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TWO-PHASE FLOW IN GEOTHERMAL SYSTEMS

BI-MONTHLY PROGRESS REPORT

for the period

December 1, 1984-January 31, 1985

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Prepared for
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I. CONTRACT MANAGEMENT SUMMARY REPORT

During December 1984 and January 1985, the research team consisted of the following individuals:

Dr. P. F. Maeder
 Dr. J. Kestin
 Dr. R. DiPippo
 Mr. D. E. Nikitopoulos
 Mr. R. N. Laoulache
 Mr. R. Follansbee

II. TECHNICAL PROGRESS REPORT

A. Meetings and Related Items of Interest

1. Dr. R. DiPippo participated in the Third Meeting of the Advisory Panel on the Miravalles Geothermal Project in San Jose, Costa Rica, from January 7-11, 1985. (No expense to contract).
2. Dr. J. Kestin is spending six months (January-June 1985) at the Institute for Advanced Study (Wissenschaftskolleg) in the Federal Republic of Germany.

B. Operation of Test Facility

1. Experimental results

The second series of measurements is now complete, and a summary of the results for the first and second series is shown in the attached figures.

By way of review, the two series were characterized by the following conditions:

	<u>Series 1</u>	<u>Series 2</u>
Flash Mach number	0.498	0.331
Flash Froude number	1.62	1.60
Flash Reynolds number	2.38×10^5	2.69×10^5

The purpose of the first two series was to explore the effect of the flash Mach number on the two-phase flow. The flash Froude numbers are essentially constant for the two series, and the Reynolds numbers are well into the turbulent regime where the difference of 13% should not influence the flow greatly.

In Figure 1 we show the reduced energy change, ΔE_R , versus the specific volume ratio, v/v_f . The ΔE_R is defined as

$$\Delta E_R = \frac{\text{sum of kinetic and dissipated energy for 2-phase flow}}{\text{dissipated energy for liquid-only flow}}$$

The data points span a range from low values of v/v_f (close to the flash point) to high values of v/v_f (close to the choking point). It is very difficult to measure very close to either extreme. However, the data extrapolate correctly to the flash point where we must have $\Delta E_R = 1$ and $v/v_f = 1$. At low v/v_f , before the kinetic and dissipation effects have built up, the flow is dominated by the gravitational effects (hydrostatic effect). This is governed by the Froude number. Since the two series were run at the same Froude number, we see no difference between the two runs up to $v/v_f = 7$, even though the flash Mach numbers differ by about 25%.

As the flows go to higher values of v/v_f , the kinetic energy effects become relatively important, the local Froude number increases, and the inertial forces gain relative to the gravitational forces. The compressibility (Mach number) effects become important; the data points thus diverge.

The data are plotted in Figure 2 as the reduced pressure difference, ΔP_R , versus v/v_f . The ΔP_R is defined as

$$\Delta P_R = \frac{P_{sat}^* - P_{2\text{-phase}}}{P_{sat}^* - P_{\text{liquid-only}}},$$

where P_{sat}^* is the saturation pressure corresponding to the flash temperature. The data should extrapolate to $\Delta P_R = 1$ at $v/v_f = 1$ (off the graph). It should be noted that $\Delta P_R > 1$ for the data taken so far, i.e., the pressure drop in vertical two-phase flow is less than that in vertical liquid-only flow. Indeed, immediately after the flash point, the ΔP_R drops dramatically mainly because of the steep reduction in the hydrostatic component caused by the evaporation of the liquid and the lower fluid density in the two-phase condition. At a certain point downstream, however, the accelerational and frictional terms become important and the curve turns up, but even close to the point of choking, the pressure drop in the two-phase flow is still considerably less than for the case of liquid-only flow. The compressibility (Mach number) effect is not noticeable at low v/v_f (as before), but becomes quite strong for v/v_f greater than about 7.

Figure 3 presents the results in the form of the Euler number, Eu , as a function of the dimensionless distance along the pipe measured from the flash horizon. The Eu is defined as

$$Eu = - \frac{P_{sat}^* - P_{2\text{-phase}}}{0.5 \cdot \rho_f^* (w_f^*)^2},$$

where the denominator is the dynamic pressure of the liquid under the flash conditions. The abscissa is the distance

measured in terms of pipe diameters, z/D . The two straight lines, solid and broken, represent the behavior that would be expected for liquid flow at $Ma^* = 0.331$ and 0.498 , respectively. This pressure drop would be dominated by the hydrostatic term with a small contribution from the frictional effects. The data at low v/v_f fall smartly on the lines; the points in the upper left-hand corner are at $Eu = 0$ and $z/D = 0$.

There are two notable effects evident in Figure 3. The first is the fact that the actual Euler numbers are smaller in magnitude than the liquid values at any given z/D beyond about 40. This has already been discussed. The second point is that the length of pipe from flash to choking is sharply reduced when the flash Mach number is increased. A 50% increase in Ma^* causes a 75% reduction in the length to choking.

2. Quick-closing valve

The construction of the second quick-closing valve (QCV) is proceeding according to schedule.

3. Next series of measurements

The third series of tests will be designed to investigate the effect of the flash Froude number on two-phase flow. The test conditions will be as follows:

Series 3

Flash Mach number	0.331
Flash Froude number	1.00
Flash Reynolds number	1.4×10^5

C. Publications

The research team wrote abstracts for two technical papers for submittal to reviewers for the 1985 Winter Annual Meeting of the ASME. Both abstracts were accepted, and the full papers are in preparation. The papers are entitled:

"A Facility for the Experimental Investigation of Single Substance Two Phase Flow" by P. F. Maeder, D. A. Dickinson, D. E. Nikitopoulos and R. DiPippo.

"Modelling of Flashing Flows Using Similarity Fluids" by P. F. Maeder, R. DiPippo, D. A. Dickinson and D. E. Nikitopoulos.

FIGURE 1

FIGURE 2

FIGURE 3