PERFORMANCE OF CONDENSATION CATCHPOTS : MODEL TESTS

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ABSTRACT

Corrosion/erosion damage in the two high pressure steam transmission lines at Wairakei was discovered in November 1977. As part of the investigation programme the University was asked to conduct model tests of the existing condensation pots. This paper describes these tests on an air/water rig and presents results demonstrating the flow behaviour in the catchpot and making recommendations as to the most suitable geometric configuration for high collection efficiency.

INTRODUCTION

During the biennial shutdown of the Wairakei Power Station in November 1977 corrosion/erosion damage was discovered in the two high pressure steam transmission lines. As a consequence various investigations were proposed, one of which was a study of the flow pattern and collection efficiency of the condensation pots/catchpots used. This paper describes tests that were conducted in an air/water rig and present results of the collection efficiency and pressure drop associated with the present design of drain.

LITERATURE SURVEY

Measurements in a rectangular cavity in the floor of a wind tunnel is described by Roshko (1955). Pressure profiles and velocity data were collected for a range of depth to breadth ratios for the cavity. For a square section (depth/breadth = 1) a single stable vortex was seen to exist. Mills (1965) carried out a theoretical and experimental investigation into the flow in rectangular cavities and established that the stability of the vortices depends on the depth to breadth ratio. The flow in shallow cavities with depth/breadth (d/b) ratios in the range 0.25 to 0.80 is unsteady, whereas the flow in near square cavaties is steady. The unsteadiness which reaches a maximum at about a (d/b) = 0.5 - 0.6 is deduced to be due to periodic fluctuations of the vortex in the vertical (normal to the free stream) direction. At $d/b \approx 2$ two superposed vortices rotating in the same sense were discovered.

Lewis (1966) describes work using a water tunnel to visulise flow in rectangular cavity in one wall of a square channel. Flow patterns in an annular cavity are also described. Various

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The patterns were linked with a spanwise ____-bution of vorticity which gave rise to a "W" type vortex pattern. For the flow in the annular cavity two distinct patterns were observed, the changeover occurring at a depth/breadth ratio of about 1.3.

Allen (1971) with this background, constructed a perspex line 76mm diameter with a 50mm catchpot sited in a region of fully developed flow. Air (mean velocity 42.7 m/s) was discharged through the pipe to atmosphere. The depth of the cavity was adjusted by a plunger up to a depth (h)/catch-pot diameter (d) ratio of 1.5. Pressure tappings, located on two diameters at right angles and on the base, were installed. Pressure profiles were measured for a range of cavity depths. In addition measured quantities of water were injected into the airstream on the bottom of the pipe upstream of the catchpot. The collection efficiency was estimated by measuring the water collected by the catchpot and comparing it with that injected. The major conclusions from this work were that for a h/d ratio of 0.5 the airflow enters the cavity across most of the width but it flows out at high velocity through narrow regions close to the side walls. Water was not retained under these conditions. In addition to the water loss by the spiral action of the airflow, a secondary loss occurred as water was torn from the surface as the liquid was forced towards the upstream wall of the cavity by the incoming airstream. Collection efficiencies were of the order 60 to 70% for depth to diameter ratios of 0.5 rising to 90 to 95% at depth/diameter ratio of 1.5. These efficiencies were a function of the air to liquid mass flow rates.

It would appear from this investigation that the water loss is caused primarily by a well defined vortex occurring at $d/b = 0.5$ and which scrubs the cavity entraining water and carrying it downstream. The mechanism is three dimensional and unlike the rectangular cavity flows described in the literature is the result of a steady vortex, not an unsteady one.

EXPERIMENT

The air/water rig of Lee (1978) was used for these tests. Air is supplied from a Roots blower via a flow measuring orifice to a 84mm diameter perspex pipe arranged in the form of a 180^0 'U' bend connecting two straight lengths 3 metres long. Water is injected through an annular injector which sprays the water on to the walls of the pipe at entry. A cyclone separator returns the water to the sump, the air being discharged to atmosphere. Water flow rate is measured by a calibrated rotameter.

A section was installed in the downstream tangent from the 180 degree bend, which included the test catchpot with an adjustable base and three other catchpots. These additional catchpots were used to collect water in the efficiency tests. This test position was chosen in order to utilise the bend to spread some water around the pipe wall, a condition which had been observed in the Wairakei pipes. The test catchpot was about 25 diameters downstream of the 'U' bend in a region which could be expected to have a reasonably well developed flow. A water outlet on the base of the test catchpot was included to empty the pot.

Two sizes of catchpot were tested, the dimensions chosen to correspond to a scaled model of those in use at Wairakei, the diameter of pipe (D) to diameter of catchpot (d) ratios being 1.5 and 1.0. Airflow was adjusted to give a pipe velocity of about 30 m/s, corresponding to the velocity in the 76cm steam lines. A water flow rate was selected to give about the equivalent of 1% wetness. In these tests no attempt to model Reynolds number was made, the available apparatus did not permit correct Reynolds number scaling.

Following the tests of the basic catchpots modifications were introduced; these are discussed later.

Pressure tappings on the top of the pipe and across the horizontal diameter were installed. These were sited one pipe diameter upstream and downstream of the pot and pressure drop measurements taken on an inclined monometer.

RESULTS AND DISCUSSION

Collection Efficiency

Three techniques were used to estimate collection efficiency. Firstly, a deep catchpot >2.0d was allowed to fill to a known depth and the discharge controlled to give a constant depth. Fig. 1 summarises typical results from this type of test. Secondly, the plunger was set at a given depth and the catchpot discharge adjusted to give a constant depth of water equal to 0.125D over the base of the catchpot. A study of these results (Fig. 1) showed that the depths greater than about 0.5D the collection efficiency was virtually independent of depth.

The third technique used was to set the plunger base to a given depth, allow the water to build up to a fixed height and discharge the water allowing it to refill for the next cycle. This procedure was considered to be an approximation to the operation of the Wairakei drain pots. The results although not covering the full range of plunger depths showed the same trends as illustrated in Figure 1. That is, a peak collection efficiency for this diameter ratio (D/d = 1.5) at about a h/d = 0.6 (h/D = 0.4) which is defined as the critical depth.

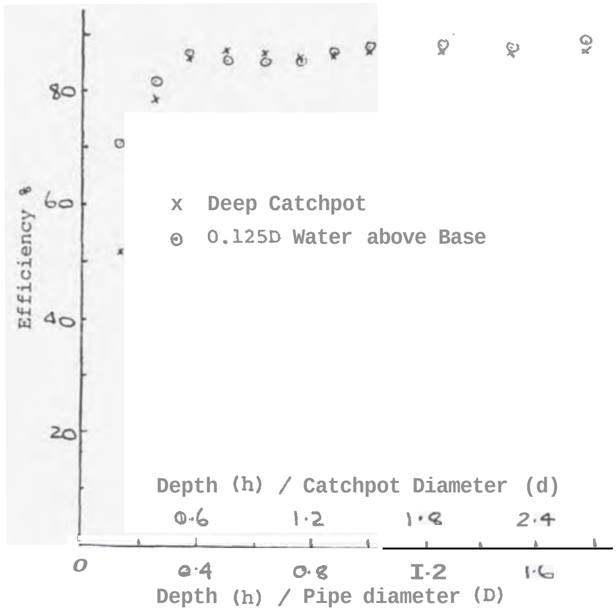

Fig. 1 CATCHPOT EFFICIENCY $\frac{D}{d}$ = 1.5

Visual observatiun of the flow into and around the catchpot largely supported the interpretation given by Allen (1971).

At depths up to the critical, the water moves across and down into the catchpot where some of it is entrained in the vortex, forced to the upstream side of the cavity and re-enters the main stream. In addition, some water is scrubbed off the interface, particularly for the shallower configurations. For the deeper catchpots, water that is carried over is generally on the walls of the pipe and bypasses the Cavity.

It was noted with interest that below the critical depth the build up of water in the catchpot was such that the air-water interface sloped in the direction of flow, i.e. the water was deeper on the upstream side. The drain exit, therefore, needs to be on the upstream half of the catchpot base. This was confirmed by the pressure distributions as measured by Allen (1971).

The sensitivity of collection efficiency to variations in water flow was investigated. Below critical depth, no significant change in efficiency was detected for small changes in water flow. However, for h/d >0.6 a 10% decrease in water flow, i.e. the air/water mixture becoming dryer, resulted in about a 7 - 10% improvement in collection efficiency. This was the result of less water spread on the pipe walls, more of the water flowing along the bottom of the pipe. Small increases in water flow did not show any measurable changes. It was not until the wetness had been increased from 1% to 4% that the collection efficiency reduced significantly.

Use of Baffles ($^D/_d$ = 1.5)

The 76cm (30in) diameter line at Wairakei has a number of drains which are 50cm(20in) diameter and 20cm (8in) deep (measured from the bottom of the pipe). These diamensions correspond to $^h/_D$ = 0.27 ($^h/_d$ = 0.4) which is below the critical depth and would be expected to have a low collection efficiency of about 60%. As discussed above, at this depth the flow inside the cavity is highly three dimensional and turbulent, but there is a tendancy for water to move to the upstream side of the catchpot and to be re-entrained with the airstream. For this geometric design, attempts were made to improve the efficiency. To prevent the reversed flow, a baffle modelled in plasticine was placed transverse to the flow direction, fixed to the base and immersed within the cavity. Two different shapes were tried and both resulted in collection efficiencies over 95%. It was necessary, however, to ensure that there was a passage for the air within the cavity to traverse upstream. This was provided by small gaps around the edge of the baffle and in the centre. The most efficient baffle under all conditions was one in which the upper edge approximated to the pipe/catchpot intersection whilst a baffle, which left the middle third of the diameter open, performed satisfactorily.

Catchpot ($^D/_d$ = 1.0)

A limited range of tests were carried out for this configuration. The collection efficiency at three depths were measured. For 0.25D and 0.75D efficiencies were of the order of 90% whilst at 0.5D a very strong pair of vortices, rotating parallel to the flow on either side of the catchpot, was observed giving a collection efficiency of about 75%. Insertion of baffles, as described above, destroyed the vortex system and gave efficiencies over 95%.

Pressure Drop

The pressure drops across the catchpots are shown in Table 1. The pressure drop coefficient is expressed in terms of the dynamic head of the airflow.

For the small catchpots at the Wairakei depths a pressure loss of about 1% of the free stream dynamic head was measured being nearly independent of water flow rate. However, for the larger pots the pressure drop was 2% except for the depth which induced the cavity vortex. For this case 13% of the dynamic head was lost in pressure across the catchpot. This gives an indication of the strength of this vortex. Allen (1971) using a catchpot of $^D/_d$ = 1.5 and with higher air velocities obtained loss coefficients approaching 10% of the dynamic head at a $^h/_d \approx 0.5$.

TABLE 1

Catchpot	Mass ratio $^{air}/_{water}$ %	Pot depth $^h/_D$	$\frac{\Delta p}{\frac{1}{2}\rho v^2}$
$\frac{D}{d}$ = 1.5	1	0.27	0.013
	1.5	0.27	0.009
	4.4	0.27	0.010
$\frac{D}{d}$ = 1.0	1	0.27	0.018
		0.52	0.131
	4.4	0.27	0.010
		0.52	0.025

CONCLUSIONS

1) For high collection efficiency in the 76cm (30 in) diameter steam line the air/water model tests show a) that the 51cm (20in) diameter catchpots should be at least 30cm (12in) deep, or b) baffles be placed as described.

2) For catchpots in which the diameter is equal to the pipe diameter, the depth should be greater than 0.25D but depths in the range 0.45D to 0.55D should be avoided. Within this range, high pressure loss will occur.

3) Baffles for these larger catchpots improve the efficiency in the same way as for the smaller designs.

4) These air/water tests, although not simulating the correct flow non-dimensional parameter, are expected to give a qualitative picture of the flow and enable an assessment to be made of the likely performance of a number of designs.

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