PHYSICAL RESEARCH AT GRACEFIELD 1953 TO 1955 "A PERSONAL VIEW"

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SUMMARY

The personnel involved with physical research into geothermal problems from 1953 to 1955 are introduced. Three experiments are discussed:

(1) The use of radioactive absorbtion methods for measuring the dryness fraction of steam, water mixtures in pipes.

(2) The measurement of the permeability of rocks to water and gas.

(3) The construction of a two-phase flow test rig for the study of the flow of air water mixtures in transparent pipes.

INTRODUCTION

During 1953,1954 and 1955, the major geothermal problems involving physicists were those involved with the flow of geothermal fluids through pipes and rocks. In November 1953 I was taken on as a technician by John Banwell in the geothermal section of the Dominion Physical Laboratory at Gracefield. John was the Senior Research Physicist at DPL at the time, and under his wing he had, as well as the Geothermal Section, the Heat Transfer and Nuclear Physics Section. The geothermal section at that time consisted of 3 engineers, Don Anson (Section Head), Murray Horlor, and Willem Stuiver, with myself as technician. Geoff Thompson was at Rotorua, and Dave Currie at Taupo, both physicists. Roy Benseman, a physicist, ran the heat transfer section, which consisted of himself and John Mautener, a technician. Lindon Bastings (one of Rutherford's protégés) was also around at the time, but I do not know what research he was engaged on. Gordon Ferguson headed the Nuclear Physics section, which consisted of George Page, *Graham* McAllum, Rudy Belin and Fred Knox, physicists, and Ken Bargh and Brian Shilton, technicians. (Gordon was soon to become well known, along with Athol Rafter, as the developers of the CO_2 gas method of C^{14} dating).

With the exception of Geoff and Dave, we all worked in numbers 1 and 2 sheds at Gracefield.

1. BETA AND GAMMA RAY ABSORBTION METHODS

At the time my work oscillated between assisting the engineers in the geothermal section and the scientists in the Nuclear Physics Section. My first job was to assist Rudy Belin and Fred Knox with experiments they were Carrying out to find out the dryness fraction of stream in pipes using beta and gamma ray absorbtion.

The idea was that if a radioactive source was placed on one side of a pipe, and a geiger counter Sensor on the other, that gamma rays would go straight through the steel of the pipe and be absorbed by water droplets. Thus the count rate would be lower when a pipe was full of water than when empty. For Beta rays special small windows in the pipes had to be constructed because of the tendency of the steel to absorb the Beta rays. To calibrate the device a section of 150 mm ID pipe was packed with 10 mm square section wooden rods (those next to the pipe wall were specially shaped to snugly fit the pipe). The wood chosen for the rods was lignum vitae, which has a density slightly greater than that of water, about 1.2 tonnes/m^3.

After experiments on the section of pipe with various numbers of rods in it to represent various amounts of water, the gamma and beta ray devices were tested using various measured fractions of steam water mixtures at Bore 9, Wairakei.

Principally the gamma ray method was used for measuring the water distribution within a cyclone separator. The beta ray system was used for measuring the water distribution and content in 4 inch horizontal pipes carrying steam water mixtures. Figure 1 shows Rudy Belin and Fred Knox testing the Beta Ray device at Bore 9, Wairakei.

I do not know why these experiments were discontinued, the methods seemed promising at the time. However, with the resignation of Rudy Belin in 1955, combined perhaps with dangers of using radioactive sources, the project seemed to lapse.

2. ROCK PERMEABILITY EXPERIMENTS

The next project I was involved with, was the measurement of rock permeability. This was under the direction of Dr

Fig. 1: Rudy Belin and Fred Knox testing the Beta Ray device at Bore 9 Wairakei.

Don Anson. Previous work by Dr T S E Thomas had shown that although the permeability (in Darcys) should have been constant for a given rock specimen regardless of the type of fluid passed through it, permeabilities to air were much greater than to water (N.B. a material having the permeability of 1 Darcy is one in which a cm^3 of fluid with a viscosity of 1 centipoise (water at 20°C) will pass through a cm^2 of cross sectional area, 1 cm thick in 1 second at a pressure of 1 atmosphere).

Don designed, and I constructed, an apparatus which could pass deairated water or dry air through a cylindrical rock specimen. Figure 2. A series of tests were carried out and we struck the same problem that Thomas had struck. Some reading of various text books showed us that the effect of different permeabilities for air and water was probably caused by the Jamin effect. Jamin in 1860 observed that in a capillary tube containing a large number of detached drops interspersed with gas, a large difference in pressure could exist between the ends of the tube without any appreciable movement of the drops along the tube. Essentially, one phase, liquid, blocks the flow of the other phase, gas, or vice versa. Another explanation for the greater permeability to air than water is that some of the minerals in the rock, particularly clay minerals, could swell and be hydrated when saturated with water and so make the pores smaller, thus decreasing permeability. After carrying out numerous experiments on six different rock types, it was decided to abandon the tests for the following reasons:

(1) The permeabilities of the samples were much too low (a maximum of about 1.6 x 10^{-3} Darcys) to sustain the flows coming from the Wairakei bores. Which lead to the realisation that the permeability of the Wairakei Borefield was essentially macro fracture permeability.

(2) The uncertainties of the two phase effects on permeability decreased the usefulness of using the values obtained in any reservoir engineering calculations.

About this time I also was engaged in making density measurements and porosity calculations of some 50 odd rock samples from Wairakei bores, so that John Banwell could make some estimate of the heat stored in the part of the Wairakei borefield which was then being exploited, namely the upper 500 metres.

3. TWO PHASE FLOW TEST RIG

One of the many problems being encountered by engineers at this time was the behaviour of water steam mixtures in the plumbing associated with geothermal bores, namely straight pipes, U-bends, U-bend separators and cyclones. To Willem Stuiver fell the task of designing a rig which used mixtures of air and water flowing through perspex plumbing so that the behaviour of these mixtures could be observed and photographed. My task was to assemble the rig, and get it running. The various components were made with typical skill and precision by the staff of the DPL workshops. For me this was quite a major job.

The rig consisted of a high capacity fan driven by a 7.5 hp (10 Kw) variable speed electric motor capable of delivering 2400 CFM (1.13 m^3/sec) and pressures up to 28 inch (0.71 m) WG into an 8 inch diameter pipe. Water was injected into the air flow by high pressure constant head (Mono) pump capable of delivering 1000 GPH (1.25 l/s) at 150 psi (10 bar) and driven by a 3 hp (4 Kw) electric motor. The water passed through a 5 ft (1.52 m) straight 1" (25 mm) pipe to a measuring venturi via a diffuser to a distributor which split the flow into twelve tubes leading to an injector into the air system. A line diagram and photograph of the rig set up for the first experiments using a straight pipe and a U-bend is shown in Figures 3 and 4 respectively.

The experiments with the rig were very successful and eventually after Willem left to take up a position overseas, it was handed over to the Chemical Engineering section of the Dominion Laboratory who carried out tests on transparent cyclones with it.

References

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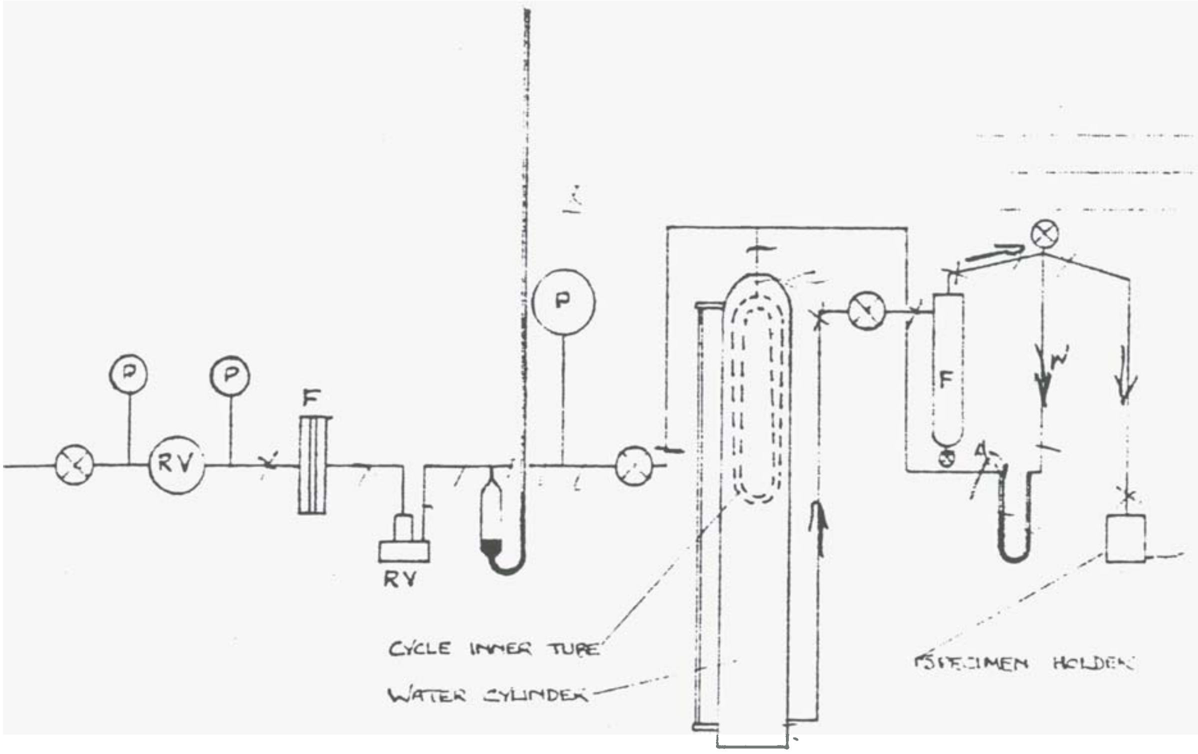

Fig. 2a: Apparatus for measuring permeability to water.

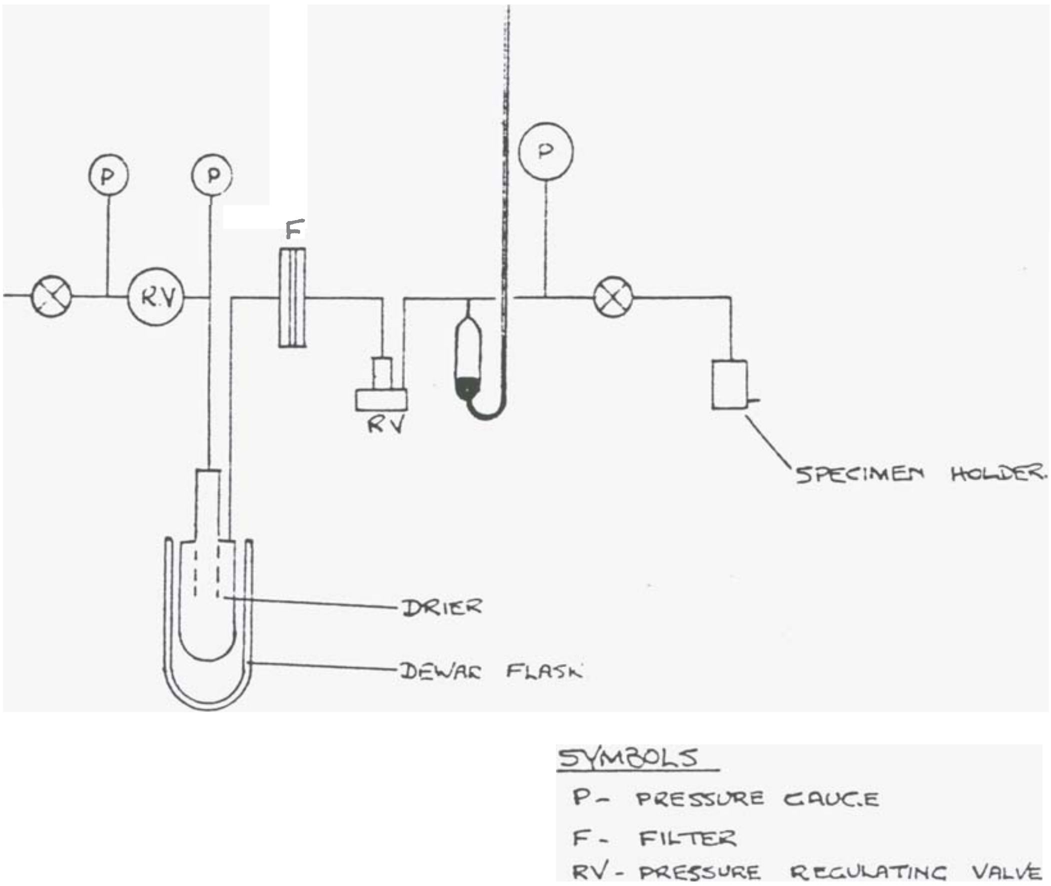

Fig. 2b: Apparatus for measuring permeability to air.

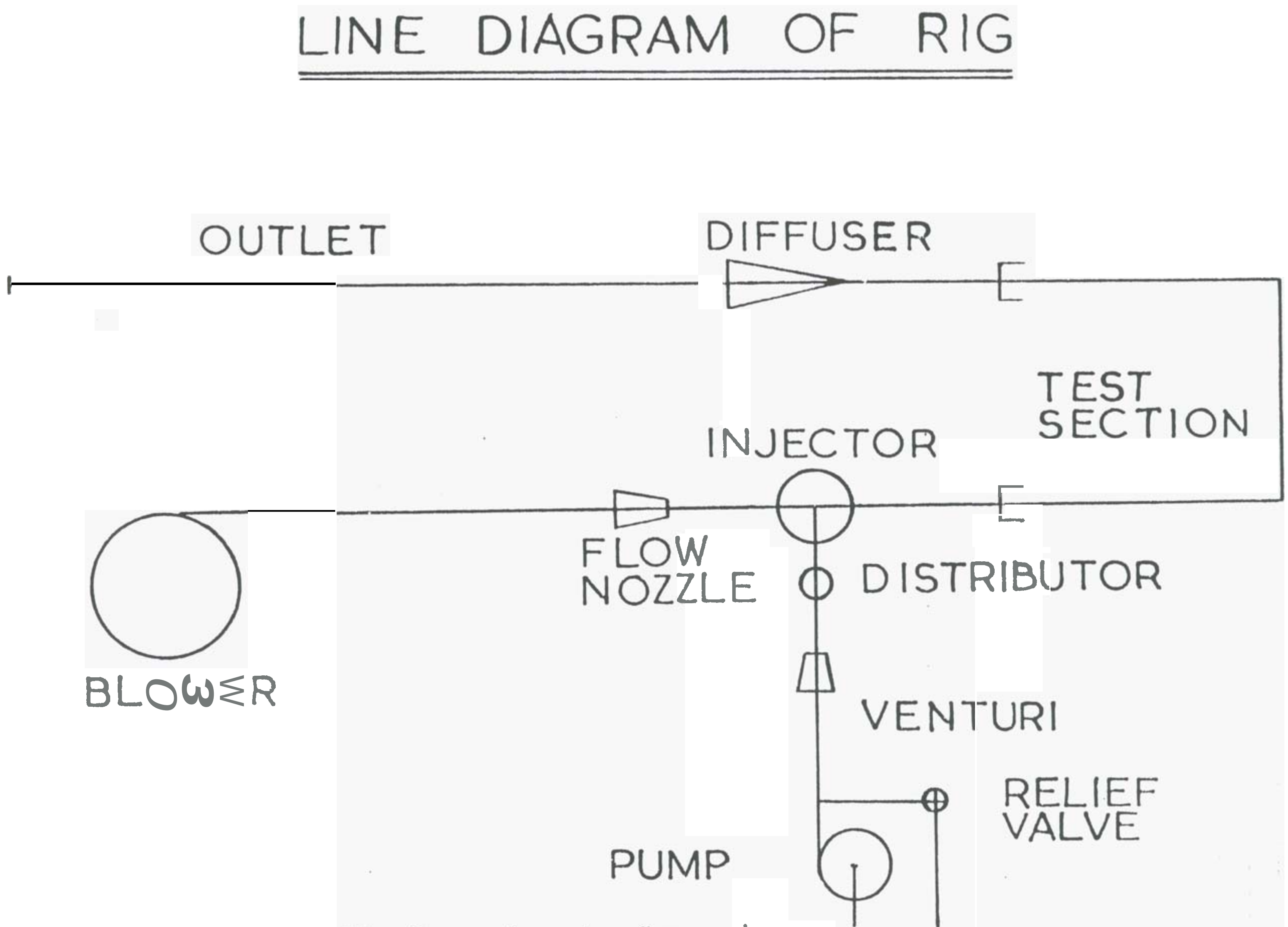

Fig. 3: Line diagram of two phase flow test rig.

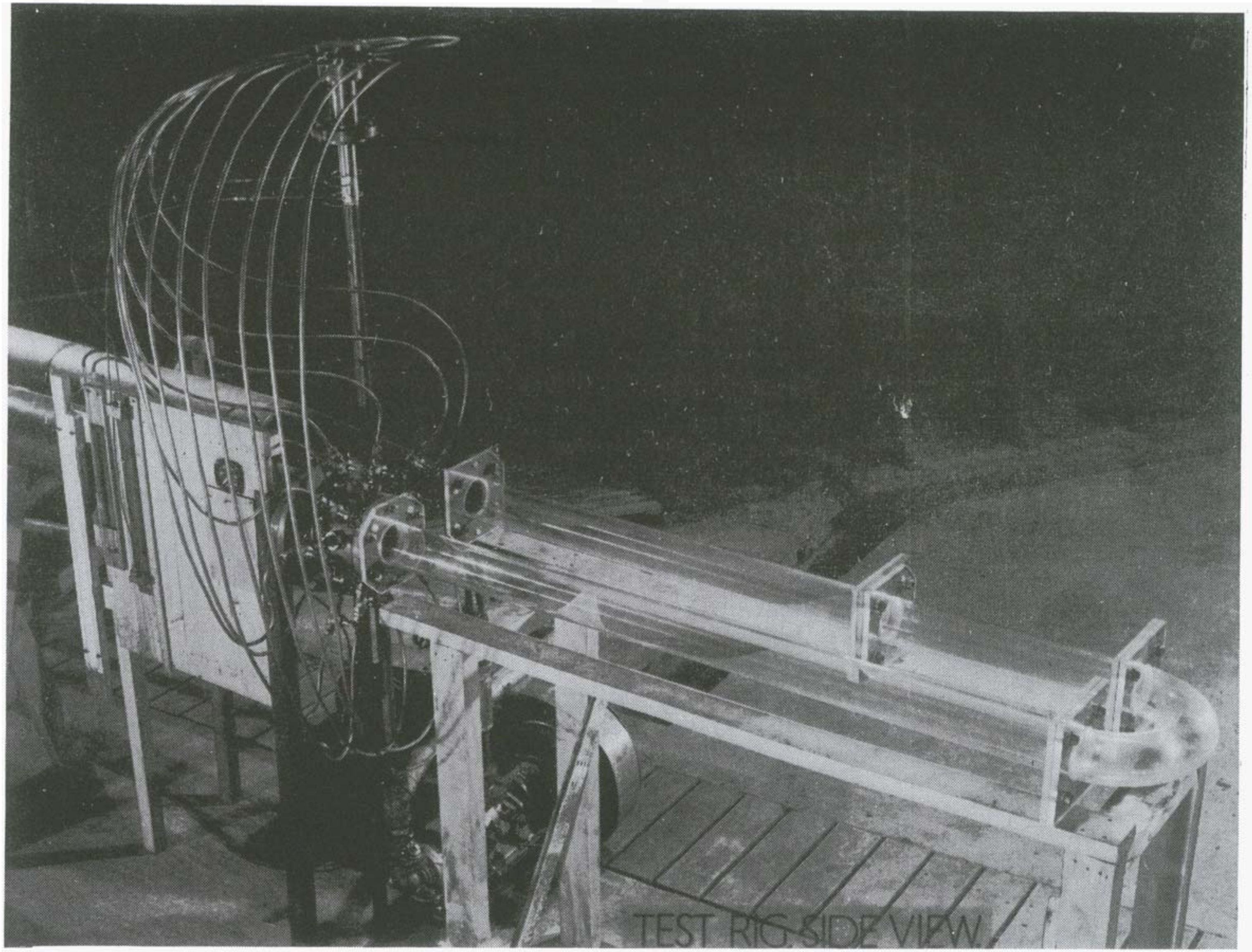

Fig. 4: Side View of two phase flow test rig.