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REFLOOD INSTRUMENTATION DEVELOPMENT AT ORNL: A STATUS REPORT

Presented
at the
SIXTH WATER REACTOR SAFETY RESEARCH INFORMATION MEETING
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by

B. G. Eads
AIRS Program Manager
Oak Ridge National Laboratory

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REFLOOD INSTRUMENTATION DEVELOPMENT AT ORNL: A STATUS REPORT*

INTRODUCTION

A program under the sponsorship of NRC-RSR was initiated at the Oak Ridge National Laboratory (ORNL) in late 1977 for development of instrumentation for measurement of in-vessel fluid phenomena in PWR reflood test facilities. This program is a part of the tripartite 2D/3D Refill and Reflood Experimental and Analytical Research Program. The goal of the ORNL program is to develop techniques and systems for measurement of fluid flow in-core, deentrainment in the upper plenum and liquid fallback from the upper plenum into the core. To meet this goal liquid film thickness and velocity and two-phase flow void fraction and velocity must all be measured. Liquid film thickness and velocity measurement systems are being developed utilizing concepts developed at Lehigh University.[1,2]

The primary technique being developed at ORNL is based on the use of electrical admittance sensors for measurement of two-phase velocity and void fraction. A number of sensor configurations have been investigated. Band and "string" probes are the primary candidates for use in the upper plenum. For in-core measurements, band probes, prong probes, and flag probes have shown promise. Electronics have been developed which separate and provide independent output signals for the conductive and capacitive components of the sensor admittances.

Analysis of stochastic signals from admittance sensors using digital processing techniques is being utilized to deduce fluid velocities. The magnitudes of the conductive and capacitive components of the admittances have been used to obtain void fraction values. The techniques were tested with various sensor and

*Research Sponsored by the Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, under Interagency Agreement DOE 40-551-75 with the U.S. Department of Energy under contract W-7405-eng-26 with the Union Carbide Corp.

electronic configurations. Steady-state tests of developmental and prototypical sensors and limited transient tests of development sensors were conducted in air-water. Steady-state "proof-of-operability" tests of the first production version of sensors in a guide tube configuration were conducted in steam-water.

To date, the band probe has given the best results when compared to independent measurements of two-phase flow parameters. The flag and prong probes for in-core measurement and the string probe for the upper plenum also yield encouraging results; however, additional development is still required.

The success of the techniques reported herein will result in the capability, for the first time, to make in-vessel localized measurements of two-phase flow characteristics. Such localized in-core and upper plenum measurements are not obtainable with other currently available two-phase flow instrumentation.

References:

[1]John C. Chen et al, "Investigation of Post-CHF Heat Transfer for Water-Cooled Reactor Application and Development of Two-Phase Flow Instrumentation, Progress Report April 1, 1977 to June 30, 1977," LU-NUREG-PR771.

[2]John C. Chen et al, "Investigation of Post-CHF Heat Transfer for Water-Cooled Reactor Application and Development of Two-Phase Flow Instrumentation, Progress Report January 1, 1978 to March 31, 1978," LU-NUREG-PR781.

B. G. EADS
PROGRAM MANAGER
ADVANCED INSTRUMENTATION
FOR REFLOOD STUDIES
PROGRAM

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THE GOAL OF ORNL PROGRAM IS TO DEVELOP AND PROVIDE ADVANCED INSTRUMENTATION FOR IN-VESSEL MEASUREMENTS

- LIQUID UPFLOW IN CORE
- DEENTRAINMENT IN UPPER PLENUM
- LIQUID FALLBACK INTO CORE

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REFLOOD FACILITY IN-VESSEL MEASUREMENTS INVOLVE WIDE RANGEABILITY AND HOSTILE ENVIRONMENT

LIQUID FILM

- THICKNESS: 0 TO 4 mm
- VELOCITY: 0 TO 1.8 meters/sec

TWO-PHASE FLOW

- VOID FRACTION: 0 TO 1
- VELOCITY: 0 TO 15 meters/sec

ENVIRONMENT

- 950°C
- 300°C/sec THERMAL SHOCK
- HIGH ELECTRIC AND MAGNETIC FIELDS

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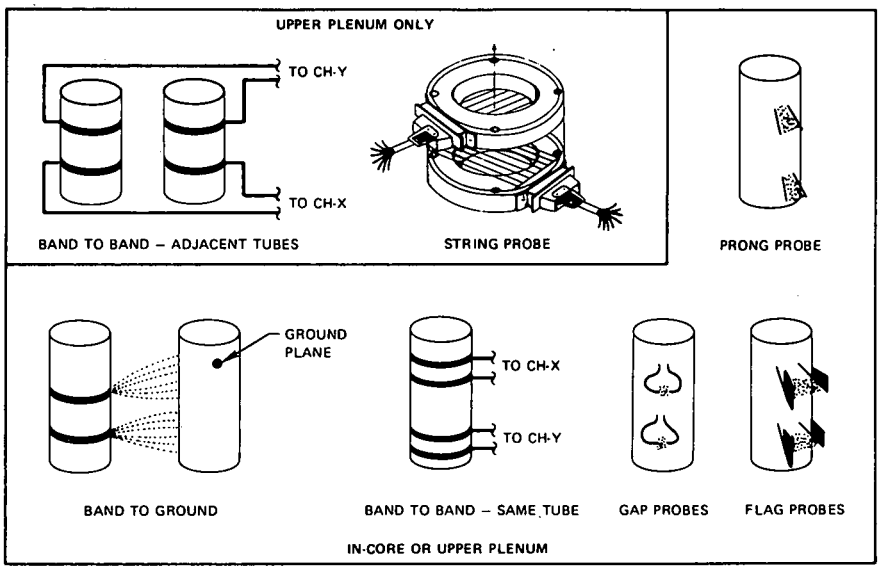
A VARIETY OF ADMITTANCE SENSOR CONFIGURATIONS ARE UNDER DEVELOPMENT FOR TRANSIT TIME AND VOID FRACTION MEASUREMENTS



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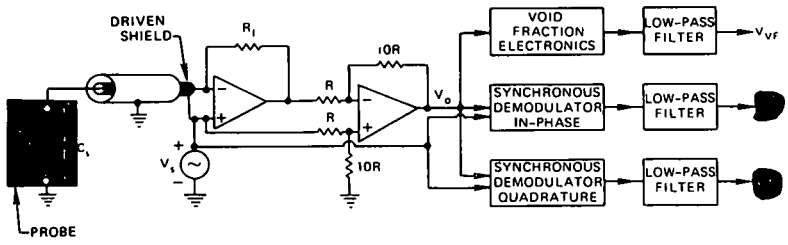
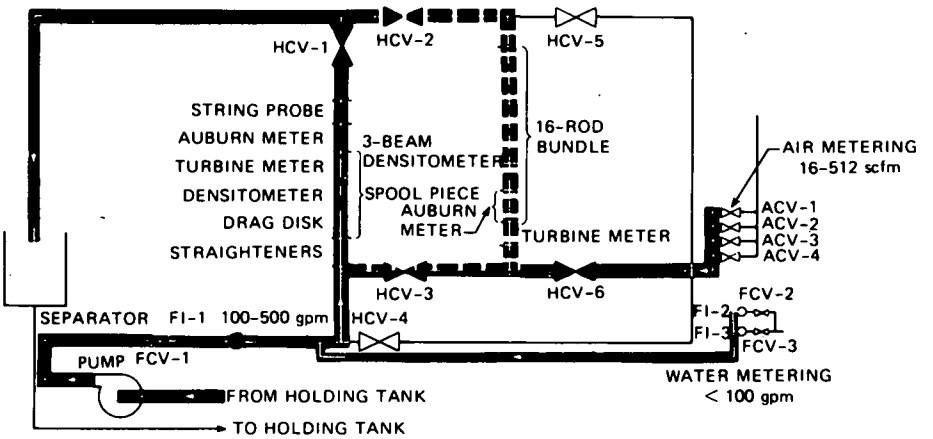
SECOND GENERATION ELECTRONICS CIRCUIT MEASURES BOTH R&C COMPONENTS AND UTILIZES DRIVEN SHIELD

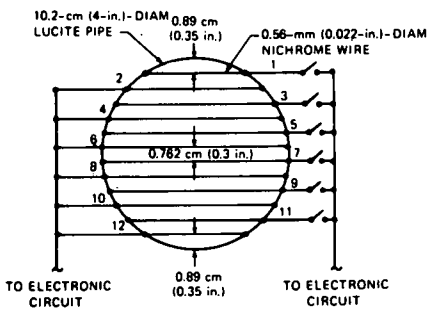


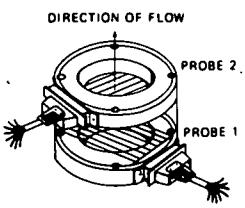
AIR-WATER LOOP CAPABLE OF ACHIEVING A WIDE RANGE OF QUALITIES AND VOID FRACTIONS USED IN THESE TESTS



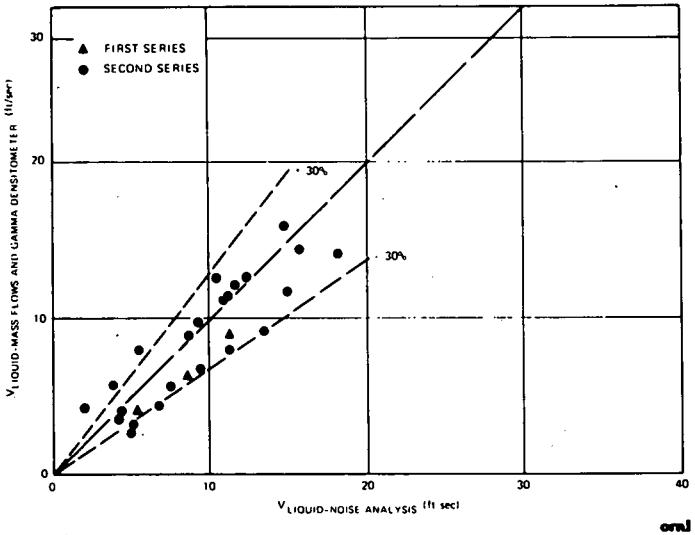
A VARIETY OF UPPER PLENUM AND IN-BUNDLE INSTRUMENTS TESTED TO DATE

UPPER PLENUM:





NOISE ANALYSIS TECHNIQUES YIELD REASONABLE ACCURACY IN LIQUID VELOCITY DATA IN STEADY-STATE AIR-WATER (VERTICAL UP-FLOW) TESTS OF THE STRING PROBE WHEN COMPARED WITH THE SEPARATED FLOW MODEL



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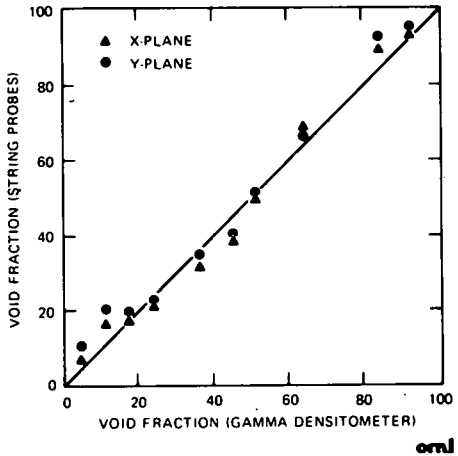
STRING PROBE IMPEDANCE MEASUREMENT AT LOW FREQUENCY (10 kHz) YIELDS VOID FRACTIONS THAT AGREE WELL WITH GAMMA DENSITOMETER VALUES IN STEADY-STATE AIR-WATER (VERTICAL UP-FLOW) TESTS



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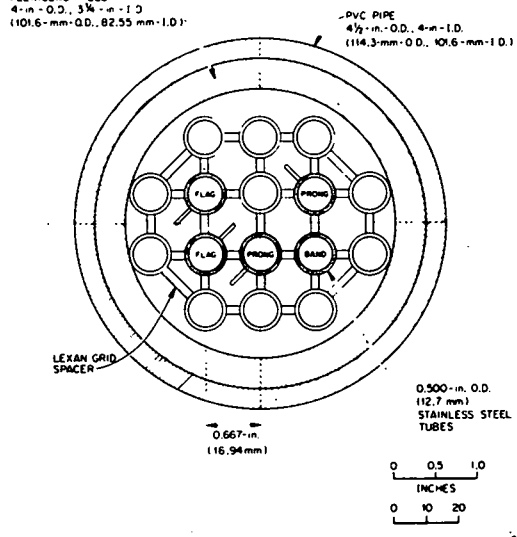
IN-BUNDLE SENSORS WERE TESTED IN AIR-WATER IN A 16-ROD BUNDLE OF 0.500-in.-O.D. RODS



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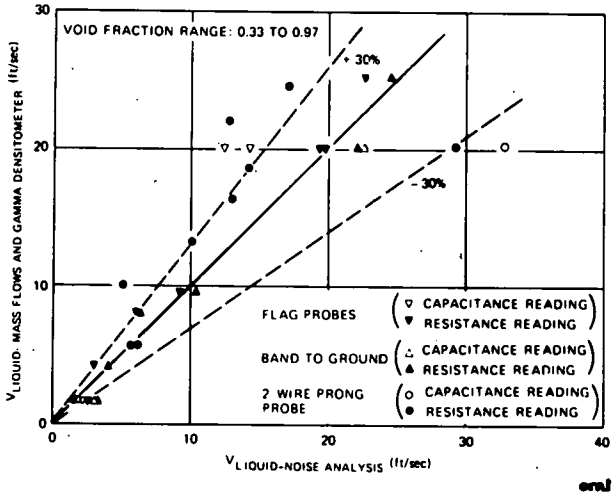
SOME IN-BUNDLE DEVICES WERE FOUND TO BE UNSATISFACTORY FOR DIRECT APPLICATION

TYPE		REASON
(a) BAND TO BAND – ADJACENT TUBES		GEOMETRY NOT APPLICABLE TO PKL (IN CORE)
(b) GAP PROBE		LACK OF COHERENCE IN THE SIGNAL BETWEEN THE 2 AXIAL LOCATIONS
(c) 4-WIRE PRONG PROBE		RESULTS OBTAINED DIFFERED MARKEDLY FROM OTHER PROBES AND FROM 2-PHASE RESULTS
(d) BAND TO BAND – SAME TUBE		INACCURATE VELOCITY OBTAINED

COMPARISON OF NOISE ANALYSIS RESULTS WITH THE SEPARATED FLOW MODEL SHOWS THAT FLAG, PRONG, AND BAND-TO-GROUND ARE PROMISING FOR IN-BUNDLE LIQUID VELOCITY MEASUREMENT. (STEADY-STATE, VERTICAL UP-FLOW, AIR-WATER TESTS)



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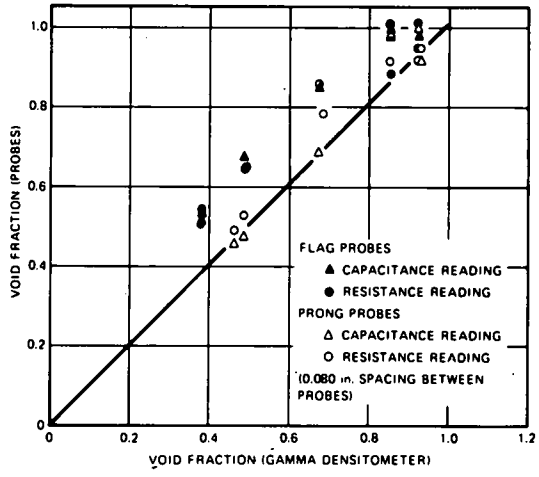
FLAG AND PRONG PROBE READINGS YIELD IN-BUNDLE VOID FRACTIONS THAT AGREE FAIRLY WELL WITH GAMMA DENSITOMETER IN STEADY-STATE, VERTICAL UP-FLOW AIR-WATER TESTS



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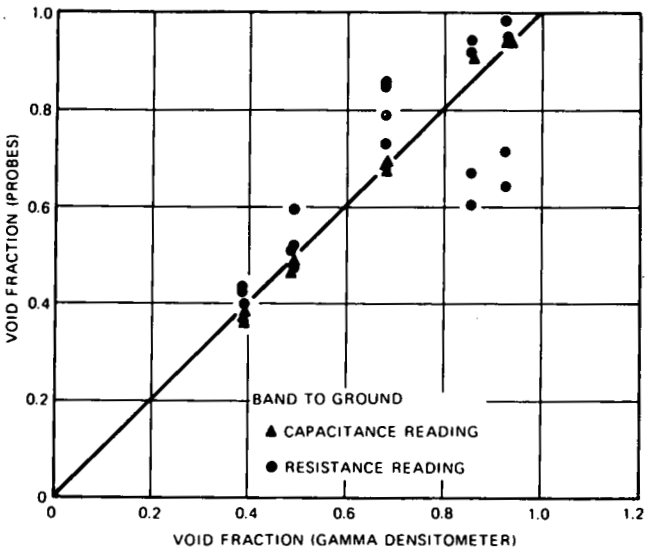
TO DATE THE BAND-TO-GROUND PROBE HAS YIELDED THE BEST IN-BUNDLE VOID FRACTION TEST RESULTS. THE CAPACITIVE COMPONENT OF THE SIGNAL YIELDS BEST RESULTS IN THE HIGH VOID FRACTION ($0.4 < \alpha < 1.0$) AIR-WATER TESTS (STEADY-STATE, VERTICAL UP-FLOW) CONDUCTED THUS FAR



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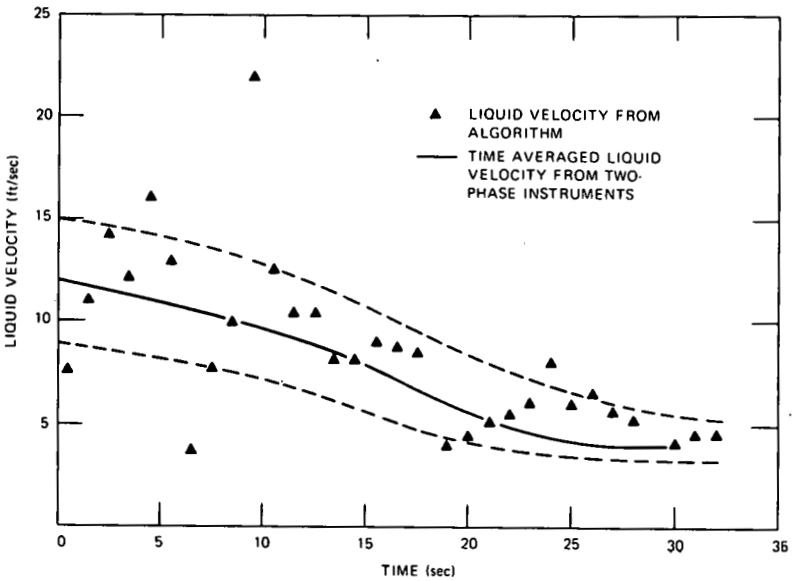
COMPARISON OF STRING PROBE LIQUID VELOCITY FROM THE ALGORITHM WITH THE LIQUID VELOCITY DETERMINED FROM TWO-PHASE INSTRUMENTATION FOR A 30 SECOND TRANSIENT IN AIR-WATER VERTICAL UP-FLOW



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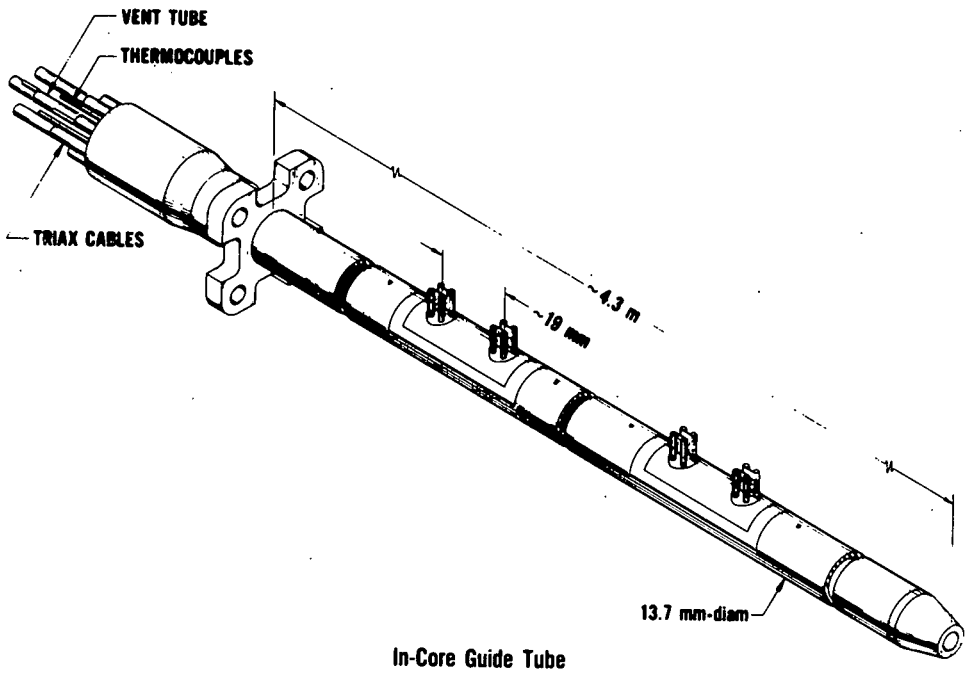

In-Core Guide Tube
Impedance Measurement Assembly
Flag Probe Type

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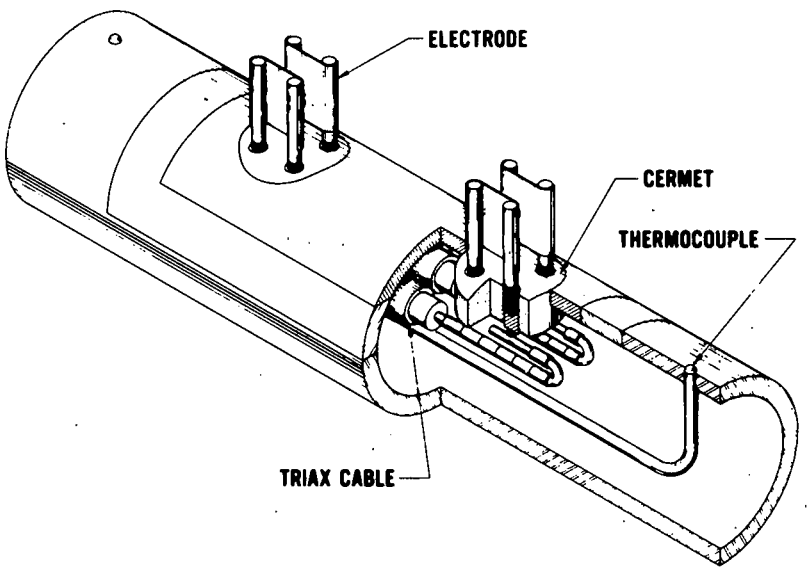

In-Core Guide Tube
Impedance Measurement Assembly
Flag Probe Sensor

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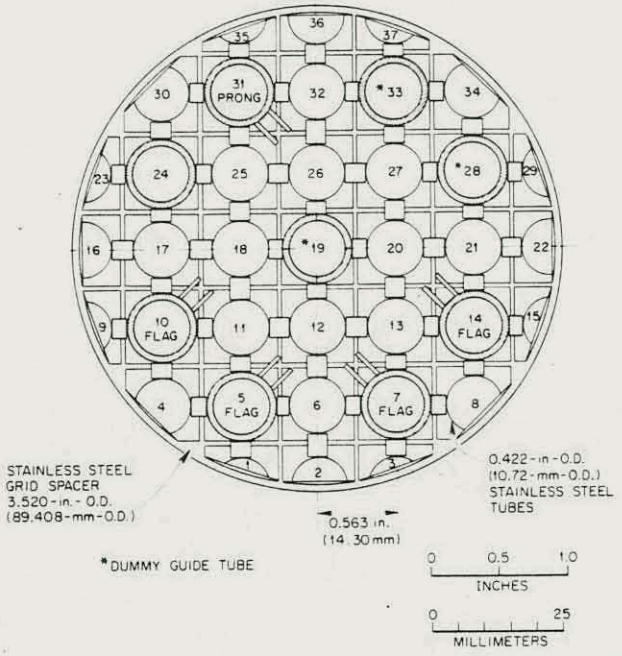
"PROOF-OF-OPERABILITY" STEAM-WATER TESTS OF FLAG AND PRONG, TYPE INSTRUMENTED GUIDE TUBES WERE CONDUCTED WITH IN-BUNDLE GEOMETRY



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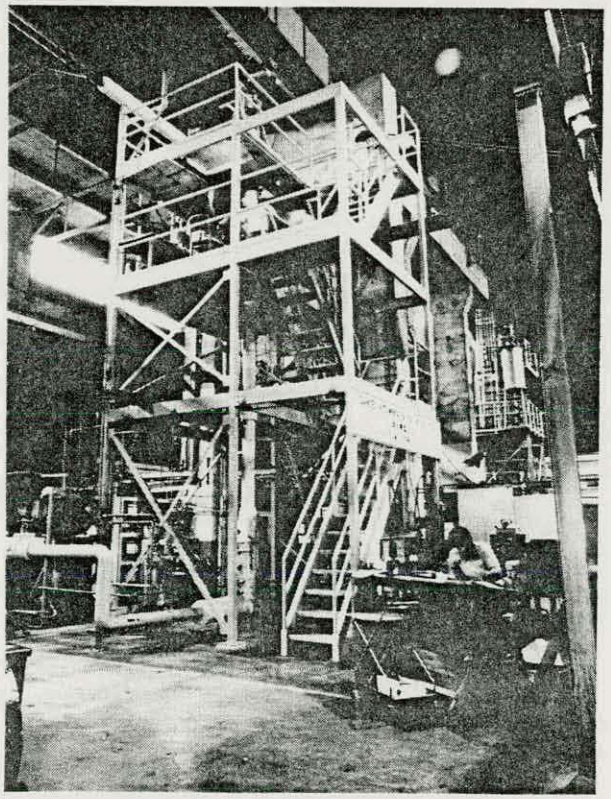

ALTHOUGH INDEPENDENT CALIBRATION OF FLAG AND PRONG PROBES IS REQUIRED, PRELIMINARY ANALYSIS OF STEADY-STATE, STEAM-WATER "PROOF-OF-OPERABILITY" RESULTS AT HIGH VOID FRACTIONS ($0.7 < \alpha < 0.9+$) SUGGEST THAT PROBES MAY GIVE AN ACCURATE MEASURE OF LIQUID VELOCITY

LOOP * CONDITION	AVERAGE NOISE ANALYSIS VELOCITY FROM FLAG AND PRONG PROBES[1] (ft/sec)	HOMOGENEOUS FLOW MODEL VELOCITY (ft/sec)	SEPARATED FLOW MODEL THOM (1964) V_f (ft/sec)	THOM (1964) V_g (ft/sec)	ZUBER AND FINDLAY (1965) V_f (ft/sec)	ZUBER AND FINDLAY (1965) V_g (ft/sec)
1	7.24	21.6	7.3	23.0	4.9	24.3
2	8.17	33.8	11.5	36.0	8.8	37.3
3	5.62	35.9	11.7	37.0	5.6	38.7
4	12.3	120	37.5	118	15.9	125
5	9.32	85.1	28.0	86.0	10.4	88.7

[1] AVERAGE OF 10 POINTS

*IN-BUNDLE PRESSURE – 105 ± 1.0 psia
IN-BUNDLE TEMPERATURE – 332 ± 2°F

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