TWO PHASE PRESSURE OROP MEASUREMENTS ON A GEOTHERMAL PIPELINE

Derek H. Freeston, Keng C. Lee

University of Auckland
New Zealand

ABSTRACT

This paper details an investigation of two phase, water/steam, pressure drop on a 10 cm diameter test loop sited on the Uairakel (NZ) steam field. Measurements of straight pipe and duct component losses are presented using a liquid velocity derived from a void fraction correlation. A horizontal flow straight pipe correlation is presented based on data from a 20 cm diameter pipeline and component pressure losses are demonstrated to be of such a magnitude as to be significant In a two phase pipeline reticulation system.

INTRODUCTION

In the majority of wet geothermal fields, the phases are separated at the well head and the vapour phase reticulated to the power statlon. Takahashi et al (1970) and Jams (1968) discuss the economics, advantages and disadvantages of a two phase transmission system. The authors state that such a system has potentially more power, improved economics, savings in surface drainage, less noise and no discharge to atmosphere. The mixture would be handled as if it were a sIngle phase fluid and would be piped from the well 'head to an overland line for transmission to the power station. Here it would be separated in a number of stages In series, the steam from each stage entering the turblne. The final reject water is then at one location instead of at each bore. James (1968) compared the exlsting Wairakel design producing 160 MW wlth that of a system, designed for an optimum well head pressure of 6.7 bar, employing steam water reticualtion and demonstrated an increase in power of the order of 90% depending upon the number of stages of separation.

The deslgn of a safe and efficient pipe network for carrying a one component two phase mixture over long distances requires information describIng the structure of the flow, the expected pressure drop and quality changes occurring due to the perturbations caused by various components and fittings. Pressure and quality gradients are not the'only two phase system design considerations. Experience with sIngle phase systems showed that a slug of water travelling-in a high velocity vapour stream or a collapsing pocket of vapour in a liquid stream can cause severe flow instabilities. It is essential to ensure that thls type of condition does not occur in a two phase reticulation system. Most investigators agree that two phase lines should be designed for flow condttlons in the annular mist regime to minimise the possibility of encountering slug flow.

Takahashl et al (1970) describes wrk on stability and pressure drop utllising a 20.13 cm diameter horizontal and inclined plpe wlth appropriate bends. The mixture flow pattern was estimated to be annular dispersed and was stable for all flow conditions tested, without slgns of water hammer or vlbratlon. The experimental data for the straight pipe correlated reasonably well wlth the Lockhart-Martinelli formulation and the bend losses were correlated using a homogeneous model. James et al (1970) presents measurements on a 30.48 cm diameter two phase pipeline at Uairakel and like the Japanese tests little vibration occurred. Harrison (1975) reports measurements he made on a 30.48 cm line and also discusses data collected by N.Z. Ministry of Works and Development at Wairakei and Broadlands. Despite these sets of data, most of the two phase flow pressure drop correlations that exist in the literature are based on measurements in small diaseter (less than 5 cm) boiler type pipes and very often with air-water mixtures, i.e. a two component flow. Seven frequently used prediction methods are compared with a wide range of experlmental adiabatic data for straight pipes in a recently Issued set of data Items by the Engineering Science Data Unit. A data bank of 2210 measurements was used to provide a statistical method of selection for the most appropriate correlation to use for a particular set of circumstances. 58% of the data was for two component fluid flow and 80% of the measurements were taken with pipe diameters in the 0.5 to 4.6 cm range.

Most of this type of information is not suitable for predicting the performance through large dlameter pipelines of a geothermal fluid. A test loop using 10 cm diameter pipe was constructed on bore 207 at Wairakei to obtain straight pipe and duct component pressure losses and this paper describes some of these measurements.

EXPERIMENTAL FACILITY

Bore 207 at Wairakei is sited on the extremity of the field. It has a maximum output of about 40 kg/s at a well head quality of 20% and a pressure of 860 kPa. The no flow well head pressure is 2700 kPa while the maximun operating pressure is limited, by a bursting disc, to 1700 kPa. A schematic of the rig is shown in Figure 1. The two phase well head mixture is first separated in a conventional cyclone separator, the water flowing under gravity into two holding drums at the bottom, with the steam phase extracted from the top of the cyclone. 20 cm diameter pipes can take the separate phases to the two silencers as shown. Water Is injected into the 20 cm diameter steam line and allowed to mix before passing through a sudden contraction down to the 10 cm diameter loop. Flow rates are controlled by gate valves and the two phases are metered separately by orifice plates before they are recombined.

The test loop consists of a 'U' bend and an 'S' bend configuration in which the spacer length can be varied. These are followed by a 45 degree 'S' bend combination. After a 6 m length of straight pipe a single right angled bend leads to a further 6 m of straight pipe before a long radius ratio (90 $\frac{R}{D}$) segmented bend. This bend is a model of a bend in a recently commissioned 46 cm line at Kawerau. A straight 18 metres long section ends at a tee, one arm of which goes to the horizontal silencer, the other to a straight section which can be inclined with discharge to atmosphere. The rig is mounted 30 cm above ground level and is unlagged. The pipework and fittings are of standard steam quallty and are butt welded together, except at the combined bend section where flanges are used to allow the use of variable spacer lengths..

Pressures were measured on calibrated Bourdon gauges with water or mercury manometers for the measurement of pressure differences. Pressure tappings (65) around the loop, terminate in a valve to which is attached a condensation pot. A soft copper line full of water was then run to the manometer from the pot.

RESULTS AND OISCUSSION

The initial test runs were done with dry steam and established that the pipes relative roughness of 0.001 to .002 was typical for a 10 cm diameter lightly rusted uncoated steel pipe (ESW data sheet 66027).

Table 1.

Separator Pressure	6.5 to 11 bar
Steam Flow	0.47 to 1.74 kg/s
Water Flow	0.54 to 11.3 kg/s
Quality	0.05 to 0.33

Table 1 illustrates the range of the major variables covered during the test programme and the superficial velocity boundaries are sketched on a Mandhane et al (1974) chart (Figure 2).

Harrison (1975)' developed, from the one dimensional separated flow model, a correlation based on conventional heat transfer and shear stress data together with a void fraction correlation based on the work of Butterworth (1975). The indices for the void fraction correlation were determined by fitting experimental measurements on a 20 cm geothermal pipeline to the model. Figure 3 shows this correlation tested against the experlmental data obtained from the 10 cm loop. The data is replotted as a function of llquid phase velocity In Figure 4. This curve Is used as the basis for calculating losses around the various fittings. The pressure losses for three of the fittings are shown in Figures 5 and 6. In each case the loss is expressed as an equivalent length of straight pipe in metres or number of diameters. Figure 5 gives data for the 4:1 area ratio contraction and that for the 45 degree 'S' configuration The 'U' bend data are presented on Figure 6. The interaction affects are clear ly seen and show similar trends to those experienced with single phase flows. As the spacer length Increases the additional loss for the 'U' could be expected to approach that of two bends in tsolation, and as for single phase flow, the minimum loss occurs when the bends are separated by a spacer length of two diameters. The 45 degree S configuration in which the bends are separated by a spacer 20 diameters long, has less loss than all three combinations (2, 5 and 10 length/diameter) tested with 90 degree bends.

The Tee bend, which in effect is a mitred bend, has a higher loss than the 90 degree elbow which is not surprising. However using a 90 degree elbow and lengths of straight pipe to achieve the change of direction between two points gives marginally less loss than the long radius ratio bend. This data demonstrates that the magnitude of secondary losses in a two phase reticulation system are significant and should be accounted for at the design stage.

ACKNOWLEDGEMENTS

This work was sponsored by the New Zealand Energy and Research Committee whose support is gratefully acknowledged. In addition D.S.I.R., M.W.D. and N.Z.E. staff at Wairakei contributed tine, material and expertise to this project.

REFERENCES

Baker, O., 1954, Design of pipelines for simultaneous flow of oil and gas. Oil and Gas Journal Vo. 53, No. 12.

Butterworth, D.A., 1975, A comparison of some void fraction relationship for concurrent gas-liquid flow. Int. 3. Multiphase Flow, Vol.1.

Harrison, R.F., 1975, Methods for the analysts of geothermal two phase flows. M.E. thesis University of Auckland.

Harrlson, R.F., 1977, Geothermal two phase pipe flow. Geothermal Circular Chemistry Division DSIR Wairakei, Sept. 1977.

Jams, R., 1968, Second generation geothermal power. N.Z. Engineering Vol. 23.

Jams, R., McDowell, GD, Allen, M.D., 1970, Flow of steam water mixtures through a 12 inch diameter pipeline: test results. Proc. UN Symposium on the Development and Utilisation of Geothermal Resources, Pisa.

Mandhane, JM, Gregory, GA, Aziz, K, 1974, A flow pattern map for gas liquid flow in horizontal pipes. Int. J. Multiphasc Flow, Vol. 1.

Takahashi, Y., Hayashida, T., Soezima, S.,

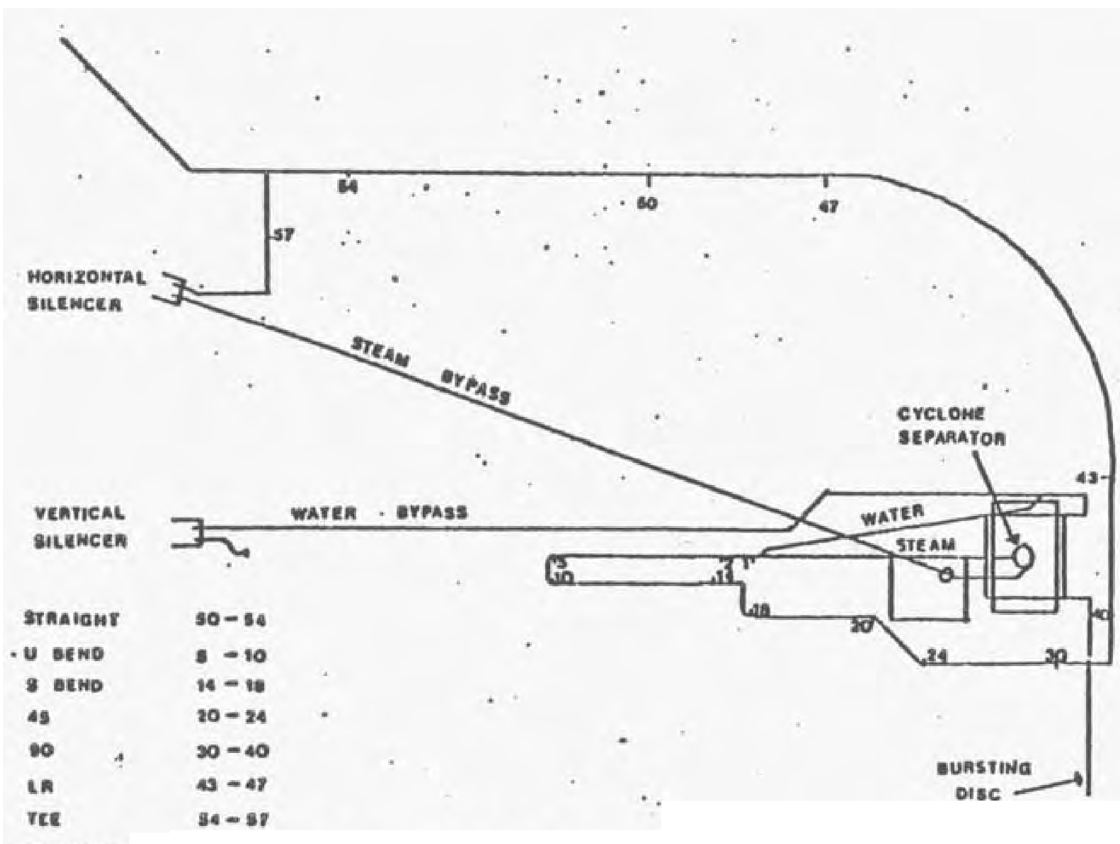
Aramaki, S, Soda, M., 1970, An experiment on pipeline transportation of steam water mixtures at Otaki Geothermal Field. Proc. UN Symposium on the Development and Utilisation of Geothermal Resources, Pisa.

Engineering Science Data Unit

Data Item 66027, 1966, Friction losses for fully developed flow in straight pipes.

Data Item 68035, 1968, Interaction factors for calculating pressure losses for incompressible flow in some combinations of two bends in series.

Data Item 76018, 1976, The frictional component of pressure gradlent for two phase gas or vapour/liquid flow through straight pipes.



Schematic of Test Rig, Wairakel FIGURE 1

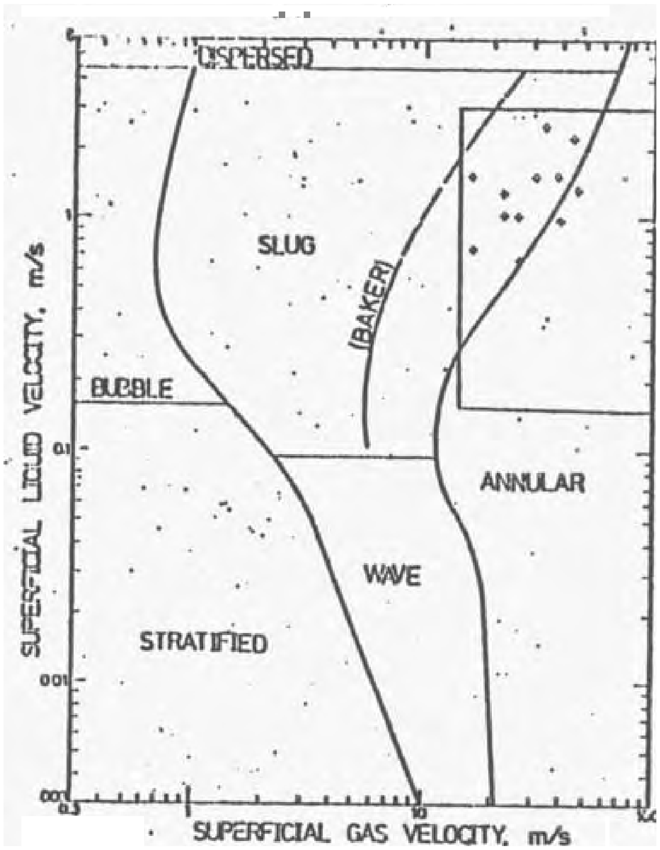


Fig. 2 Flow Pattern Map after Mandhane et al (1974)

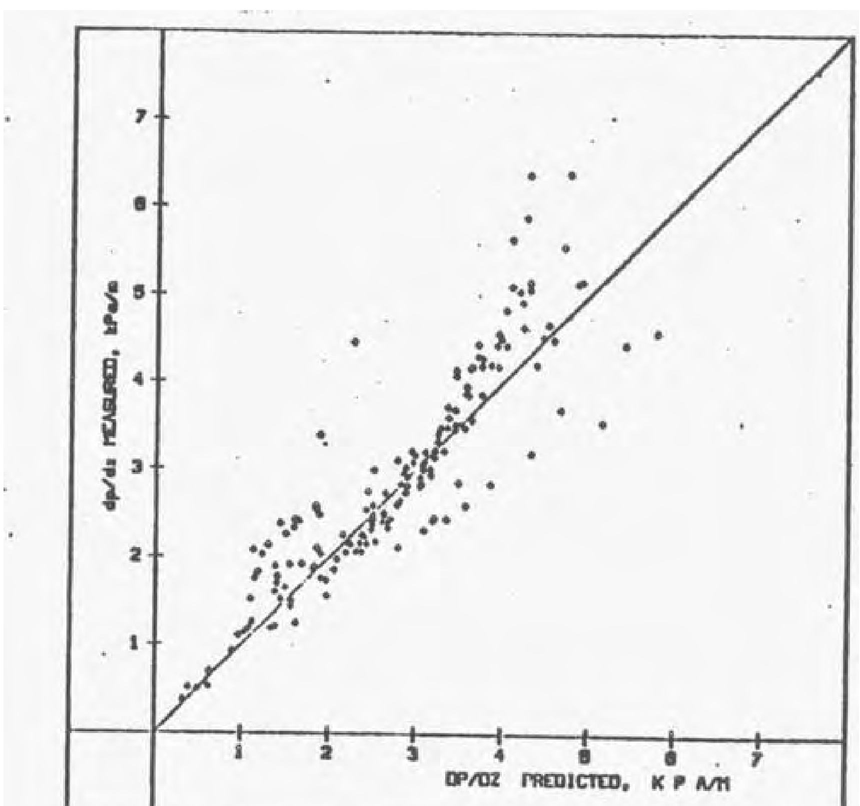


Fig. 3 Experimental Data Tested against Harrison (1975) Correlation

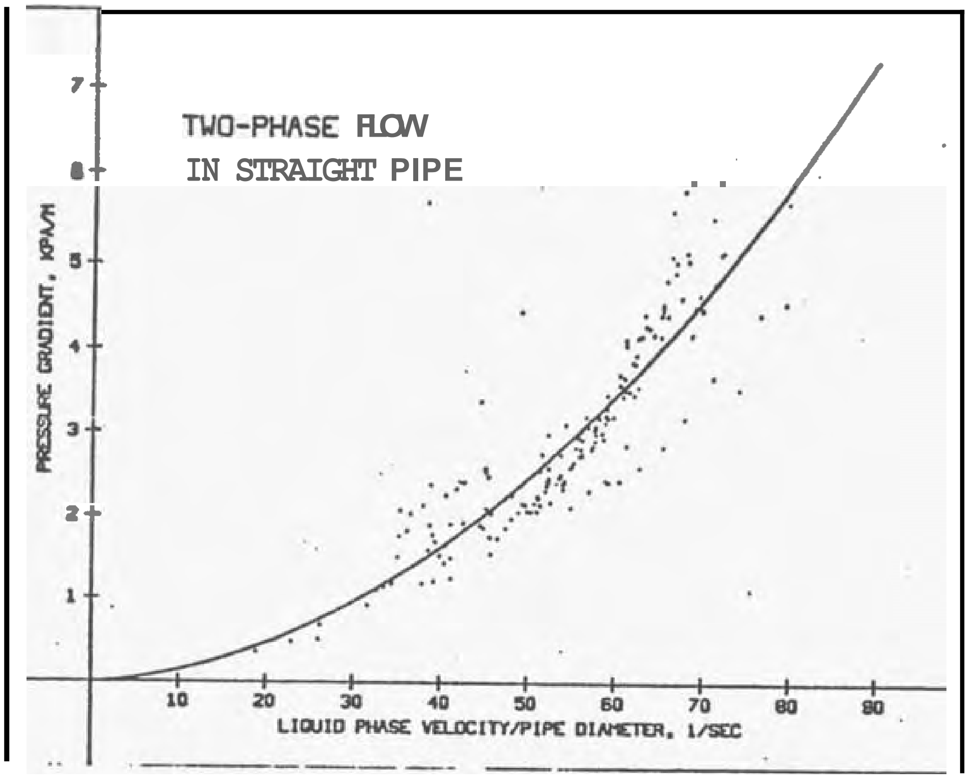


Fig. 4 - Straight Pipe Pressure Loss

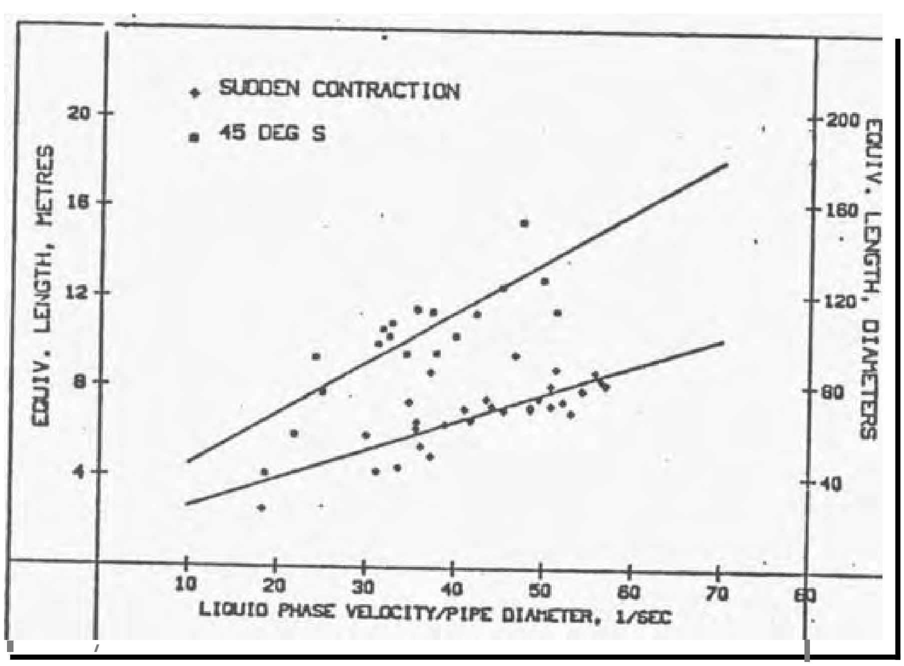


Fig. 5 Sudden Contraction and 45 Degree Bend Pressure Loss

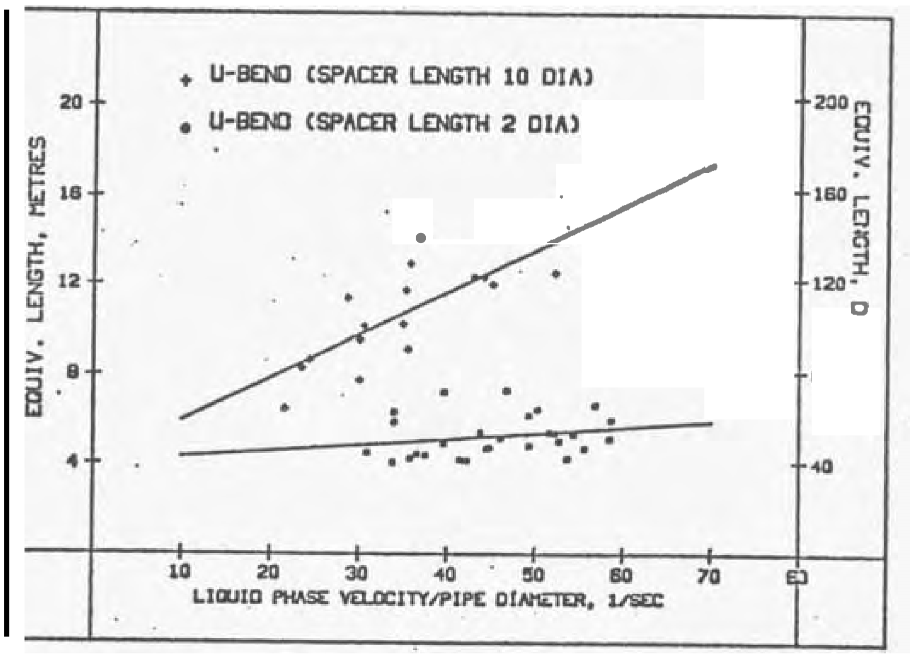


Fig. 6 U Bend Pressure loss