PDR

BNL-NUREG-32101

INDEPENDENT CODE ASSESSMENT AT BNL IN FY 1982 *

by

P. Saha, U. S. Rohatgi, J. H. Jo, L. Neymotin

G. Slovik and C. Yuelys-Miksis

Department of Nuclear Energy
Brookhaven National Laboratory
Upton, New York 11973

Prepared for the

Tenth Water Reactor Safety Research Information Meeting

October 12 - 15, 1982

*Work performed under the auspices of U.S. Nuclear Regulatory Commission

1. INTRODUCTION

Independent assessment of the advanced codes such as TRAC [1,2] and RELAP5 [3] has continued at BNL through the Fiscal Year 1982. The specific codes assessed and the tests simulated during FY 1982 are shown in Table 1. The tests can be grouped into the following five categories:

1. Critical Flow
2. Counter-Current Flow Limiting (CCFL) or "Flooding"
3. Level Swell
4. Steam Generator Thermal Performance
5. Natural Circulation

Notice that the TRAC-PF1 (Version 7.0) and RELAP5/MOD1 (Cycle 14) codes were assessed by simulating all of the above experiments, whereas the TRAC-BD1 (Version 12.0) code was applied only to the CCFL tests. The results and conclusions of the BNL code assessment activity of FY 1982 are summarized below.

2. RESULTS

2.1 Critical Flow

2.1.1 Moby-Dick Nitrogen-Water Tests [4]

Two tests (Run Nos. 3087 and 3141) with very different flow qualities (5.91×10^{-4} and 51.3×10^{-4}, respectively) were simulated with the TRAC-PF1 (Version 7.0) code. The predicted water flow rates are compared with the experimental values in Table 2. It can be seen that TRAC-PF1 with the annular flow friction factor option underpredicts the mass flow rate whereas the same with the homogeneous flow friction factor option overpredicts the water flow rate. This is in agreement with the TRAC-P1A results reported earlier [15], and was of no surprise because of the large differences in the wall friction factors for these options. The predicted axial pressure distributions, however, were in good agreement with the data for both runs and both options since the pressure boundary conditions were used for the simulation.

It should be noted that the earlier versions of TRAC, i.e., TRAC-P1A and TRAC-PD2, used a drift-flux formulation for the PIPE component and were unable to reach a steady-state for the high void fraction case, i.e., Run No. 3141. TRAC-PF1, on the other hand, uses a two-fluid model and produced stable solutions for both the low and high void fraction cases.

Simulation of the same two tests was also attempted with the RELAP5/MOD1 (Cycle 14) code. However, the code was unable to produce a stable solution for either case. No attempt was made to manually control the time steps. The RELAP5 input deck has been sent to the code developers at INEL for their review.

2.1.2 BNL Flashing Flow Tests [5]

Four tests with different operating conditions were selected for simulation with both TRAC-PF1 (Version 7.0) and RELAP5/MOD1 (Cycle 14) codes. The pressure boundary conditions at both ends were imposed, and the code predicted

Table 1. BNL Independent Code Assessment Matrix of FY 1982

EXPERIMENT \ CODE	TRAC-PF1 (Version 7.0)	RELAP5/MOD1 (Cycle 14)	TRAC-BD1 (Version 12.0)
1. Critical Flow			
a) Moby-Dick Nitrogen Water Tests [4] Run Nos. 3087, 3141	X	0	
b) BNL Nozzle Tests [5] Runs Nos. (291-295), (309-311), (318-321) (339-342)	0	0	
c) Marviken Critical Flow [6] Run No. 24	X	X	
2. CCFL or Flooding			
a) University of Houston Tests [7]	X	X	X
b) Dartmouth College Single Tube Tests [8]	0	0	0
c) Dartmouth College Parallel Tube Tests [9]	0		0
3. Level Swell			
a) GE Large Vessel Test [10] Run No. 5801-15	X	X	
4. Steam Generator Thermal Performance			
a) B&W Tests [11,12] Series (68-69-70) Series (28-29)	X	0	
b) FLECHT-SEASET Tests [13] Run Nos. 21806,22010	X	X	
5. Natural Circulation			
a) FRIGG-Loop Tests [14] Run Nos. (301017-022), (301001-009, 301012 - 016, 301044-047), (301023-030)	X	X	

NOTE: X - COMPLETE

0 - IN PROGRESS

the water flow rate through the converging-diverging test section. The predicted water flow rates are compared with the data in Table 3. The results of TRAC-PD2 are also shown for comparison purposes. In can be seen that the TRAC-PF1 and TRAC-PD2 results are comparable even though a two-fluid model is being used in TRAC-PF1 as opposed to a drift-flux model used in TRAC-PD2.

The RELAP5 flow predictions are also much lower than the data and are comparable with the TRAC predictions. Analyses of these tests are still in progress.

2.1.3 Marviken Critical Flow Test [6]

The Marviken Test 24 was simulated with both the TRAC-PF1 (Version 7.0) and RELAP5/MOD1 (Cycle 14) codes. This test is probably the most challenging of all the Marviken tests since it employed a very short nozzle with the length-to-diameter ratio of 0.33.

Figures 1 and 2 show the comparison between the measured and calculated break flow rate and vessel top pressure, respectively. The nodalization for the vessel and the discharge pipe was the same for all calculations. However, the nozzle was modeled differently in various calculations, and that led to some differences in the results.

Two calculations were performed using the TRAC-PF1 code. In one case, the nozzle was represented by 40 cells and the no-choking option was used. In the other case, the nozzle was divided into two volumes and the TRAC-PF1 choking option (modified Burnell model) was used. As shown in Figure 1, the TRAC-PF1 break flow rate prediction with the self- or no-choking option yielded slightly better results than that with the choking option. However, both calculations significantly underpredicted the break flow rate during the subcooled blowdown period, i.e., $t < 20$ seconds. The vessel top pressure, as shown in Figure 2, was also underpredicted at the early part of the transient ($t < 15$ seconds) and was overpredicted thereafter.

For the RELAP5 calculation, the nozzle was modeled with one volume and the RELAP5 choking option was used. The predicted break flow rate (see Figure 1) was in better agreement with the data than the TRAC predictions, although the vessel top pressure (see Figure 2) was not predicted that well. The same calculation was repeated with a zero-volume nozzle as suggested by the RELAP5 code developers. In this case, the predicted break flow rate was in very good agreement with the data, but the pressure prediction did not improve.

In short, the RELAP5/MOD1 code yielded slightly better results for the break flow rate, particularly during the subcooled blowdown period, than the TRAC-PF1 code. However, neither code was able to predict <u>both</u> the break flow rate and the vessel pressure accurately. Moreover, the results seem to depend on nodalization which should be studied further.

Table 2. Summary of Moby-Dick N_2/Water Results

Run Number	Flow Quality	Water Mass Flow Rate (kg/s)				
		Experiment	TRAC-PF1 Calculation: Annular Friction Factor Option	Error (%)	TRAC-PF1 Calculation: Homogeneous Friction Factor Option	Error (%)
3087	5.91×10^{-4}	1.915	1.786	-6.7	2.205	+15.1
3141	51.3×10^{-4}	1.222	1.074	-12.1	1.4978	+22.5

Table 3. Summary of BNL Flashing Flow Test Results

Run Nos.	Inlet Pressure (kPa)	Inlet Temperature (°C)	Exit Pressure (kPa)	Experiment Mass Flow Rate (kg/s)	TRAC-PF1		TRAC-PD2		RELAP5/MOD1	
					Mass Flow Rate (kg/s)	% Error	Mass Flow Rate (kg/s)	% Error	Mass Flow Rate (kg/s)	% Error
291-295	502	148.9	471	6.43	4.74	-26.2	5.08	-21.0	4.92*	-23.5
309-311	556	149.1	397	8.79	7.10	-19.2	7.28	-17.2	7.12	-19.0
318-321	322	121.1	167	8.98	7.74	-13.8	7.79	-13.2	7.85	-12.6
339-342	320	121.3	252	8.97	7.63	-14.9	7.69	-14.3	7.62	-15.1

*Prediction using the RELAP5 choking option; the calculation without the choking option failed.

2.2 CCFL or "Flooding"

2.2.1 University of Houston Tests [7]

Two test series with two different water feed rates of 100 lb/hr and 1000 lb/hr were simulated with the TRAC-PF1 (Version 7.0), TRAC-BD1 (Version 12.0) and RELAP5/ MOD1 (Cycle 14) codes. The tests were conducted in a 2-inch inside diameter vertical pipe where air and water were injected at the bottom and middle of the test section, respectively. The predicted and measured water downflow rates vs. the injected air flow rate for both test series are shown in Figures 3 and 4.

It can be seen that TRAC-PF1 underpredicts the air flow rates necessary at the inception and completion of flooding. There is also a slight difference between the TRAC-PF1 and TRAC-PD2 results (see Figure 3). This is due to the use of Dukler's interfacial shear correlation [16] in TRAC-PF1 instead of Wallis' interfacial shear correlation [17] for the annular flow regime. Moreover, the high entrainment rate in both TRAC-PF1 and TRAC-PD2 contributed significantly to the underprediction of the air flow rate for flooding.

The TRAC-BD1 results, on the other hand, are in much better agreement with the University of Houston data. TRAC-BD1 (Version 12.0) employs the Wallis correlation for the interfacial shear, the Ishii-Grolmes [18] correlation for the onset of entrainment, and the Ishii-Mishima correlation [19] for the entrainment rate. The combined effect of these correlations produced good agreement between the data and the TRAC-BD1 predictions as shown in Figures 3 and 4.

The RELAP5 predictions for these tests are very poor. Very little air flow rate is required to cause upflow of all the injected water in the RELAP5 calculation (see Figure 3 and 4). This is caused by the inadequacy of the RELAP5 flow regime map at high void fractions ($\alpha > 0.95$). At these void fractions, the code assumes all the liquid to be in the droplet form which was not the case in the Houston test. Clearly an improved flow regime map is needed in RELAP5 for high void fractions.

2.2.2 Dartmouth College Single Tube Tests [8]

Two series of tests with two different tube diameters (1-inch and 6-inch) were selected for simulation with the TRAC-PF1, TRAC-BD1 and RELAP5/MOD1 codes. The preliminary results for the small diameter (1-inch) tube showed some anomalous behavior and the analyses are still in progress.

The results for the 6-inch diameter tube test are shown in Figures 5 and 6. The TRAC-PF1 calculations, as shown in Figure 5, are in good agreement with the data except for the nondimensional air flow rate of approximately 0.4. Here the code calculated an unreasonably low value of the liquid downflow rate. The problem has been traced back to the sharp discontinuity in the Dukler interfacial shear correlation at lower void fractions or thicker films.

Figure 6 shows the results of the TRAC-BD1 calculation for the 6-inch tube test. The code without the CCFL option overpredicted the average water downflow rate for a given air flow rate. However, as expected, the prediction with the CCFL option was slightly closer to the data.

RELAP5 predicted very little water downflow even for a low value of the air flow rate. This is consistent with the RELAP5 predictions of the University of Houston tests discussed earlier.

2.2.3 Dartmouth College Parallel Tube Tests [9]

A Dartmouth College test series conducted with three parallel tubes each of 1-inch in inside diameter has been selected for simulation with both TRAC-PF1 and TRAC-BD1. Preliminary calculations with the TRAC-BD1 code agree with some features of the experiment. However, the calculations are still in progress and it is premature to make any conclusion at this time.

2.3 Level Swell

2.3.1 GE Large Vessel Test [10]

The GE large vessel level swell test No. 5801-15 has been simulated with both the TRAC-PF1 and RELAP5/MOD1 codes. The resultant vessel pressures are shown in Figure 7, whereas the axial void distributions at various times are presented in Figure 8. The TRAC-PF1 pressure prediction is in good agreement with the data except for the very early part when a pressure dip was observed in the experiment. This discrepancy is due to the lack of a flashing delay model in TRAC-PF1. RELAP5, on the other hand, significantly underpredicts the vessel pressure throughout the transient.

Figure 8 reveals that, in general, TRAC-PF1 overpredicts the void fraction and the rate of level swell. This is in agreement with the TRAC-PD2 results for the Battelle-Frankfurt level swell test reported earlier [20]. Both of these trends could be due to the higher interfacial shear in TRAC for the bubbly and bubbly-slug regimes.

The RELAP5 results for the axial void distribution show irregularities which may be due to some errors in the interfacial shear package. A nodalization study with finer mesh did not resolve this irregular behavior.

2.4 Steam Generator Thermal Performance

2.4.1 B&W Steam Generator Tests [11, 12]

Two test series, one with the 19-tube Integral Economizer Once-Through Steam Generator (IEOTSG) and the other with the 19-tube Once-Through Steam Generator (OTSG), have been simulated with both the TRAC-PF1 and RELAP5/MOD1 codes. The IEOTSG test series 68-69-70 simulated a load change transient from 15% to 25% of the full power, whereas the OTSG test series 28-29 simulated the loss-of-feedwater transient.

Figure 9 shows the TRAC-PF1 and RELAP5 results for the IEOTSG test along with the experimental data. The vertical scales are withheld because the data are B&W proprietary. The TRAC-PF1 results are in reasonably good agreement with the data whereas the RELAP5 results show some numerical oscillations. Further analysis with RELAP5 is in progress where the maximum time step will be controlled manually.

Figure 10 shows the TRAC-PF1 results for the OTSG test along with the data. Again, the vertical scales are withheld because the data are B&W proprietary. The original TRAC-PF1 (Version 7.0) results did not agree well with the experimental data. One of the major deficiencies in the TRAC calculation was very little condensation of the bled steam coming through the aspirator into the downcomer. This resulted in a lower liquid inventory in the downcomer and a two-phase mixture at the bottom of the tube bundle during the steady-state. Therefore, when the feedwater was lost, TRAC-PF1 considerably underpredicted the exit steam flow rate. A sensitivity study showed that if the steam-water condensation rate were increased such that the bled steam would condense completely, TRAC-PF1 would predict the steam flow rate very well. However, there was still a problem with the exit steam temperature. This was caused by the slightly lower primary-to-secondary heat transfer rate at the steady-state.

2.4.2 FLECHT-SEASET Steam Generator Tests [13]

Two tests, namely ID=21806 and ID=22010, have been simulated with both the TRAC-PF1 and RELAP/MOD1 codes. In these tests, the secondary side of the model U-tube steam generator was filled with stagnant water at high pressure ($\sim$57 bar), and a high void ($\alpha > 0.99$) steam-water mixture at low pressure ($\sim$3 bar) flowed through the primary tube. The direction of heat transfer was predominantly from the secondary to the primary.

Figures 11 through 13 show some of the TRAC-PF1 and RELAP5 results for Test ID=21806 along with the data. It can be seen that both TRAC and RELAP5 underpredicted the secondary side pressure which was the result of overprediction of the secondary-to-primary heat transfer rate. Figures 12 and 13 support this notion. It can be seen from Figure 12 that TRAC and RELAP5 did not predict any liquid carryover until the second half of the transient, although there was always some carryover during the experiment. Figure 13 depicts the primary side steam and secondary side fluid temperatures at t = 338 seconds. Notice that both codes underpredict the secondary side fluid temperature which is the direct proof of overprediction of the secondary-to-primary heat transfer rate. However, the TRAC-PF1 results are more reasonable than the RELAP5/MOD1 results. The experimental primary steam temperature shows a sharp increase between 3 and 4 m elevation at t = 338 seconds which was not predicted by either code. This sharp increase in the steam temperature represents a highly nonequilibrium situation where droplets coexist with the superheated vapor. In TRAC-PF1, the steam was superheated although the degree of superheat was not as high as in the experiment. This led to the larger temperature differential between the secondary and the primary and hence, the greater heat transfer rate. RELAP5, on the other hand, could not predict any steam superheat until all the droplets were evaporated. Thus, the temperature differential and the secondary-to-primary heat transfer rate was even greater in RELAP5/MOD1.

Similar results were obtained for test ID=22010 and they will not be repeated here because of space limitation.

2.5 Natural Circulation

2.5.1 FRIGG-Loop Natural Circulation Tests [14]

Three test series with different entrance loss coefficients (K_{ent} = 4.5, 14.0 and 19.0) have been simulated with both the TRAC-PF1 and RELAP5/MOD1 codes. Since the results of these test series were very similar, only the series with K_{ent} = 14.0 will be discussed here.

Figure 14 shows the predicted and measured flow rates as a function of bundle power. TRAC-PF1 with the annular flow friction factor produced the correct trend, although the predicted flow rates were somewhat higher than the experimental values. Since the homogeneous flow friction factor yields lower wall friction than the annular flow friction factor, the TRAC-PF1 flow rates with the former option were considerably larger than the data. The RELAP5 predictions for flow rates were also larger than the data, particularly at high bundle powers.

Figure 15 compares the bundle wall heat flux with the various CHF correlations as a function of power. The CHF was experienced during the experiment at approximately 6.2 MW. However, neither TRAC-PF1 nor RELAP5/MOD1 was able to predict this accurately. The TRAC-PF1 code which uses the Biasi correlation would highly overestimate the power needed for the CHF condition, whereas the RELAP5/MOD1 code which uses the W-3 correlation would miss the CHF completely. However, it has been found that the RELAP4/MOD7 CHF correlation [21] would predict the CHF point quite accurately for this particular FRIGG test.

3. CONCLUSIONS

3.1 Critical Flow

Both TRAC-PF1 (Version 7.0) and RELAP5/MOD1 (Cycle 14) underpredicted the steady-state subcooled critical flow rate through a converging-diverging nozzle, i.e., the BNL test section. For the Marviken Test 24, the RELAP5 critical flow rate was in better agreement with the data. However, neither code could predict both the break flow rate and the vessel inside pressure well. Further work on the subcooled critical flow rate is needed for both codes.

3.2 CCFL or Flooding

TRAC-BD1 (Version 12.0) yielded the best prediction for the University of Houston tests conducted in a 2-inch diameter pipe. However, for the Dartmouth College tests conducted in a 6-inch diameter pipe, TRAC-BD1 tends to overpredict the liquid downflow rate. TRAC-PF1 yielded better results for the same test series with the exception of one data point. Discontinuity in the Dukler interfacial shear correlation incorporated in TRAC-PF1 seems to be the reason for this discrepancy.

The RELAP5/MOD1 predictions of the University of Houston tests were very poor. The code should employ an annular-mist flow regime at high void fractions instead of only a mist or droplet regime.

Analyses of the Dartmouth single and multiple tube tests using 1-inch diameter pipe(s) are still in progress.

3.3 Level Swell

TRAC-PF1 tends to overpredict the level swell rate and the void fraction below the mixture level, although it predicts the depressurization rate quite well. Higher interfacial shear in the bubbly and bubbly-slug regimes seems to be the reason.

RELAP5/MOD1, however, tends to underpredict the level swell rate and exhibits some irregularities in the axial void fraction profile. Some errors or lack of smoothing in the interfacial shear package could be the reason.

3.4 Steam Generator Thermal Performance

For the B&W IEOTSG test, both TRAC-PF1 and RELAP5/MOD1 yielded reasonable average results, although the latter showed some numerical instabilities. Manual control of maximum time step is probably necessary to avoid these instabilities.

For the B&W OTSG test, TRAC-PF1 underpredicted the exit steam flow rate during a loss-of-feedwater transient. This was caused by the lower initial (steady-state) water inventory due to the lower rate of aspirator steam condensation. An increase in the condensation rate improved the TRAC-PF1 results. Simulation of the same experiment with the RELAP5/MOD1 code is still in progress.

For the FLECHT-SEASET U-tube steam generator tests, both TRAC-PF1 and RELAP5/MOD1 codes overpredicted the secondary-to-primary heat transfer rate. One of the main reasons for this discrepancy seems to be the higher interfacial heat transfer rate in the droplet flow regime in both codes, particularly in RELAP5 which did not produce any steam superheat until all the droplets were evaporated. There were also some numerical instabilities in RELAP5 which disappeared when the calculations were repeated with manually controlled time step.

3.5 Natural Circulation

Both TRAC-PF1 and RELAP5/MOD1 overpredicted the flow rates for the FRIGG-Loop natural circulation tests. However, slightly increased values of wall friction factors and/or form losses would yield reasonable agreement with the data.

The CHF correlations used in both codes, i.e., the Biasi and the W-3 correlations, were unable to predict the CHF condition in the FRIGG test. However, the RELAP4/MOD7 CHF correlation predicted the same condition quite well.

3.6 Computer Run Time

The BNL code assessment activity did not reveal any clear computer run time advantage for either TRAC-PF1 or RELAP5/MOD1. The run time statistics for most of the transient tests simulated at BNL are presented in Table 4. The time steps for all the calculations were selected by the time step control of the codes and no manual intervention was made. It can be seen that although RELAP5/MOD1 has a factor of three advantage in the grind time, i.e., the CPU time per cell per time step, the advantage is lost because it takes smaller time steps. Furthermore, for some calculations such as steam generator tests where wall heat transfer is involved, the user may have to restrict the maximum time step to avoid numerical instability. In these cases, TRAC-PF1 will run significantly faster than RELAP5/MOD1.

4. FUTURE WORK

BNL will continue the independent code assessment activity in FY 1983. The codes to be assessed are: TRAC-PF1/MOD1, TRAC-BD1/MOD1 and RELAP5/MOD2. The assessment matrix will contain some of the tests simulated earlier. However, some new types of tests such as NRU reflood and ORNL post-CHF tests will be added.

Table 4. Comparison of Computer (BNL CDC-7600) Run Times for TRAC-PF1 and RELAP5/MOD1

Experiment Simulated	Code	Real Time (s)	No. of Cells	No. of Time Steps	CPU Time (s)	CPU/Real	CPU(s)/(cell-time step)
Marviken Test 24	TRAC-PF1	55	42	1202	127	2.31	2.5×10^{-3}
	RELAP5/MOD1	60	41	6034	193	3.22	0.8×10^{-3}
GE Large Vessel Test (No. 5801-15)	TRAC-PF1	20	17	236	21	1.05	5.2×10^{-3}
	RELAP5/MOD1	20	14	28814	400	20	1×10^{-3}
B&W IEOTSG Test (No. 68-69-70)	TRAC-PF1	50	26	255	21	0.42	3.2×10^{-3}
	RELAP5/MOD1	50	26	400	12	0.24	1.2×10^{-3}
FLECHT-SEASET Steam Generator Test ID=21806	TRAC-PF1	1300	46	31022	4419	3.40	3.1×10^{-3}
	RELAP5/MOD1	1300	46	42322	2568	1.98	1.3×10^{-3}
FLECHT-SEASET Steam Generator Test ID=22010	TRAC-PF1	1300	46	7048	1115	0.86	3.4×10^{-3}
	RELAP5/MOD1	1300	46	167370	9271	7.13	1.2×10^{-3}

REFERENCES

1. Safety Code Development Group, "TRAC-PF1: An Advanced Best Estimate Computer Program for Pressurized Water Reactor Analysis," Los Alamos National Laboratory Report, Draft, November 1981.

2. Jay W. Spore, et al., "TRAC-BD1: An Advanced Best Estimate Computer Program for Boiling Water Reactor Loss-of-Coolant Accident Analysis," NUREG/CR-2178, EGG-2109, October 1981.

3. V. H. Ransom, et al., "RELAP5/MOD1 Code Manual," NUREG/CR-1826, EGG-2070, March 1982.

4. C. Jeandey and G. Barriere, "Part I, Etude Experimentale d'Ecoulements Eau-Air a Grande Vitesse," DTCE/STT/SETRE Note T.T. No. 599, Janvier 1979.

5. N. Abuaf, et al., "A Study of Nonequilibrium Flashing of Water in a Converging-Diverging Nozzle," NUREG/CR-1864, BNL-NUREG-51317, June 1981.

6. L. Ericson, et al., "Marviken Critical Flow Tests," Joint Reactor Safety Experiments in Marviken Power Stations, MXC-224, September 1979.

7. A. E. Dukler, and L. Smith, "Two-Phase Interactions in Counter-Current Flow: Studies of the Flooding Mechanism," NUREG/CR-0617, January 1979.

8. D. Bharathan, "Air-Water Countercurrent Annular Flow," EPRI Report NP-1165, September 1979.

9. C. R. Clark, et al., "Flooding in Multi-Path Vertical Counter-current Air-Water Flow," Dartmouth College Report, NRC0193-5, September 1978.

10. J. A. Findlay, "BWR Refill-Reflood Program Task 4.8 - Model Qualification Task Plan," NUREG/CR-1899, EPRI NP-1527, GEAP-24898, August 1981.

11. G. W. Loudin and W. J. Oberjohn, "Transient Performance of a Nuclear Integral Economizer Once-Through Steam Generator," B&W Alliance Research Center Report 4679, B&W Proprietary, January 1976.

12. H. R. Carter and D. D. Schleappi," Nuclear Once-Through Steam Generator (OTSG and IEOTSG) Loss of Feedwater (LOFW) Test," B&W Alliance Research Center Report 4707, B&W Proprietary, March 1978

13. R. C. Howard, et al., "PWR FLECHT-SEASET Steam Generator Separate Effects Task Data Report," NUREG/CR-1366, January 1980.

14. O. Nylund, et al., "Hydrodynamic and Heat Transfer Measurements on a Full-Scale Simulated 36-Rod Marviken Element with Uniform Heat Flux Distribution," FRIGG-2, R4-447/RTL-1007, 1968.

15. P. Saha, "Moby-Dick Nitrogen-Water Experiments," in the BNL Quarterly Progress Report for January 1 - March 31, 1980, NUREG/CR-1506, BNL-NUREG-51218, pp. 28-33, June 1980.

16. A. E. Dukler, "Two-Phase Interactions in Countercurrent Flow," Univ. of Houston, Department of Chemical Engineering, Annual Report for Nov. 1978 - Oct. 1979, January 1980.

17. G. B. Wallis, "Annular Two-Phase Flow, Part 1, A. Simple Theory," Journal of Basic Engineering, ASME, Vol. 92, pp. 59-72, March 1979.

18. M. Ishii and M. A. Grolmes, "Inception Criteria for Droplet Entrainment in Two-Phase Concurrent Film Flow," AIChE Journal, Vol. 21, pp. 308-318, 1975.

19. M. Ishii and K. Mishima, "Correlation for Liquid Entrainment in Annular Two-Phase Flow of Low Viscous Fluid," ANL/RAS/LWR 81-2, March 1981.

20. L. Neymotin, "Battelle Institute (Frankfurt-Main) Vessel Top Blowdown Test," in BNL Quarterly Progress Report for January 1 - March 31, 1981, NUREG/CR-2160, BNL-NUREG-51401, pp. 37-41, May 1981.

21. K. G. Condie and S. G. Bengston, "Development of the MOD7 Correlation," EG&G Report, Attachment PN-181-78, 1978.

RECENT BNL PUBLICATIONS ON CODE ASSESSMENT

1. P. Saha, et al., "LWR Code Assessment and Application," in Safety Research Programs Sponsored by Office of Nuclear Regulatory Research, BNL Quarterly Progress Reports for Oct. 1 - Dec. 31, 1981, Jan. 1 - March 31, 1982, April 1 - June 30, 1982, and July 1 - Sept. 30, 1982, NUREG/CR-2331, BNL-NUREG-51454, Vol. 1, No. 4, Vol. 2., No. 1, 2, 3.

2. L. Neymotin, "TRAC-PD2 Prediction of a FLECHT-SEASET Bottom Reflood Experiment, " ANS Transactions, Vol. 39, pp. 563 - 564, December 1981.

3. J. H. Jo, U. S. Rohatgi, and P. Saha, "Simulation of an Overcooling Transient at Rancho Seco with TRAC-PD2," ANS Transactions, Vol. 39, pp. 625 - 627, December 1981.

4. L. Neymotin, "TRAC-PD2 and RELAP5/MOD1 Predictions of Heated Rod Bundle Experiments," ANS Transactions, Vol. 39, pp. 1018 - 1019, December 1981.

5. U. S. Rohatgi, "Assessment of TRAC-PD2 with University of Houston Countercurrent Flow Tests," ANS Transactions, Vol. 39, pp. 1038-1039, December 1981.

6. P. Saha, "A Simple Subcooled Boiling Model," ANS Transactions, Vol. 39, pp. 1058-1060, December 1981.

7. G. Slovik and P. Saha, "Analysis of the BCL Transient ECC Bypass Test with the TRAC-PD2/MOD1 Code," ANS Transactions, Vol. 41, pp. 386 - 387, June 1982.

8. P. Saha, "Use of Separate Effects Experiments in Verification of System Thermal Hydraulics," ANS Transactions, Vol. 41, pp. 673 - 674, June 1982.

9. U. S. Rohatgi, J. H. Jo, and L. Neymotin, "Constitutive Relations in TRAC-PD2," NUREG/CR Report in press.

10. P. Saha, et al., "Independent Assessment of TRAC-PD2 and RELAP5/MOD1 Codes at BNL in FY 1981," NUREG/CR Report to be published soon.

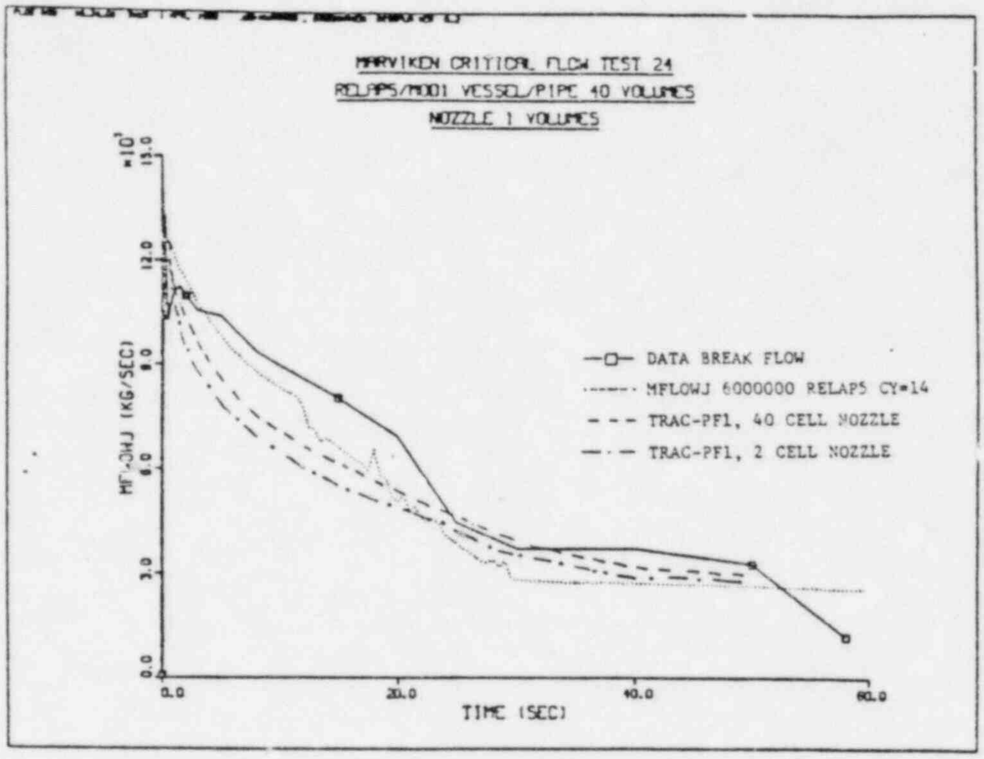


Figure 1 Comparison Between the Measured and Predicted Break Mass Flow Rate for Marviken Test 24

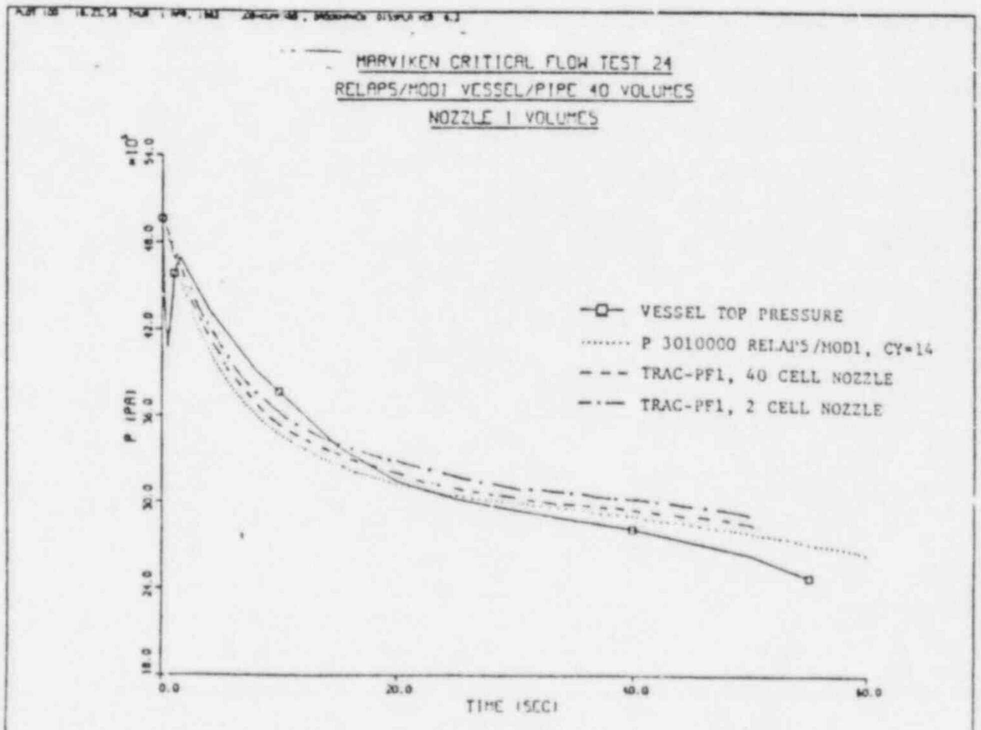


Figure 2 Comparison Between the Measured and Predicted Vessel Top Pressure for Marviken Test 24

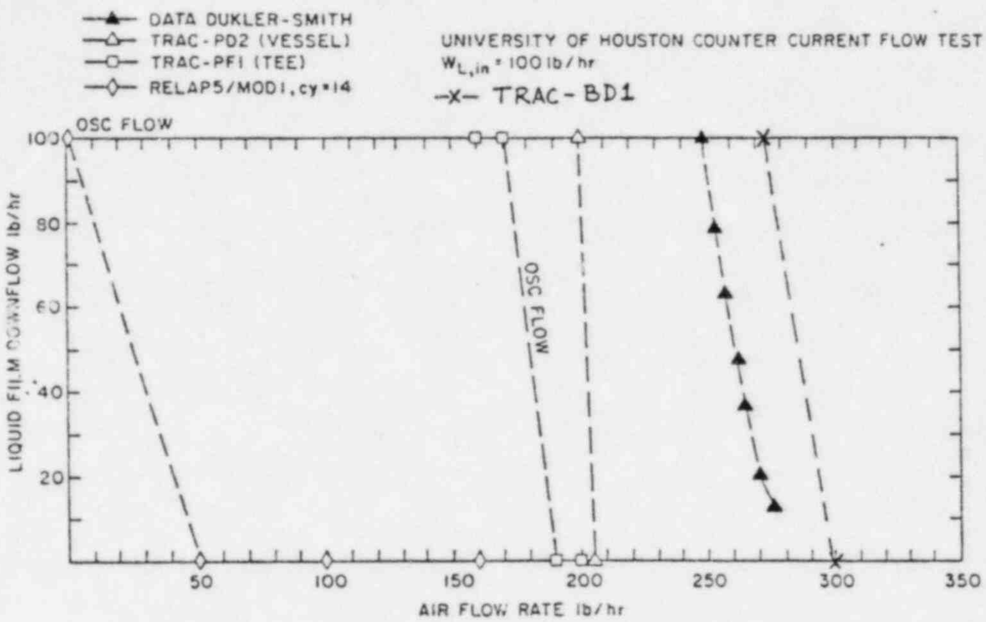


Figure 3 Comparison Between the Measured and Predicted Water Downflow Rate vs. Air Flow Rate for Water Feed Rate of 100 lb/hr

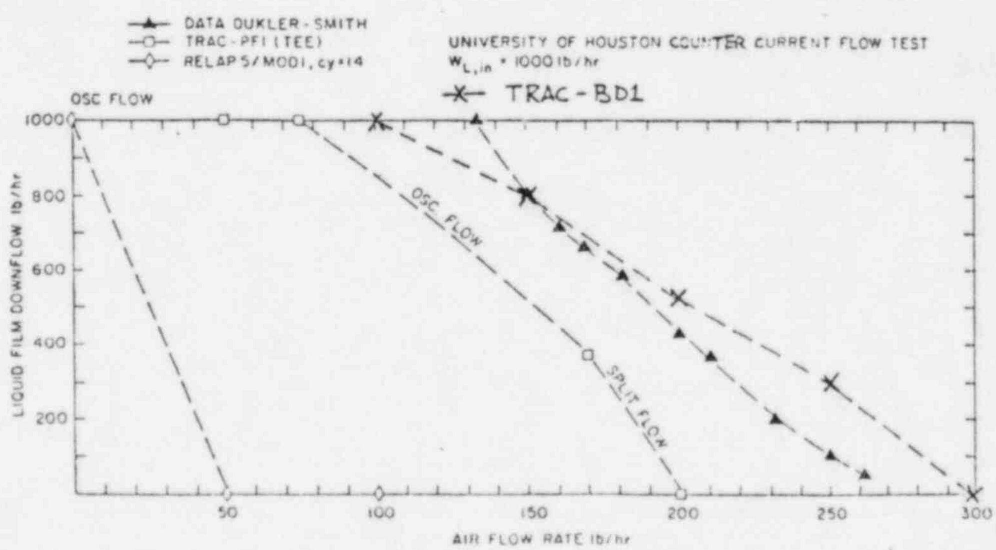


Figure 4 Comparison Between the Measured and Predicted Water Downflow Rate vs. Air Flow Rate for Water Feed Rate of 1000 lb/hr

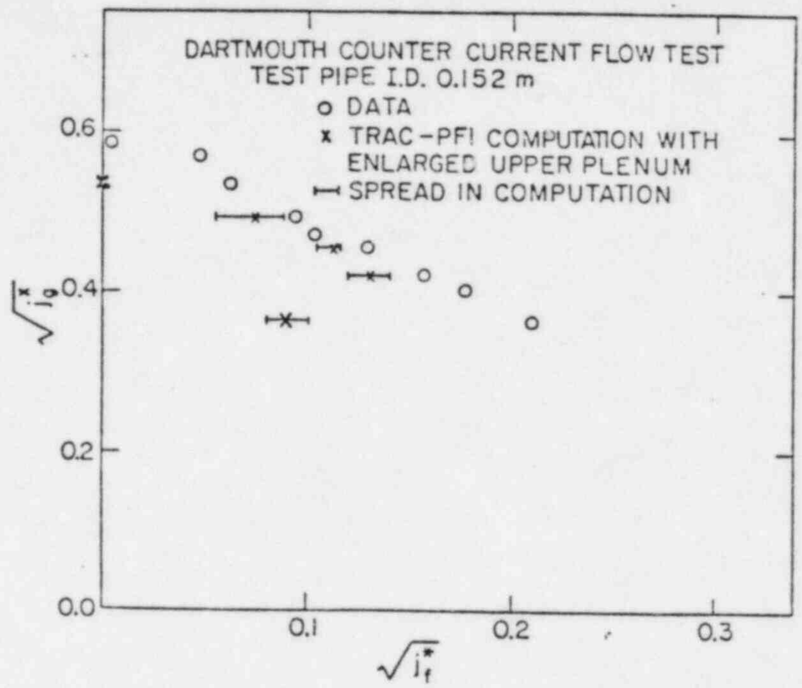


Figure 5 Comparison between the Measured and Predicted Non-Dimensional Filling Rate for the Dartmouth Large Diameter Pipe Test

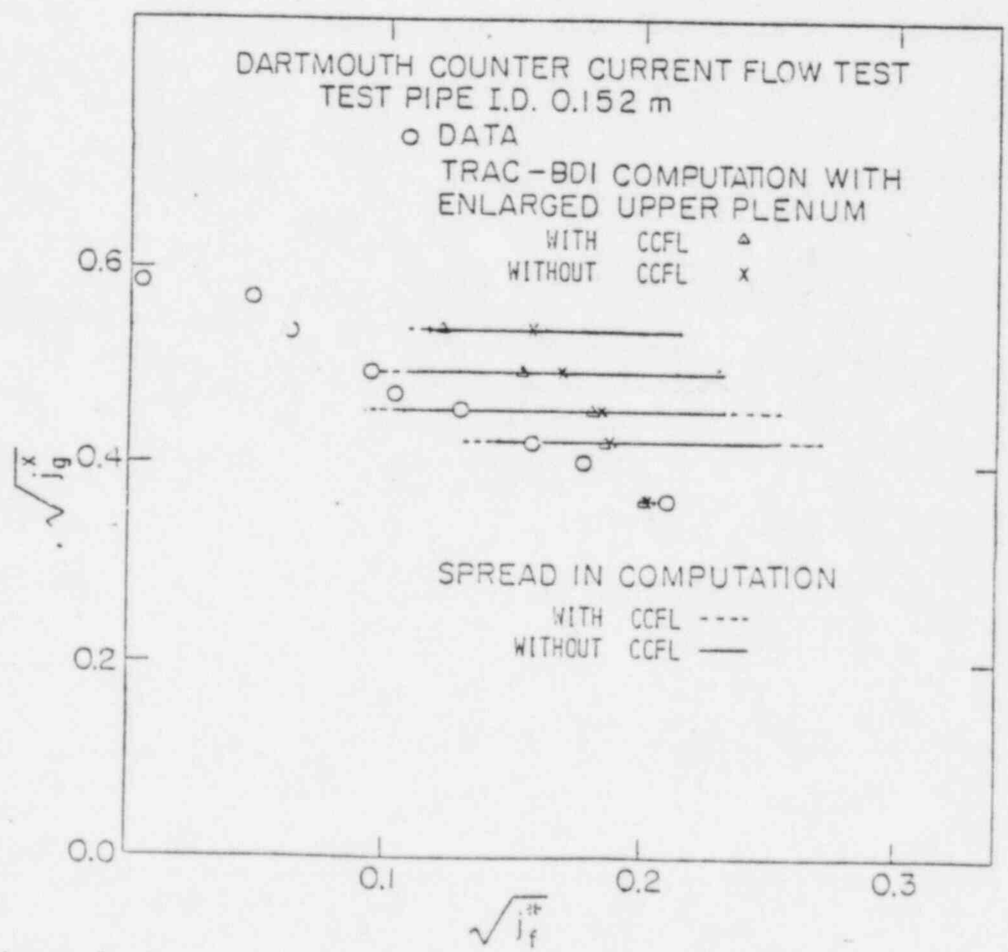


Figure 6 Comparison Between the Measurements and TRAC-BD1 Predictions for the Dartmouth Large Diameter Pipe Test

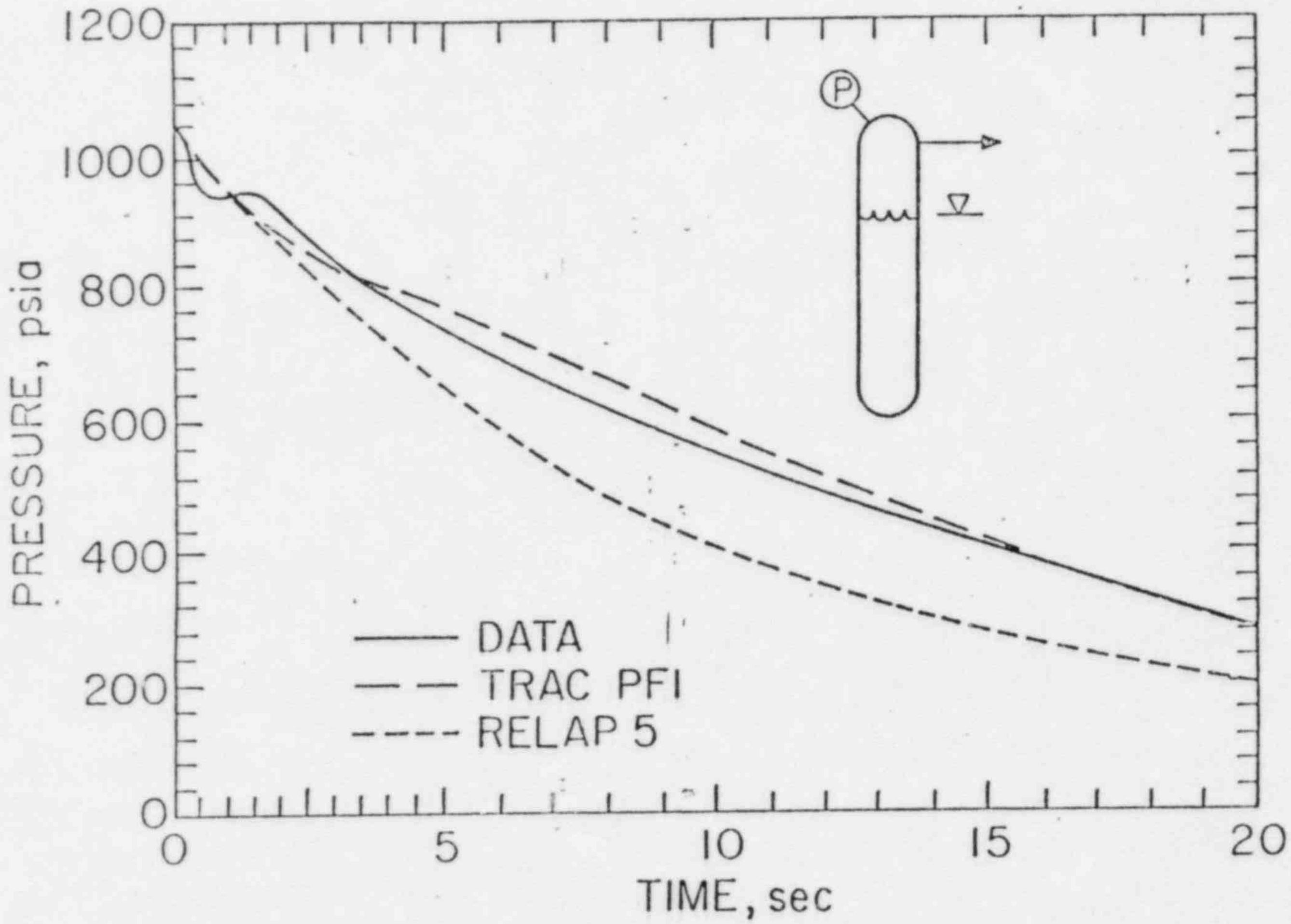


Figure 7 Comparison Between the Measured and Predicted Vessel Pressures in the GE Large Vessel Level Swell Test

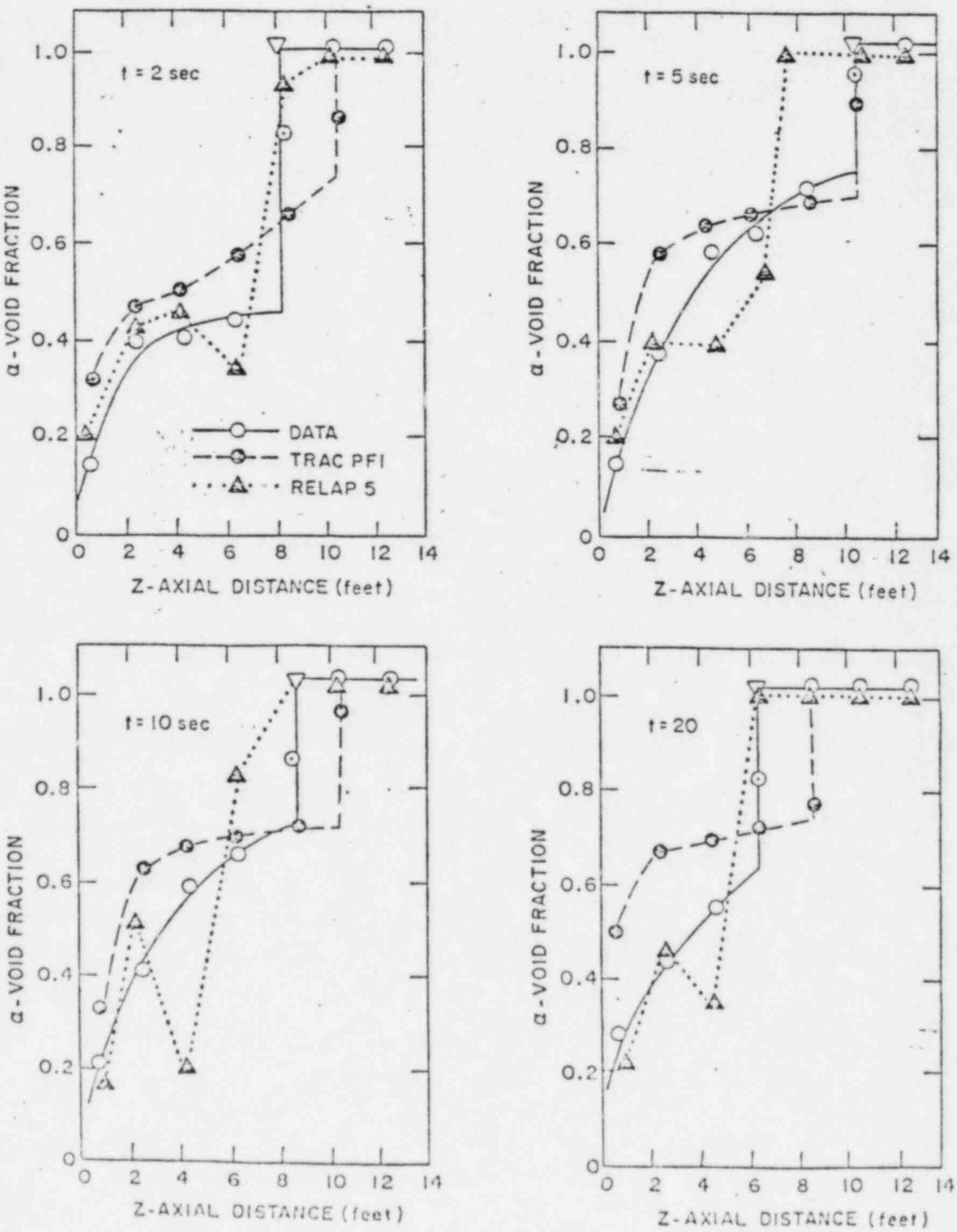
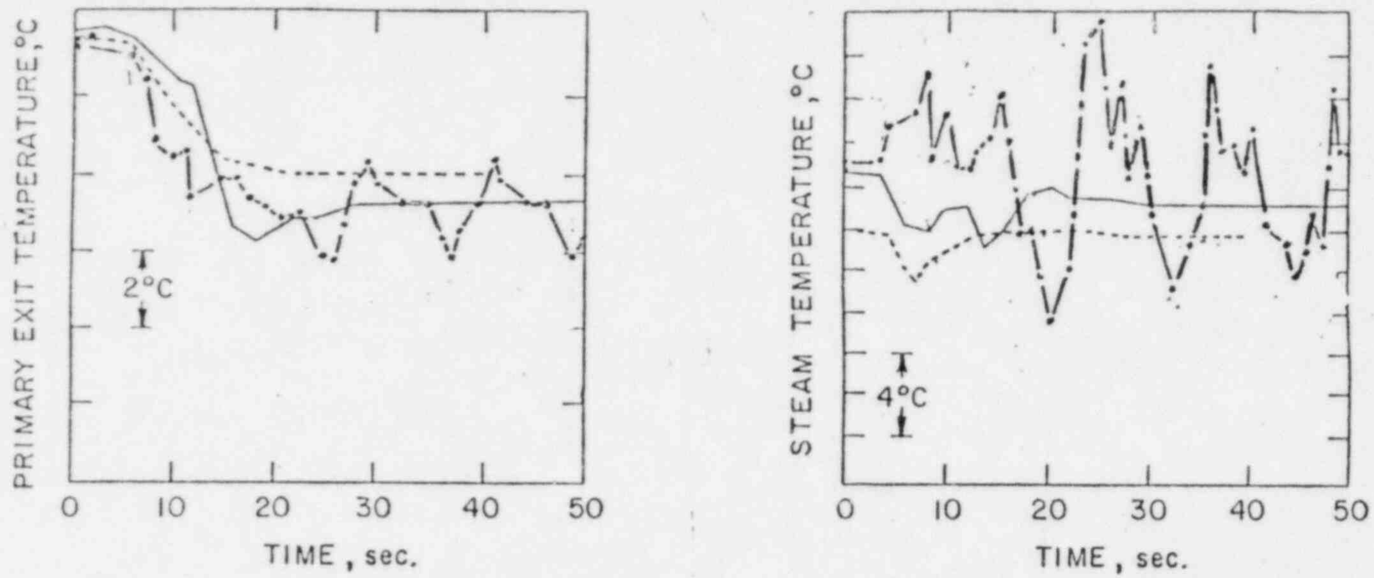
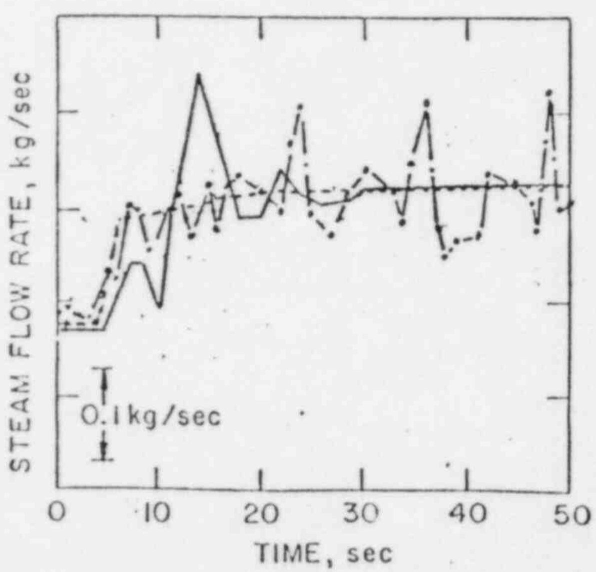


Figure 8 Comparison Between the Measured and Predicted Axial Void Distributions in the GE Level Swell Test





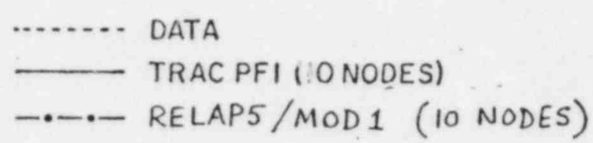


Figure 9 Comparison Between the Measurements and the Predictions of the B&W IEOTSG Test

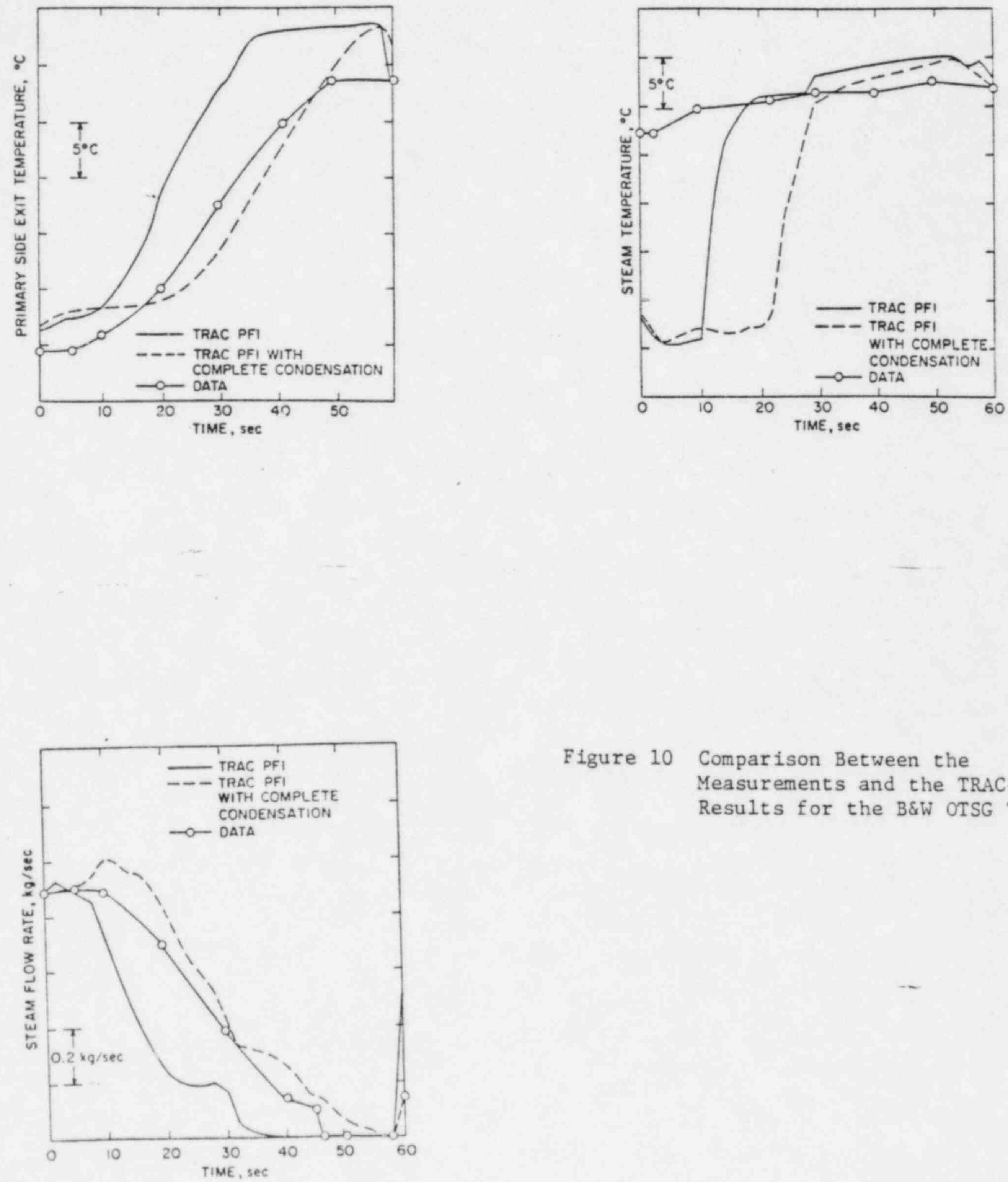


Figure 10 Comparison Between the Measurements and the TRAC-PF1 Results for the B&W OTSG Test

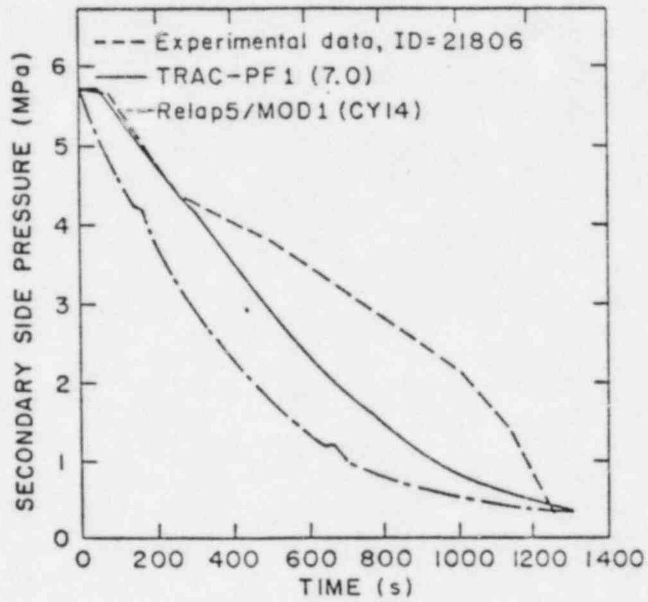


Figure 11 Comparison Between the Measured and Predicted Secondary Side Pressure for ID=21806

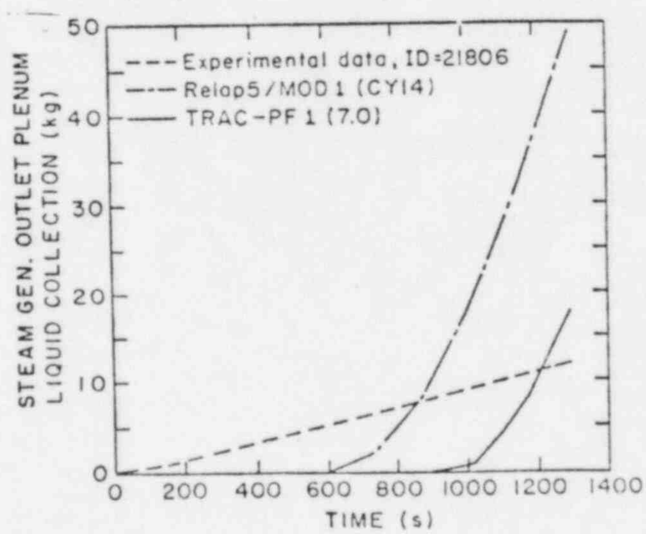


Figure 12 Cc parison Between the Measured and Predicted Li uid Mass at the Primary Side Outlet Plenum for ID=21806

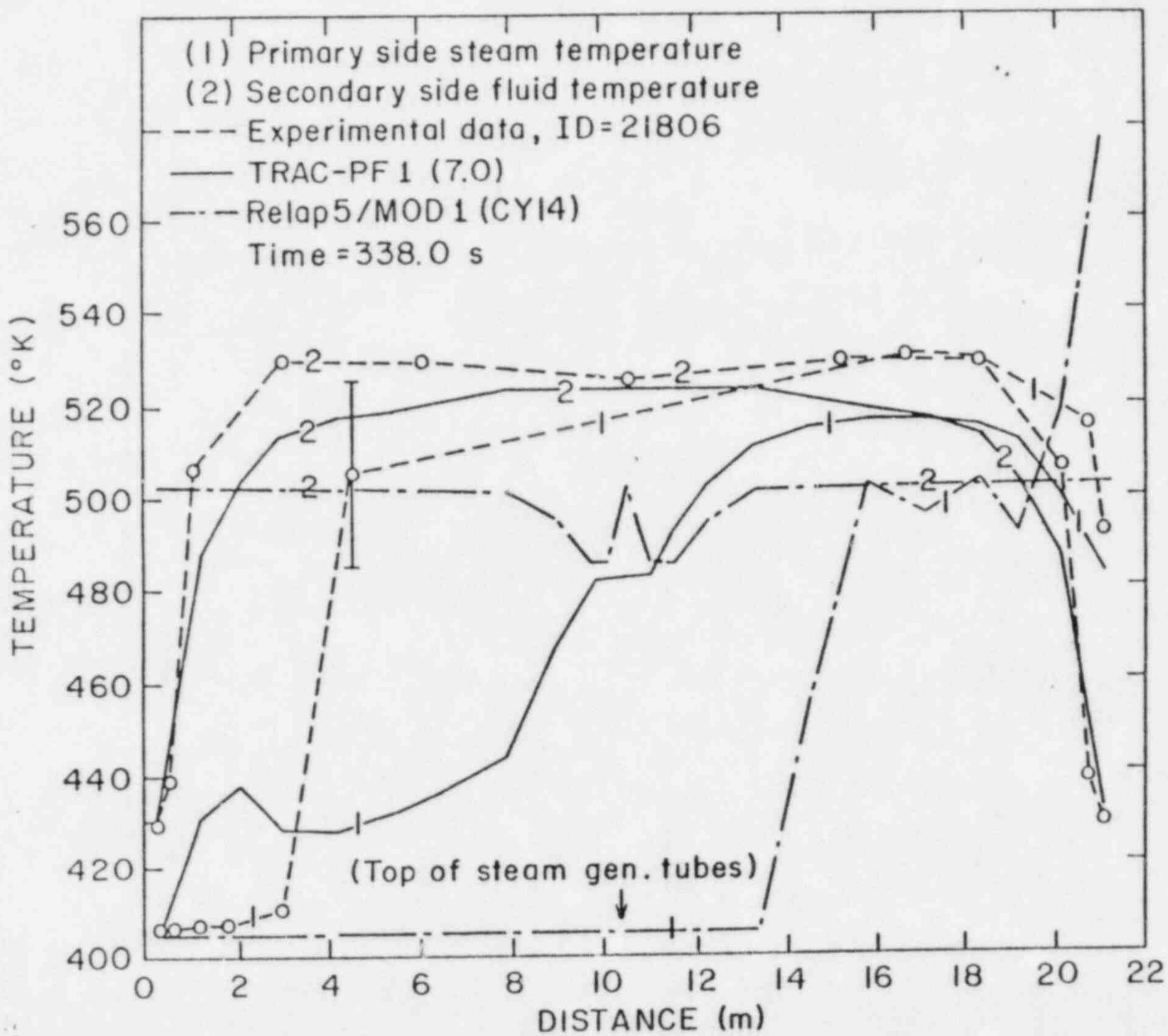


Figure 13 Comparison Between the Measured and Predicted Primary Side Steam and Secondary Side Fluid Temperatures for Test ID = 21806 at 338 s.

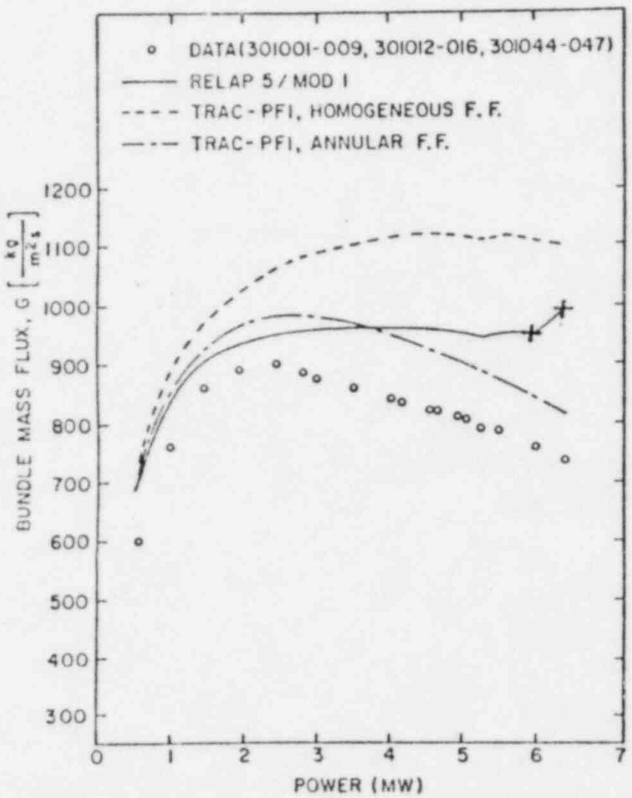


Figure 14 Comparison Between the Measured and Predicted Bundle Mass Fluxes for K_{ent}=14.0

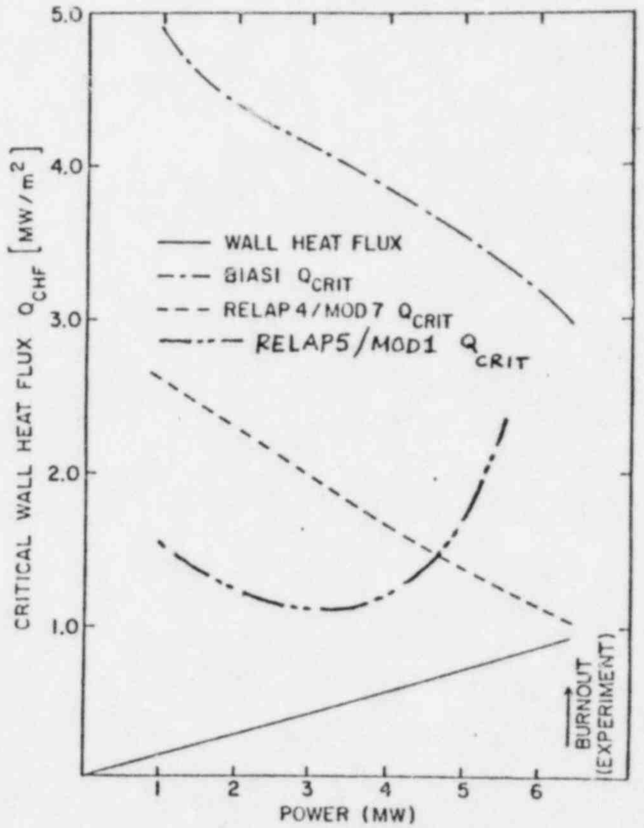


Figure 15 Comparison Between the Measured and Predicted Power for CHF or Burnout