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TWO-PHASE PRESSURE LOSSES

EIGHTH QUARTERLY PROGRESS REPORT

November 12, 1963 - February 11, 1964

E. Janssen and J. A. Kervinen

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TABLE OF CONTENTS

SUMMARY

Voids were measured in a 1/2-inch by 1-3/4-inch channel with the S-1 insert (B_0/B_1 = 0.4, L_0 = 0.1 inch), at 2 inches ahead of the insert (position A), 1/2 inch past the insert (position B), 5 inches past (position C), and 12 inches past (position D). The conditions were: P = 1000 psia, G = 1.00 × 10^6 lb/h-ft^2, and x = 18.8 percent. Average void and void distribution at position A are the same as for flow in a straight channel. Void distribution at position B shows that the stagnation region downstream of the inserts contains a high fraction of voids. Average void and void distribution at positions C and D show that the two-phase mixture becomes strongly mixed (homogenized) as a result of passing through the contraction-expansion inserts. Distribution at position D approaches the distribution at position A; i.e., the straight channel distribution. Full re-establishment of the flow must occur downstream of position D.

A list of reports which have been issued and reports now in preparation is included.

INTRODUCTION

This is the eighth and last, quarterly report on the work done under Contract AT(04-3)-189, Project Agreement No. 27, and covers the period November 12, 1963 to February 11, 1964.

The objectives for the program have been to:

1. Determine, for a range of geometries, pressures, flows, and qualities, the two-phase pressure loss in channels with relatively sudden changes in cross-sectional area.
2. Determine the two-phase pressure loss in straight channels, also for a range of pressures and flows, and particularly at high qualities.
3. Determine the two-phase pressure loss in straight channels with heat addition.

Two basic channel geometries have been used:

1. A rectangular (two-dimensional) channel.
2. A circular (three-dimensional) channel.

Channel orientations have been with flow up, flow down, and flow horizontal.

Void measurements for one two-phase flow condition in the 1/2-inch by 1-3/4-inch channel with the S-1 insert ($B_0/B_1 = 0.4$, $L_0 = 0.1$ inch) were made during the quarter ending February 11. Also, pressure drop measurements were attempted for two-phase flow in the 1/2-inch by 1-3/4-inch straight channel with heat addition, but were not made because of repeated equipment failure. This concludes all the experimental work on this program. The data reduction and writing-up of the results are not yet finished. These are expected to be completed by the end of April, 1964.

Results of the void measurements and status of the reports are described here.

VOID MEASUREMENT RESULTS

Voids were measured in the 1/2-inch by 1-3/4-inch channel with the S-1 insert, flow up. The equipment and general procedure have already been described in an earlier report. (1) The 1/32-inch by 1-inch slot was used for gamma ray columnation. The unique feature about the work reported here is the presence of the insert in the channel. Figure 1 is a sketch of the channel, showing the insert in place, and also the four axial positions at which voids were measured. Note that position A is 2 inches ahead of the insert, position B is 1/2-inch past the insert, position C is 5 inches past, and position D is 12 inches past.

The voids were measured for the single set of conditions: P = 1000 psia, $G = 1.00 \times 10^6$ lb/h-ft^2, and x = 18.8 percent. Measurements were made at ten traverse positions across the channel, and four axial positions along the channel (see Figure 1). Equation (14) of Reference 1 was employed in reducing all the void data. The results are plotted in Figure 2.

Refering to Figure 2, the void fraction at position A rises moderately steeply from the wall, and tends to level off over the middle 65 percent of the channel. Comparison with Figure 7 of Reference 1 shows good agreement with the void distribution in the straight channel at the same flow and quality condition.

The void fraction at position B, 1/2 inch past the insert, rises much more steeply from the wall, in contrast to the distribution at position A. It is apparent from this that the stagnation region along the walls downstream of the inserts has a high concentration of vapor, at least for this particular test condition. The void fraction is fairly constant over the middle 80 percent of the channel. The average void fraction at position B is lower, relative to the average values at the other three positions, than was expected. The difference between position B and position C, for instance, is about equal to the expected limit of error (±8 percent) in the measurement of voids. The apparent low void readings at position B could be due to instrument error. It should be pointed out that the results at position B show only an average distribution for the 1-inch length of channel directly downstream from the inserts. No abrupt axial change in the void distribution, whether present or not, can show up in the results.

The void fraction at position C, 5 inches past the insert, rises steeply from the wall, the same as at position B, and is fairly constant over the middle 80 percent of the channel. The void distribution at position C is quite similar to the distribution at position B.

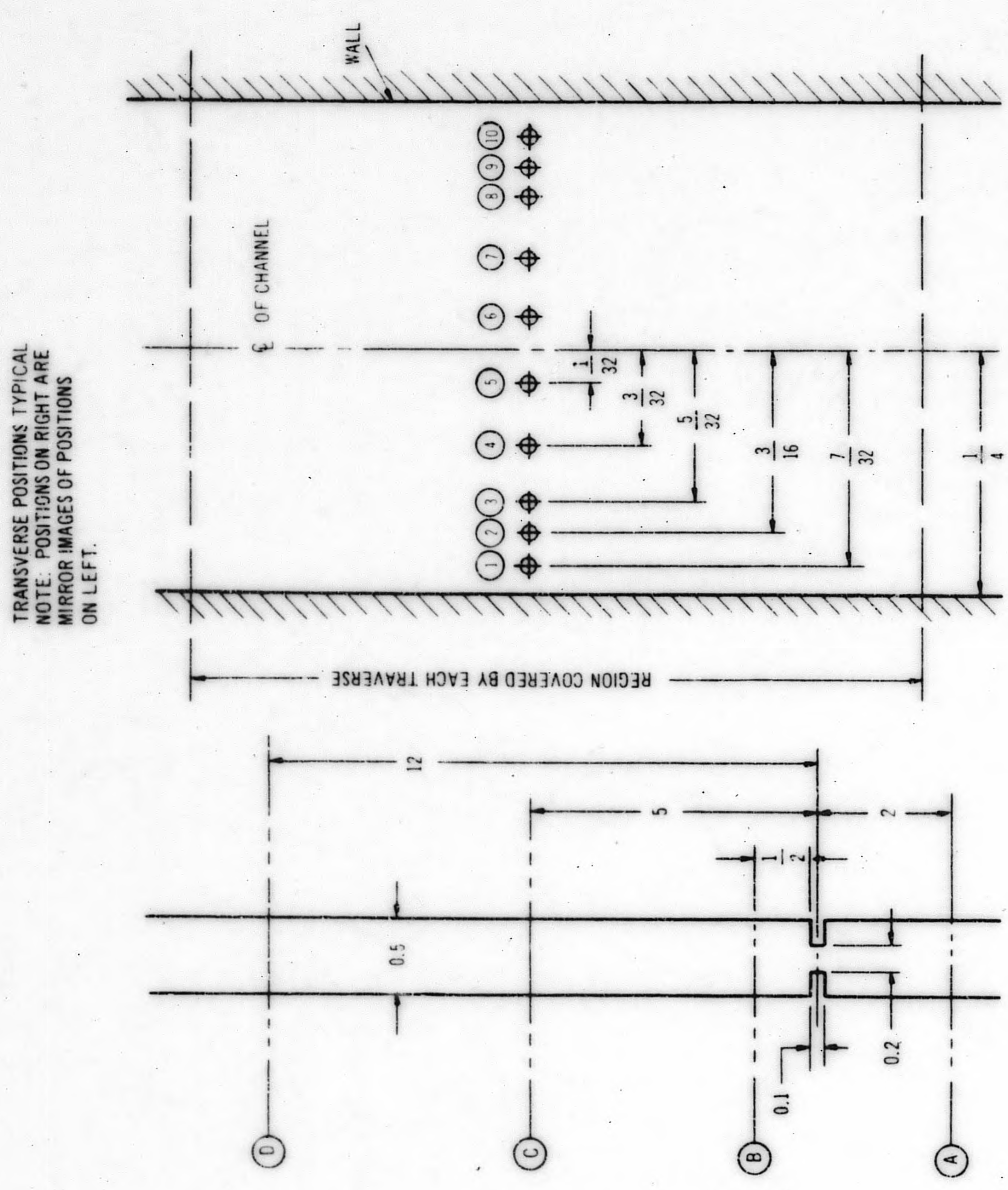

Figure 1. Traverse Positions for 1/2-Inch × 1-3/4-Inch Channel with S-1 Insert

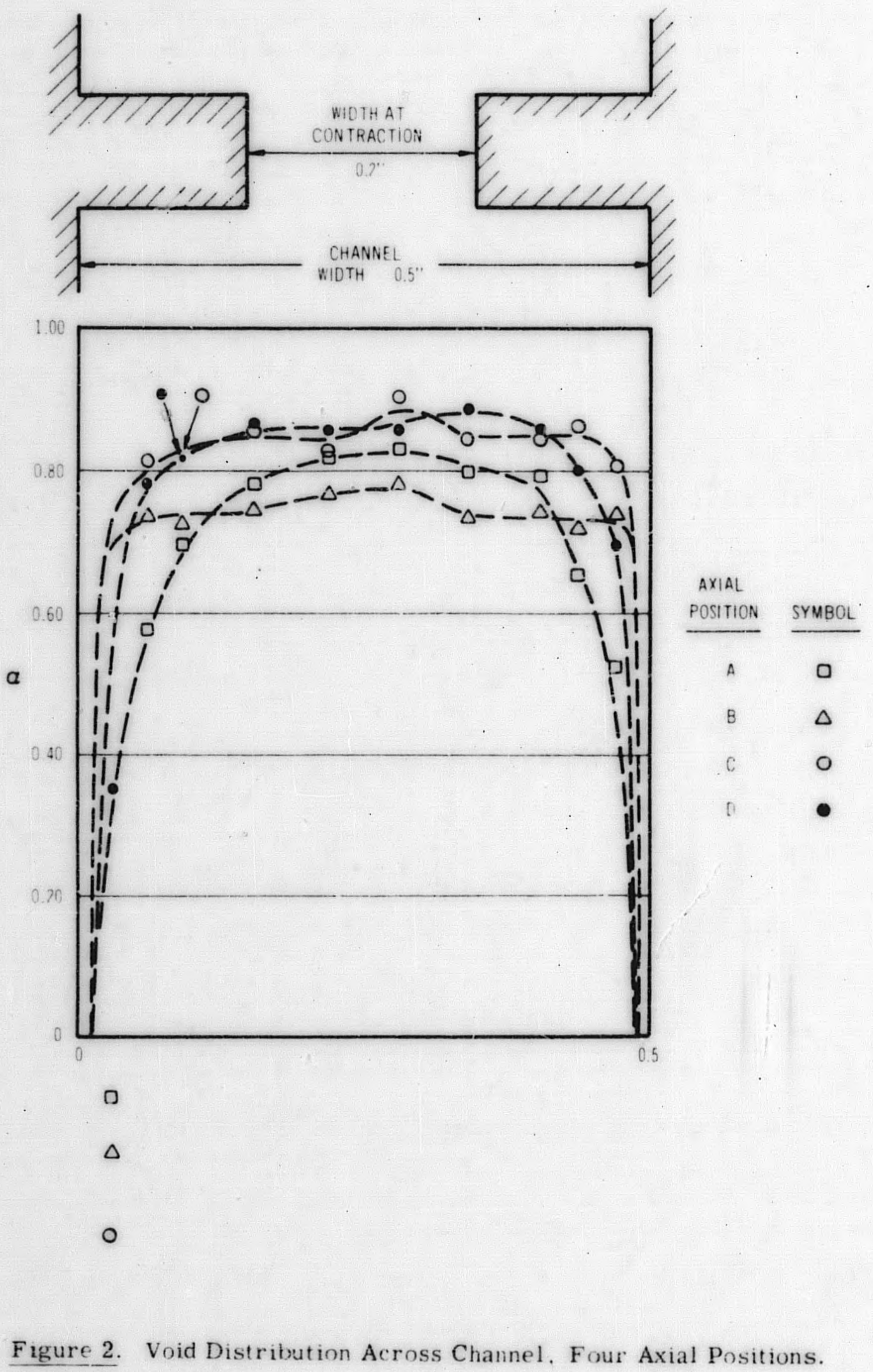

Figure 2. Void Distribution Across Channel, Four Axial Positions.

The void fraction at position D, 12 inches past the insert, rises steeply from the wall, but not as steeply as at position C. It then tends to be constant over the middle 65 percent of the channel. The void distribution at position D is approaching the void distribution at position A, which is the distribution for the straight channel with no insert. It is obvious that more than 12 inches are needed past the S-1 insert to completely re-establish the flow. (It should be added parenthetically that the static pressure profile for two-phase flow past the S-1 insert, not yet reported, shows that about 18 inches are required for fully developed flow.)

The average void fraction, and the calculated ratio of average vapor velocity to average liquid velocity, are listed below:

Position	$\overline{\alpha}$	$S = \frac{U_g}{U_f}$
A	0.69	2.1
B	0.71	1.9
C	0.80	1.2
D	0.78	1.4

The value for $\overline{\alpha}$ at position B is in question, as explained earlier. Neglecting position B, the values at the other three positions show that the contraction-expansion insert has a strong mixing action which makes the two-phase flow behave more like a homogeneous mixture. The high-speed movies, described in References 2 and 3, also show this strong mixing action.

STATUS OF REPORTS

The reports which have been completed and distributed on this project are:

1. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Losses, Second Quarterly Progress Report, May 12 - August 12, 1962", GEAP-4086.
2. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Losses, Third Quarterly Progress Report, August 12 - November 12, 1962", GEAP-4148.
3. Levy, S., "Analysis of Various Types of Two-Phase Annular Flow, Part I - Annular Flow Without Liquid Entrainment", GEAP-4193, February 15, 1963.
4. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Losses, Fourth Quarterly Progress Report", November 12, 1962 - February 12, 1963, GEAP-4202.
5. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Losses, Fifth Quarterly Progress Report", February 12 - May 12, 1963, GEAP-4275.
6. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Losses, Sixth Quarterly Progress Report", May 12 - August 12, 1963, GEAP-4362.
7. Levy, S., "Prediction of Two-Phase Critical Flow Rate", GEAP-4395, October 1963.
8. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Losses, Seventh Quarterly Progress Report", August 12 - November 11, 1963, GEAP-4431. (This report is still awaiting AEC approved for distribution, as of February 28, 1964.)

The reports now in preparation are:

1. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Losses, Eighth Quarterly Progress Report", November 12, 1963 - February 11, 1964, GEAP-4576.
2. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Drop in Straight Pipes and Channels: Water - Steam Mixtures at 600 to 1400 psia".
3. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Drop Past Contractions and Expansions: Water - Steam Mixtures at 600 to 1400 psia".
4. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Drop in an Internally Heated Annulus: Water - Steam Mixtures at 600 to 1400 psia".
5. "Two-Phase Pressure Losses, Final Report".

REFERENCES

1. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Losses, Fifth Quarterly Progress Report", February 12 - May 12, 1963, GEAP-4275.

2. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Losses, Third Quarterly Progress Report", August 12 - November 12, 1962, GEAP-4148.

3. Janssen, E., and Kervinen, J. A., "Two-Phase Pressure Losses, Fourth Quarterly Progress Report", November 12, 1962 - February 12, 1963, GEAP-4202.

Approved By:

E. Janssen, Project Engineer
Two-Phase Pressure Losses

Approved By:

D. H. Imhoff, Manager
Engineering Development