formation kg/hr	Without baffles at A4/5 and A5 drain pots: Collection efficiency %	Total condensate kg/hr	Condensate discharge kg/hr	Residual condensate kg/hr	With baffles at A4/5 and A5 drain pots: Collection efficiency %	Total condensate kg/hr	Condensate discharge kg/hr	Residual condensate kg/hr
A1	144	133	85	176	149	26	85	175	149	26
A1/2	147	136	85	283	241	43	85	281	239	42
A2	146	135	40	245	98	147	40	241	97	145
A2/3d	146	135	40	183	73	110	40	177	71	106
A2/31	45	41	40	81	32	48	40	70	28	42
A3	110	102	85	263	223	39	85	191	162	29
A4	154	142	40	269	108	161	40	148	59	89
A4/5	128	118	40	211	85	127	95	126	120	6
A5	129	119	40	155	62	93	95	155	147	8
A5/6	187	173	85	240	204	36	As without baffles	As without baffles	As without baffles	As without baffles
A6	77	71	40	112	45	67				
A6/7	46	42	85	269	228	40				
A7	177	163	40	378	151	227				
A7/8	141	131	40	357	143	214				
A8	180	167	40	377	151	226				
A8/9	143	132	40	351	140	211				
A9	181	167	40	366	146	219				
A9/10	134	124	40	330	132	198				
A10	224	207	40	344	138	206				
A10/13	162	150	40	228	91	137				
A13	61	57	40	130	52	78				
A13/14	53	49	40	123	49	74				
A14	98	91	40	124	50	74				
A14/14A	60	55	40	55	22	33				

Table 1: Condensate discharge predictions before and after the installation of baffle plates at A4/5 and A5 drain pots of 'L' line.

Drain pots	Conditions*	Predicted discharges kg/hr	February-June 1981 Measured discharges kg/hr	Oct 1979-Feb 1981 Measured discharges kg/hr
A1	Shallow	70	-	37–98
A1	Deep	149		99–162
A2/3d	A1 shallow	73		38–88
A2/3d	A1 deep	73	-	26–64
A4	No baffles at A4/5 and A5	108	27–63	-
A4	Baffles at A4/5 and A5	59	9–61	
A4/5	No baffle	85	36–70	
A4/5	With baffle	120	112–139	-
A5	A1 shallow	62	-	58–85
A5	No baffle	62	33–72	80-118**
A5	With baffle	147	127–153	-

* Unless otherwise stated, A1 drain pot is deep (63 cm); A2/3d, A4, A4/5 and A5 drain pots are shallow (29 cm).

** *Two* readings only.

Table 2: Predicted and measured condensate discharge rates of 'L' line drain pots.

Steam lines	L	J	B
Steam pressure, bg	7.3	7.3	3.7
Pressure gradient, Pa/m	28	39	20
Drain pot pressure drop, Pa	186	225	137
Steam velocity, m/s	30	36	26
Baffle installed?	Yes	No	No
Pipe bore, mm	762	762	508
Pressure drop coefficient, %	10	8	17

Table 3: Pressure drops across drain pots at A5.