INTERIM REPORT

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Author(s): G. W. Burnette

Date of Document:

Responsible NRC Individual and NRC Office or Division: W. D. Beckner

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Prepared for
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

INTERIM REPORT

R/R

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, 175 CURTNER AVE., SAN JOSE, CALIFORNIA 95125

NUCLEAR ENERGY
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November 20, 1980

Edward L. Halman, Director
Division of Contracts
U.S. Nuclear Regulatory Commission
Washington, D.C.

Dr. M. Merilo
Safety & Analysis Department
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303

Subject: BWR Refill-Reflood Program
Contract No. NRC-04-79-184
Informal Monthly Progress Report for October 1980

Gentlemen:

The following summarizes the subject matter covered in the attached report:

> The Core Spray Distribution Final Report draft was completed and will be given to the PMG for review and comment. Single Heated Bundle separate effects testing has been completed and agreement reached on the acceptability of these tests. Modification to the 30° Sector is progressing and a series of cold checkout tests was successfully completed. The planned steam injection for simulating fuel bundles in the 30° Sector was documented for presentation at the November 5th and 6th PMG meeting and was approved by the PMG. Preliminary assessment of the TRAC-BWR is underway. Work continued in preparation for TRAC-BWR qualification.

Distribution of this report is being made in accordance with the "Monthly Distribution List" provided with W. D. Beckner's letter of September 6, 1979.

Sincerely,

G. E. Dix

G. E. Dix, Manager
Safety & Thermal Hydraulic Technology

cc: R. G. Bock, M/C 110

Attachments

BWR REFILL REFLOOD PROGRAM

SIXIETH MONTHLY PROGRESS REPORT

OCTOBER 1980

Prepared for: Division of Reactor Safety Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC-FIN-NO. B5877

and: Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94303
EPRI Project No. RP-1377-1

and: General Electric Company
175 Curtner Avenue
San Jose, California 95125

by: General Electric Company

under: Contract No. NRC-04-79-184

BWR Refill-Reflood Program

SIXTIETH MONTHLY PROGRESS REPORT

October 1980

Summary

The Core Spray Distribution Final Report draft was completed and will be given to the PMG for review and comment. Single Heated Bundle separate effects testing has been completed and agreement reached on the acceptability of these tests. Modification to the 30° Sector is progressing and a series of cold checkout tests was successfully completed. The planned steam injection for simulating fuel bundles in the 30° Sector was documented for presentation at the November 5th and 6th PMG meeting and was approved by the PMG. Preliminary assessment of the TRAC-BWR is underway. Work continued in preparation for TRAC-BWR qualification.

Significant Decisions/Upcoming Events

Concurrence is needed on the 30° Sector shakedown and facility performance tests by December 15, 1980.

The TRAC qualification plan and division of work between the Refill-Reflood Program and the National Laboratories need to be developed and agreed upon.

Program Plan (Task 4.1)

Comments were received from EPRI in early November regarding the Refill-Reflood Program Plan document. Following incorporation of these comments, this document will be prepared for publication. A brief program overview including some experimental results were presented at the Eight Water Reactor Safety Information Meeting in Gaithersburg, Maryland on October 29, 1980. A copy of the presentation is included as Appendix A.

Core Spray Distribution (Task 4.2)

Core Spray Distribution Final Report was completed and is now undergoing PMG review.

Single Heated Bundle (Task 4.3)

Separate effects testing was completed including several Priority 2 tests. A special PMG meeting was held in Silver Springs, Maryland on October 30, 1980, to review the acceptability of several test series. Agreement was reached on these tests, and it was decided that no more Single Heated Bundle tests be conducted.

CCFL/Refill System Effects [30° Sector] (Task 4.4)

Modification of the 30° Sector Facility continued through October with several significant accomplishments listed below.

1. Completion of blowdown tank fabrication;
2. Completion of modifications to the test section internals;
3. Completion of new steam line installation with the exception of hangers, insulation, compensating dump silencer, and control valves;
4. DAS/DR hardware delivery and installation; and
5. ECCS booster pump installation and checkout.

Ongoing efforts continue in instrumentation installation, blowdown system construction, steamline installation, and DAS/DR software development.

A set of facility equipment performance tests was conducted in October to address water piping and test section leaks, ECCS pumping capacity, and bypass leakage through LPCI injection. These cold checkout tests went smoothly and no significant problems were encountered. Test planning for shakedown, separate effects, and system effects tests continued. A facility description report and a shakedown plan document are in preparation.

The planned core steam injection method to be used in the 30° Sector to simulate bundles has been documented for presentation at the November PMG meeting.

Basic Models and Correlations (Task 4.7.1)

Some minor modifications have been made to the constitutive correlations for interface shear and the heat transfer, primarily to smooth transitions and correct bugs discovered during the initial phase of the developmental assessment.

Single Channel Code (Task 4.7.2)

No effort this month.

TRAC BWR Support (Task 4.7.3)

The simple upper plenum model that allows a user specified void and enthalpy distribution for the spray system has been tested and is now available for the developmental assessment process.

General

The TRAC program has undergone some minor refinements, and is now ready for development assessment. For this purpose, a copy of the computer program has been implemented on the INEL Cyber 173 computer. A version of the BWR/6 deck with 6 parallel fuel channels and 2 external loops has been received from INEL and implemented on the GE computer. This deck will be used in the developmental assessment.

A TRAC development meeting was held in Idaho on October 16, 1980. The minutes from this meeting have been issued separately.

The TRAC-BD model development at GE was presented at the Eighth Water Reactor Safety Information Meeting in Gaithersburg, Maryland; October 27-31, 1980. A copy of the presentation is attached as Appendix B.

Task 4.8

Comments were received from EPRI in early November regarding the Model Qualification Task Plan report. These comments will be addressed in the final draft. Studies

are continuing using the TRAC deck setup for the Single Heated Bundle facility. A TRAC deck has also been set up and is now running for comparisons with level and void distribution data from the Large Blowdown Vessel Facility (PSTF).

G. E. Dix, Manager
Safety & Thermal Hydraulic Technology
(408) 925-3488,

/kc

Attachments

APPENDIX A

BWR REFILL-REFLOOD PROGRAM

OVERVIEW AND EXPERIMENTAL RESULTS

GW Burnette

GENERAL ELECTRIC COMPANY
NUCLEAR FUEL AND SERVICES ENGINEERING DEPARTMENT
SAN JOSE, CALIFORNIA

FOR PRESENTATION AT:

The 8th Water Reactor Safety Research Information Meeting
October 29, 1980
National Bureau of Standards
Gaithersburg, Maryland

PROGRAM SPONSORS:

US NUCLEAR REGULATORY COMMISSION
ELECTRIC POWER RESEARCH INSTITUTE
GENERAL ELECTRIC COMPANY

BWR REFILL-REFLOOD PROGRAM

OVERVIEW AND EXPERIMENTAL RESULTS

GW Burnette

The BWR Refill-Reflood Program is jointly sponsored by the U.S. Nuclear Regulatory Commission, Electric Power Research Institute and General Electric Company. The program will address the thermal-hydraulic behavior of BWR's during the refill and reflood phases of postulated LOCA's on a generic basis. A primary output of this program will be a set of best estimate models which can be used for realistic LOCA predictions. These models are being developed in conjunction with INEL and are suitable for incorporating into the TRAC-BWR system code. The experimental data from this program will be a major factor in the assessment of these models.

The program features a balanced combination of realistic model development and appropriate supporting experiments for model development and qualification. Separate effects tests are included for use in realistic model development while large scale system experiments are planned for use in independent qualification. A full radius, 30° Sector Facility at Lynn, Massachusetts is the primary large scale facility to be used within the program, but data from many other experiments will also be utilized for model assessment.

Early results from the program have confirmed that the GE core spray distribution prediction methodology [1] is sufficiently general to apply to an alternate geometry (BWR/4) and set of spray conditions in the 30° Sector (previously confirmed for a BWR/6

system design). The 30° Sector is presently being modified in preparation for conducting transient refill-reflood tests.

Development of a steam injection technique for simulating fuel bundles in the 30° Sector has been achieved using a single bundle system facility. Separate effects tests for model development are now underway in this single bundle system. A number of preliminary models for simulating BWR component performance and thermal-hydraulic phenomena have been developed. These results and the status of model development are detailed in the Model Development presentation.

Reference

1. SA Sandoz, et. al., "Core Spray Design Methodology Confirmation Tests", NEDO-24712, August, 1979.

BWR REFILL-REFLOOD PROGRAM

PROGRAM OVERVIEW	GW BURNETTE
EXPERIMENTAL RESULTS AND STATUS	GW BURNETTE
MODEL DEVELOPMENT AND STATUS	JGM ANDERSEN

SPONSORED BY:

USNRC,	PMG MEMBER - WD BECKNER
EPRI,	PMG MEMBER - M MERILO
GE,	PMG MEMBER - GW BURNETTE

OCTOBER 29, 1980

REFILL-REFLOOD PROGRAM OVERVIEW

O B J E C I I V E S

PAYOFF:

QUALIFIED BEST ESTIMATE LOCA METHODS

SPECIFIC OBJECTIVES:

- IMPRO'ED UNDERSTANDING OF PHENOMENA CONTROLLING REFILLING AND REFLOODING OF THE BWR
- BASIS FOR AND SUPPORT TO DEVELOPMENT AND QUALIFICATION OF BWR THERMAL-HYDRAULIC LOCA CODES
- BASIS FOR ASSESSING ASSUMPTIONS USED IN ESTABLISHING BWR LOCA SAFETY MARGINS

GWB
10/29/80

REFILL-REFLOOD PROGRAM OVERVIEW

MAIN ELEMENTS AND STATUS

TASK	STATUS
CORE SPRAY DISTRIBUTION	COMPLETE
SINGLE HEATED BUNDLE	SYSTEM EFFECTS TESTS COMPLETE ADIABATIC STEAM INJECTION TESTS COMPLETE SEPARATE EFFECTS TESTS IN PROGRESS
CCFL/REFILL SYSTEM EFFECTS TESTS	MODIFICATIONS UNDERWAY MEASUREMENT PLAN FINALIZED
360° UPPER PLENUM TESTS	NOT STARTED
MODEL DEVELOPMENT	MANY BASIC MODELS DEVELOPED/IMPROVED (CONSTITUTIVE AND HEAT TRANSFER) SINGLE CHANNEL MODEL STARTED
MODEL QUALIFICATION	TASK PLANNING COMPLETE

GWB
10/29/80

REFILL-REFLOOD PROGRAM EXPERIMENTAL RESULTS

SINGLE BUNDLE SYSTEM TESTS

OBJECTIVES

- IDENTIFY AND EVALUATE PHENOMENA CONTROLLING THE REFILL AND REFLOOD PHASE OF A BWR LOCA

- DEVELOP AN ADIABATIC INJECTION TECHNIQUE FOR THE 30° SECTOR FACILITY

- OBTAIN SEPARATE EFFECTS THERMAL-HYDRAULIC PERFORMANCE DATA FOR MODEL DEVELOPMENT

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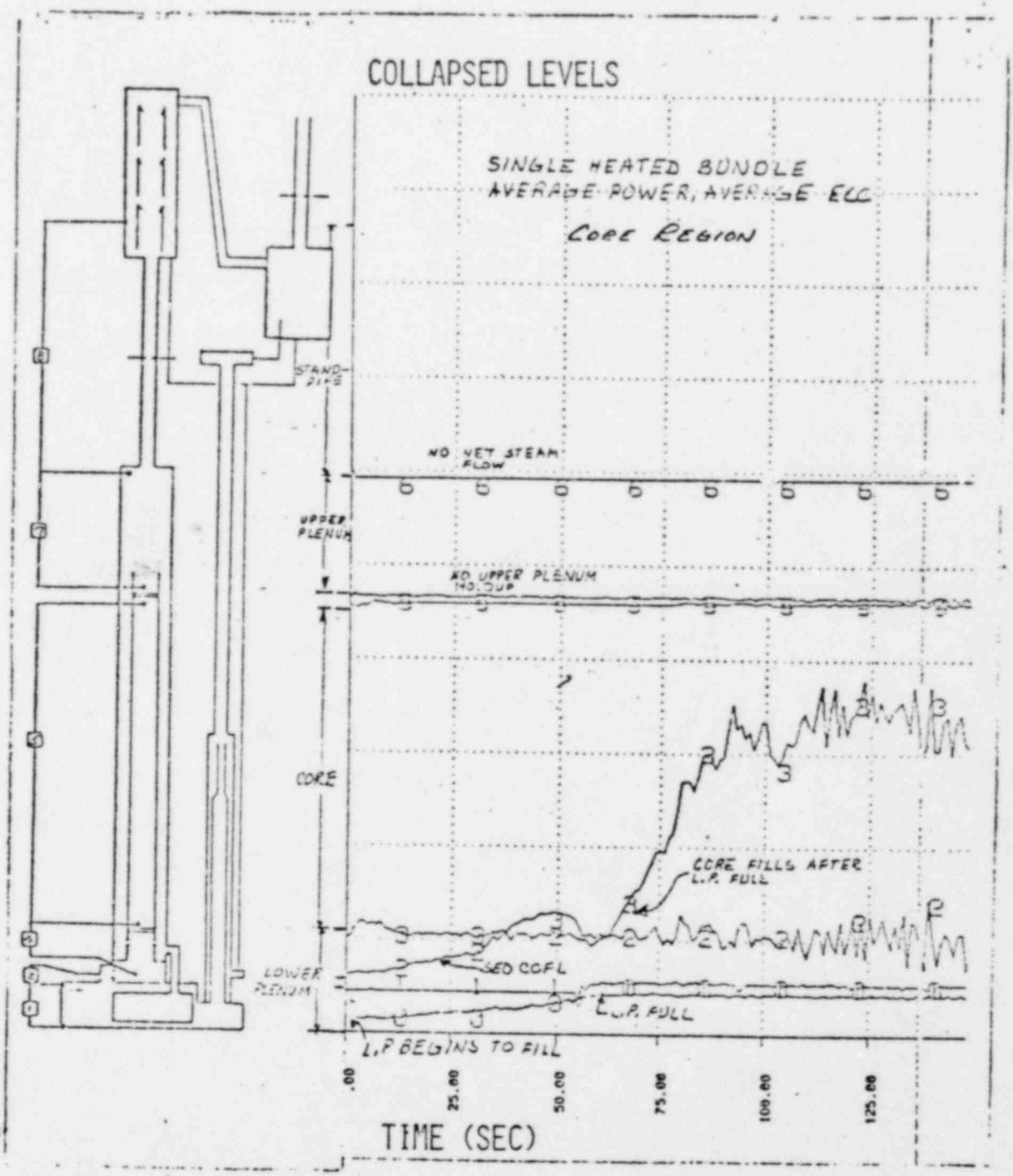
10/29/80

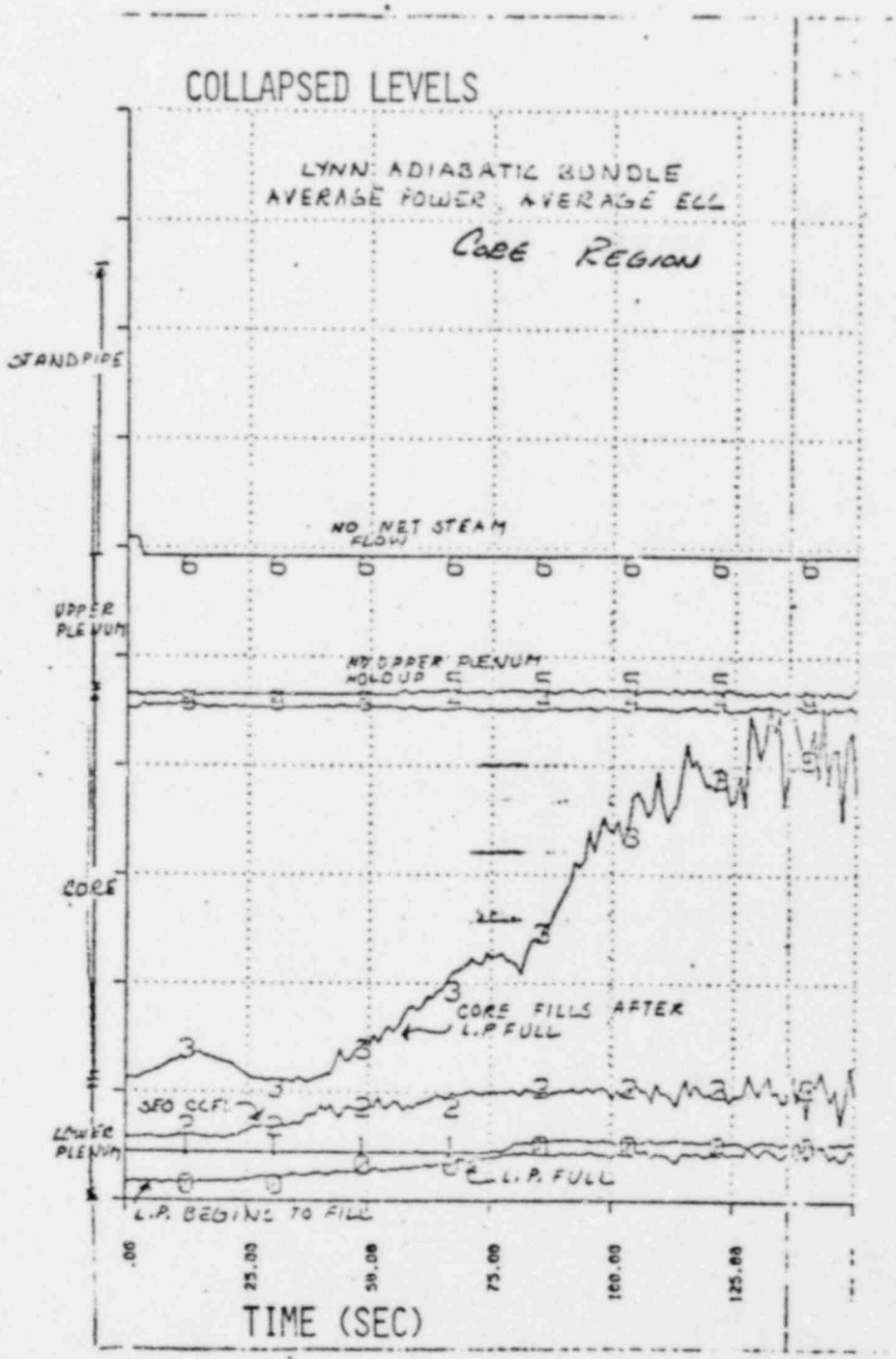
SINGLE BUNDLE SYSTEM TESTS

HEATED BUNDLE



SINGLE BUNDLE SYSTEM TESTS

ADIABATIC STEAM INJECTION



SINGLE BUNDLE SYSTEM TESTS

PRELIMINARY CONCLUSIONS

- SIMILAR LOWER PLENUM AND CORE REGION REFILL CHARACTERISTICS
- REFILLING INSENSITIVE TO BUNDLE-UPPER PLENUM FEEDBACK OVER EXPECTED CONDITION RANGE
- STEAM INJECTION CAN BE USED TO SIMULATE HEATED BUNDLES IN 30° SECTOR

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REFILL - REFLOOD PROGRAM EXPERIMENTAL RESULTS

30° SECTOR FACILITY

BACKGROUND

- BWR RESPONSE INFLUENCED BY CCFL BREAKDOWN IN UPPER PLENUM
- BREAKDOWN TIME DEPENDENT UPON MIXING
- GOOD MIXING MODELS NEEDED FOR REALISTIC RESPONSE PREDICTIONS

OBJECTIVE

- OBTAIN REALISTIC, LARGE SCALE REFILL-REFLOOD PERFORMANCE DATA FOR MODEL QUALIFICATION/DEVELOPMENT

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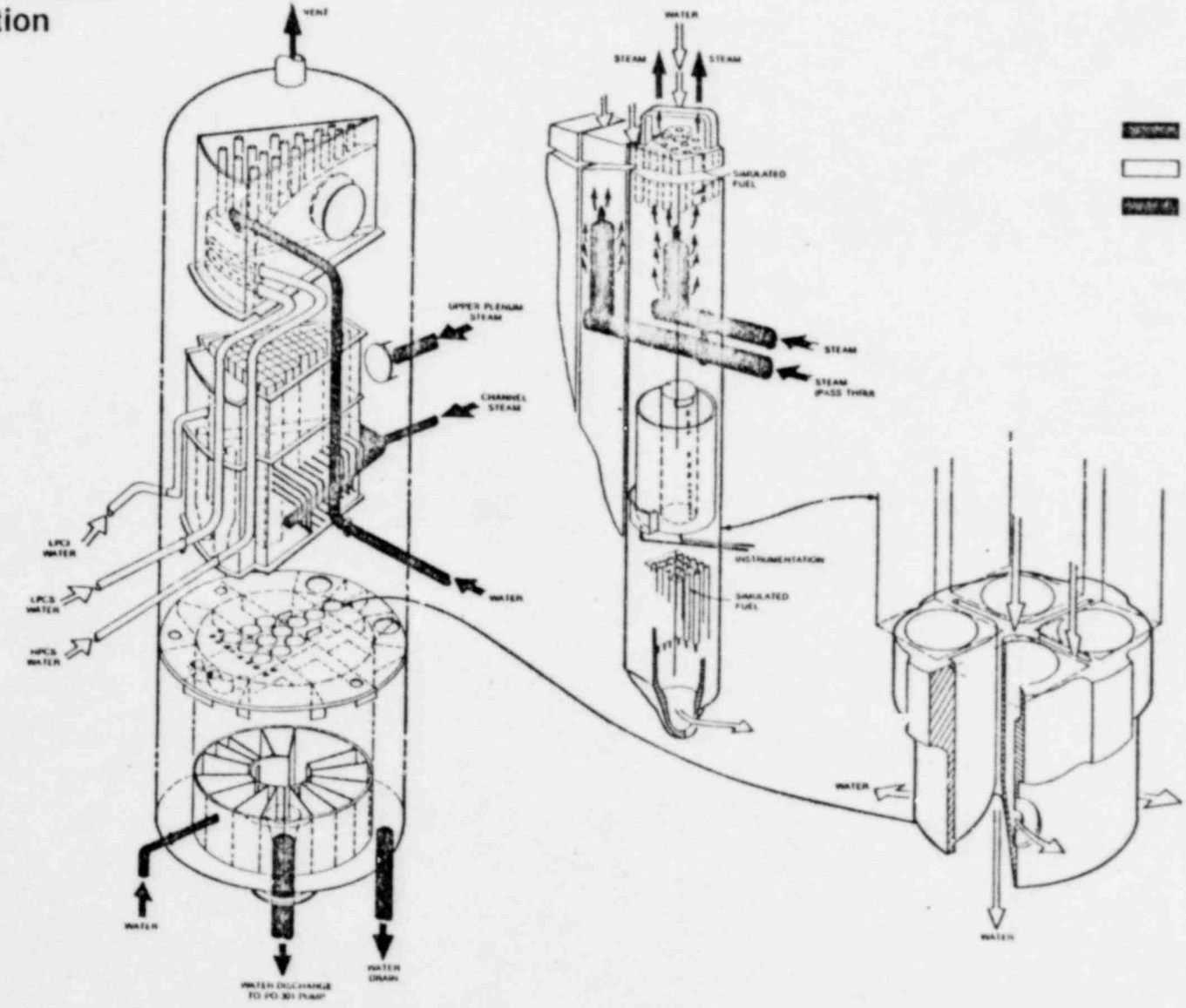
10/29/80

30° Steam Sector Test Section



30° SECTOR FACILITY

MODIFICATION NEEDS

FACILITY HARDWARE

- BLOWDOWN SYSTEM
- INITIALIZATION EQUIPMENT
- EXCESS VOLUME VENT SYSTEM
- VESSEL INTERNALS

TEST INSTRUMENTATION (AUGMENTATION)

- REGIONAL FLUID INVENTORIES AND LEVELS
- TEMPERATURE FIELDS IN ECC INJECTION REGIONS
- LOCAL SUBCOOLING MEASUREMENTS
- SYSTEM BOUNDARY CONDITIONS

DATA ACQUISITION/DATA REDUCTION

- INCREASED MEASUREMENT CAPABILITY
- INCREASED INSTRUMENT/DATA QA CHECKS
- DERIVED QUANTITIES FOR MODEL ASSESSMENT

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10/19/80

30° SECTOR FACILITY

MILESTONES

MAJOR HARDWARE INSTALLED	4Q80
COMPLETE SYSTEM INSTALLATION	1Q81
SHAKEDOWN COMPLETE	2Q81
BEGIN TESTING	3Q81

APPENDIX B

BWR REFILL-REFLOOD PROGRAM

MODEL DEVELOPMENT FOR TRAC-BD

JGM Andersen

GENERAL ELECTRIC COMPANY
NUCLEAR FUEL AND SERVICES ENGINEERING DEPARTMENT
SAN JOSE, CALIFORNIA

FOR PRESENTATION AT:

The 8th Water Reactor Safety Research Information Meeting
October 29, 1980
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BWR REFILL-REFLOOD PROGRAM

MODEL DEVELOPMENT FOR TRAC-BD

JGM Andersen

A part of the Refill-Reflood Program is concerned with the development of models for the BWR version of TRAC. The main goal is to develop models that allow a best estimate simulation of all components and phenomena in a BWR system. The BWR components to be modelled are:

- Jet Pump
- Steam Separator
- BWR Fuel Bundle (done by EG&G)
- Steam Dryer
- Upper Plenum Phenomena

The basic phenomena of importance for the BWR LOCA transient are

- Interface shear and wall friction
- Interface and wall heat transfer
- Entrainment and deposition

The development of models for BWR components and phenomena is being done in two steps:

- Development of an intermediate set of component and phenomena models that allow a reasonably good simulation of a BWR LOCA transient. This task is to be completed in 1980.
- Assessment of the intermediate models and development of final models for a best estimate BWR-LOCA simulation. This task is to be completed in 1982. Furthermore, in this period the models are to undergo independent qualification.

A jet pump model, including appropriate losses (form, mixing and other irreversible), has been developed. This model has been used to predict small scale as well as full scale jet pump performance with good results. Simple models for the steam separators and dryers, giving full separation of the phases, have also been developed.

A new methodology that allows the correlation of interface shear and wall friction based on void fraction and pressure drop data has been developed. The main new feature is that the model for the interface drag and shear accounts for the effect of the phase and velocity distribution in the calculation of the average relative velocity. Furthermore, the interfacial force accounts for the effect of drag, phase distribution and wall friction. Based on this model a new set of constitutive correlations for the interface shear and drag has been developed. The model has been tested against void fraction data, with good results. The heat transfer models have been upgraded to include several new phenomena. The major improvements are the inclusion of subcooled boiling and thermal radiation. The latter is particularily important for PWR's during spray cooling. Furthermore, the critical heat flux correlation has been replaced with a boiling length correlation, which improves the prediction of early boiling transition in high power fuel bundles during a DBA-LOCA.

The above accomplishments represent the scope of the intermediate step in the model development. The modesl will undergo an extensive developmental assessment during the remainder of 1980. The development of the final models will start in 1981.

BWR REFILL-REFLOOD PROGRAM

MODEL DEVELOPMENT FOR TRAC-BD

GENERAL ELECTRIC

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OCTOBER 1980

OBJECTIVE

Best Estimate Simulation of a BWR LOCA Transient.

TASK

Develop Models for BWR Components and Phenomena of Importance for BWRs.

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October 1980

BWR COMPONENT MODELS

- JET PUMP
  - MIXING
  - MIXING AND IRREVERSIBLE LOSSES
  - REVERSIBLE LOSSES
- STEAM SEPARATOR
  - PRESSURE DROP
  - CARRY OVER AND CARRY UNDER
- DRYER
  - PRESSURE DROP
- UPPER PLENUM
  - MIXING
  - VOID AND ENTHALPY DISTRIBUTION
  - SUBCOOLED CCFL BREAKDOWN
- FUEL BUNDLE (INEL)

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MODELS FOR IMPORTANT BWR PHENOMENA

- COUNTER CURRENT FLOW LIMITATION
- VOID FRACTION AND PRESSURE DROP
  - INTERFACE SHEAR
  - WALL FRICTION
- HEAT TRANSFER
  - INTERFACE HEAT TRANSFER
  - WALL HEAT TRANSFER

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OCTOBER 1980

SCHEDULE

- First Version — End 1980
  - Jet Pump
  - Simple Separator and Dryer Models
  - Simple Upper Plenum Model
  - CCFL
  - Void Fraction and Pressure Drop
  - Heat Transfer
- Final Version — Mid 1982
  - Separator and Dryer Models
  - Upper Plenum Model

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October 1980

JET PUMP MODEL

- BASED ON TRAC TEE COMPONENT
- MODEL DEVELOPMENT
  - MOMENTUM EQUATION MODIFIED TO IMPROVE PREDICTION OF REVERSIBLE LOSSES AT AREA CHANGES.
  - MIXING PROCESS IN MIXING REGION.
  - MIXING LOSSES.
  - IRREVERSIBLE LOSSES IN DRIVE LINE, SUCTION, AND DISCHARGE.
  - FORWARD AND REVERSE FLOW.
- ASSESSED ON INEL JET PUMP DATA

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OCTOBER 1980

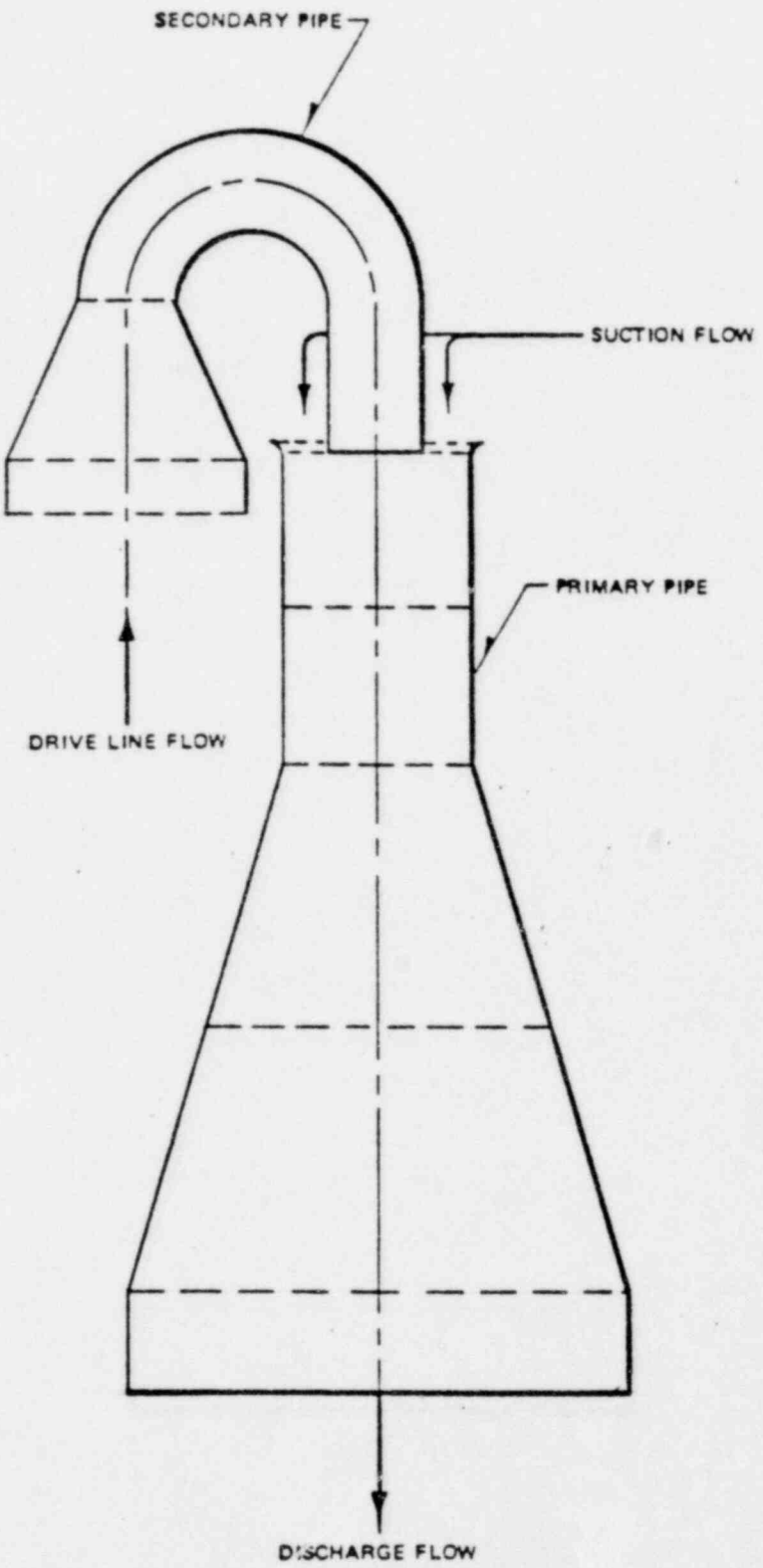


Figure 12. Two-Fluid Jet Pump Model II

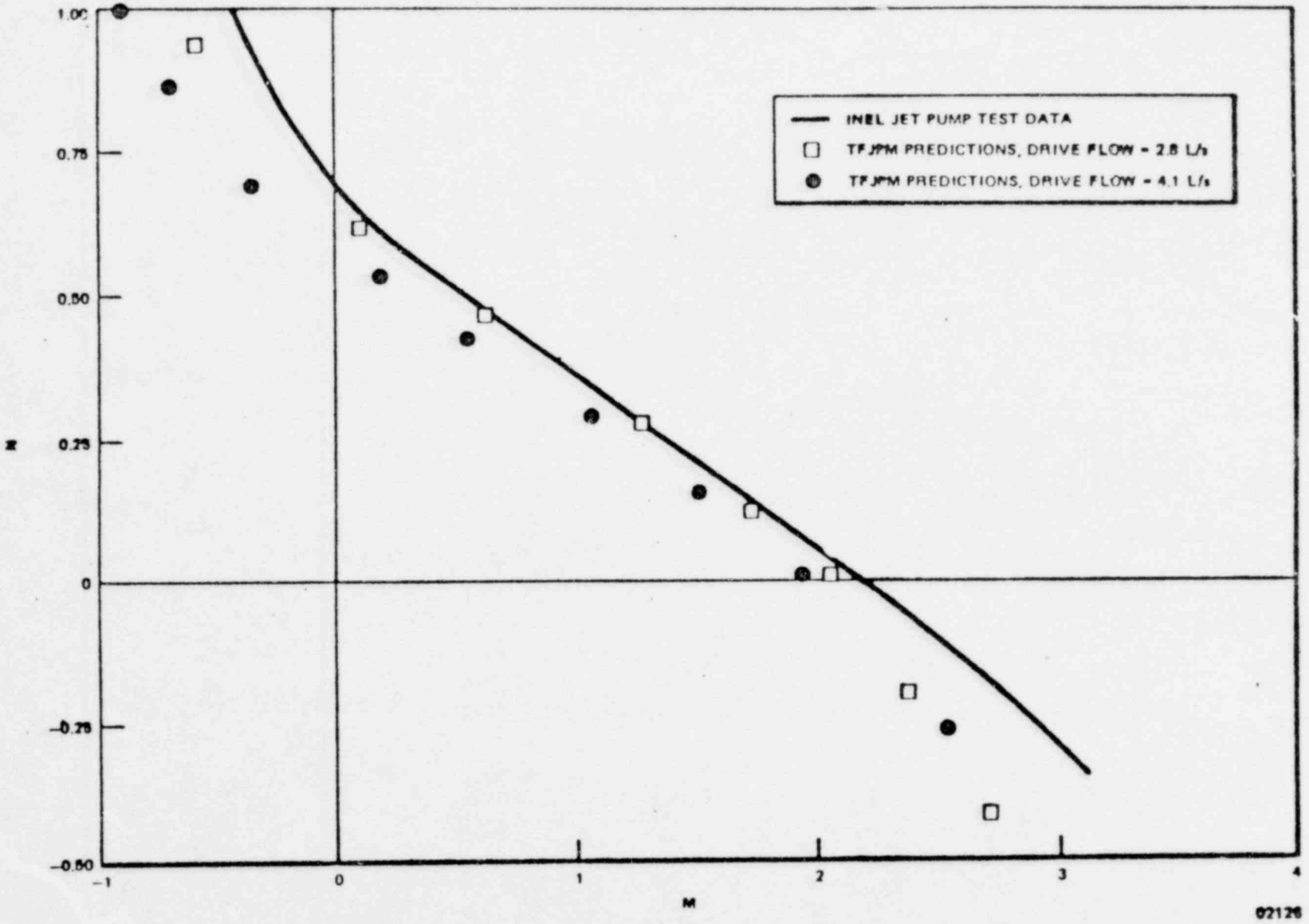


Figure 16. Comparison of TFJPM Predictions with INEL Test Data for +ve Drive Flow

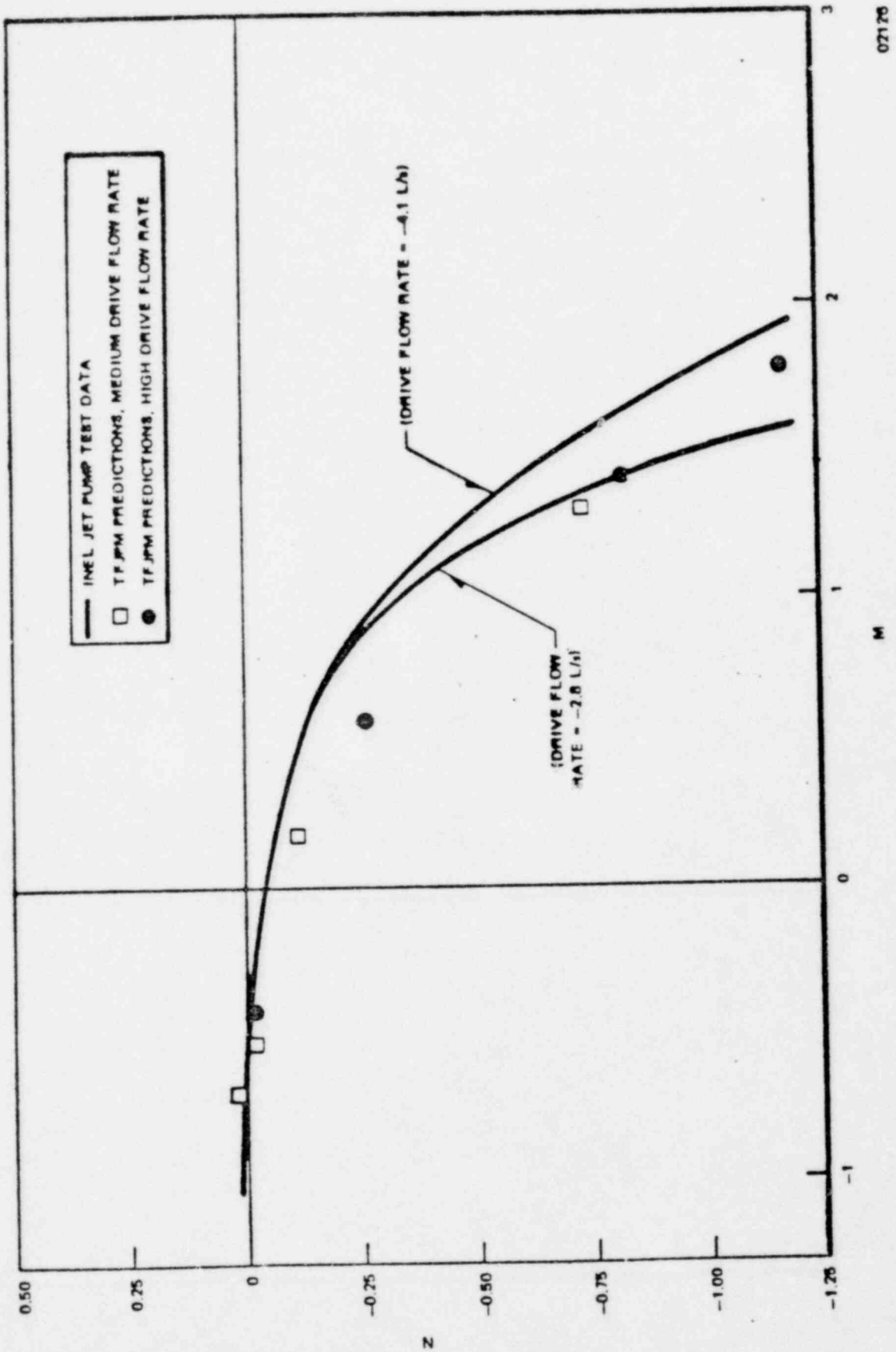


Figure 17. Comparison of TF JPM Predictions with INEL Test Data for −ve Drive Flow

VOID FRACTION MODEL

INTERFACE SHEAR

- Based on Void Fraction Data

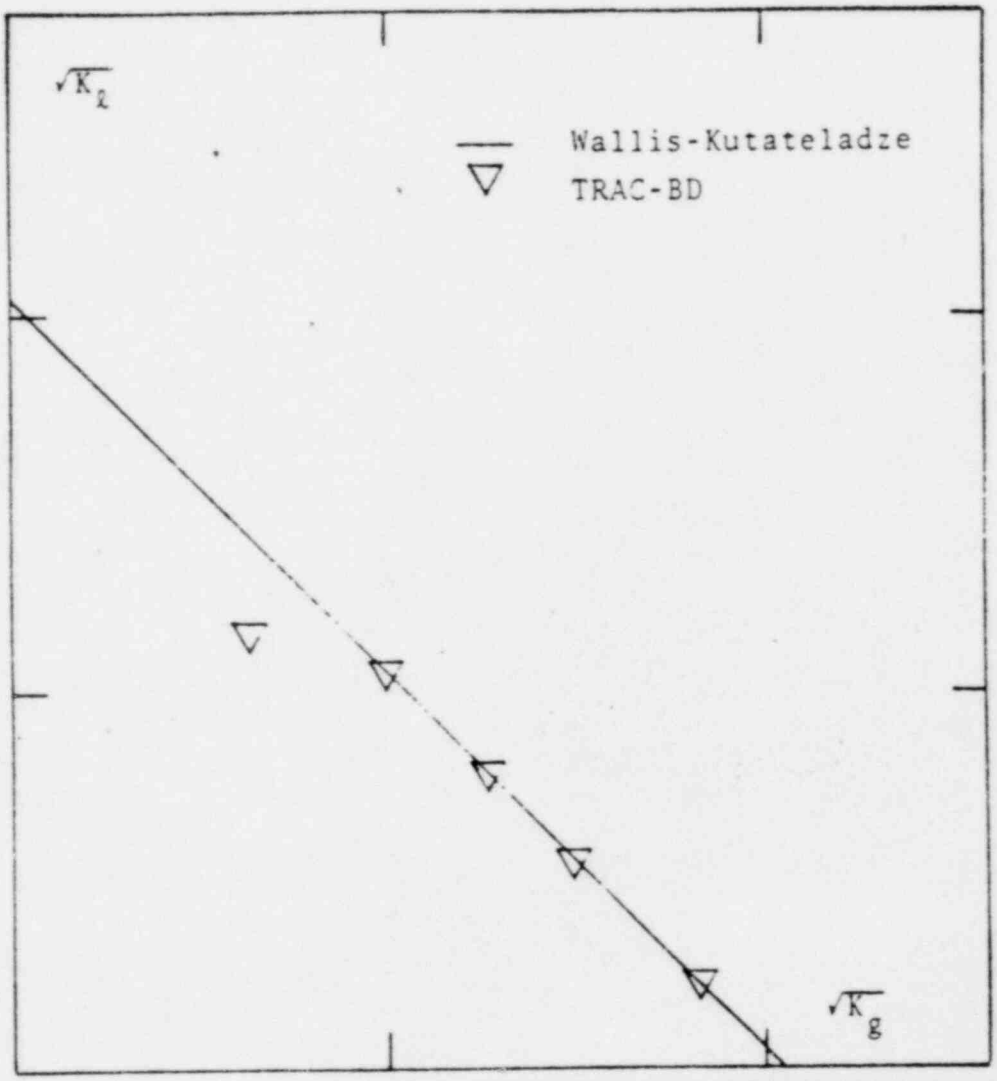
- Model Features
  - Interfacial Force Depends on:
    - Drag due to relative motion of phases
    - Shear due to phase distribution
    - Phase and velocity distribution
    - Wall friction governed shear field
  - Match to Counter Current Flow Limiting Data

- Flow Regimes
  - Bubbly/Churn Flow
  - Annular Flow
  - Dispersed Droplet Flow
  - Single Phase Flow

- Assessed on Separate Effects Tests

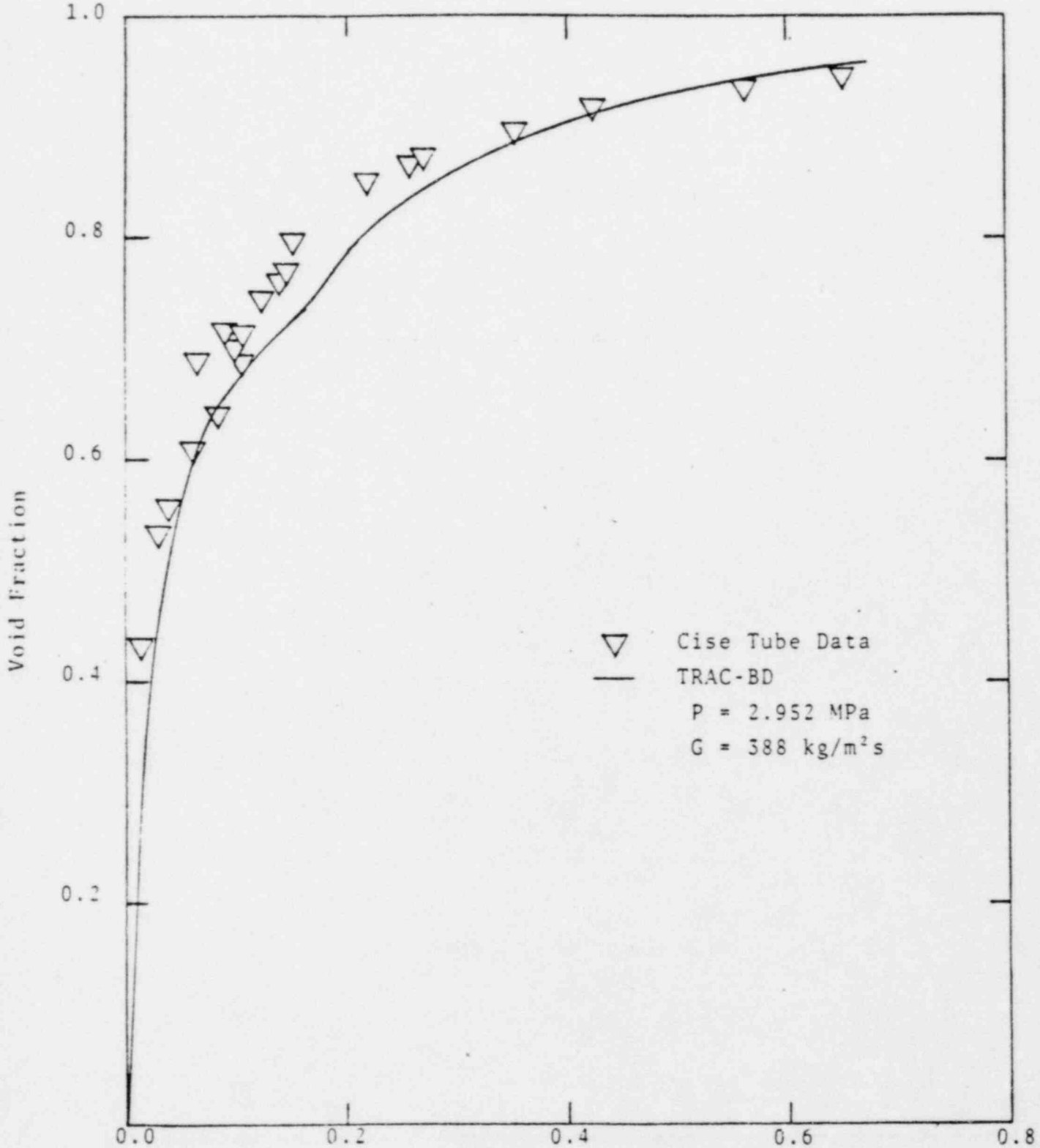
JGM Andersen

October 1980



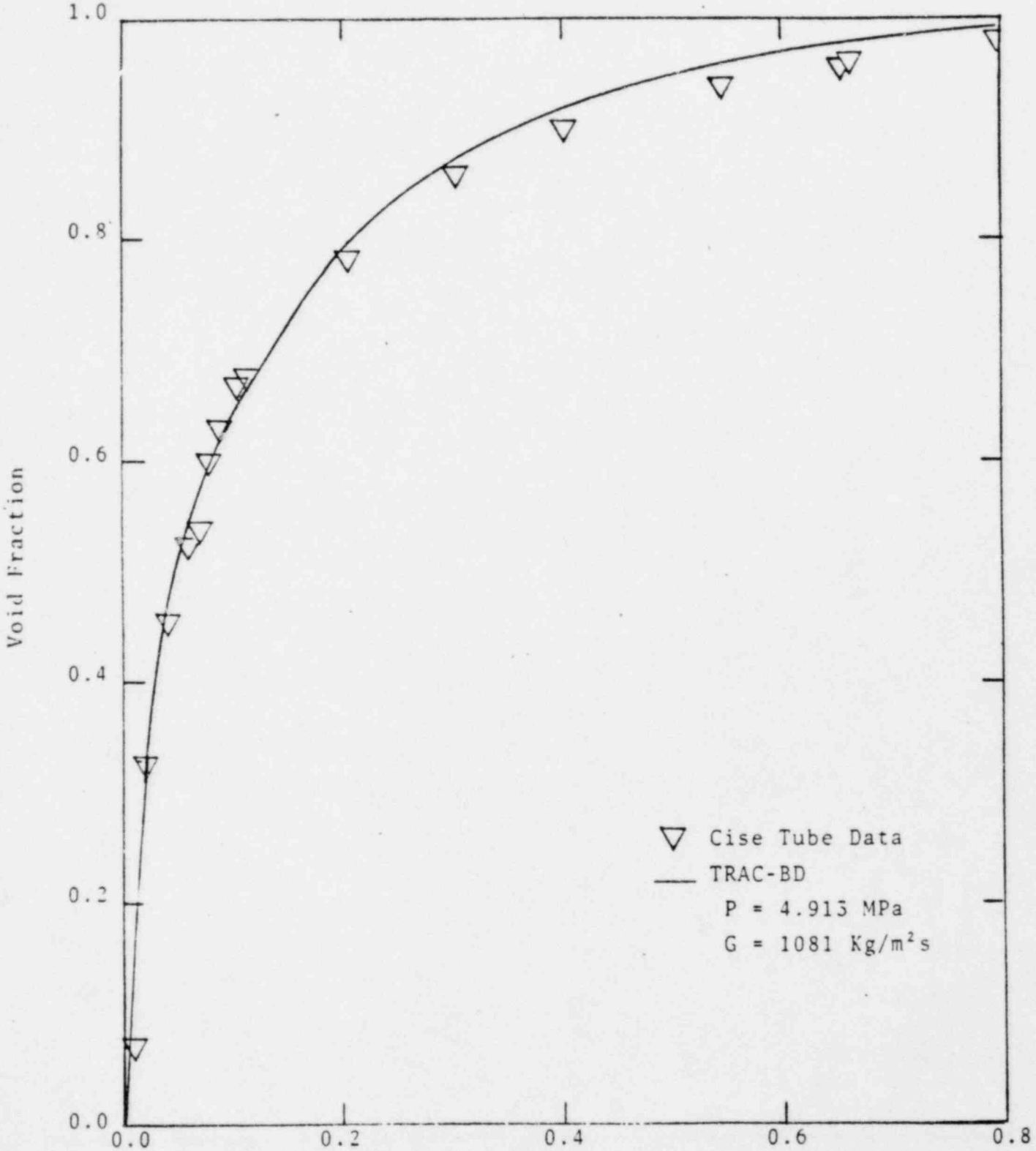
CCFL

Preliminary Assessment of TRAC-BD Models



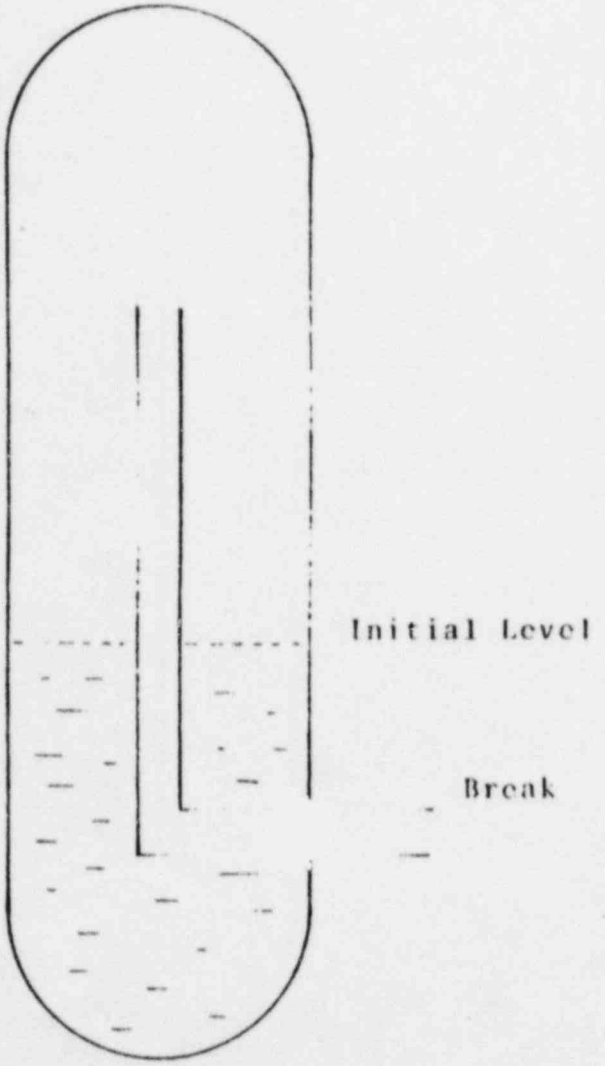
Interface Shear

Preliminary Assessment of TRAC-BD Models

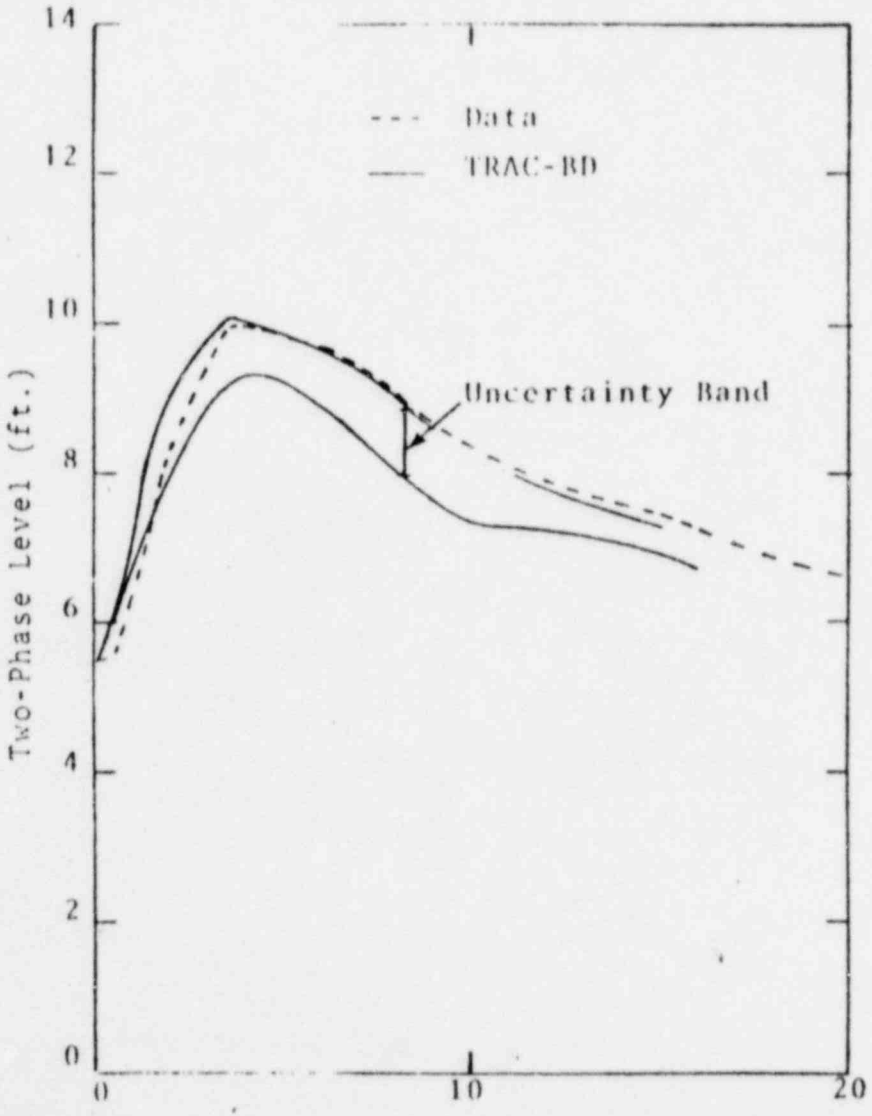


Interface Shear

Preliminary Assessment of TRAC-BD Models



Level Swell Test



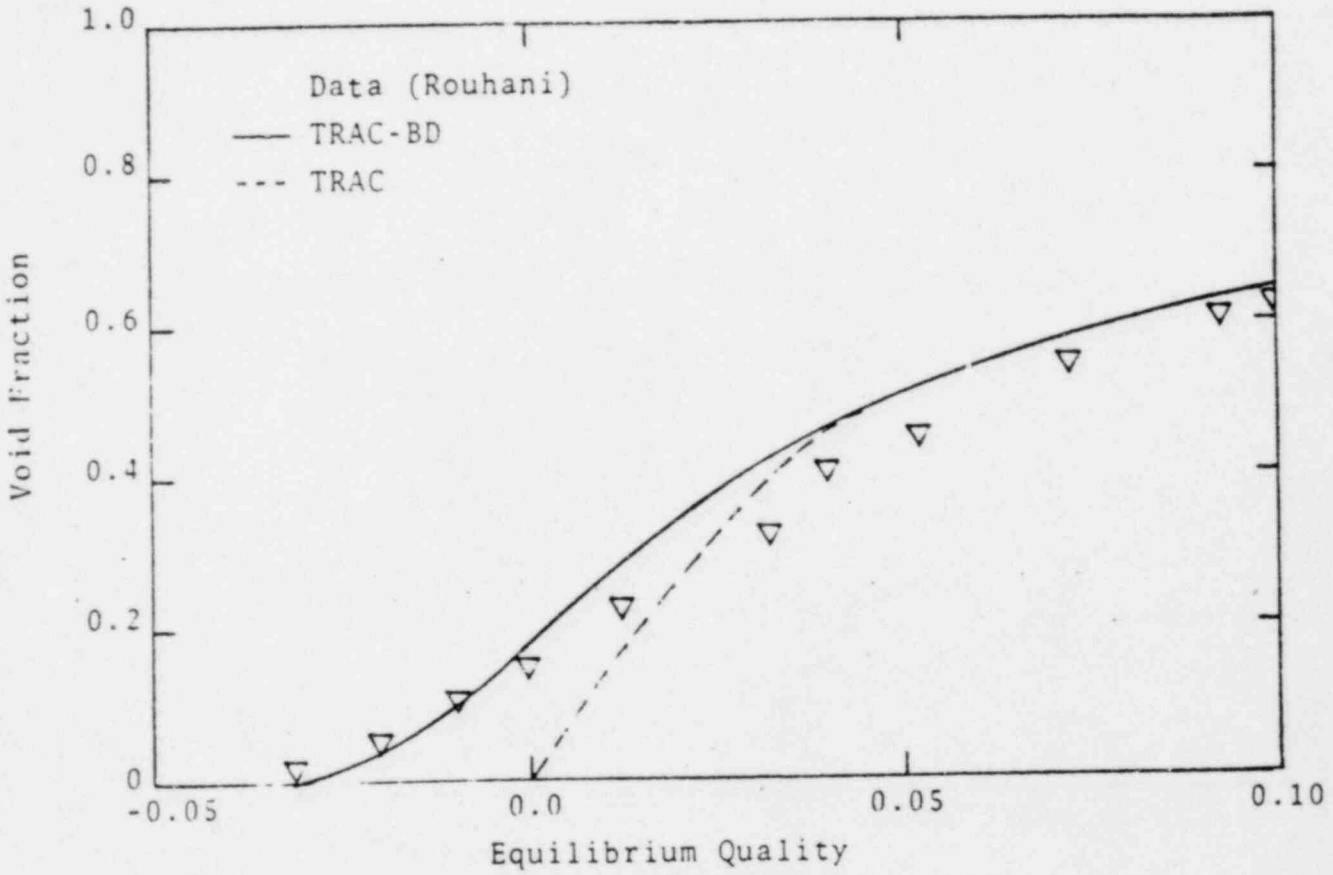
Preliminary Assessment of TRAC-BD Models

HEAT TRANSFER IMPROVEMENT

- SUBCOOLED BOILING
  - MECHANISTIC HEAT TRANSFER MODEL (BOWRING, ROUHANI)
  - NET VAPOR GENERATION (SAHA-ZUBER)
- CRITICAL HEAT FLUX
  - BOILING LENGTH CORRELATION (CISE-GE)
- THERMAL RADIATION
  - ALL SURFACES ARE GREY
  - ALL SURFACES HAVE UNIFORM TEMPERATURE
  - ALL SURFACES EMIT RADIATION UNIFORMLY
  - TWO-PHASE FLOW ABSORBS AND EMIT RADIATION
  - SEMI-GRAY MODEL
  - FIRST ORDER ANISOTROPIC TRANSPORT CORRECTION

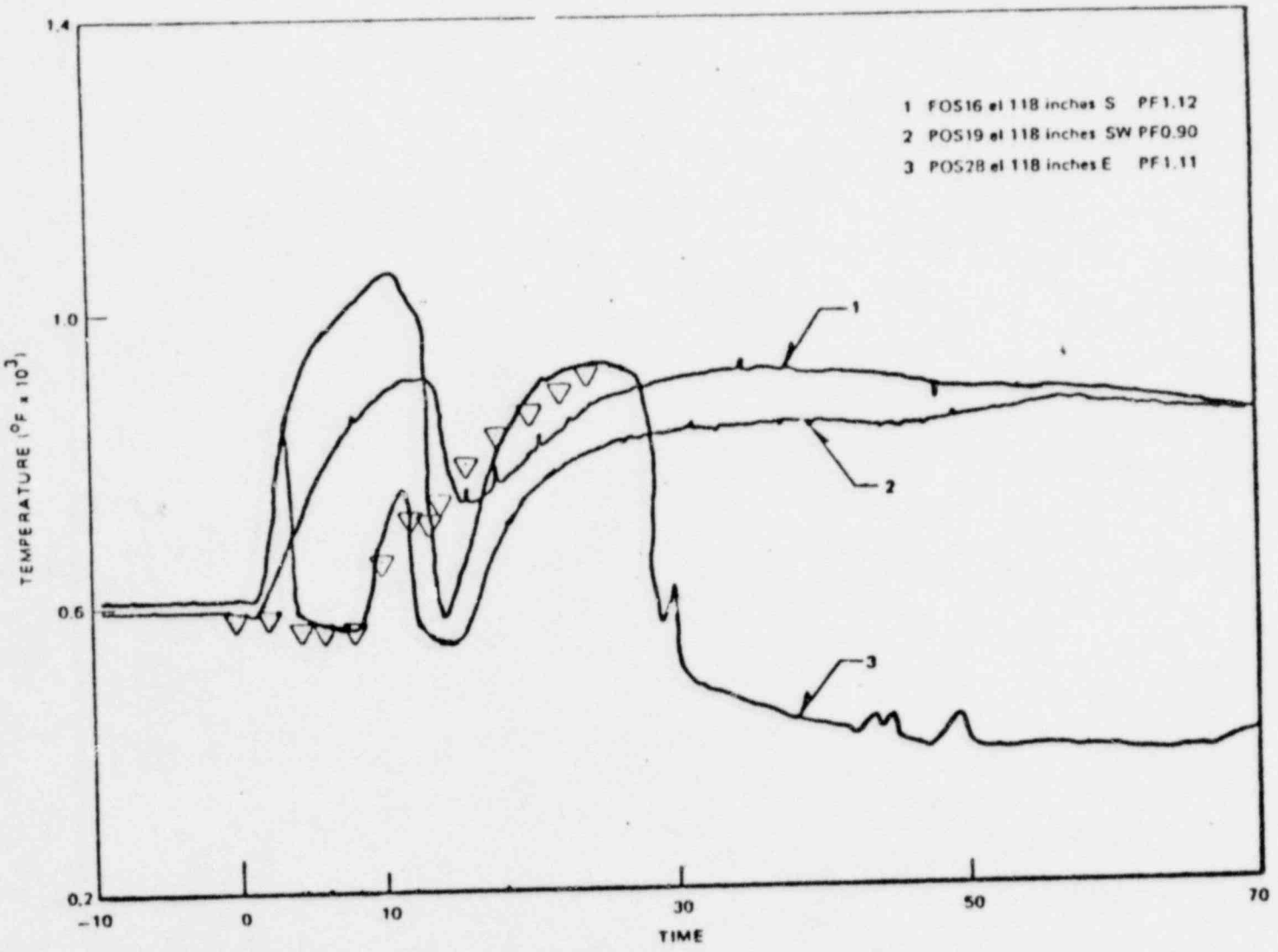
JGM ANDERSEN

OCTOBER 1980

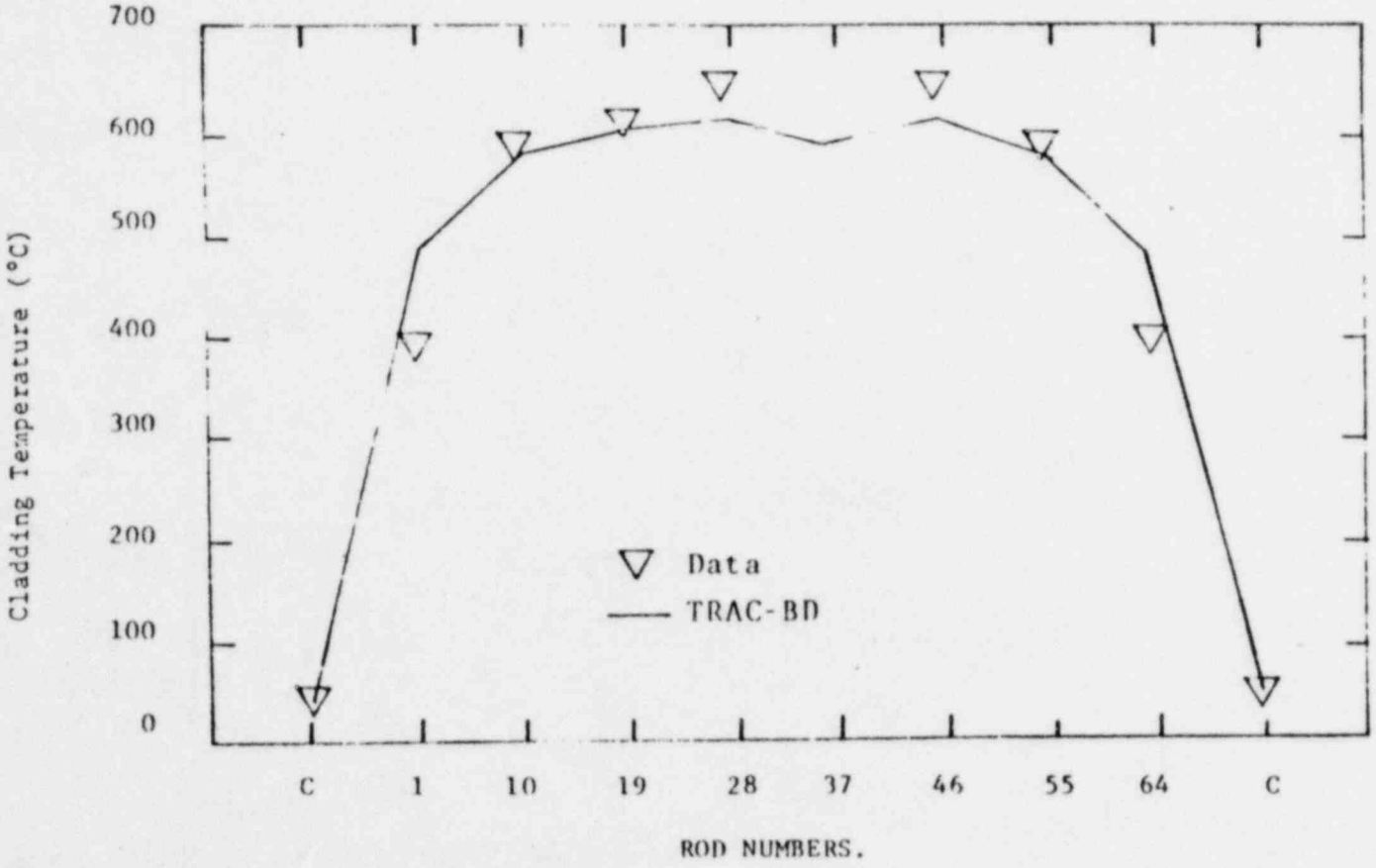


SUBCOOLED BOILING

Preliminary Assessment of TRAC-BD Models



Test 4904 Run 45



Radiation Calculation
Assessment of TRAC-BD Models

STATUS

- DEVELOPMENT OF FIRST VERSION OF COMPONENT AND PHENOMENA MODELS OF TRAC BD COMPLETE.

- TESTING AND DEVELOPMENTAL ASSESSMENT THROUGH 1980.

- INDEPENDENT ASSESSMENT OF MODELS IN 1981.

- DEVELOPMENT OF FINAL MODELS IN 1981.

JGM ANDERSEN

OCTOBER 1980