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TWO PHASE FLOW IN GEOTHERMAL SYSTEMS

BI-MONTHLY PROGRESS REPORT

for the period

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I. RESEARCH STAFF

During the reporting period, the project team consisted of the following individuals:

Dr. Paul F. Maeder, Professor of Engineering

Dr. Joseph Kestin, Professor of Engineering (Research)

Dr. Ronald DiPippo, Adjunct Professor of Engineering (Research)

Mr. Dimitris E. Nikitopoulos, Research Assistant

Mr. Raymond N. Laoulache, Research Assistant

Mr. Roger Follansbee, Senior Technical Assistant

II. TEST PLAN

The quick-closing valves (QCVs) have been tested in the flow facility and perform according to design. Several preliminary test runs have been conducted to permit us to adopt an appropriate routine for conducting the actual test measurements. The plan which we will be using in conjunction with the QCVs is as follows:

- 1 - Record 8 scans with test section filled with R-114 vapor only. (A scan is a complete record of all outputs of the test section instruments.)
- 2 - Open gate valve (located downstream of test section) to a pre-determined position.
- 3 - Open both butterfly isolation valves, thereby initiating flow.
- 4 - Wait 15 seconds.
- 5 - Record 8 scans.
- 6 - Close both QCVs and the downstream (or upper) butterfly isolation valve only. (Closing time is about 35 msec for QCVs and 2 sec for butterfly valves.)
- 7 - Observe liquid level in section between QCVs and measure the "hold up" manually.

- 8 - Open QCVs and the upper butterfly isolation valve.
- 9 - Repeat Steps 4 to 8 five times.
- 10 - Empty test section and store R-114 in dump tank.

For the next two months, we will conduct a series of measurements, Series 3A, under the same conditions as for Series 3, namely:

$$Ma^* = 0.33$$

$$Fr^* = 1.00$$

$$Re^* = 140000$$

$$\dot{m} = 2 \text{ kg/s.}$$

One purpose of this series (Series 3A) will be to compare the previously determined average void fractions measured over the entire length of the test section with the local void fraction to be obtained with the QCVs. Also we will compare the results of the previous series with the new series to see the effect, if any, of the two different data acquisition methods.

III. EXPERIMENTAL RESULTS

Three runs were conducted to test the repeatability of measured outputs under the new routine. Runs were performed at roughly the same flashing Mach number Ma^* , flashing Froude number Fr^* , and flashing Reynolds number Re^* . The values of these important dimensionless variables were as follows:

	RUN 1	RUN 2	RUN 3
Flash Mach no., Ma^*	.320	.323	.316
Flash Froude no., Fr^*	.975	.975	.963
Flash Reynolds no., Re^*	139,346	138,931	137,673

An effort was made to maintain the same conditions for all runs; however, Run 3 had slightly lower conditions than Runs 1 and 2. The average relative deviation of Ma^* , Fr^* , and Re^* from Series 3 are 3%, 2.9%, and 1%, respectively.

In these three runs, the following variables were measured:

Venturi temperature,	$T_{vti}/^{\circ}C$
Venturi pressure,	P_{vti}/kPa
Stagnation temperature,	$T_{stg}/^{\circ}C$
Stagnation pressure,	T_{stg}/kPa
Test section temperature (before first QCV),	$\Omega 4/^{\circ}C$
Test section temperature (after second QCV),	$\Omega 2/^{\circ}C$

A total of 48 scans were measured for each of the variables listed above. However, the recording of the 48 scans was not continuous. The two-phase flow was interrupted immediately after the 8th scan by closing the QCVs, allowing the "hold-up" to be measured.

Photographs 1, 2, and 3 illustrate the flow through the section between the QCVs. The lower (i.e., upstream) QCV is visible; the upper QCV is just out of view at the top. Photo 1 shows the flow before closure of the valves; Photo 2 was taken just a fraction of a second after the QCVs were shut; Photo 3 shows the situation after the phases have separated. The hold-up is calculated from the length of the liquid column and the known internal geometry of the test section.

The flow is then allowed to resume and the scheme repeated five times. The resumption of the flow after each 8 scans is evident from the measurements of $\Omega 4$ and $\Omega 2$ in Figures 1, 2, and 3. The periodicity of the results is well established at the onset of 17th scan. Therefore it was decided to reject the first 16 scans since they represent transients. The interruption and resumption of the flow did not affect the mass flow

rate (m/t). This can be seen clearly in Figures 1, 2, and 3.

Figures 4, 5, and 6 show how the transient in the stagnation temperature vanishes after the 17th scan, with this temperature becoming indistinguishable from that of the venturi. As for the stagnation pressure, control is not as perfect as for temperature. However, stagnation pressure measurements are acceptably constant within their standard deviations.

Upon inspecting Ω_4 and Ω_2 in Figures 1, 2, and 3, one observes that temperatures reach a steady-state during the last 4 scans of each 8-scan period. Therefore it was decided to use the following scans to obtain averaged data:

Scans 29 to 32,
Scans 37 to 40, and
Scans 45 to 48.

These averaged variables are printed out for the three runs in Tables 1, 2, and 3, respectively.

The average **void fraction** for the three runs were found to be 0.896, 0.90, and 0.895, respectively. The maximum error in the measurement of the **hold-up** is about 5%. The **slip** defined as the ratio of vapor velocity to liquid velocity was calculated; the average slip for the three runs turned out to be $\sigma = 2.80$.

Therefore, the use of the QCVs appears to be a very accurate method for measuring the hold-up and determining the average slip in two-phase flow.

IV. MEETINGS

1. Dr. R. DiPippo participated in the First Meeting of the Technical Advisory Committee for the U.S.A.I.D. Central America Energy Resources Project at Los Alamos National Laboratory on October 7 - 8, 1985. (No expense to contract.)

PHOTOGRAPH 1

Two-Phase Flow [Photos by R. DiPippo]

PHOTOGRAPH 2

Condition Just After Shutting QCVs

PHOTOGRAPH 3

Condition After Phase Separation

Plot of Q2, Q4, and m for Run 1

FIGURE 1

Plot of Q2, Q4, and m for Run 2

FIGURE 2

FIGURE 3

Plot of 02, 04, and m for Run 3

FIGURE 5

Plot of Psta, Tsta, and Tvti for Run 2

Plot of Pstg, Tstg, and Tvti for Run 3

FIGURE 6

```

*****
*** AVERAGED DATA ***
*** FROM SCAN 29 TO SCAN 32 ***
*****11/11B***

```

Time for 4 scans = 4 s

VAR	MEAN	S-DV	M-DV:SC	ROW
m/t	2.06	.00	.00:31	1
Tvti	18.39	.03	.04:29	2
Psta	264.78	.79	1.03:30	3
Tsta	18.44	.04	.04:32	4
P30	176.18	1.13	1.38:29	5
Q4	3.46	.09	.11:29	6
Q2	2.29	.04	.05:29	7

```

*****
*** AVERAGED DATA ***
*** FROM SCAN 37 TO SCAN 40 ***
*****11/11B***

```

Time for 4 scans = 4 s

VAR	MEAN	S-DV	M-DV:SC	ROW
m/t	2.06	.00	.00:40	1
Tvti	18.40	0.00	0.00:37	2
Psta	263.96	1.04	1.44:40	3
Tsta	18.47	.03	.03:37	4
P30	176.18	1.13	1.38:37	5
Q4	3.33	.09	.11:40	6
Q2	2.21	.09	.10:40	7

```

*****
*** AVERAGED DATA ***
*** FROM SCAN 45 TO SCAN 48 ***
*****11/11B***

```

Time for 4 scans = 4 s

VAR	MEAN	S-DV	M-DV:SC	ROW
m/t	2.05	0.00	0.00:45	1
Tvti	18.47	.03	.04:47	2
Psta	262.52	.48	.42:45	3
Tsta	18.48	.02	.03:46	4
P30	176.18	1.13	1.38:45	5
Q4	3.31	.05	.06:46	6
Q2	2.18	.05	.07:46	7

TABLE 1

Averaged Data, Scans 29-32, 37-40, and 45-48 for Run 1

```

*****
*** AVERAGED DATA ***
*** FROM SCAN 29 TO SCAN 32 ***
*****11/12A*****

```

Time for 4 scans = 4 s

VAR	MEAN	S-DV	M-DV:SC	ROW
m/t	2.07	0.00	0.00:29	1
Tvti	18.26	.03	.04:32	2
Psta	266.01	1.23	1.44:30	3
Tsta	18.33	.03	.02:29	4
P30	174.80	1.13	1.38:29	5
Q4	3.61	.06	.09:32	6
Q2	2.51	.04	.06:29	7

```

*****
*** AVERAGED DATA ***
*** FROM SCAN 37 TO SCAN 40 ***
*****11/12A*****

```

Time for 4 scans = 4 s

VAR	MEAN	S-DV	M-DV:SC	ROW
m/t	2.06	.00	.00:38	1
Tvti	18.26	.03	.04:38	2
Psta	264.16	.47	.41:37	3
Tsta	18.32	.02	.03:39	4
P30	175.15	1.32	1.73:37	5
Q4	3.48	.05	.06:39	6
Q2	2.45	.06	.07:37	7

```

*****
*** AVERAGED DATA ***
*** FROM SCAN 45 TO SCAN 48 ***
*****11/12A*****

```

Time for 4 scans = 5 s

VAR	MEAN	S-DV	M-DV:SC	ROW
m/t	2.05	0.00	0.00:45	1
Tvti	18.30	0.00	0.00:45	2
Psta	261.69	.47	.41:45	3
Tsta	18.28	.02	.03:48	4
P30	174.80	0.00	0.00:45	5
Q4	3.41	.03	.04:47	6
Q2	2.37	.04	.06:48	7

TABLE 2

Averaged Data, Scans 29-32, 37-40, and 45-48 for Run 2

```

*****
*** AVERAGED DATA ***
*** FROM SCAN 29 TO SCAN 32 ***
*****11/13A*****

```

Time for 4 scans = 4 s

VAR	MEAN	S-DV	M-DV:SC	ROW
m/t	2.05	.00	.00:31	1
Tvti	18.48	.03	.03:29	2
Psta	252.10	.67	.83:29	3
Tsta	18.59	.04	.06:31	4
P30	175.15	1.32	1.73:29	5
Q4	4.00	.03	.03:29	6
Q2	2.88	.03	.02:29	7

```

*****
*** AVERAGED DATA ***
*** FROM SCAN 37 TO SCAN 40 ***
*****11/13A*****

```

Time for 4 scans = 4 s

VAR	MEAN	S-DV	M-DV:SC	ROW
m/t	2.03	.00	.00:40	1
Tvti	18.52	.03	.04:39	2
Psta	260.46	.67	.83:37	3
Tsta	18.56	.02	.03:38	4
P30	176.87	1.38	2.07:40	5
Q4	3.86	.06	.09:40	6
Q2	2.85	.14	.14:38	7

```

*****
*** AVERAGED DATA ***
*** FROM SCAN 45 TO SCAN 48 ***
*****11/13A*****

```

Time for 4 scans = 5 s

VAR	MEAN	S-DV	M-DV:SC	ROW
m/t	2.02	0.00	0.00:45	1
Tvti	18.52	.03	.04:45	2
Psta	257.99	0.00	0.00:45	3
Tsta	18.56	.02	.03:45	4
P30	175.84	2.07	2.42:47	5
Q4	3.82	.08	.10:46	6
Q2	2.72	.10	.13:46	7

TABLE 3

Averaged Data, Scans 29-32, 37-40, and 45-48 for Run 3