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

INTERIM REPORT

GENERAL ELECTRIC

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NUCLEAR ENERGY

BUSINESS GROUP

Mail Code 583

November 19, 1981

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SUBJECT: BWR Refill-Reflood Program
Contract No. NRC-04-79-184
Informal Monthly Progress Report for October, 1981.

Gentlemen:

Please find attached subject report:

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.

Regards,

J. C. Black, Senior Program Manager
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Attachments

/lk

BWR REFILL REFLOOD PROGRAM

TWENTY - FIFTH INFORMAL MONTHLY PROGRESS REPORT

OCTOBER

PREPARED FOR:

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

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BY:

General Electric Co.

UNDER:

Contract No. NRC-04-79-184

SUMMARY

The system response tests of the BWR/4 ECCS variation tests series were completed. By agreement of the PMG this concludes the current SSTF test series on the Refill-Reflood Program.

The major model development activities included closure of the open items from the technical reviews of TRAC.

SIGNIFICANT DECISIONS/UPCOMING EVENTS

The SSTF testing was terminated by the PMG and facility wrap-up activities initiated. The decision whether to lay-up or scrap the facility is still pending PMG direction.

The next PMG meeting was tentatively scheduled for January '82 in the West Coast.

SINGLE HEATED BUNDLE (Task 4.3)

The work remaining on Task 4.3 is being reviewed as proposed at the October PMG meeting in Lynn, to determine what might be subcontracted to INEL.

CCFL/REFILL SYSTEM EFFECTS [30° Sector] (Task 4.4)

The system response tests of the BWR/4 ECCS Variation test series were completed in October. These transient blowdown tests with BWR/4 LPCS (lower header) and LPCI injection locations demonstrated quick refill-reflood. In these tests, decaying amplitude post reflood oscillations in jet pump flow induced by the BWR/4 jet pump LPCI injection location, provide thermal-hydraulic data of interest for model assessment application.

CCFL/REFILL SYSTEM EFFECTS [30° Sector] (Task 4.4) - (continued)

Technical presentations of SSTF test results (SSTF Parallel Channel Flow Phenomena, BWR/6 System Response Tests, BWR/4 Seperate Effect and System Response Tests) were prepared and presented at the October PMG meeting at Lynn, Massachusetts. In response to the PMG decision tc conclude test operation, the SSTF minicomputer has been returned to San Jose for data evaluation support.

Data evaluation activity for the month of October was directed at initial evaluation of BWR/4 ECCS Variation separate effect and system response test results and at continuing analysis of BWR/6 Reference Blowdown Test.

4.7 MODEL DEVELOPMENT

General

A major activity in October was the closure of the open items from the technical reviews of TRAC. This has now been completed.

A TRAC development meeting was held in Idaho on October 22, and a separate trip report for this meeting has been issued.

The TRAC development and assessment was presented at the Ninth Water Reactor Safety Information Meeting, Gaitherburg, Maryland October 26-30, 1981. The presentation was well received.

4.7.1 Basic Models and Correlations

The new heat transfer package is currently being tested.

4.7.3 TRAC BWR Support

A model for two phase levels in TRAC is currently under development. Encouraging results have been obtained so far, but further refinement of the model is still required.

Further development of the steam separator model has been performed, and good results have now been obtained when compared to data for all three generations of separators. The next step in the development of the separator model is implementation into TRAC.

The development of an upper plenum model continued during this period. The submerged jet model has been tested against single phase jet data and good results have been obtained. For the spray, encouraging results have been obtained.

4.8 MODEL QUALIFICATION

Qualification results from the TLTA studies are described in the attachment.

ATTACHMENT - Refill-Reflood Program Informal Monthly Progress Report for September, 1981

CURRENT MODEL QUALIFICATION ACTIVITIES (Task 4.8)

External Design Review Support

Results of TRAC preliminary Assessment (qualification) studies were prepared and presented to an exteranl design review committee consisting of members from NRC, EPRI, EG&G and GE. These results included qualification runs for the integral system tests of the TLTA, the SHB, vessel blowdown tests, the ORNL single bundle and the single bundle TLTA.

As a result of the design review, several items were identified related to providing more clarification and substantiation of the qualification results presented. Some minimal effort was spent toward the resolution of these items during the reporting period.

TLTA Integral System Tests

The following sections describe the salient features of TRAC preliminary assessment runs for the TLTA reference DBA tests (average power, with and without ECC) and the TLTA Boiloff test. The purpose of this simulation was to assess TRAC's capability for predicting integral system interaction phenomena observed during blowdown-reflood phase of simulated LOCA and that during a slow inventory boiloff type transient.

Appendix A describes TRAC nodalization scheme used for simulating these TLTA tests.

TLTA 6426 Run 1 (No ECC)

This was a reference blowdown case in which all of the emergency core

TLTA 6426 Run 1 (No ECC) - (continued)

cooling systems were shut off. Following blowdown the system inventory depleted continuously, the bundle lost its inventory, the rods dried out, and their temperature increased linearly until the end of the test. The PCT was $\approx$1400°F at the time the test was terminated.

TRAC predicted system pressure very well in the early blowdown phase (Fig. 1). When the mixture level in the lower plenum reached the bottom of jet pump, TRAC began underpredicting the system pressure. This has been traced to lack of sufficient carryover of liquid from the lower plenum to the break pipes via the jet pumps, and overprediction of the void fraction in the lower plenum for low void counter current flow. Both these factors result in a predominantly steam blowdown causing the system to depressurize faster. Of these, the overprediction of lower plenum void fraction had a more pronounced effect on the predicted response in various parts of the system as discussed below. Figures 2, 3, and 4 show TRAC prediction of core inlet flow and jet pump flows. The intact and broken loop jet pump flows are very well predicted. TRAC predicts some varations in intact loop flow following uncovery of jet pump, but the overall flowrates and trends are well predicted. The net effect of the good prediction of these jet pump flow rates result in the good prediction of the core inlet flow shown in Fig. 2.

Comparison of suction line break flow is shown in Fig. 5.TRAC predicts the magnitude of single phase break flow and the transition from single to two - phase flow quite well. However, the break flow is overpredicted following the isolation of intact loop recirculation pump (t=20 sec.) and underpredicted in the long term (t=70 sec. and beyond). In keeping with the intent of the test the intact loop was assumed to have isolated at 20 sec. Following the isolation of the intact loop the predicted flow through the bundle inlet orifice changed from low void upflow to counter current flow. This resulted in counter current flow in the lower plenum. It is apparent that TRAC over predicted the lower

TLTA 6426 Run 1 (No ECC) - (continued)

plenum void fraction for this flow regime. The problem has been traced to the void distribution model. In low void counter current flow there are two possible solutions that result in either a high void fraction consistent with counter current flow limiting or a lower void fraction consistent with counter current flow near a two phase mixture level as in a pool. Presently the code cannot explicitly track the mixture level in a node and the solution scheme seeks the higher void fraction. The higher void solution results in a lower calculated inventory ($\approx$50%) remaining in the lower plenum (Fig. 6). The balance of the inventory was lost through the breakline via jet pump and bundle paths. The latter is evidenced by higher calculated core pressure drop (Fig. 7) during $20<t<35$ sec, which is the interval during which the two phase level and inventory is depleted in the lower plenum.

Generation of steam due to flashing is directly proportional to the amount of liquid present. Therefore, with less net inventory remaining in the lower plenum, there is proportionally less steam generation calculated. The bundle heat transfer is mainly from steam cooling following bundle uncovery at $\sim$35 sec. (Dittus Boelter Correlation). The predicted wall heat transfer coefficient was thus reduced by nearly a factor of two causing the code prediction for the heat up rate (Fig. 8) to be higher than that in the test. The heatup rate depends on the heat transfer coefficient and the heat generation rate. The degree of discrepancy of the calculated heatup rate from the data at various bundle elevations appear to depend on the magnitudes of the heat generation rate. For this simulation the heat generation rate is maximum at the bundle mid-plane (chopped cosine power profile) and the heatup rate discrepancy is most pronounced at this location. Thus it can be concluded that the deviation of bundle thermal response is a result of a shortcoming in the void distribution model and not in the applicable core heat transfer models.

TLTA 6425 Run 2 (with ECC)

This test is more complicated than the earlier No-ECC test because of the interaction of the ECC fluid with the system, specially within the bundle. The controlling/governing phenomena observed in this system type test presented quite a challenge to TRAC. TRAC predictions show good overall agreement with the test. The shortcoming in the void distribution model identified in earlier sections is manifested in this simulation as well. However, it affected the bundle thermal hydraulic response differently because of different modes of bundle heat transfer encountered in this test, especially those during post dryout and rewet.

As before, TRAC underpredicted system pressure (Fig. 9) which again can be traced to overprediction of void fraction in low void counter current flow and insufficient liquid carryover. The prediction of break flow (Fig. 10 and Fig. 11) shows very good comparison for the early period but conclusively shows the lack of predicted liquid carryover from lower plenum to break lines via the jet pump in the long term period. The predicted upper plenum, bypass and bundle pressure drop (inventory) shown in Figures 12, 13 and 14 respectively indicate very good comparison with the data. TRAC predicted the controlling phenomenon of CCFL at the top of bypass and guide tube-bypass inlet very well. TRAC also accurately predicted the time of CCFL breakdown at these locations.

Reasonable agreement of bundle thermal response (time to dryout initiation, rod temperatures and time to rewet) was obtained. This is shown by the predicted rod temperatures in the low, middle and upper bundle elevations in Fig. 15. For heater rods in the vicinity of the mid-plane test data shows two modes of rewet: The first type is "top down" quenching caused by CCFL controlled liquid drainage from the upper

TLTA 6425 Run 2 (with ECC) - (continued)

tieplate; the second type is "bottom-up" rewet. This occurs when the LPCI fluid gets into the core through the core-bypass leakage holes. This process is also accentuated by droplet entrainment as lower plenum steam flows up into the bundle through the relatively low void mixture in the lower part of the bundle.

While TRAC predicted the CCFL controlled liquid drainage from the upper plenum to the bundle, it did not predict top down quenching for the mid-plane region. However, it did so for all other elevations.

TLTA 6441 Run 6-1 (Boiloff test)

A TRAC calculation was performed for a natural circulation boiloff type test in the TLTA. In this test the system pressure and bundle power were kept constant at 400 psia and 250 kw (decay power level) respectively. The inventory in the system slowly depleted as liquid in the bundle boiled off and was vented out through the steamline at vessel top. As a result the mixture level, originally at the top of the bundle, decreased to $\approx 2/3$ bundle height at the end of the test. With core uncovery, bundle temperatures kept increasing and reached a maximum value of 800°F. At this point feedwater was injected in the annulus, and through natural circulation the bundle was quenched to saturation temperature.

The TRAC case was run by imposing measured system pressure as a boundary condition (Fig. 16). Prior to the actual transient run, another transient run was made starting with the mixture level in the bundle being slightly above the upper tie plate. The purpose was to arrive at a condition where the mixture level was just at bundle top (test initial condition). At this point regional inventory distribution were checked and except for the bundle were

TLTA 6441 Run 6-1 (Boiloff Test) - (continued)

found to match with initial conditions in the test. As expected, the calculation predicted counter current flow near the bundle mixture level. However, due to the shortcoming in the void prediction in counter current flow mentioned in earlier sections, bundle void fraction was overpredicted in the upper elevations. While this higher void fraction became imposed, the code predicted a flow of liquid out of the bundle into the lower plenum/annulus region. But this created a hydrostatic imbalance between the annulus/bypass and the bundle and a subsequent restoring flow up through the side entry orifice was predicted by the code (Fig. 17). This fluctuating behavior continued throughout the duration of the prediction and upto the point of feedwater injection into the annulus. The net result was that due to the overprediction of void fraciton in the vicinity of the mixture level, the calculated two phase level dropped faster than that in the test and rods dried out earlier as shown in Fig 18.

In general the prediction of steam line flow (Fig. 19) and regional inventory in the annulus (Fig. 20) and bypass (Fig. 21) were fairly well predicted by TRAC. The quenching of the bundle due to feedwater injection into the annulus was well captured (Fig. 17). It appears that accurate prediction of bundle void fraction for counter current flow and a level tracking model are necessary for accurate prediction of bundle thermal response for such slow transients.

TLTA 6426 Run 1 (No ECC Test, DBA)

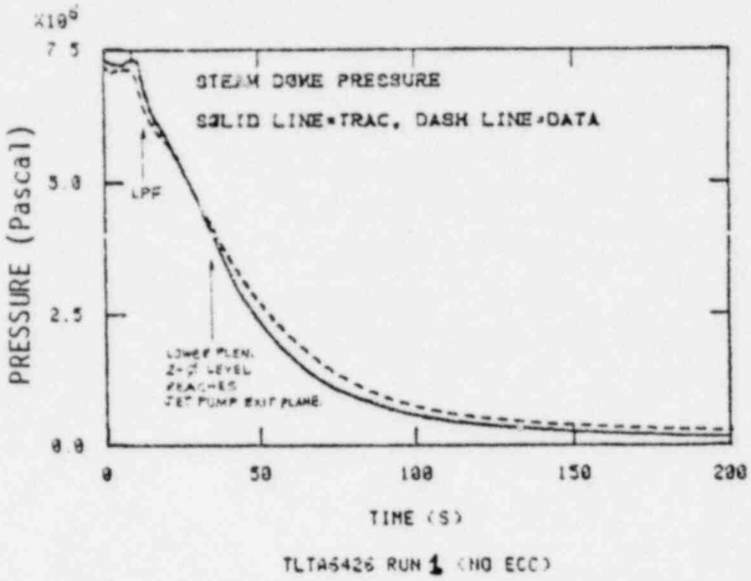


FIG. 1 COMPARISON OF SYSTEM PRESSURE

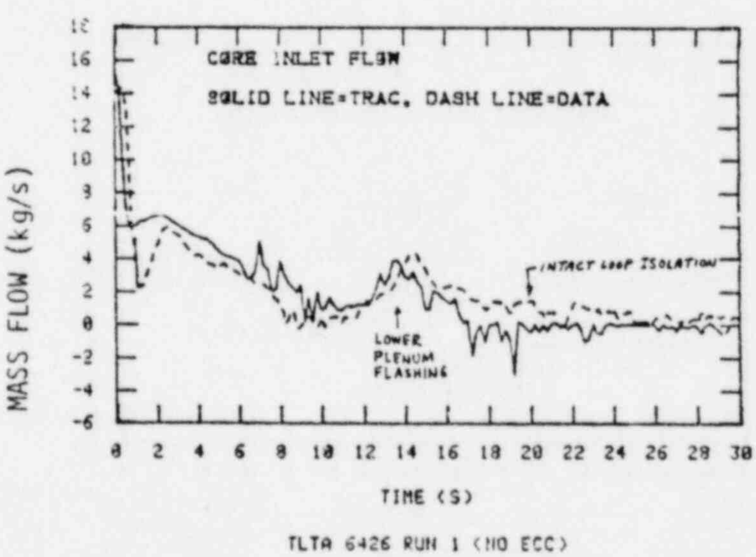


FIG. 2 CORE INLET FLOW

TLTA 6426 Run1 (No ECC, DBA)

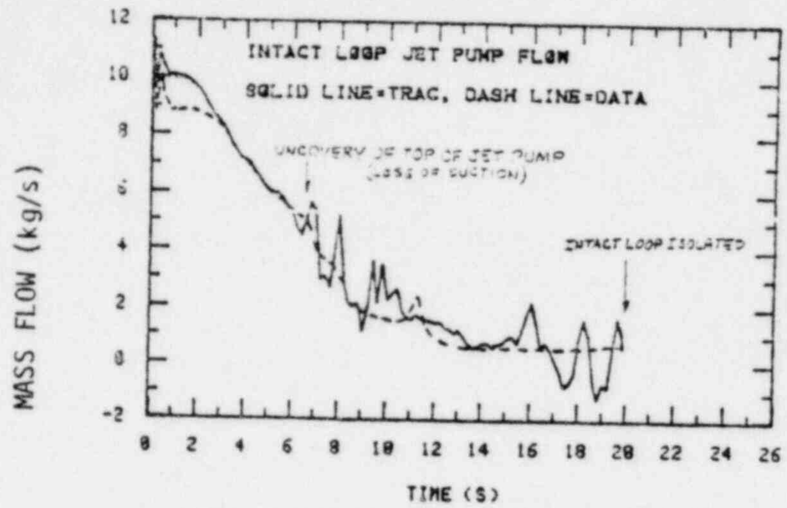


FIG. 3 INTACT LOOP JET PUMP FLOW

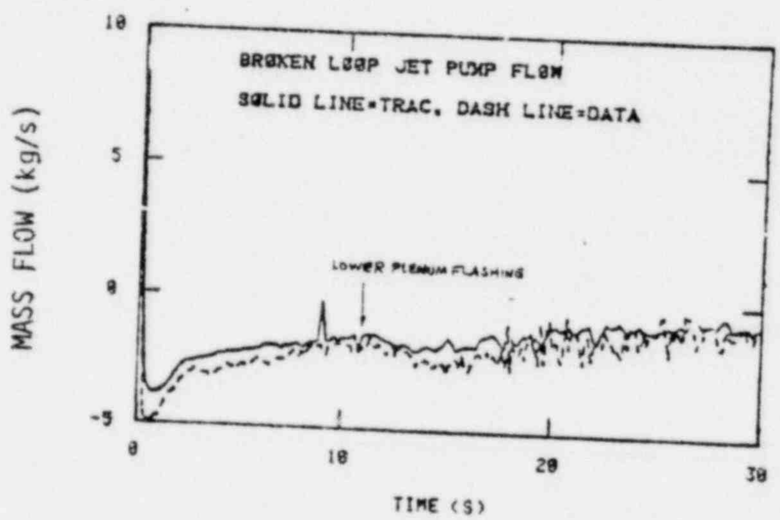


FIG. 4 BROKEN LOOP JET PUMP FLOW

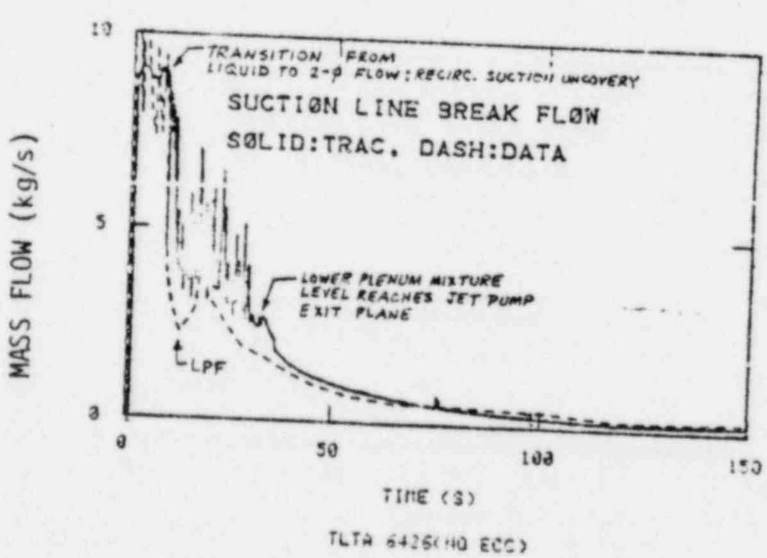


FIG. 5 SUCTION LINE BREAK FLOW

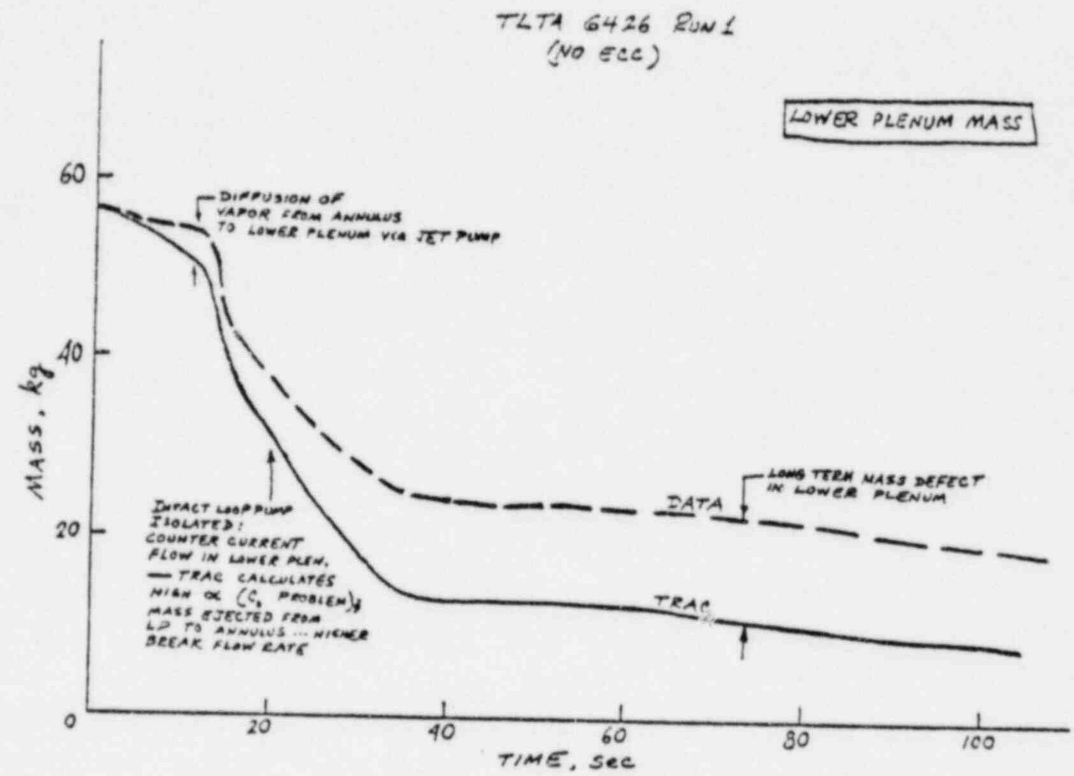


FIG. 6 COMPARISON OF LOWER PLENUM MASS

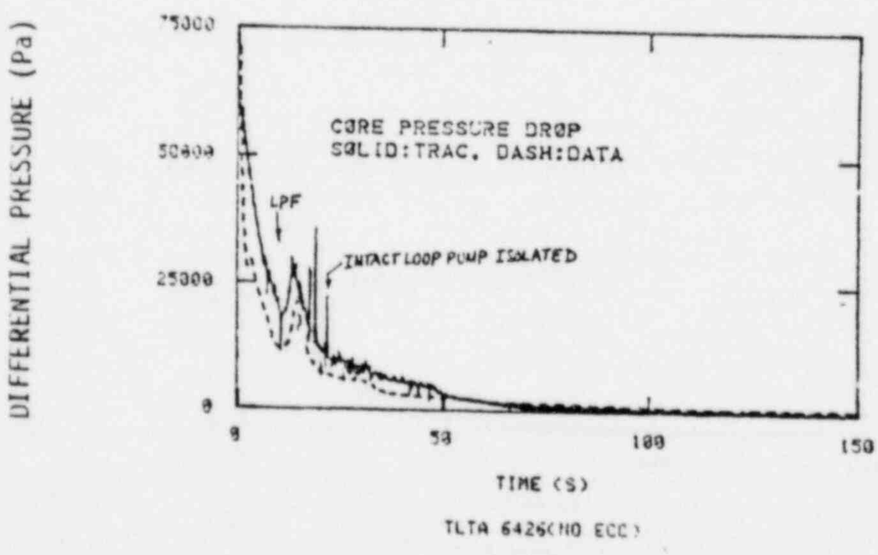
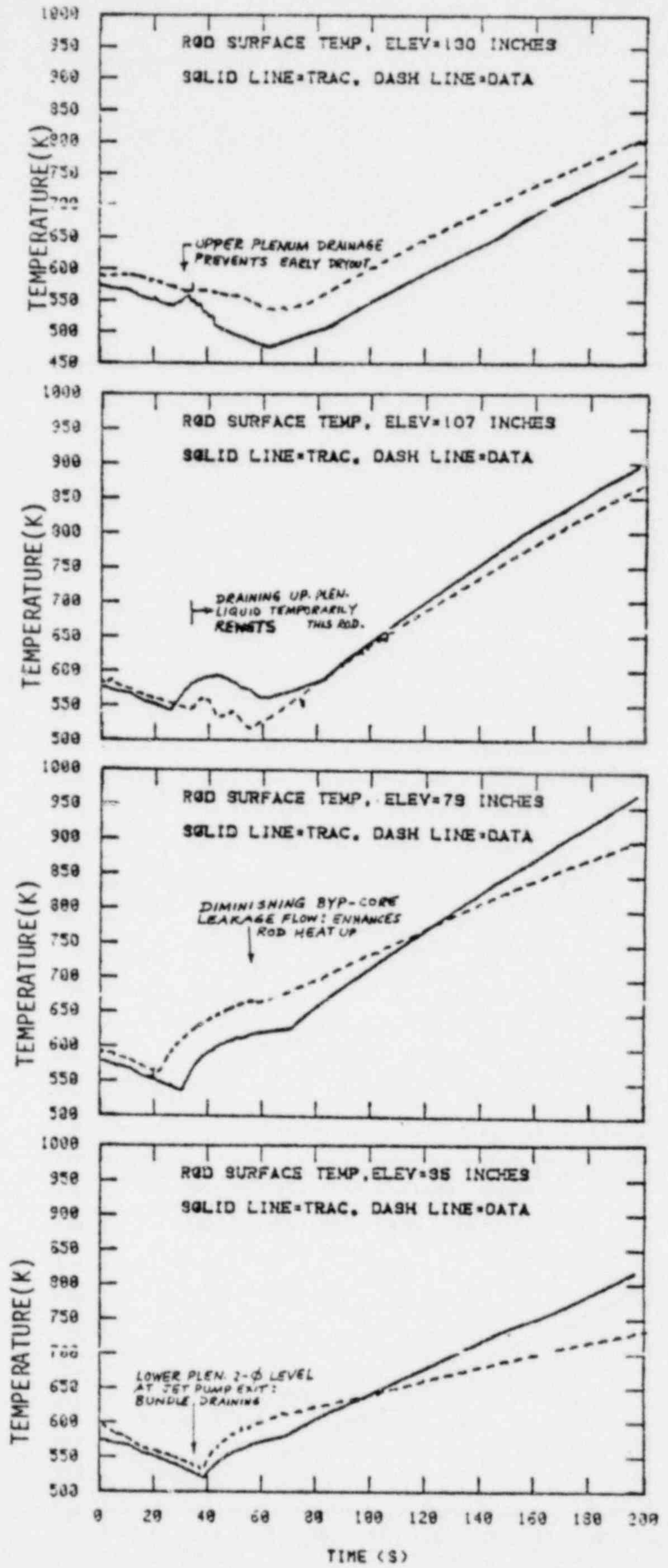


FIG. 7 COMPARISON OF BUNDLE PRESSURE DROP



TLTA 6426 RUN 1 (NO ECC)

FIG. 8 COMPARISON OF HEATER ROD TEMPERATURES AT VARIOUS BUNDLE ELEVATIONS

TLTA 6425 RUN 2 (ECC TEST, DBA)

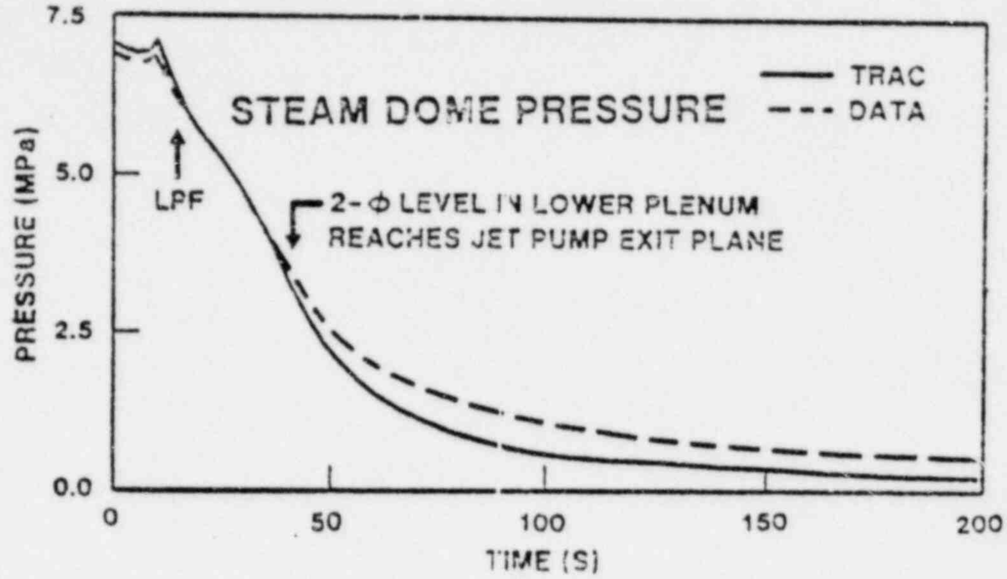


FIG. 9 COMPARISON OF SYSTEM PRESSURE

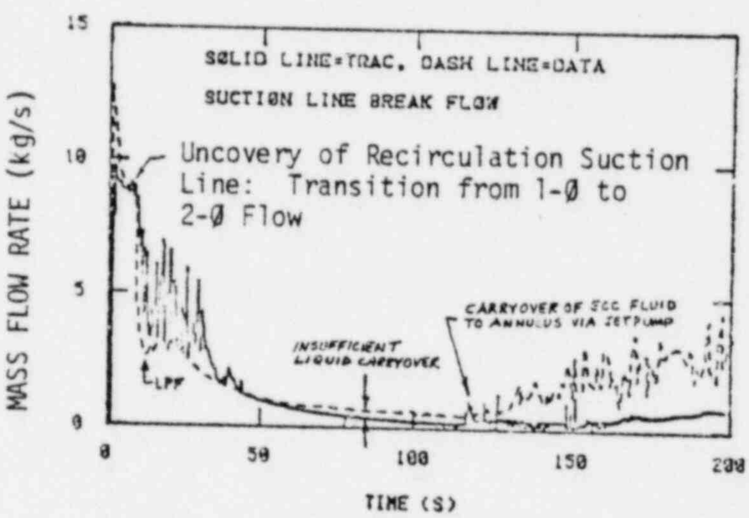


FIG. 10 SUCTION LINE BREAK FLOW

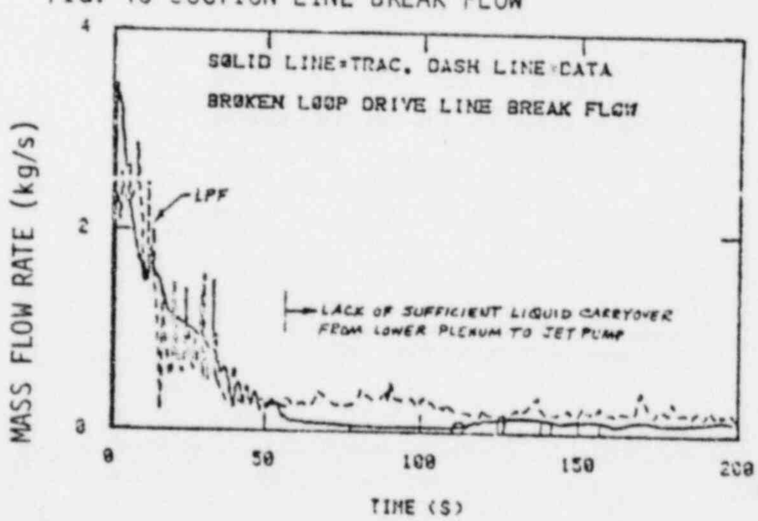


FIG. 11 DRIVE LINE BREAK FLOW

TLTA 6425 Run 2 (Avg. ECC, DBA)

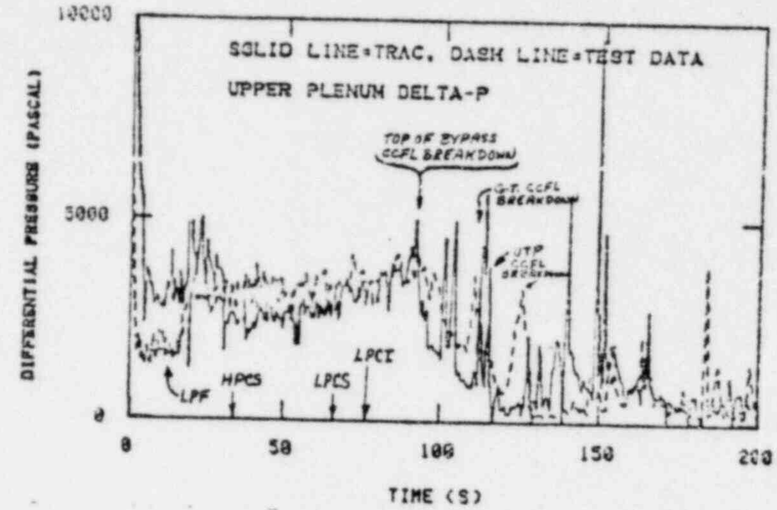


FIG. 12 UPPER PLENUM PRESSURE DROP

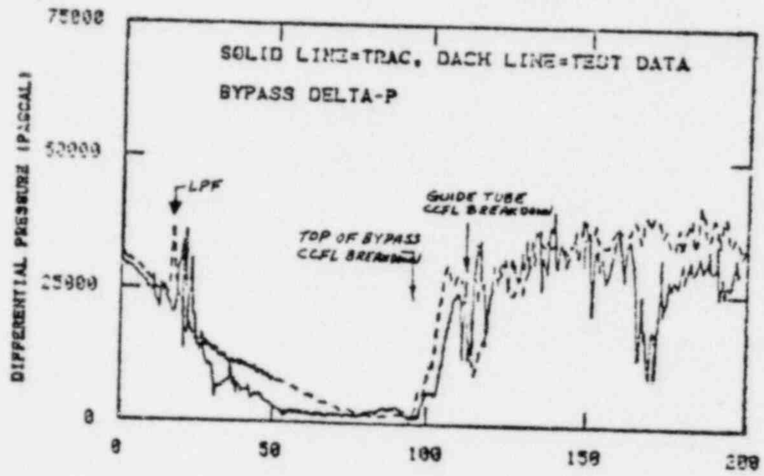


FIG. 13 BYPASS PRESSURE DROP

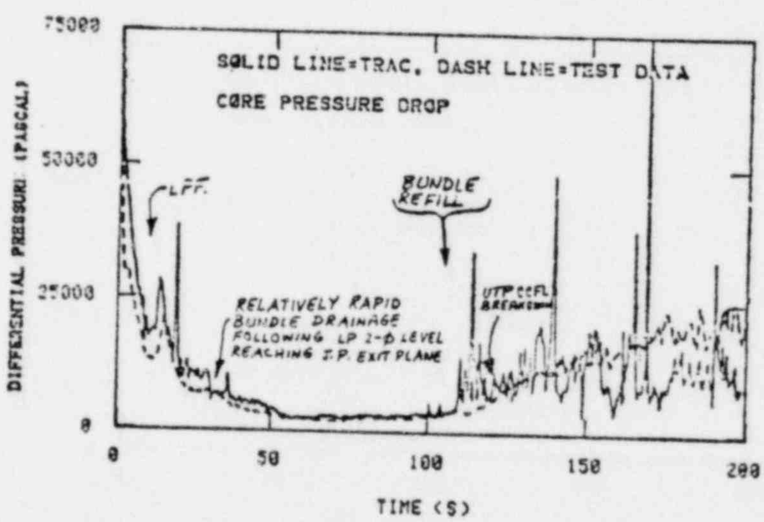


FIG. 14 BUNDLE PRESSURE DROP

TLTA 6425 Run 2 (Avg. ECC, DBA)

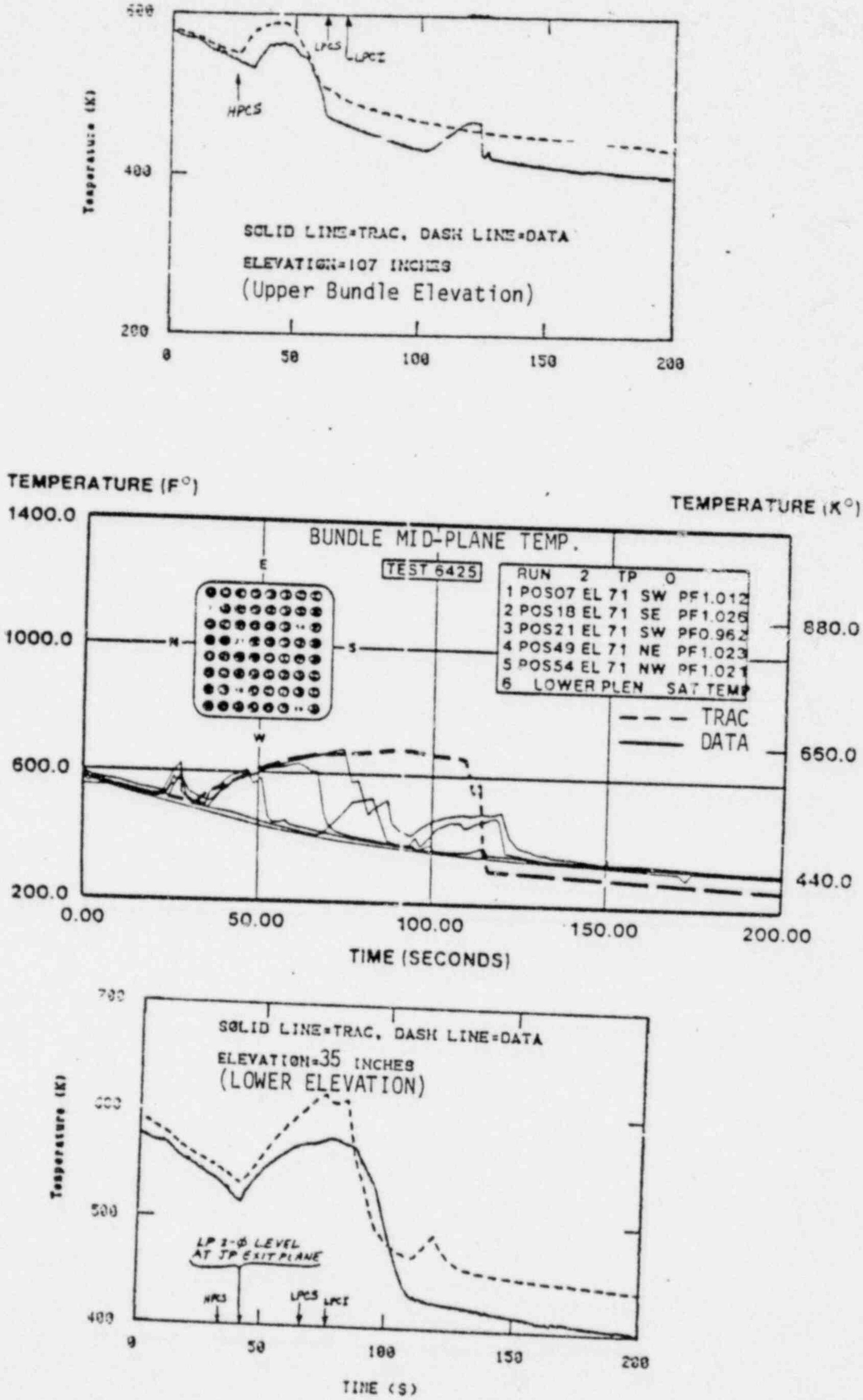


FIG. 15 COMPARISON OF HEATER ROD TEMPERATURES AT VARIOUS BUNDLE ELEVATIONS

TLTA 6441 Run 6-1 (Boiloff Test)

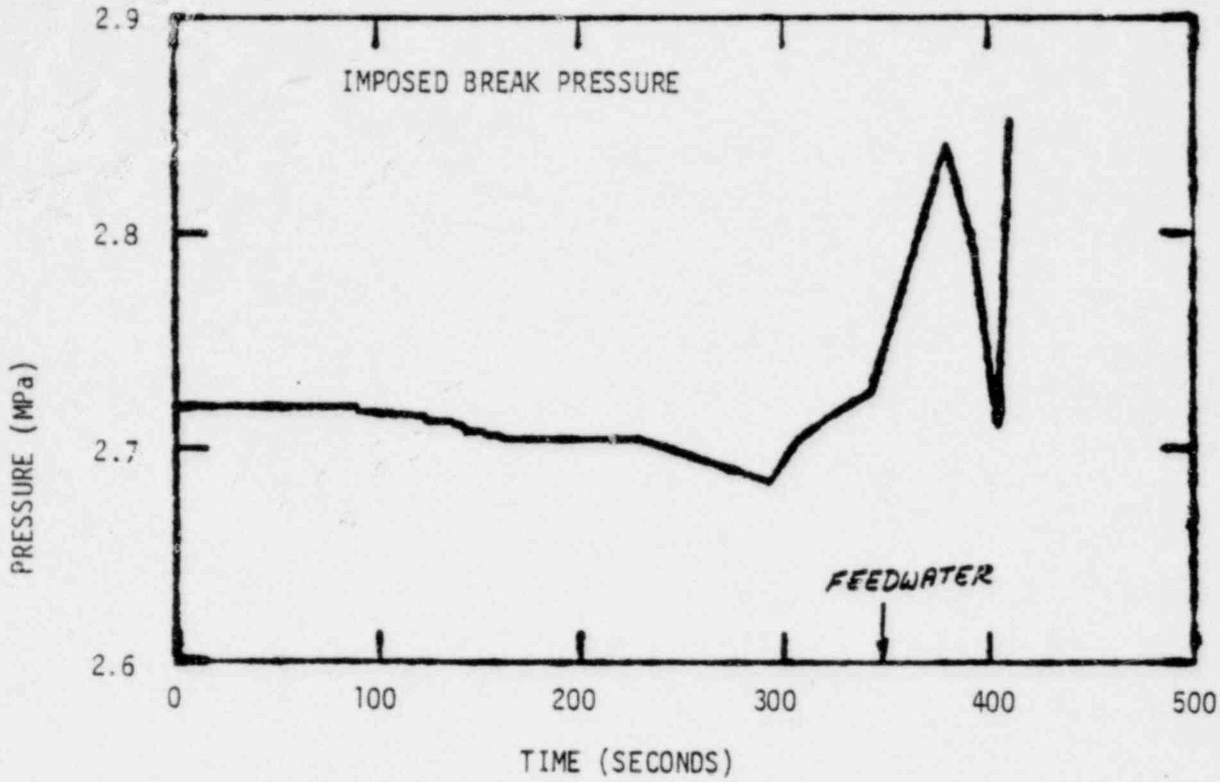


FIG. 16 PRESSURE BOUNDARY CONDITION IMPOSED AT VESSEL TOP

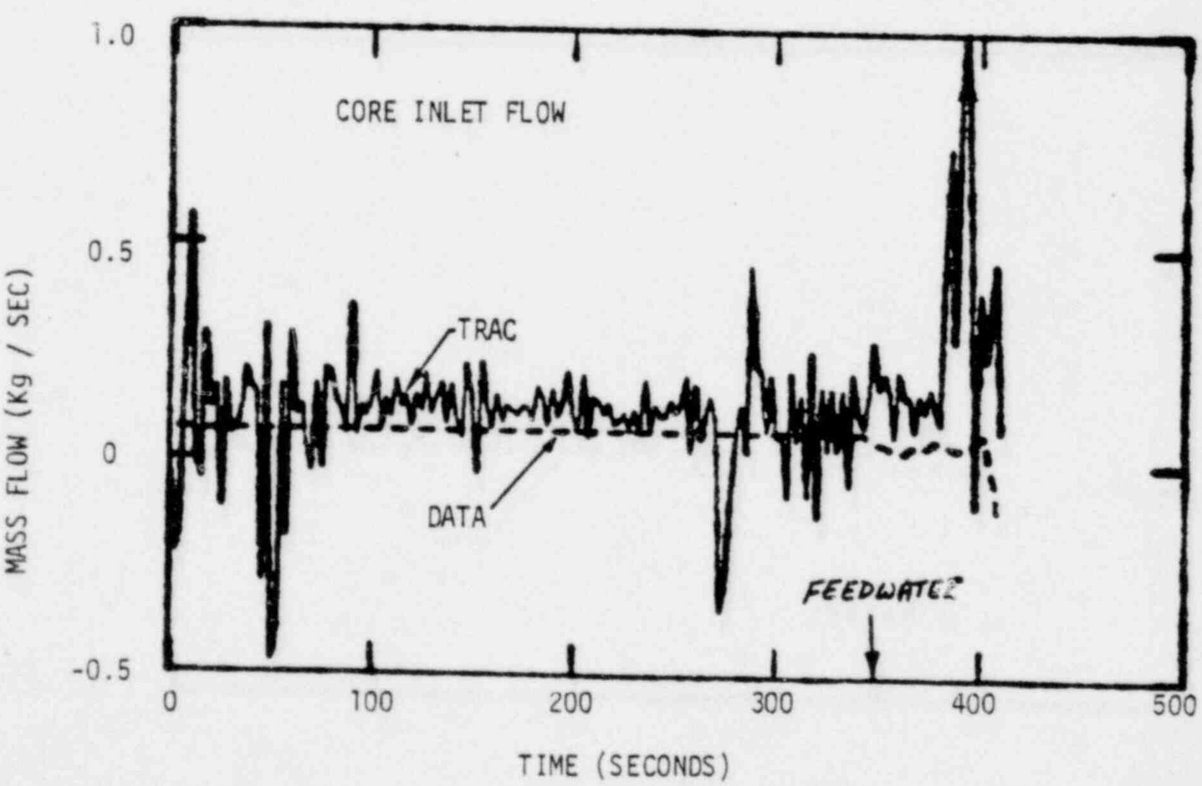


FIG. 17 CORE INLET FLOW

TLTA 6441 Run 6-1 (Boiloff Test)

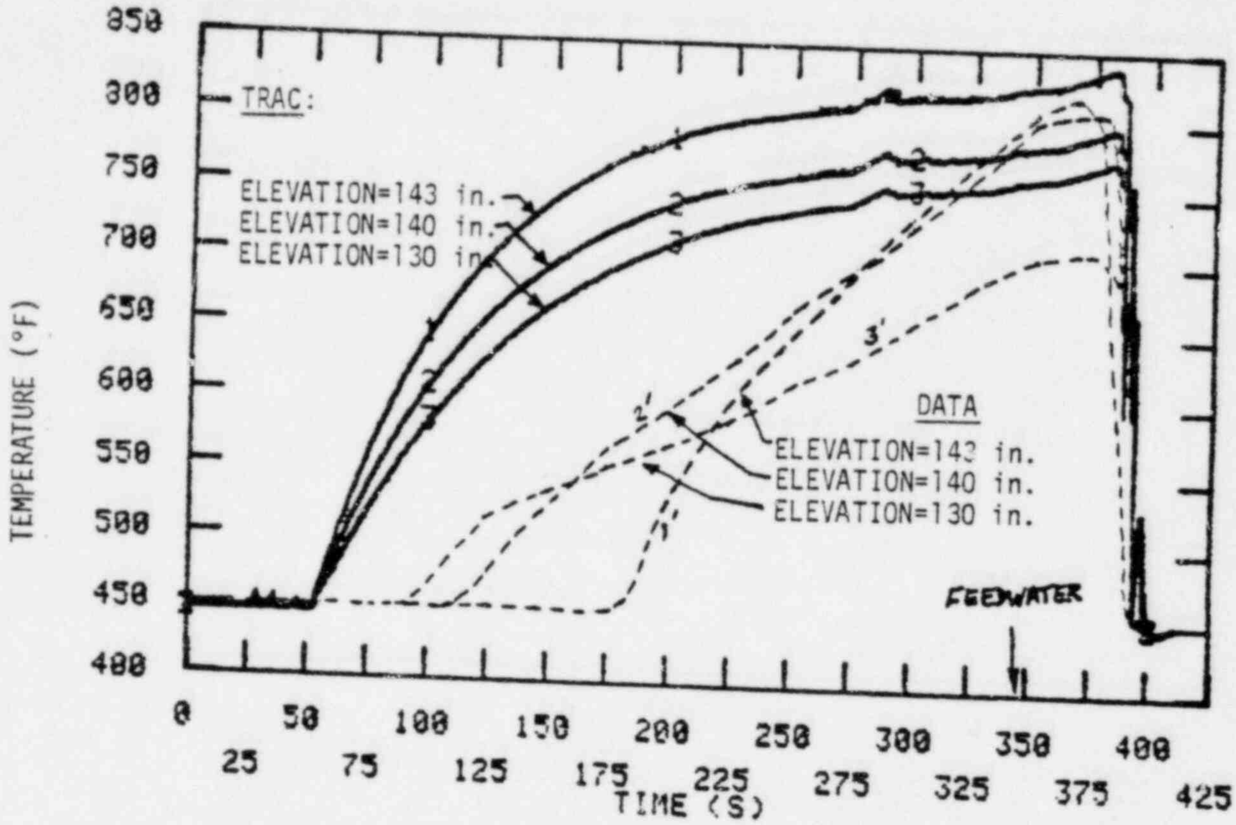


FIG. 18 ROD TEMPERATURES AT BUNDLE UPPER ELEVATIONS

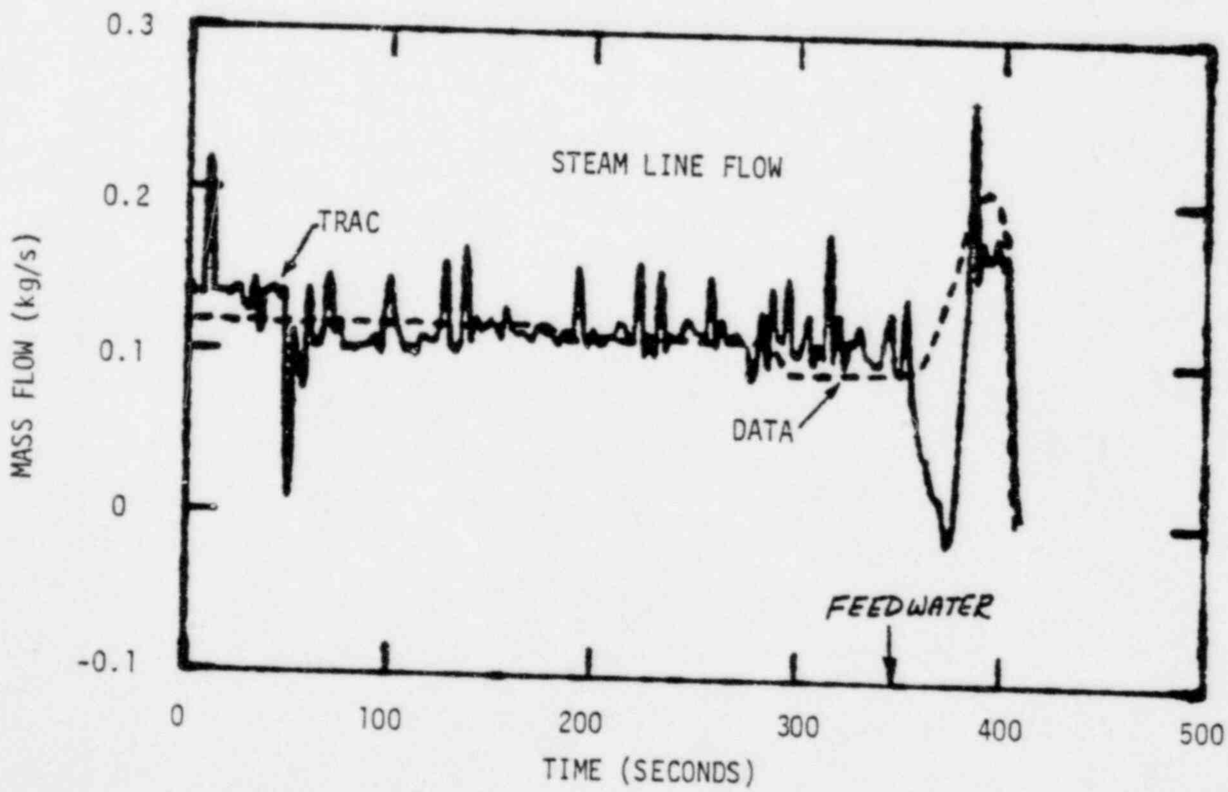


FIG. 19 STEAM LINE MASS FLOW RATE

TLTA 6441 Run 6-1 (Boiloff Test)

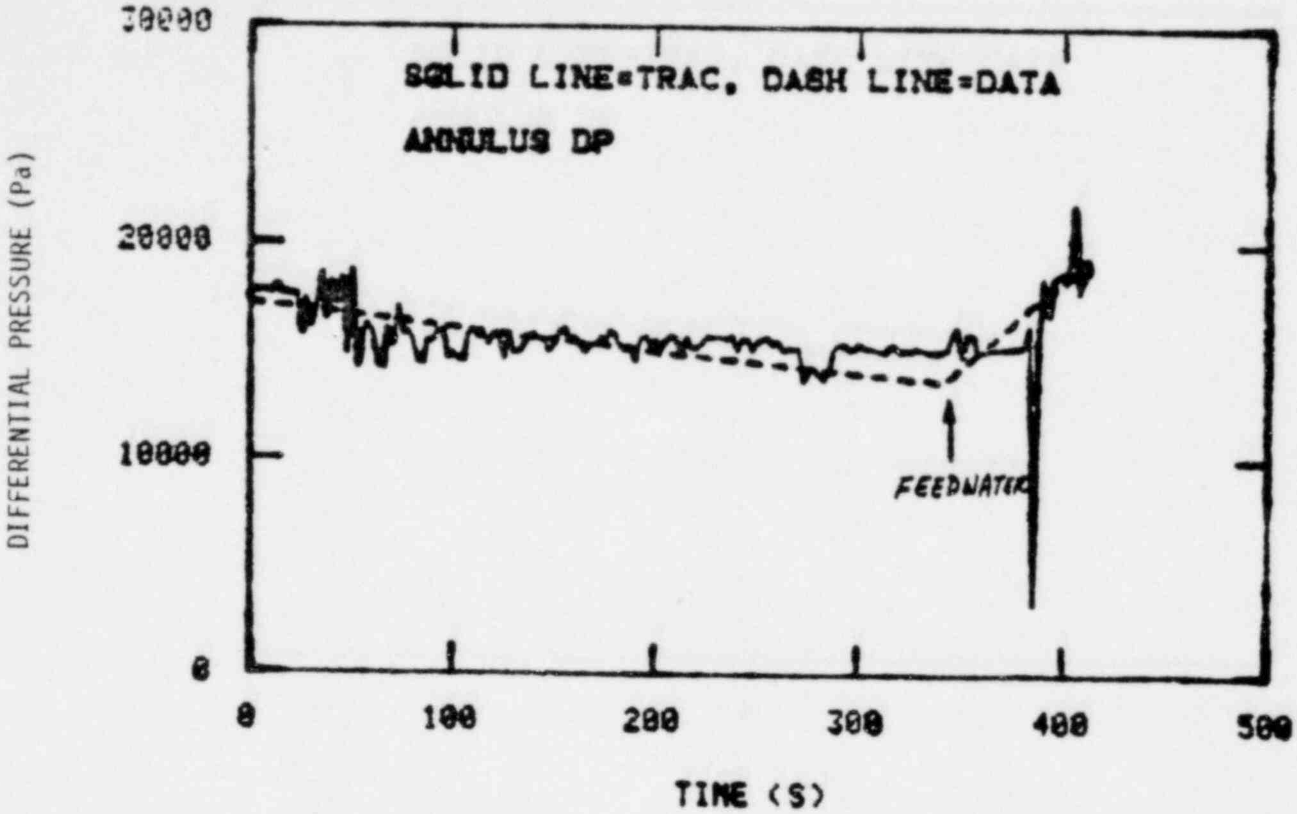


FIG. 20 ANNULUS PRESSURE DROP

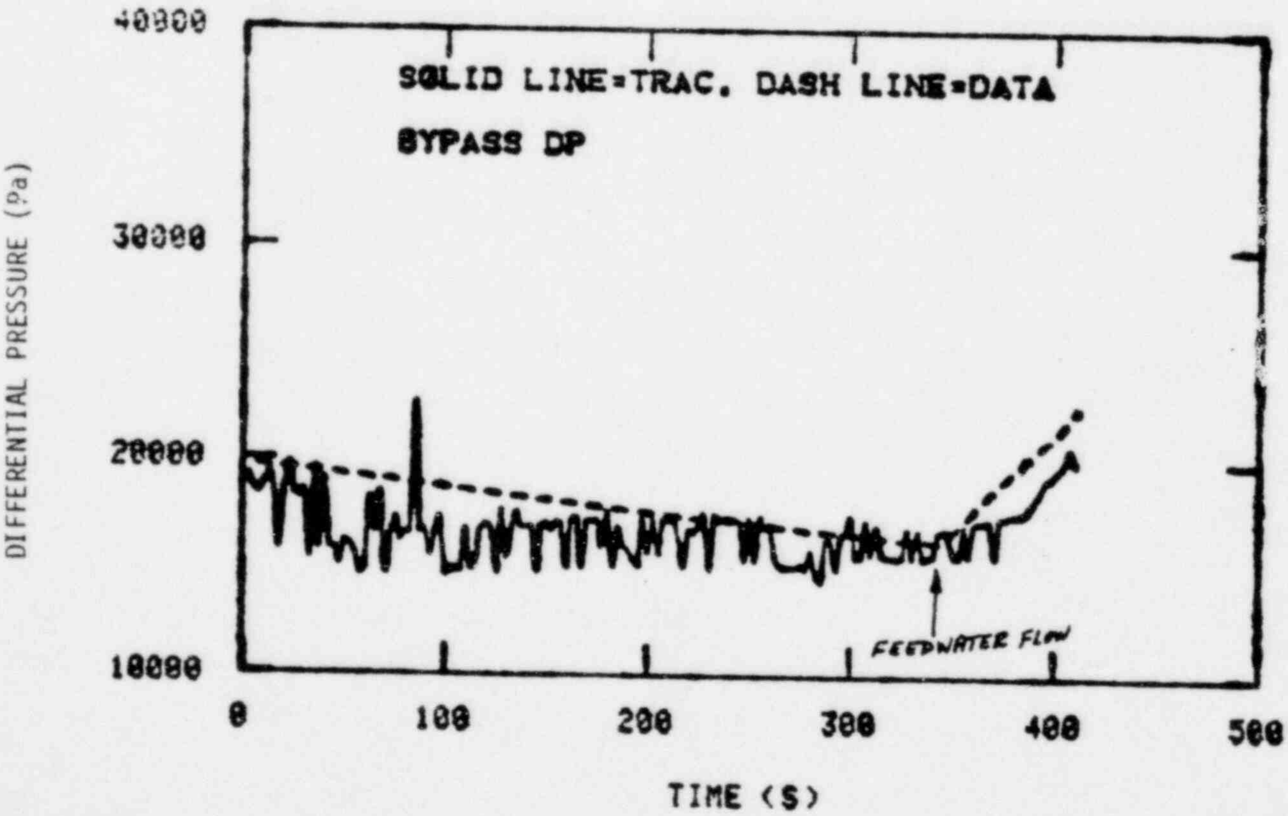


FIG. 21 BYPASS PRESSURE DROP

APPENDIX - A

TLTA NODALIZATION

The nodalization scheme for the TLTA facility was governed by the following factors:

1) Type of Test to be simulated
2) Limitations in the current version of TRAC
3) Cost
4) Ability to compare TRAC predictions with Test data
5) Consistency with TRAC Numerics

Nodalization bases for the TLTA were the DBA type LOCA Tests, with and without ECC. Later this was modified to simulate the slow Boiloff transient. It was decided to choose a cylindrical vessel geometry in keeping with the geometry of the facility. As a starting point the minimum number of axial levels required to capture the phenomena were determined, as shown in Figure 1. This choice was influenced by the lack of multiple source connection and level tracking model in the current version of TRACB01. The former allows connection of only one 1-D component to any vessel cell. The latter gives a homegeneous mixture in any mesh cell there by masking existence of any level in that cell.

From Figure 1 we recognize 7 distinct axial zones. The phenomena of interest in each zone and how the number of axial levels chosen would affect the test simulation is shown in Table 1. The bundle was nodalized with the purpose of making detailed and one to one comparison with of measured ΔP's and temperatures. Heater rods were modelled to match heat capacity and thermal diffusivity as well as to match radial location of T/C's within the heater rods. Particular attention was paid to nodalization of the break pipe. TRACB01 used the INEL choking model to calculate critical flow. The model is similar in nature to finding the

TRAC NODALIZATION OF TLTA VESSEL

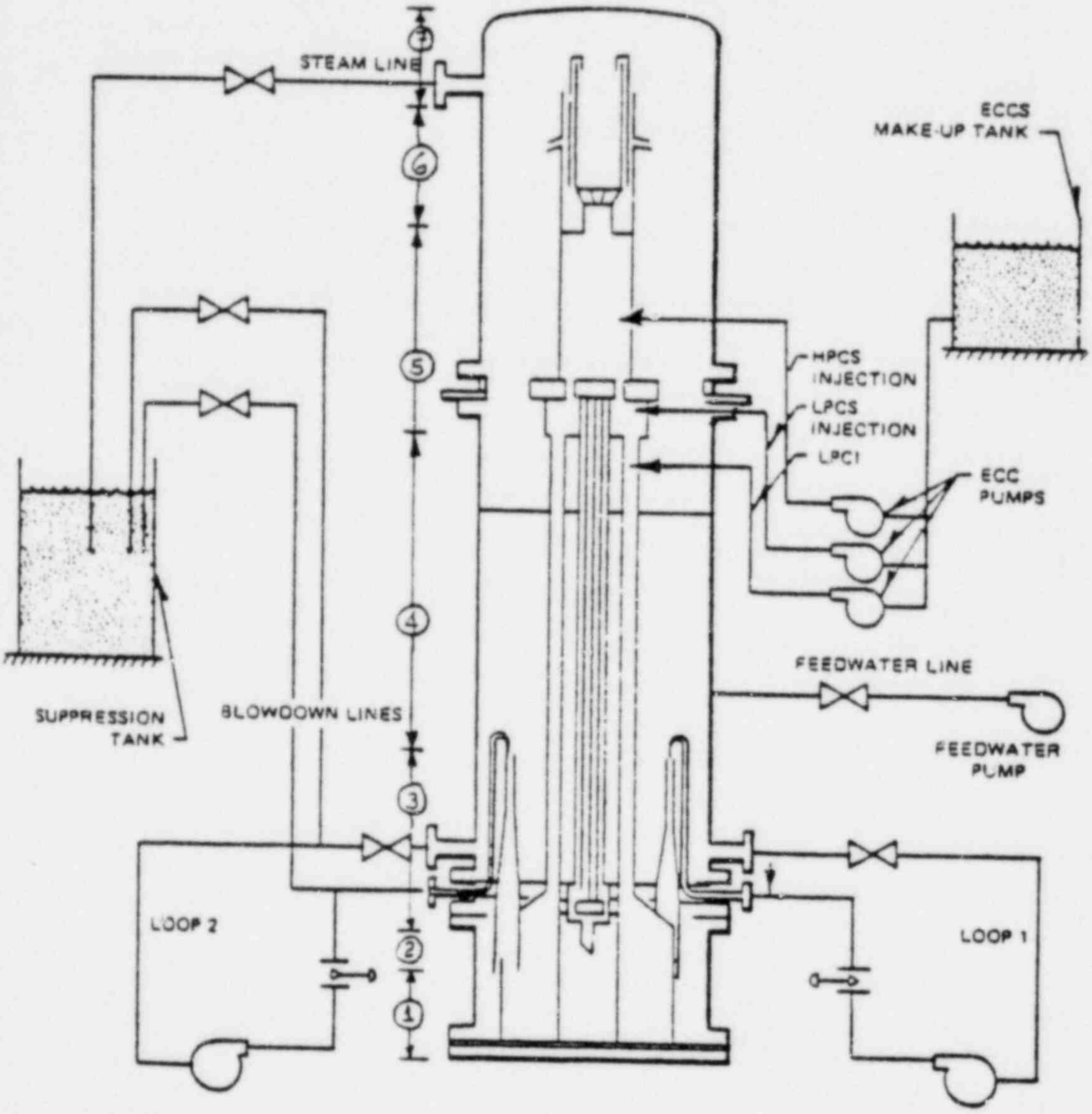
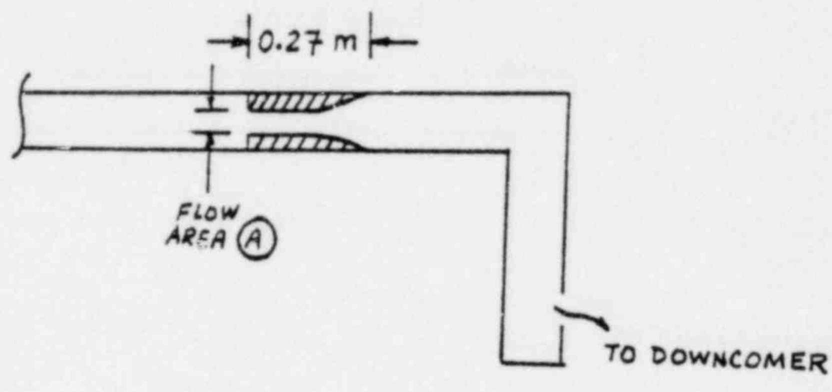


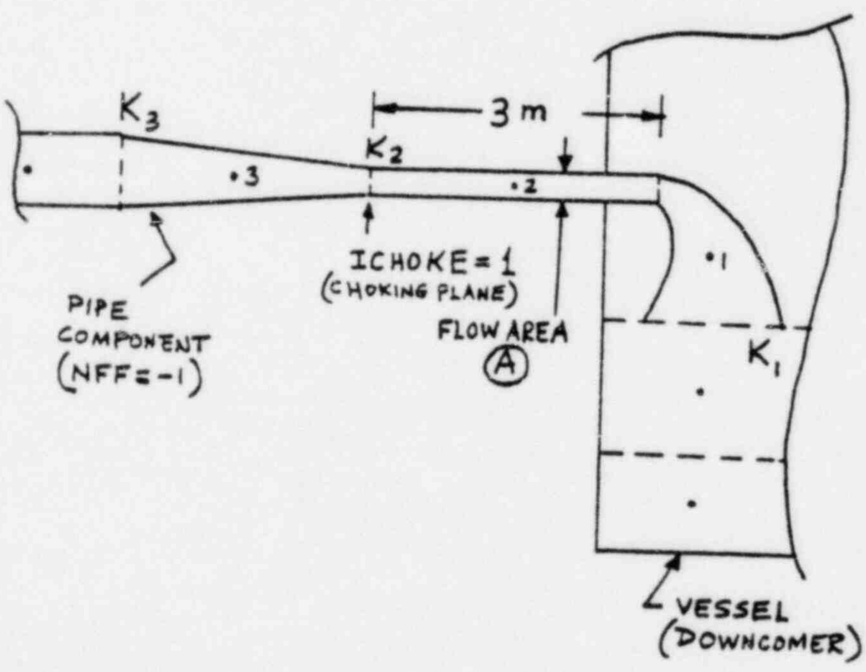
Figure 1. TLTA5 (Two-Loop Test Appartus Configuration 5) with ECCS showing Minimum Number of Axial Levels for a DBA LOCA Test

smallest eigenvalue of a set of quasi-linear equations comprising the conservation equations. Choking condition corresponds to the inability of a signal to propagate across and upstream of the choking plane. In this model the choking condition and critical flowrate is based on local conditions at the choking plane. Therefore, it was necessary to nodalize the break pipe as shown in Figure 2. Among other things this scheme gives the correct accelerational pressure drop as the fluid flows from stagnation condition to the throat of a nozzle. To maintain similarity in frictional losses between the actual nozzle and TRAC model, L/D and local losses (K) were matched in the two. Generally L was large in the TRAC input model to improve running cost; hence the hydraulic diameter D had to be adjusted. The central difference scheme (NFF = -1) was used for the break pipe.

The balance of the TLTA facility was modelled as indicated in Table 1. The resulting overall nodalization for the ECC test is shown in Figure 3. For the "NO-ECC" test the ECC flowrates were set to zero. For the boil-off test the intact/broken loops and the ECC lines were not modelled. The nodalization scheme for the boiloff test is shown in Figure 4.

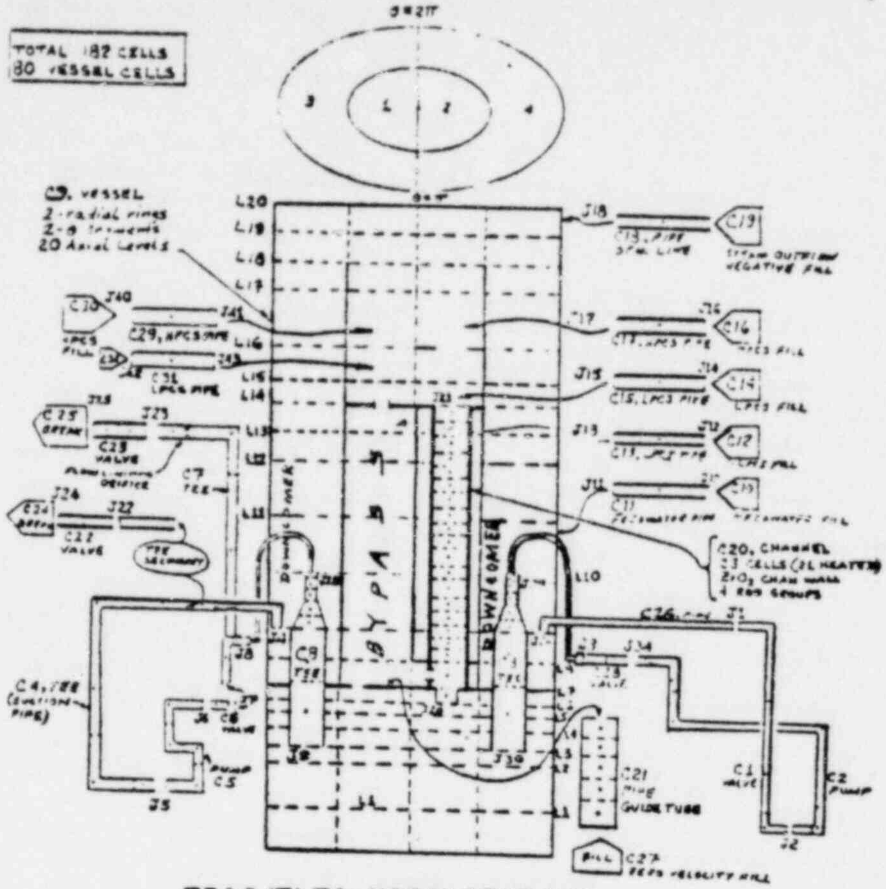


TLTA BREAK FLOW NOZZLE

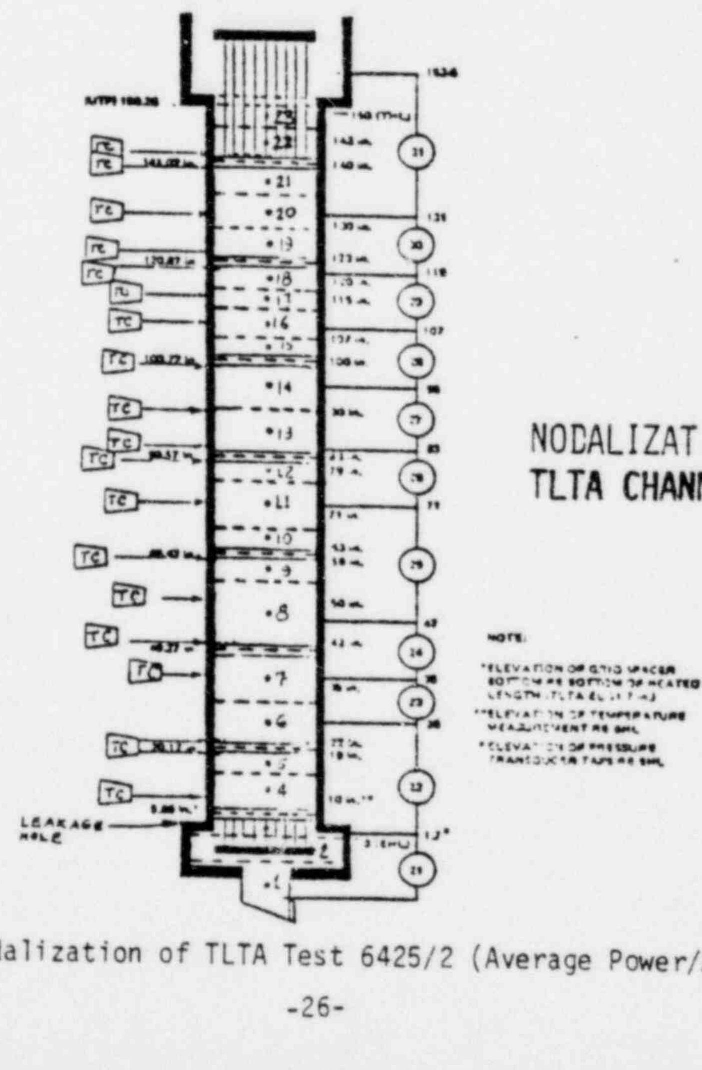


TRAC NODALIZATION

Figure 2: TRAC Nodalization of TLTA Suction Line Break Nozzle



TRAC/TLTA NODALIZATION



NODALIZATION OF TLTA CHANNEL

Figure 3: TRAC Nodalization of TLTA Test 6425/2 (Average Power/Average ECC)

Table 1

Effect of Number of Cells Chosen in Various VESSEL Zones on System Test Simulation

AXIAL ZONE	RELEVANT EVENTS, PHENOMENA AFFECTED	SUGGESTED NUMBER OF AXIAL LEVELS	NO. OF LEVELS USED	REMARKS
1	Lower Plenum void distribution, up flow through Jet Pump, lower plenum stored heat release.	>1	3,5	Level aligned to ΔP taps and level probes
2 between SEO and bottom Jet Pump	2-Ø mixture level, JP tailpipe uncovery, Core inlet flow, SEO CCFL, rod dryout initiation	>1	4	Level aligned to ΔP taps and level probes
3 SEO to top of Jet Pump	Bypass-bundle leakage flow, recirc. Suction uncovery (LP flashing), break flow (1-Ø,2-Ø)	≥ 2	3	Alignment of center of CHAN leakage cell with Bypass
4 Core-Bypass	Interface of Saturated/ Subcooled water, top of bypass CCFL, breakflow	≥ 3	4	Levels aligned to ΔP taps
5 Mixing Plenum/ Upper plenum	Δp, ECC Subcooling, CCFL/CCFL breakdown, Upper plenum void distribution.	≥ 2	4	"
6 Separator/ Dryer	P, Void distribution, steam separation	1	1	
7 Steam Dome	Not significant	1	1	

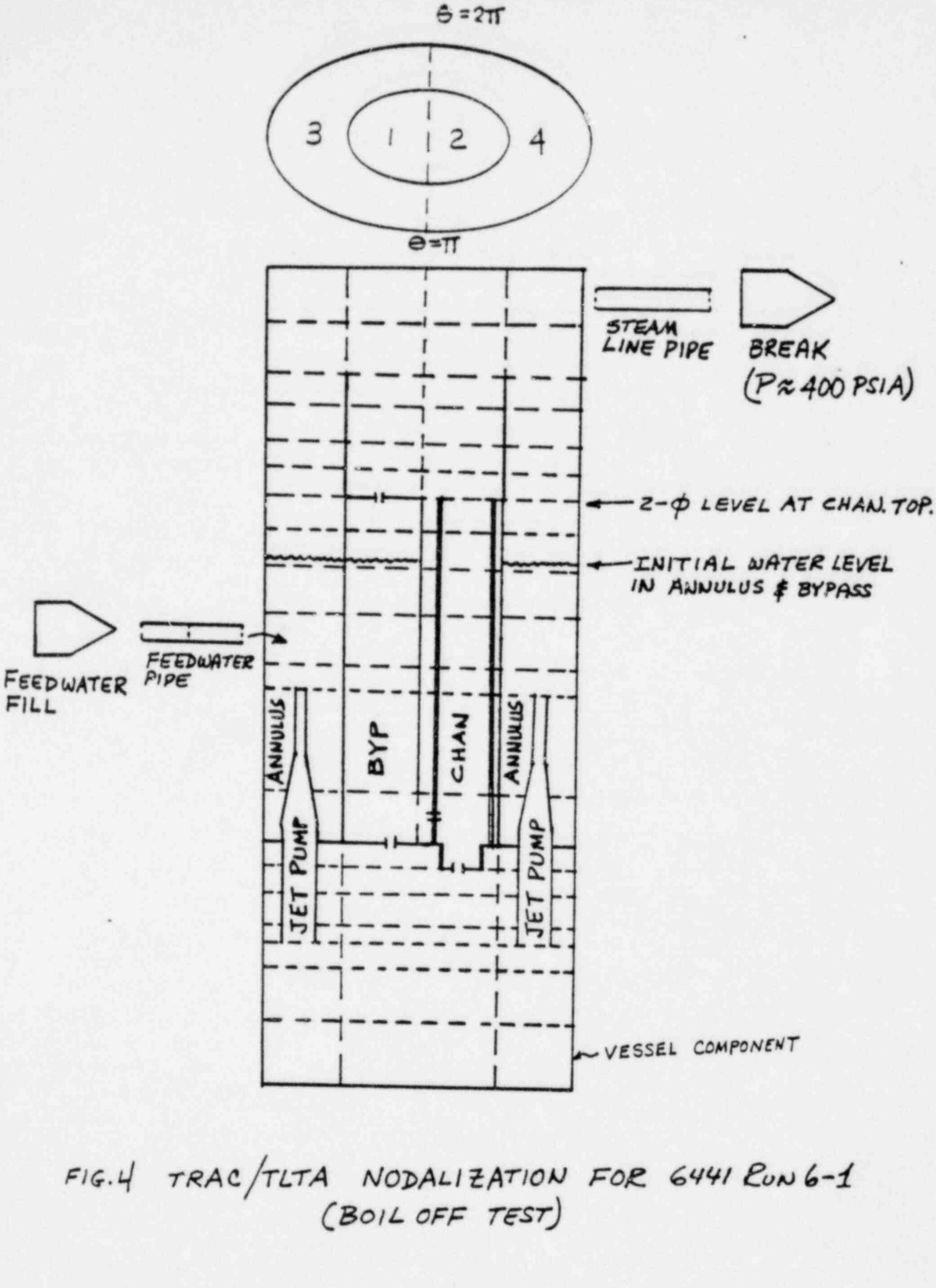


FIG. 4 TRAC/TLTA NODALIZATION FOR 6441 RUN 6-1
(BOIL OFF TEST)