MASTER

MEASUREMENT OF TWO-PHASE FLOW AT THE CORE UPPER PLENUM INTERFACE UNDER SIMULATED REFLOOD CONDITIONS*

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The Instrument Development Loop (IDL) Program is part of the International 2D/3D Refill and Reflood Experimental and Research Program. The principal experimental facilities in the International Program are the Slab Core Experiment in Japan and the Upper Plenum Test Facility (UPTF) in Germany. Among the objectives of the international program are: the study of the steam binding effect during reflood for various emergency core cooling combinations; the study of the reflood flow distribution (chimney effect) in a heated core; and the study of the flow hydrodynamics in the core, downcomer and upper plenum during refill and reflood.

A major problem is coupling the results to be obtained at the two major experiments. One approach is to measure the flows at the interface boundary of the two experiments and attempt to match them as closely as possible. Therefore the two major objectives of the IDL Program were to simulate expected flows at the core/upper plenum interface during the reflood phase of a postulated LOCA and to develop instrumentation systems for mass flow measurement at the core/upper plenum interface.

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Two experimental facilities were used in these studies: a three-bundle air/water loop and a one-bundle steam/water loop. Both loops represent full-scale vertical sections of the UPTF, extending from spray nozzles to the top of the upper plenum and including a short length of dummy fuel rods, upper end boxes, core support plate and control rod guide tubes.

Since testing was completed on this program just within the last month, all results must be considered as preliminary and are subject to change in the final report.

Three flow regimes were identified and studied: (1) all liquid down, (2) counter-current flow in which gas (or vapor) goes up and liquid goes both up and down, and (3) cocurrent flow in which both gas (or vapor) and liquid go up. Instruments necessary to measure mass flow under these conditions are (1) Tie-plate drag body or equivalently ΔP across tie plate, (2) free field turbine meter located above the tie plate, (3) temperature, (4) pressure, and (5) collapsed liquid level ΔP measurement. The tie-plate drag body was unique because it utilized part of the end box as a drag body and all transducers were contained within structural members of the end box. This meant that this instrument sampled a large amount of the flow with minimum disturbance to the flow.

Some of the significant achievements of the IDL program include:

The tie-plate drag body was developed and tested successfully; measurement with tie-plate drag body was shown to be equivalent to the ΔP measurement; the tie-plate drag body gave a useful measurement in pure downflow situations and the combination of drag/turbine correlates with mass flow for high upflow.

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INFORMATION MEETING
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THE OVERALL OBJECTIVES OF THE INTERNATIONAL 2D/3D REFILL AND REFLOOD PROGRAM

- TO STUDY THE STEAM BINDING EFFECT DURING REFLOOD FOR VARIOUS ECCS COMBINATIONS
- TO STUDY THE REFLOOD FLOW DISTRIBUTION (CHIMNEY EFFECT) IN A HEATED CORE
- TO STUDY THE FLOW HYDRODYNAMICS IN THE CORE, DOWNCOMER AND UPPER PLENUM DURING REFILL AND REFLOOD

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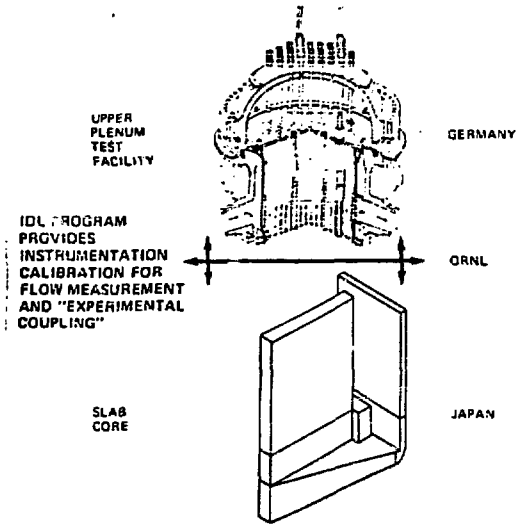
THE PRINCIPAL EXPERIMENTAL FACILITIES IN THE 20/3D REFILL AND REFLOOD PROGRAM ARE SLAB CORE AND UPTF



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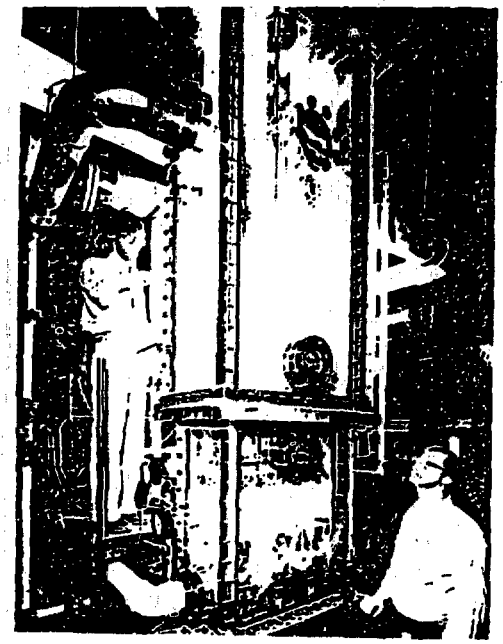
PRINCIPAL OBJECTIVES OF INSTRUMENT DEVELOPMENT LOOP (IDL) PROGRAM

- SIMULATE EXPECTED FLOWS AT THE CORE/UPPER PLENUM INTERFACE DURING THE REFLOOD PHASE OF A POSTULATED LOCA
- SCOPE POSSIBLE INSTRUMENTATION SCHEMES FOR MASS FLOW MEASUREMENT AT CORE-UCSF INTERFACE
- EVALUATE INSTRUMENT ACCURACY
- ~~VERIFICATION OF INSTRUMENT SCHEME MODEL~~
- PHENOMENOLOGICAL STUDIES
- DEVELOPMENT OF MASS FLOW MEASUREMENT SYSTEM

FLOWS ARE SIMULATED IN A THREE MODULE TRANSPARENT REPRESENTATION OF THE UPTF USING AIR AND WATER



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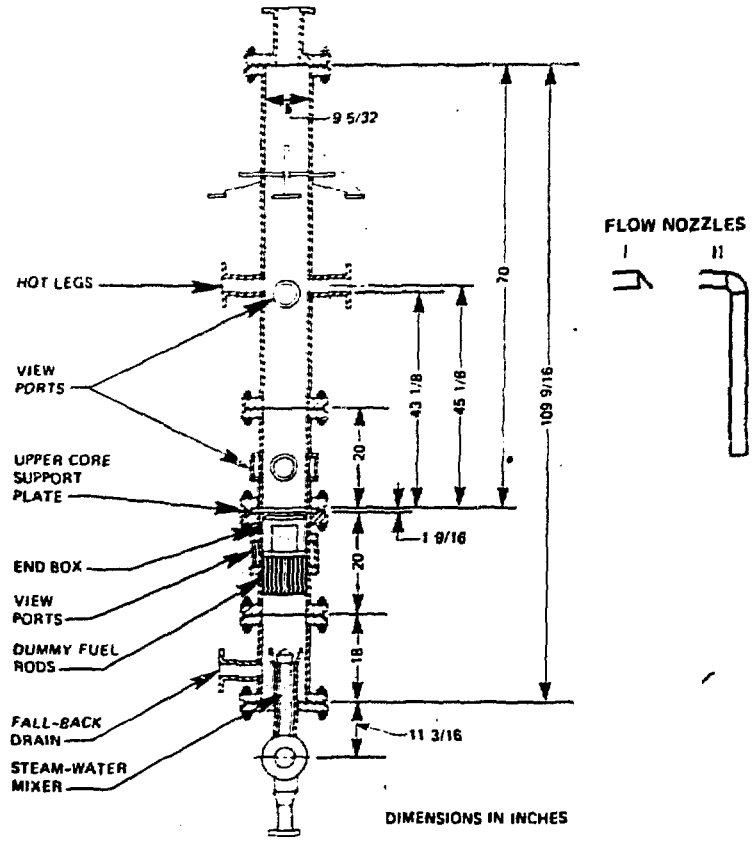
IDL STEAM WATER LOOP HAS THE CAPABILITY OF INJECTING HOT-LEG WATER IN TWO DIFFERENT CONFIGURATIONS



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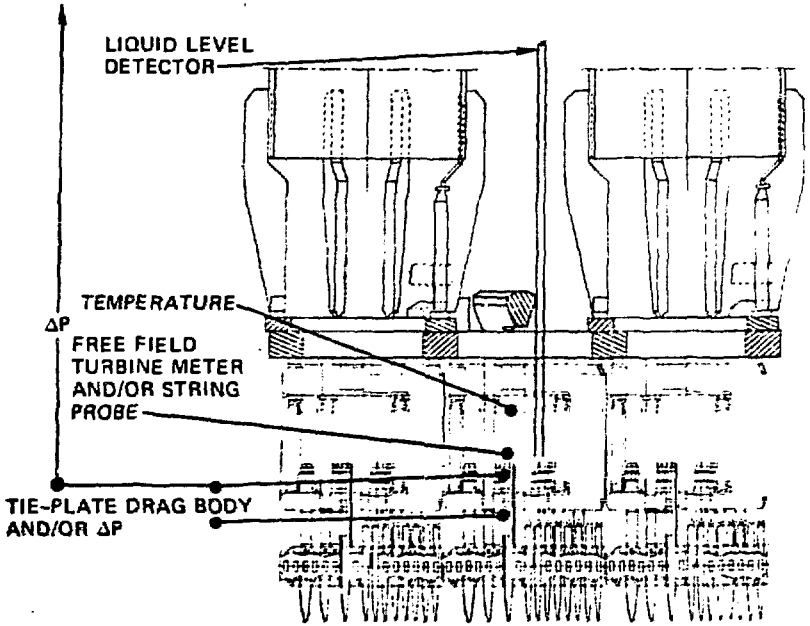
INSTRUMENTATION SCHEME PROPOSED BY THE UNITED STATES



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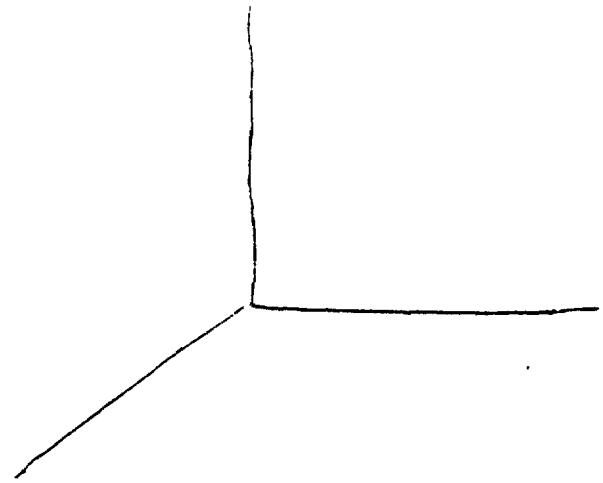
THREE KEY INSTRUMENTS AT CORE UPPER PLENUM INTERFACE ARE TIE PLATE DRAG BODY, TIE PLATE TURBINE AND TIE PLATE ΔP.

New Photo

ORNL TEST MATRIX FOR IDL STEAM/WATER TESTS.

TEST SERIES	PRESSURE (psia)	CORE SPRAY SUBCOOLING (°F)	CORE SPRAY (gpm)	HOT-LEG TEMPERATURE (°F)	HOT-LEG (gpm)	Number OF TESTS	CUMULATIVE NUMBER OF TESTS
AS-65	65	—	—	—	—	10	10
AS-100	100					14	24
12	65	10	35	—	—	7	31
13	65	10	5	—	—	6	37
14	65	10	20	—	—	14	51
15	65	10	55	—	—	12	63
16	100	10	50	—	—	18	81
17	100	10	5	—	—	13	94
18A	100	10	20	—	—	18	112
19	100	10	35	—	—	16	128
20	100	10	44	—	—	14	142
21	65	10	44	—	—	10	152
22	65	10	35	—	—	12	164
23	30	10	5	—	—	8	172
24	30	10	20	—	—	7	179
25	30	10	50	—	—	5	184
26	65	—	—	—	—	10	194
27	30	—	—	—	—	3	197
28	100	—	—	—	—	13	210
29	100	10	20	90	100	5	215
30	65	10	20	90	100	4	219
36	100	—	—	150	90	6	225
37	100	—	—	150	50	6	231
39	65	—	—	90	100	8	239
40	65	10	20	90	100	6	245
41	65	—	—	90	50	7	252
43	65	—	—	150	100	7	259
44	65	—	—	150	50	7	266

ORNL FLOW REGIMES OBSERVED IN STEAM WATER LOOP



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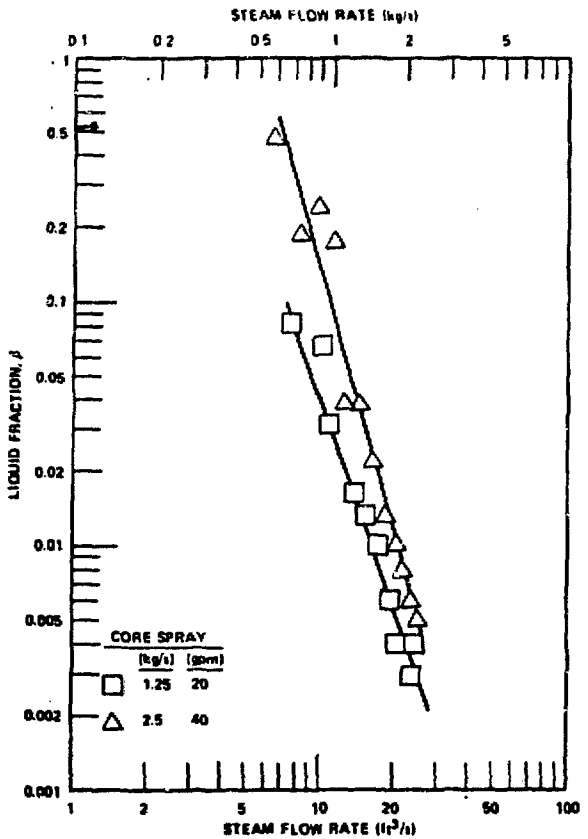
LIQUID FRACTION JUST ABOVE TIE-PLATE MEASURED WITH STRING PROBE IN STEAM/WATER LOOP



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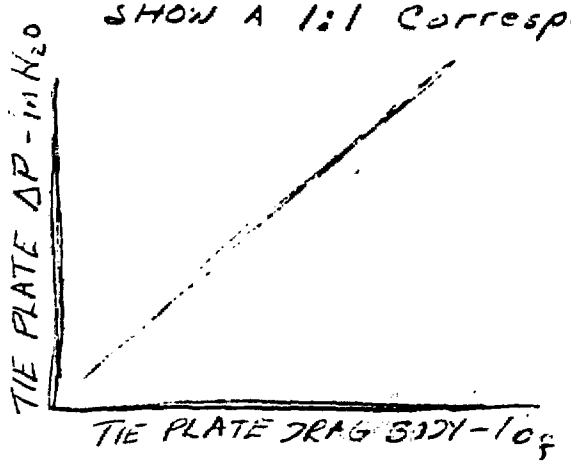
TIE PLATE DRAG BODY AND TIE PLATE ΔP MEASUREMENT SHOW A 1:1 Correspondence



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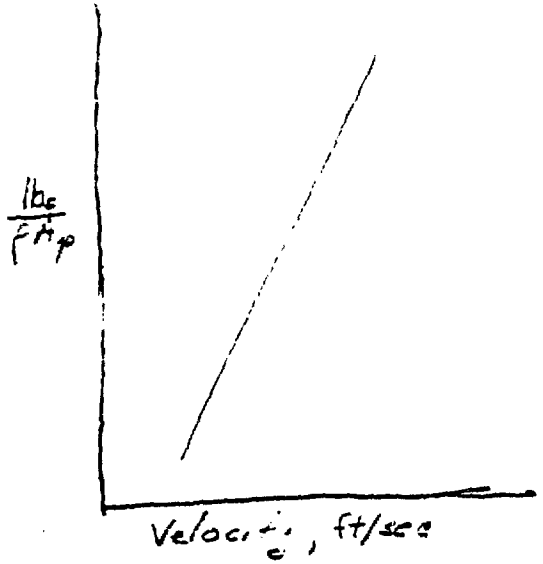
IN SMALL SCALE FLOW, TIE PLATE DRAG BODY YIELDS A GOOD CALIBRATION CURVE FOR A NOZZLE AT A FLOW RATE OF IN BOTH AN 8 MODULE LOOP.



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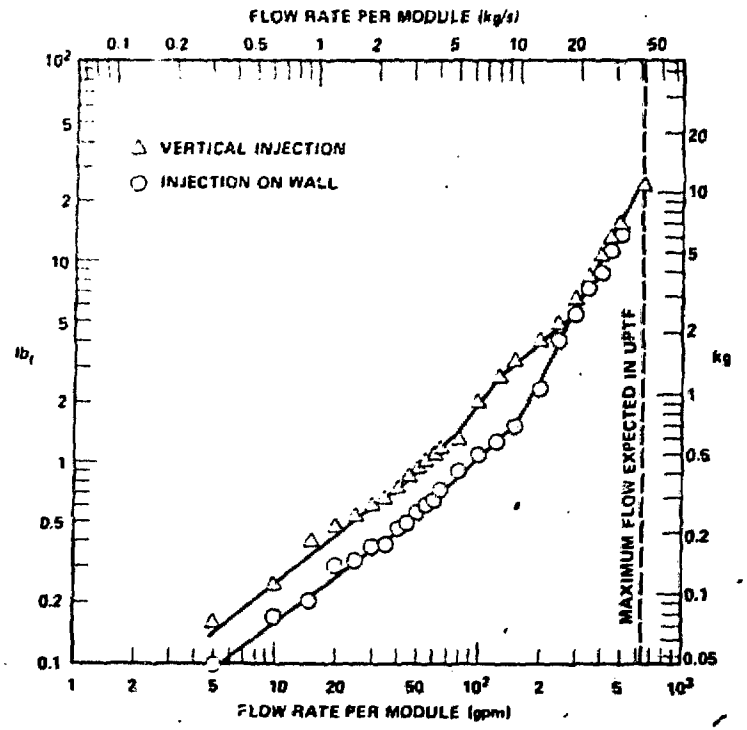
DOWNFLOW CALIBRATION OF TIE-PLATE DRAG BODY IN SINGLE MODULE LOOP



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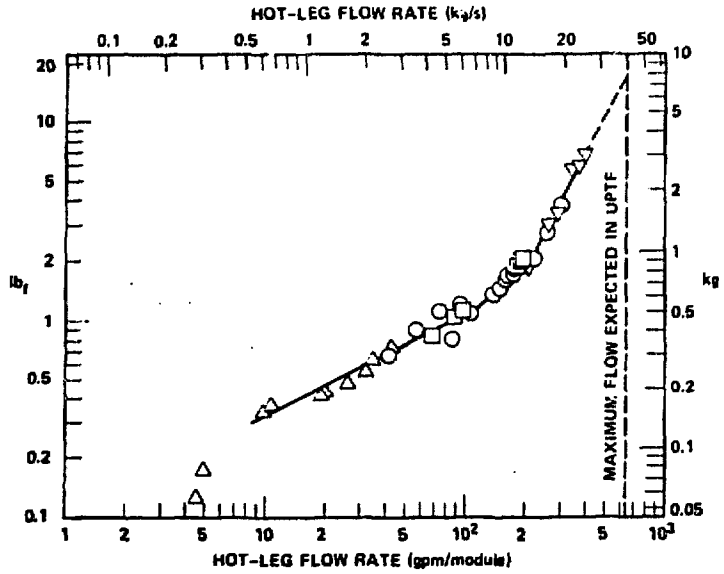
DOWNFLOW CALIBRATION OF SIMULATED TIE-PLATE DRAG BODY IN THREE MODULE AIR/WATER LOOP



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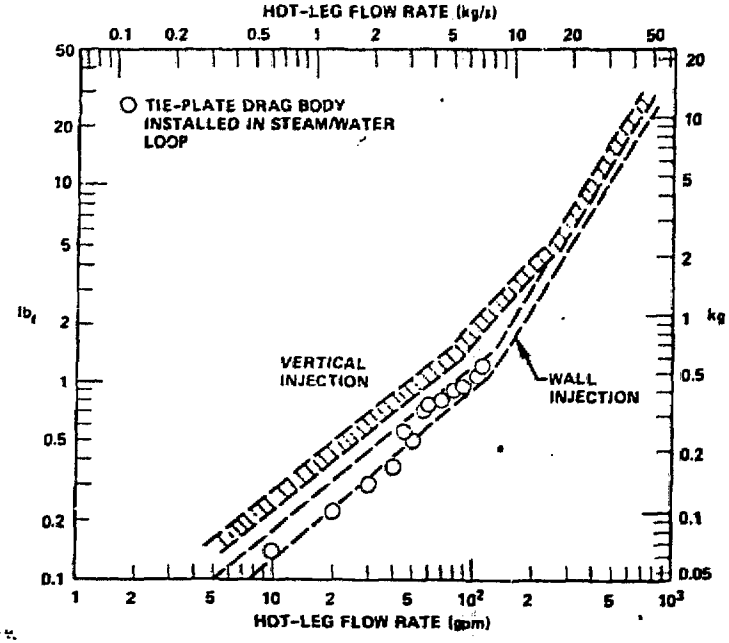
AFTER TIE-PLATE DRAG BODY WAS INSTALLED IN STEAM/WATER LOOP, DOWNFLOW RESULTS WERE IN GOOD AGREEMENT WITH PREVIOUS WALL INJECTION STUDIES



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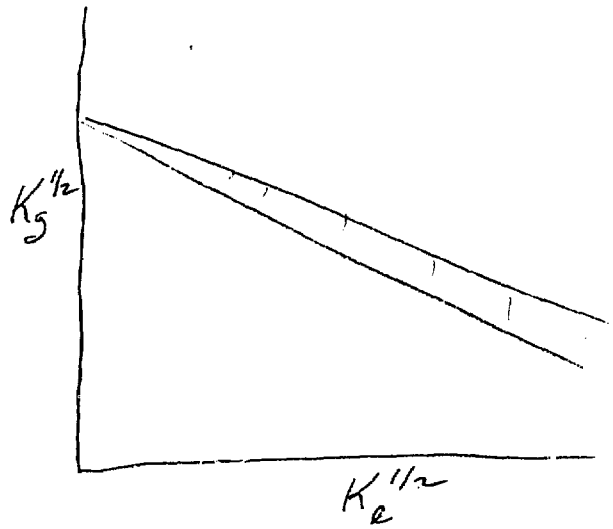
STEAM/WATER COUNTERCURRENT RESULTS FOR CAT JET FLOOD SPRAY.



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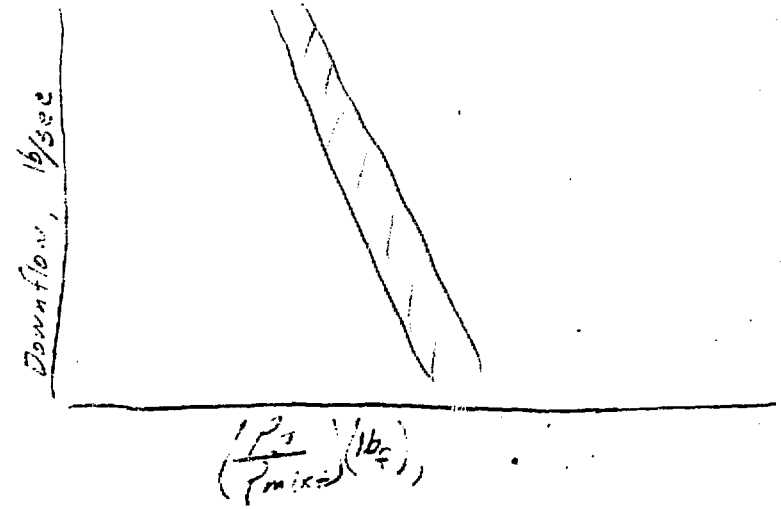
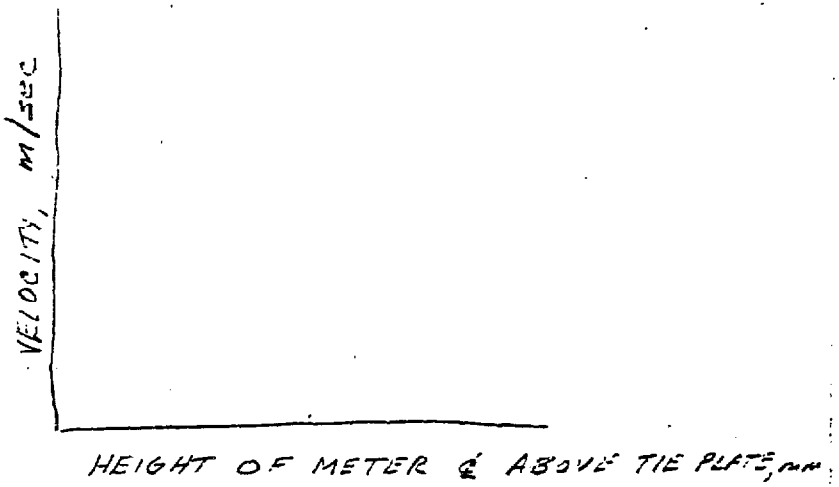
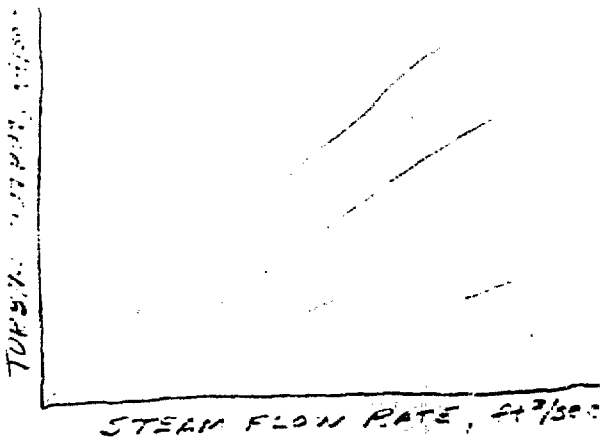
PRELIMINARY CORRELATION FOR DOWNFLOW IN COUNTER CURRENT FLOW REGIME



TIE PLATE TURBINE METER ORIFICE READING DECREASED AS DISTANCE METER WAS LOCATED ABOVE TIE PLATE

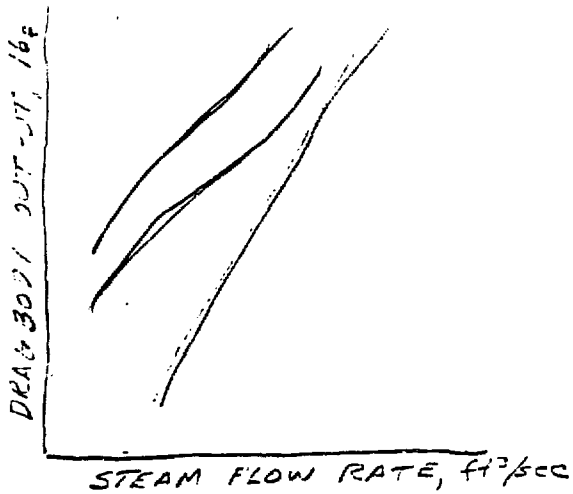


TIE PLATE TURBINE METER OUTPUT ORIFICE DECREASED AS WATER CONTENT OF CORE SPRAY INCREASED.



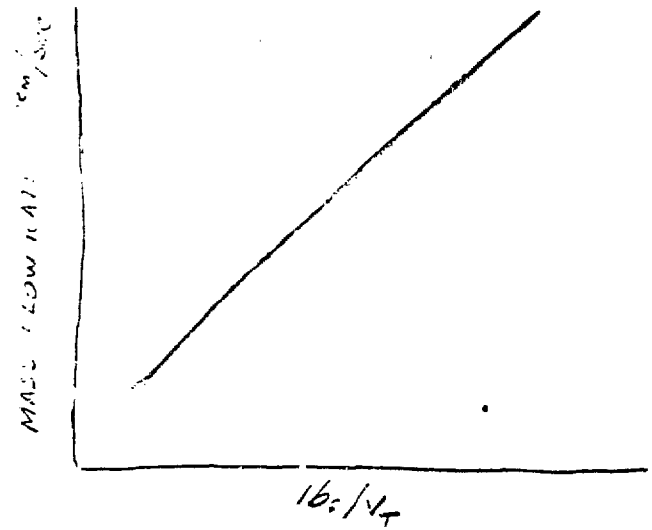
DRAG

TIE PLATE DRAG BODY INTENSITY INCREASED AS WATER CONTENT OF ROLL WAVE INCREASED



DRAG

IN HIGH FLOW OPTION, MASS FLOW RATE IS WELL CORRELATED BY THE TIE-PLATE DRAG BODY AND TIE PLATE TURBINE



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MODEL EQUATIONS FOR CALCULATING MASS FLOW RATE THROUGH TIE PLATE

- HIGH FLOW UPFLOW
- DOWN FLOW
  - NO SEAL ON TIE PLATE
  - SEAL ON TIE PLATE
- COUNTER CURRENT FLOW

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RESULTS OF IDL PROGRAM

- TIE PLATE DRAG BODY WAS DEVELOPED AND TESTED SUCCESSFULLY
- MEASUREMENT WITH TIE PLATE DRAG BODY WAS SHOWN TO BE EQUIVALENT TO ΔP MEASUREMENT
- TURBINE METERS WERE SHOWN TO HAVE SERIOUS PROBLEMS IN LOW UPFLOW
- TURBINE METERS WERE USEFUL IN HIGH UPFLOW
- ΔP IS NOT A USEFUL MEASUREMENT IN SOME DOWNFLOW SITUATIONS
- TIE PLATE DRAG BODY GIVES A USEFUL MASS FLOW MEASUREMENT IN PURE DOWNFLOW SITUATIONS
- DEMONSTRATED THAT DRAG/TURBINE CORRELATES WITH MASS FLOW FOR HIGH UPFLOW

- TIE PLATE DRAG BODY AND COLLAPSED LIQUID LEVEL MAY GIVE A USEFUL MASS FLOW MEASUREMENT IN COUNTERCURRENT FLOW