NUREG/IA-0006

International Agreement Report

Assessment of RELAP5/MOD 2 Against Marviken Jet Impingement Test 11 Level Swell

Prepared by
O. Rosdahl, D. Caraher

Swedish Nuclear Power Inspectorate
P.O. Box 27106
S102 #52 Stockholm, Sweden

Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

September 1986

Prepared as part of
The Agreement on Research Participation and Technical Exchange
under the International Thermal-Hydraulic Code Assessment
and Application Program (ICAP)

Published by
U.S. Nuclear Regulatory Commission

Available from

Superintendent of Documents
U.S. Government Printing Office
P.O. Box 37082
Washington, D.C. 20013-7082

and

National Technical Information Service
Springfield, VA 22161

NUREG/IA-0006

International Agreement Report

Assessment of RELAP5/MOD 2 Against Marviken Jet Impingement Test 11 Level Swell

Prepared by
O. Rosdahl, D. Caraher

Swedish Nuclear Power Inspectorate
P.O. Box 27106
S102 #52 Stockholm, Sweden

Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

September 1986

Prepared as part of
The Agreement on Research Participation and Technical Exchange
under the International Thermal-Hydraulic Code Assessment
and Application Program (ICAP)

Published by
U.S. Nuclear Regulatory Commission

NOTICE

STUDSVIK ENERGITEKNIK AB

STUDSVIK/NP-86/97

1986-07-11

Project 85026, Ref 13.3-917/84
Swedish Nuclear Power Inspectorate

Östen Rosdahl
David Caraher*

ICAP
ASSESSMENT OF RELAP5/MOD2 AGAINST MARVIKEN JET IMPINGEMENT TEST 11 LEVEL SWELL

ABSTRACT

RELAP5/MOD2 simulations of level swell of saturated liquid in a large (5 m diameter, 22 m high) vessel are reported. For certain nodalizations RELAP5 is shown to predict the measured void fraction profile with fair accuracy. RELAP5 results are shown to be dependent upon nodalization with the accuracy of computed results deteriorating significantly when a large number of nodes is employed.

* Engineering Software Consulting

Approved by Eric Wallsbeck

LIST OF CONTENTS

EXECUTIVE SUMMARY

RELAP5/MOD2 simulations have been conducted for MARVIKEN Jet Impingement Test 11 (JIT 11). The purpose of the simulations was to assess the ability of RELAP5/MOD2 to simulate level swell in a large vessel.

The experimental facility consisted of a large vessel 5.2 m in diameter and 22 m high having a total volume of 420 m^3. A standpipe 1 m in diameter and 18 m tall was inserted in the vessel. A discharge pipe containing a valve, nozzle, and rupture disks was attached to the lower end of the standpipe at the bottom of the vessel.

The vessel was filled to the 10.2 m elevation with nearly saturated liquid; the remaining part of the vessel and the standpipe were filled with saturated steam. The initial pressure in the vessel was 5.0 MPa.

The test was initiated by breaking the rupture disks. Because of the standpipe only steam flowed from the vessel. Differential pressures were recorded at various elevations in the vessel, thus affording a history of fluid density versus elevation to be obtained. Discharge mass flow rate was also measured. The experiment was terminated when the pressure in the vessel reached 1.9 MPa.

After the rupture disks broke bulk flashing occurred in the liquid. The level of the resulting two phase mixture rose rapidly and reached a maximum height of about 18 m - the top of the standpipe - within 15 seconds. The mixture level declined slowly thereafter receding to near the

14 m elevation by the time the test ended (80 seconds). For elevations below the 13 m height the differential pressure measurements remained fairly constant over the 15 to 80 second time period; indicating that the void fraction was fairly constant.

RELAP5/MOD2 simulations were conducted using 20, 40 and 100 nodes to model the annular region in the vessel below the top of the standpipe. The experimental mass flow rate was used as a boundary condition. Differential pressures calculated by RELAP5 were compared to measured ones.

The 20 node and the 40 node simulations showed similar results. Both calculations indicated that the RELAP5 underpredicted the void fraction of the swelled two phase mixture for elevations below 13 m and overpredicted the void fraction for higher elevations. The results imply that the interfacial drag force in RELAP5 fell off too rapidly with increasing void fraction. Consequently RELAP5 carried less liquid to the upper elevations than was actually carried there and RELAP5 allowed the liquid to drain from the upper elevations somewhat faster than it actually did.

The 100 node simulation was characterized by very erratic differential pressure histories which were, for some elevations, much different from the dP histories of the 20 and 40 node cases. Moreover, the 100 node simulation was found to be sensitive to time step size - changing the step size from 0.1 s to 0.05 s (material Courant limit = 0.12 s) produced large changes in void fraction profiles. The behaviour of the 100 node simulation is believed to be related to the

interphase drag model in RELAP5 - its strong dependence on void fraction in the bubble-to-slug flow transition region; its explicit connection to the numerical solution; and its algorithm for damping large changes in computed values.

Time step studies on the 20 node model revealed that the RELAP5 calculation was sensitive to time step size during the time period (0-30 s) when the level swelled to its maximum height.

The 20 and 40 node simulations have demonstrated that RELAP5/MOD2 can give a fairly accurate simulation of the void profile occurring during level swell in large vessels. Improvements in the RELAP5 interphase drag model could lead to better simulations but would probably sacrifice the generality of the present model.

The 100 node simulation has demonstrated that the RELAP5 solution does not converge with increasing nodalization - at least not for time step sizes allowed by RELAP5's automatic time step control algorithm. The results suggest that at some level of nodalization the numerical models for smoothing locally computed variables begin to overshadow the physics.

1. INTRODUCTION

The International Thermal-Hydraulic Code Assessment and Applications Program (ICAP) is being conducted by several countries and coordinated by the USNRC. The goal of ICAP is to make quantitative statements regarding the accuracy of the current state-of-the-art thermal-hydraulic computer programs developed under the auspices of the USNRC.

Sweden's contributions to ICAP relate both to TRAC-PWR (1) and RELAP5 (2). The assessment calculations are being conducted by Studsvik Energiteknik AB for the Swedish Nuclear Power Inspectorate. The assessment matrix is shown in Table 1-1.

This report presents the results of an assessment of RELAP5's ability to calculate level swell. In particular, Jet Impingement Test 11(JIT 11) has been simulated using RELAP5. JIT 11 was one of a series of full scale jet impingement experiments conducted at the Marviken power station, Marviken, Sweden, during 1981.

This report is organized as follows: section 2 describes the experimental facility and section 3 describes the RELAP5 model used to simulate the experiments. In section 4 results from the simulations are presented and discussed. Computational efficiency of RELAP5 and numerical problems encountered during the simulations are given in section 5. Conclusions are presented in section 6.

Table 1

ICAP Assessment Matrix - Sweden.

Code	Facility	Type		Description
		Sep effect	Integral	
RELAP5	Marviken21	X		Subcooled Critical Flow
RELAP5	Marviken11	X		Critical Flow, Level swell
RELAP5	FIX-II		X	Recirculation Line (10 %) break
RELAP5	FIX-II		X	Recirculation Line (31 %) break
RELAP5	FIX-II		X	Recirculation Line (200 %) break
RELAP5	LOFT		X	Cold Leg Break (4") pumps off
RELAP5	LOFT		X	Cold Leg Break (4") pumps on
RELAP5	FRIGG	X		Subcooled Void Distribution
RELAP5	FRIGG	X		Critical Heat Flux
RELAP5	RIT	X		Post Dryout Heat Transfer
TRAC/PF1	Ringhals		X	Loss of Load

2. FACILITY AND TEST DESCRIPTION

The Marviken Power Plant was built as a boiling heavy water direct cycle nuclear reactor but was never commissioned. The nuclear steam supply system was left intact and an oil fired boiler was built to provide steam for the turbine. During 1981 and 1982 Marviken was the site of the Jet Impingement Test (JIT) program. One of the tests, JIT 11, examined the flow of steam from the Marviken vessel onto a test plate. Differential pressure measurements made in the vessel during JIT 11 provided data regarding the level swell occurring in the vessel as steam flowed out of the vessel.

Figure 2-1 depicts the Marviken pressure vessel and the location of the differential pressure measurements. For JIT 11 a standpipe was inserted into the vessel to ensure that only steam flowed out of the vessel. The outlet nozzle was located beneath the vessel. The piping leading to the nozzle and the nozzle are depicted in Figure 2-2. Initial and boundary condition for JIT 11 are summarized in Table 2-1. A complete description of the experimental facility for the JIT program is given in Reference 3. A description of JIT 11 is presented along with test results in Reference 4. The probable error (one standard deviation) in the measured differential pressure values shown in this report is 0.6 kPa; the 99 % confidence error is 1.5 kPa.

Table 2-1

Important parameters for Marviken JIT 11.

Vessel volume (net internal)	420 m^3
Vessel inside diameter	5.22 m
Stand pipe:	
height	18 m
outside diameter	1.04 m
wall thickness	8.8 mm
Discharge nozzle:	
diameter	0.299 m
area	702×10^{-4} m^2
length	1.18 m
Initial pressure	5.0 MPa
Final pressure	1.88 MPa
Initial water level	10.2 m
Final water level	8.0 m
Initial inventory:	
water	145×10^3 kg
steam	5×10^3 kg

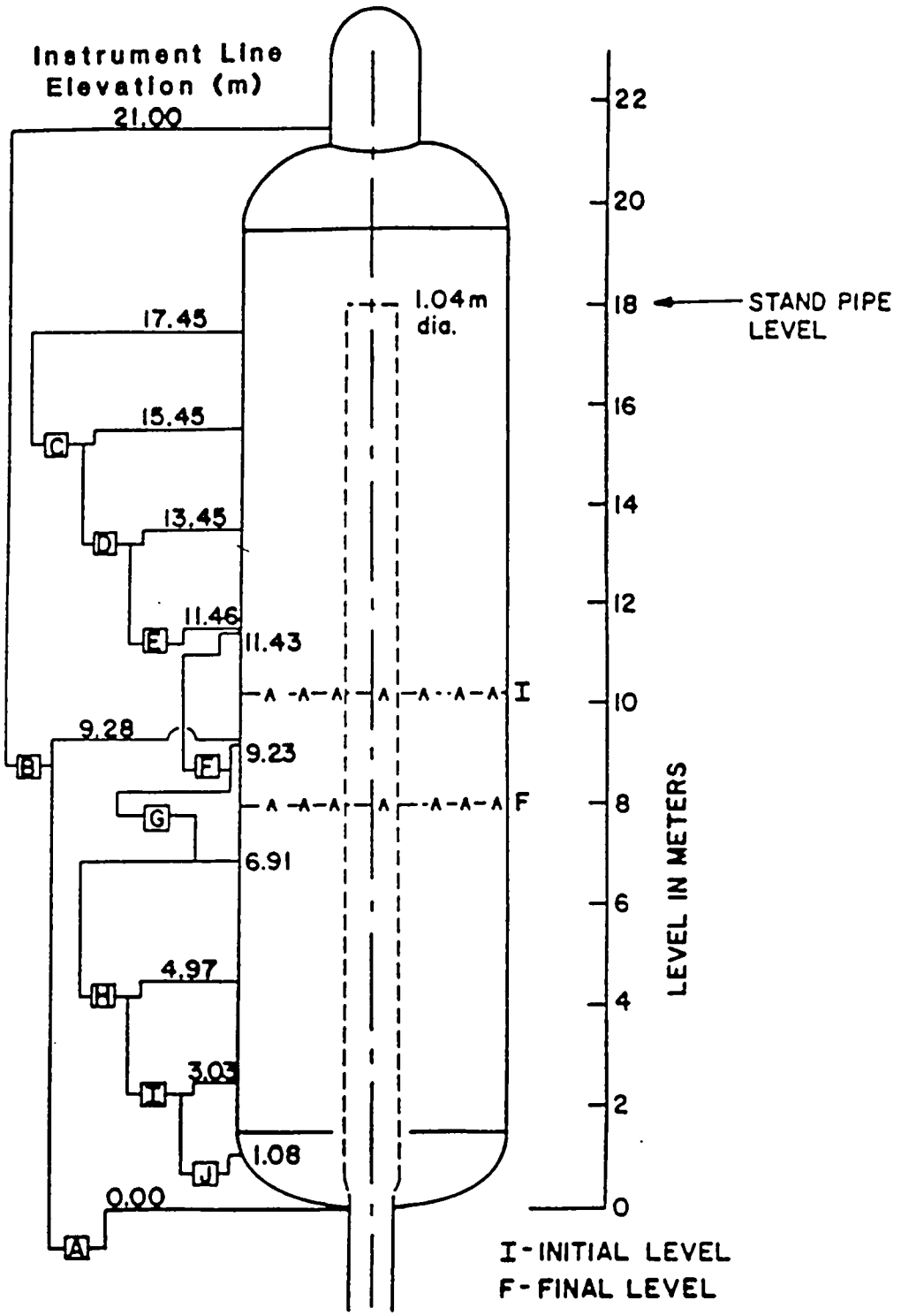

Figure 2-1

Marviken test vessel. Differential pressure transducers A through J, internal standpipe and initial (I) and final (F) inventory level are shown for Test T-11.

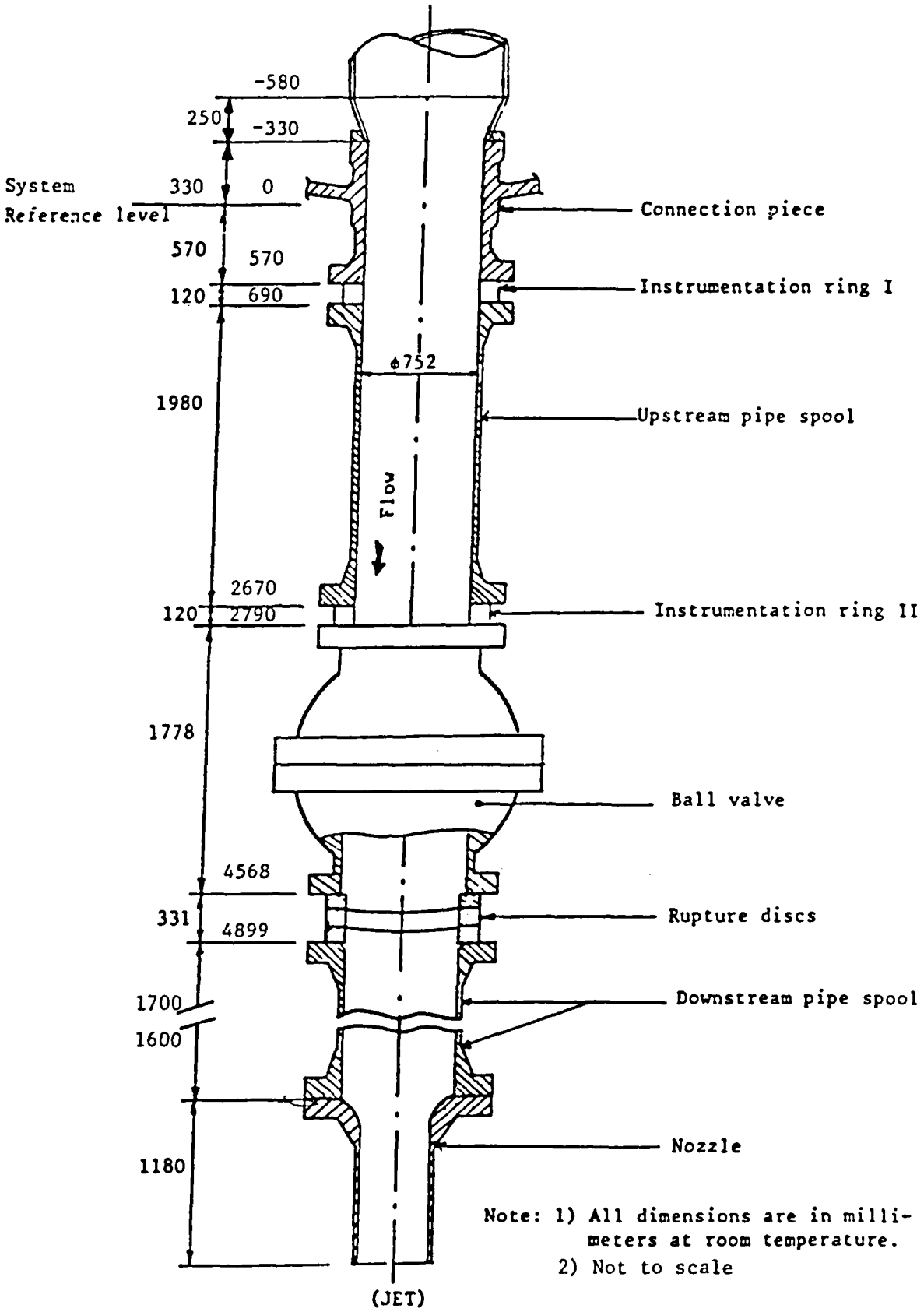

Figure 2-2

Arrangement of components in the discharge pipe.

3. CODE AND MODEL DESCRIPTION

The simulations of JIT 11 were made with RELAP5/MOD2, cycle 36.02.

3.1 Input description

The RELAP5 model of the Marviken vessel is shown in Figure 3-1. The standpipe was modelled by a single volume pipe component. At its upper end, this pipe was connected to a branch component which corresponded to the vessel region from the top of the standpipe to 0.5 m above the standpipe. The upper region of the vessel was modelled by a pipe component having 3 volumes.

The annular vessel region lying below the top of the standpipe was modelled as an annulus component. For the base case this component was divided into 20 nearly equally sized volumes. For nodalization studies the number of cells in this component was increased to 40 and then to 100.

A mass flow rate boundary condition was applied to the lower end of the component representing the standpipe. The boundary condition was taken from the experimental data.

The RELAP5 control system was used to calculate differential pressures for comparison with experimentally measured ones. In constructing the control system it was assumed that the pressure, which is a point quantity in RELAP5, varied linearly between the midpoints of adjacent cells. With this assumption pressure could be calculated at the exact location of each of the differential pressure taps. The assumption is a good one as long as the pressure variation with

elevation is dominated by the gravity head of the fluid rather than its acceleration. This is the case throughout most of JIT 11 which was, for the most part, a quasi-steady flow test.

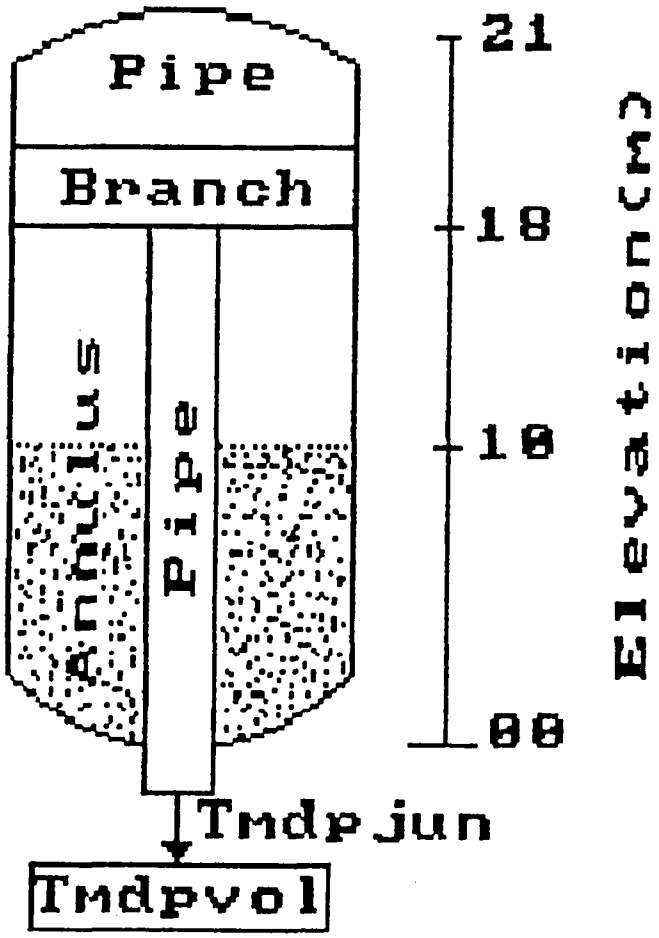

Figure 3-1

Schematic of RELAP5 model for JIT 11 level swell simulations.

4. RESULTS AND DISCUSSION

For the level swell simulations a discharge mass flow rate was imposed as a boundary condition. The boundary condition was obtained by drawing a smooth curve through the measured discharge flow rate. The boundary condition is compared to the measured flow rate in Figure 4-1. Figure 4-2, which compares the computed pressure response to the measured pressure response, demonstrates that the boundary condition served its purpose.

4.1 Base case

For the base case simulation the vessel region below the level of the standpipe was represented by 20 nodes (ΔZ = 0.9 m). Differential pressures were computed for comparison with measured differential pressures.

Figure 4-3 compares computed and measured dPs over the top and bottom halves of the vessel. The center tap for these measurements was initially located in the liquid but was uncovered at the end of the experiment. The fairly good agreement between the calculated and measured dPs indicates that RELAP5 calculated the gross behaviour of level swell correctly; that is, it correctly calculated the mass of liquid which was lifted above the 9.28 m elevation. It remains to be seen if the distribution of mass above and below the 9.28 m elevation was computed correctly.

The fact that the RELAP5 calculated dP203 lies below the measurement and the calculated dP205 lies slightly above the measurement during the quasi-steady part (20-70 s) of the experiment

indicates that RELAP5 lifted slightly more liquid above the 9.28 m elevation than was actually transported there.

Besides dP203 one other valid measurement of differential pressure below the 9.28 m elevation was obtained during JIT 11. It is shown together with the corresponding RELAP5 value in Figure 4-4. The fact that the computed dP lies above the measured dP means that the average void fraction in the region being spanned by the dP taps was higher in RELAP5 than in the experiment (approximately 0.05 higher at 50 s).

The "overshoot" in the calculated dP in the 15-20 s time period is related to time step size. The base calculation generally proceeded at the maximum specified time step size (0.5 s). The differential pressure histories at all locations changed significantly in the 0-25 s range when time step size was reduced (see section 4.3).

Differential pressure measurement 213 spanned the initial liquid level surface (Figure 4-5). The experimental dP response over this span (9.23 to 11.43 m) showed that the average void fraction initially decreased (0-3 s) as the liquid level swelled then increased (3-20 s) to a value near the initial value as the two phase mixture rose to its maximum elevation. The average void fraction remained fairly constant until 60 s when it began decreasing as liquid drained into the region. When the outlet valve was completely closed (85 s) the average void fraction increased rapidly to unity as all liquid drained out of the region.

The RELAP5 simulation of dP213 behaved qualitatively the same as the measurement. However, RELAP5 calculated the average void fraction in the 9.23 m to 11.43 m region to be lower than it was in the experiment. The 2 kPa difference in dP between the measurement and the calculation corresponds to a void fraction difference of about 0.13 between the experiment and the calculation (~ 0.60 in the experiment versus ~ 0.47 in the calculation).

When the outlet valve began closing at 75 s the RELAP5 calculation responded immediately - the dP decreased, indicating that liquid was draining into the region from above. The experiment showed no such behaviour. The calculated dP began increasing at 82 s, before the valve was fully closed (84 s), and before the experimental dP began increasing. By 90 s the experimental dP had risen nearly to its maximum value (no liquid in the region) whereas the calculation showed a significant amount of liquid remained in the region. The inability of RELAP5 to mimic the experiment during the 5-20 s time period and the 85-90 s time period is attributed to the nature of the interfacial friction model in RELAP5. For the geometry and mass fluxes under consideration RELAP5 assumes that bubbly flow exists for void fractions less than 0.25 and slug flow exists for void fractions between 0.25 to 0.95. The interfacial friction associated with bubbly flow is much larger than that associated with slug flow. In the early (t < 20 s) part of the transient RELAP5 was unable to lift enough liquid out of the 9.23 - 11.43 region because the drag between the vapor and liquid diminished too quickly as the void fraction increased. Near the end of the transient RELAP5 was unable to let liquid drain out of the region as fast as it really did because

of an increasing drag between the rising vapor and falling liquid as the local void fraction dropped below 0.25. In the experiment it is quite likely that, once the valve was closed, the flow regime in the 9.23 - 11.43 region switched from slug flow to annular flow (the liquid draining downward along the vessel and stand pipe surfaces) - a flow regime change which cannot be simulated in RELAP5 with the current flow regime maps.

The measured dP response over the 11.47 m to 13.46 m range (Figure 4-6) shows the same qualitative response as seen at the 9.23 to 11.43 m range. A rapid decrease in differential pressure occurred as liquid entered the region followed by an increase as the local void fraction increased. The dP, and hence the average void fraction, in the region remained relatively constant between 20 and 75 seconds. The dP increased sharply as the valve was closed and liquid drained out of the region.

RELAP5 calculated the dP response in the 9.23 - 11.43 range qualitatively correctly. However, it calculated too low a void fraction in the region during most of the transient. Unlike the calculated dP213 (Figure 4-5), the calculated dP212 showed the same response as the measured dP212 when the valve was closed. This is because the local void fraction in the computational cells which spanned the region never dropped below a value of 0.25 as they drained.

Differential pressure dP211 (Figure 4-7) spanned the 13.46 m to 15.45 m elevation. The accuracy of this measurement is questionable because it did

not return to the correct final value at the end of the experiment - it was low by 4 kPa. The instruments response does appear to be correct at 10 s, because it indicates a dP value slightly less than that of dP210, which lies above it. This is reasonable, assuming a linear increase in void fraction with elevation. It is also likely that the instrument's response in the 10 - 50 s range is reasonably good because it remains fairly constant, exhibiting a behaviour similar to dP212 and dP213. If one assumes that the two phase level in the experiment declined steadily then dP211 should have remained constant until 50 s and then should have increased at the same rate as dP210 above it. In fact, the instrument shows this response which suggests that the instruments response is correct over the 0-80 s temperature range.

The uppermost dP measurement, dP210, spanned the 15.45 m to 17.45 m elevation. The response of dP210 (Figure 4-8) shows that a two phase mixture passed the 15.45 elevation at about 10 seconds, reached its maximum level at 15 s, and slowly subsided over the next 30 seconds. Measurements of the discharge flow rate indicated that a small amount of liquid entered the standpipe during the 17 to 25 s time period. From this one concludes that the maximum elevation reached by the two-phase level was about 18 m.

RELAP5 calculated the dP210 response to decline less than it actually did and to rise more rapidly. RELAP5 carried somewhat less liquid into the region spanned by dP210 than did the experiment. RELAP5 also calculated that the liquid drained from the region much faster than it actu-

ally did. This faster drainage manifests itself in the different slopes of the measured and calculated dPs after 20 s.

Time step studies conducted subsequent to the base calculation have shown that when smaller time steps were used the RELAP5 calculated history of dP210 dipped briefly to a value of about -1.0 kPa then recovered to zero. Thus the calculated history shown in Figure 4-8 is an unconverged one.

The RELAP5 simulation of the level swell, which occurred in experiment JIT 11, can be summarized as follows:

RELAP5 calculated that somewhat more liquid was lifted above the initial liquid level than actually was (Figure 4-3, 4-4). Even though RELAP5 carried more liquid above the initial liquid level, it did not calculate the two-phase level to rise and remain as high as it did in the experiments (Figure 4-8, 4-7).

For the quasi-steady part of the experiment (30 - 50 s) RELAP5 calculated the liquid fraction profile in the swelled region (the region above the original water level) to be more concentrated in the lower elevations than it actually was (Figure 4-5 and 4-6). The latter observation is a recognition of the fact that the RELAP5 overprediction of void fraction in the 4.97 to 9.23 m range (Figure 4-4) is more than offset by the underprediction of the void fraction in the 9.23 to 13.43 m range (Figures 4-5, 4-6.

4.2 Nodalization studies

In order to determine the sensitivity of computed results to nodalization the RELAP5 calculation of JIT 11 was repeated using 40 and 100 nodes to represent the 18 m long annular region from the vessel bottom to the top of the standpipe. Some results from the 20, 40, and 100 node cases are given in Figures 4-9 through 4-12.

The most significant feature in Figures 4-9 through 4-12 is the erratic nature of the 100 node calculation. Other notable features are the reduction, with increasing nodes, in the dP "overshoot" in the lower elevations (Figure 4-9, 4-10; $15 < t < 25$ s), and the decreasing calculated height of the two-phase level with increasing number of nodes (Figure 4-12). Figures 4-9 to 4-12 show that the RELAP5 calculation is sensitive to nodalization and does not converge with increasing nodalization.

The reason for the erratic calculated dPs in the 100 node calculation is revealed in Figure 4-13, which shows the void fraction profile in the vessel at 42.5 and 43.5 seconds. For the region spanned by dP212 (11.47 to 13.46 m) the average void fraction changes from a value of 0.49 at 42.5 s to a value of 0.64 at 43.5 s. The calculated change in dP use to this change in void fraction is ($\Delta dP = \Delta\alpha\rho_{fg}\,\Delta z$) 2.3 kPa which is about the change in dP shown in Figure 4-10. The erratic nature of the results from the 100 node calculation are due to RELAP5 calculating a fluctuating axial void profile (for elevations between 9 and 15 m) rather than the quasi-steady void profile indicated by the experimental measurements and by the 40 and 20 node RELAP5 calculations.

4.3 Time step studies

The 100 node calculation was examined further by restarting it at 40 s and reducing the maximum time step from 0.1 s to 0.05 s (the material Courant limit was 0.12 s). The axial void profile from these two calculations are shown in Figure 4-14. Local differences in void fraction are large even though the average step size utilized for the two calculations (0.075 s and 0.05 s for DTMAX = 0.1 and DTMAX = 0.05 respectively) was much less than the Courant limit.

The sensitivity of the 100 node calculation to time step size demonstrates the unreliability of the mass error time step control algorithm - the algorithm does not necessarily produce time step sizes which lead to a convergent solution.

It is believed that the erratic solution and the time step sensitivity exhibited to the 100 node calculated are related to the strong coupling between void fraction and interfacial drag in the 20 - 40 percent void fraction range. Because of the large flow areas and short lengths of the cells in the 100 node simulation void fractions were observed to sometimes change dramatically from one time step to the next. As a consequence the interfacial drag changed by as much as a factor of 10 from one time step to the next.

Having seen the sensitivity of the 100 node calculations to time step size we decided to investigate the sensitivity of the base (20 node) calculation to time step size.

The original calculation proceeded at the specified maximum time step which was 0.5 s. For the

two sensitivity studies the maximum step size was set to 0.1 s and 0.05 s. The results of the sensitivity calculations are depicted, along with the base case results in Figure 4-15 to 4-19.

The figures show that the RELAP5 base case solution was not converged during the first 30 seconds of the transient. Using large time steps, although entirely consistent with the mass error time step control algorithm, gave an artificial increase in the amount of liquid being carried upward.

It is believed that the sensitivity to time step is caused by the relaxation algorithm being used in the interphase drag model. The model calculates an interphase drag coefficient based upon new time level hydraulic parameters and then, to get a interphase drag coefficient for use in the momentum equations, weights the new time level value with the old time level value, giving favor to the old value. The result of the scheme is that the code "remembers" previous values of the interphase drag for several time steps regardless of time step size. During a period of rapidly changing interphase drag (bubble-to-slug flow) the computed results therefore become sensitive to time step size.

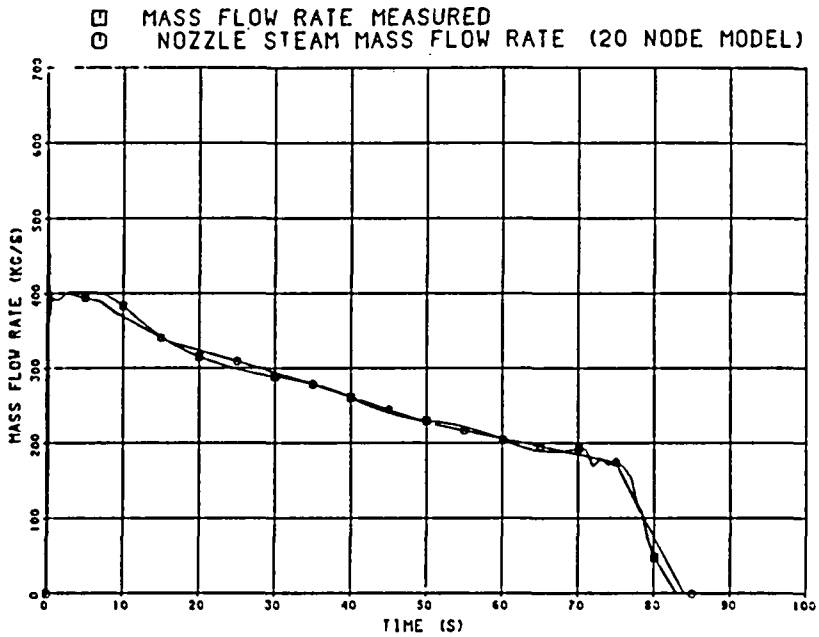

Figure 4-1

Mass flow rate boundary condition and experimental discharge flow rate.

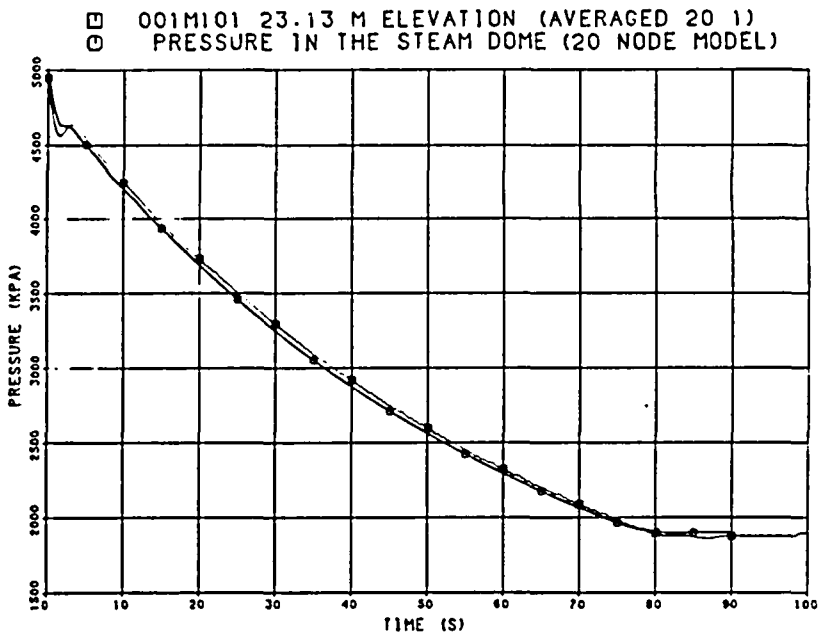

Figure 4-2

Measured and calculated pressure response for JIT 11.

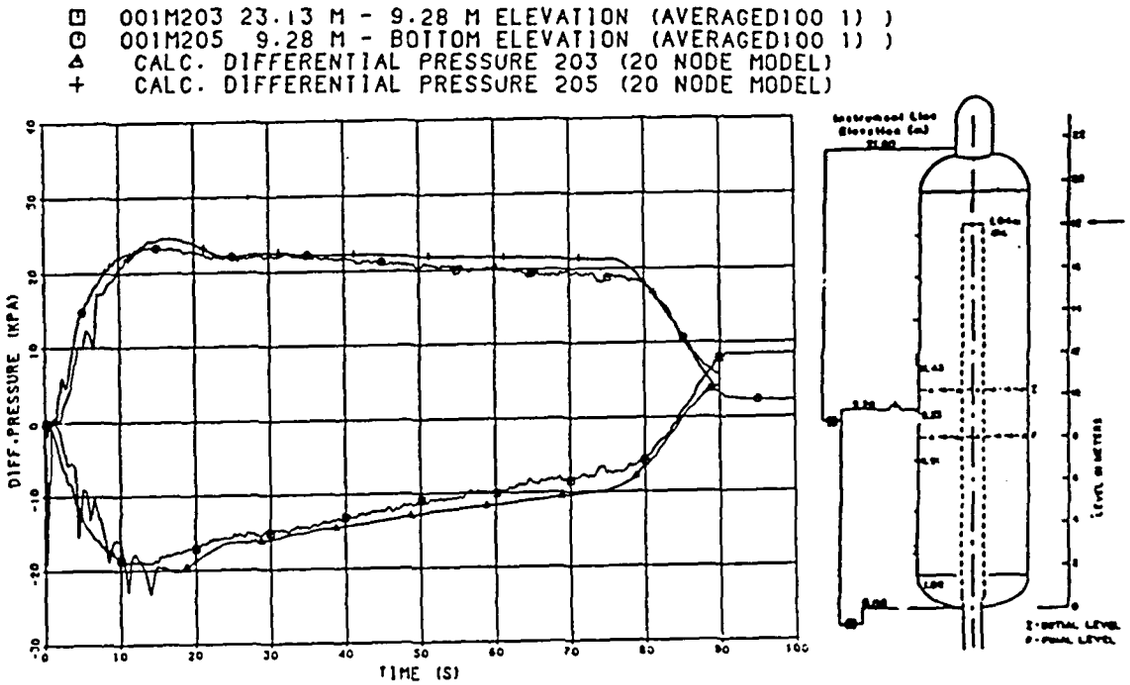

Figure 4-3

Comparison of computed and measured dP's over the top and bottom halves of the vessel.

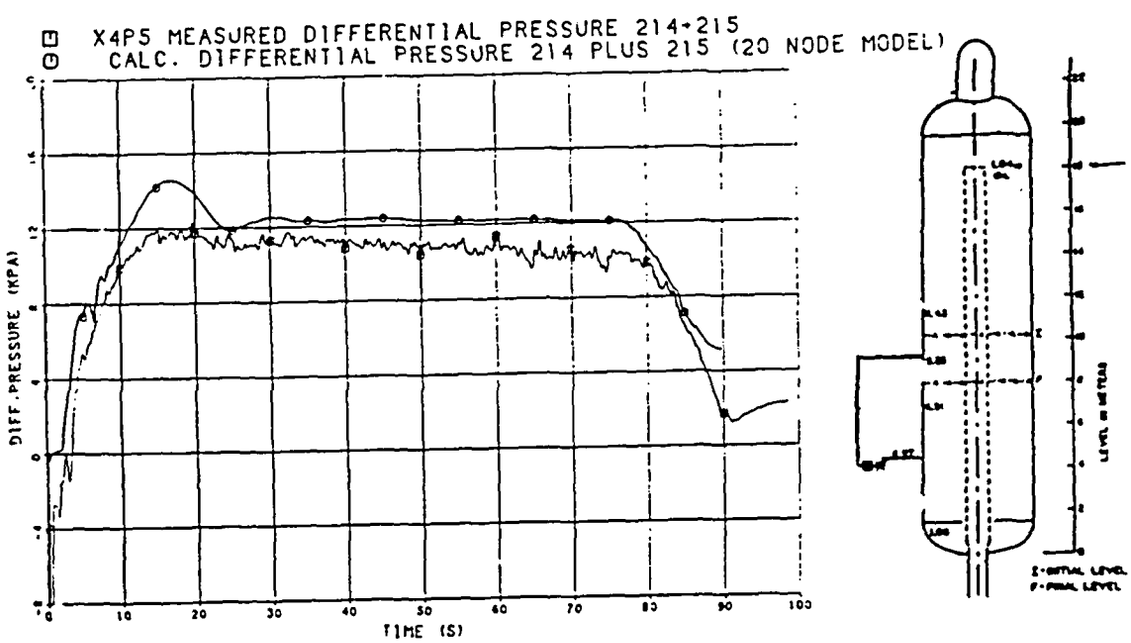

Figure 4-4

Measured and calculated dP over the 4.97 m to 9.73 m span.

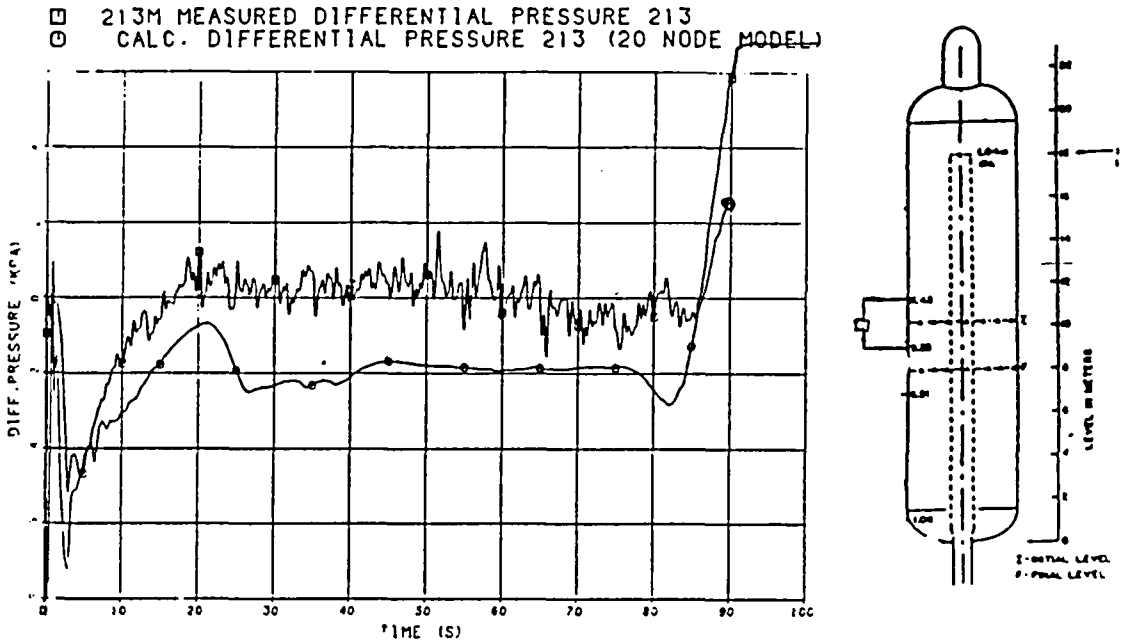

Figure 4-5

Measured and calculated dP over the 9.23 to 11.43 m Span.

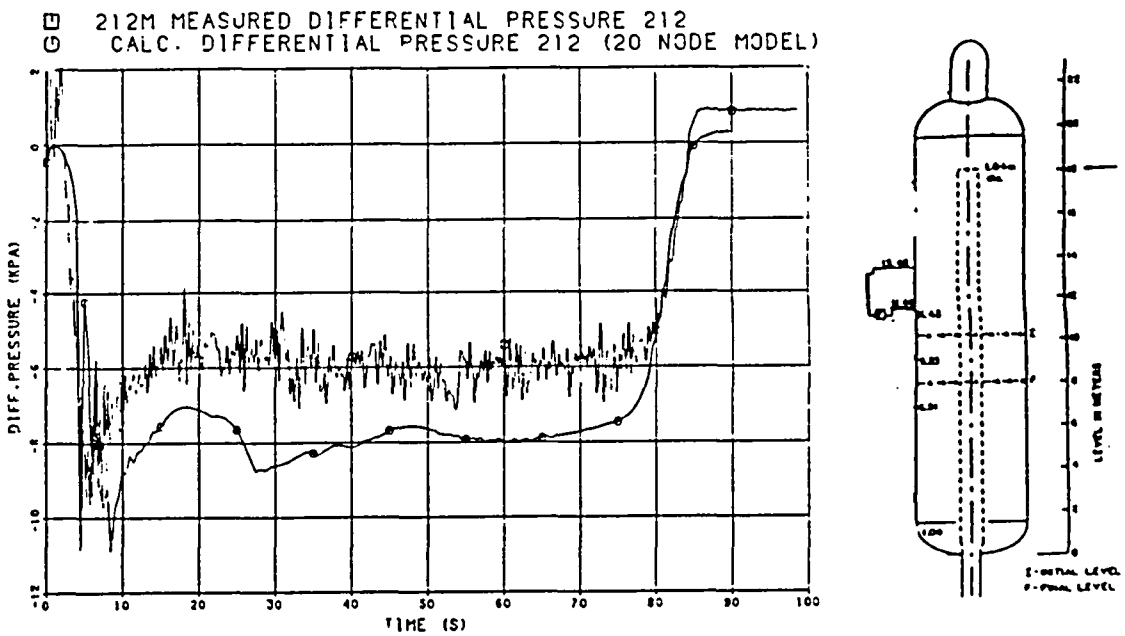

Figure 4-6

Measured and calculated dP over the 11.47 to 13.43 m range.

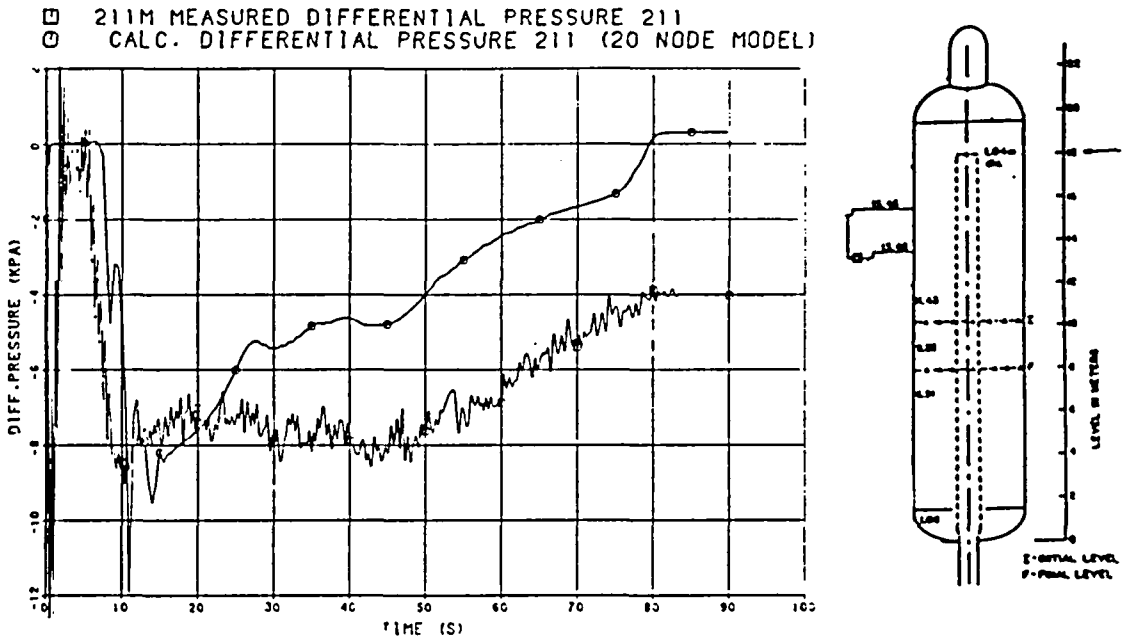

Figure 4-7

Measured and calculated dP over the 13.46 to 15.45 m range.

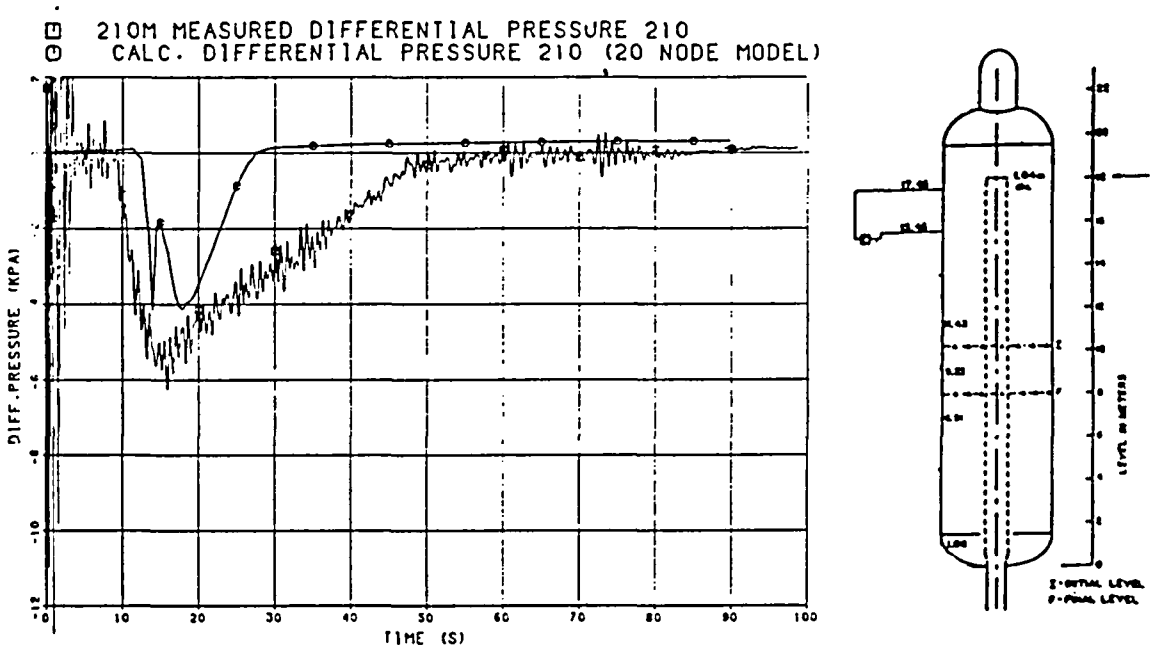

Figure 4-8

Measured and calculated dP over the 15.45 to 17.45 m span.

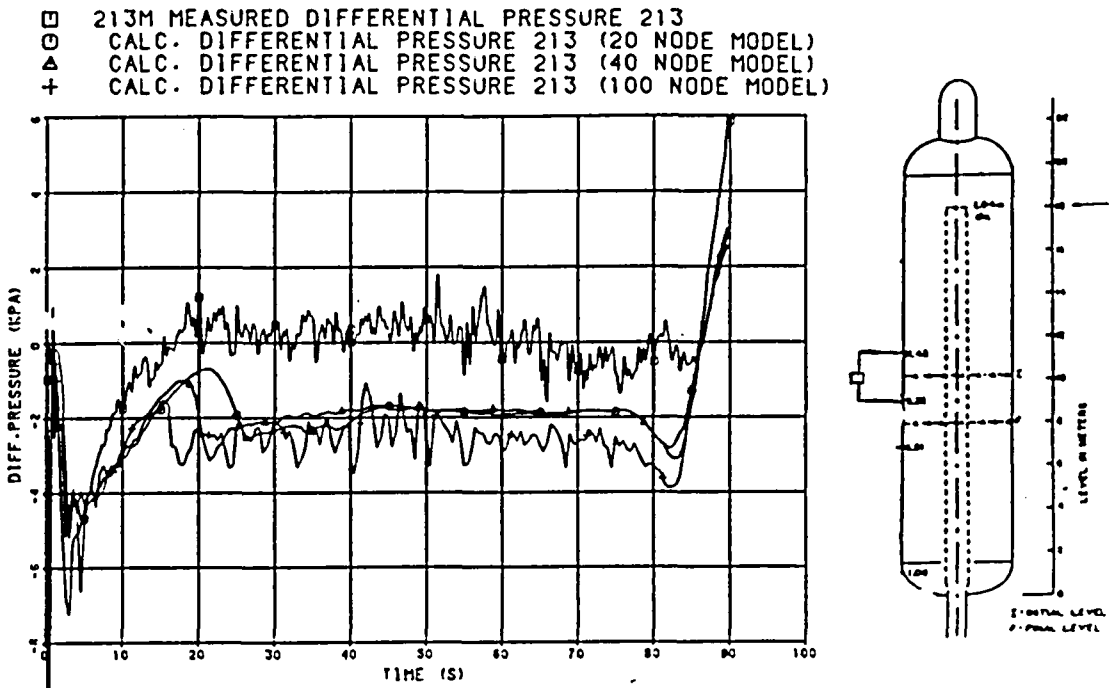

Figure 4-9

Measured and calculated dPs over the 9.23 to 11.43 m elevation.

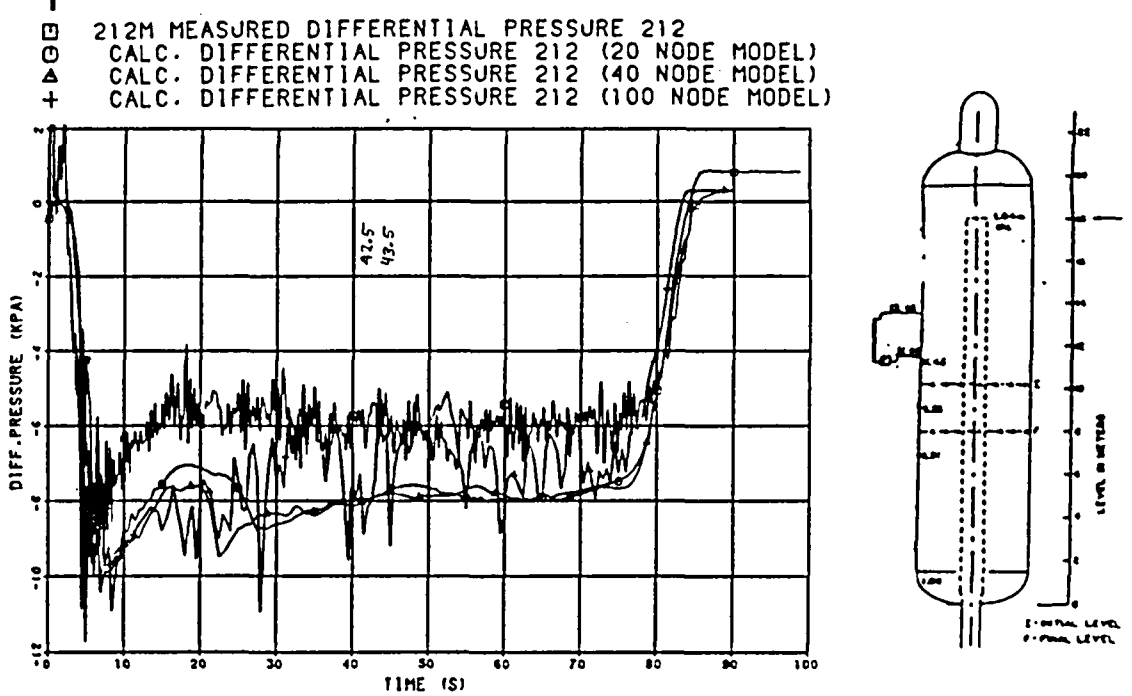

Figure 4-10

Measured and calculated dPs over the 11.47 to 13.46 m elevation.

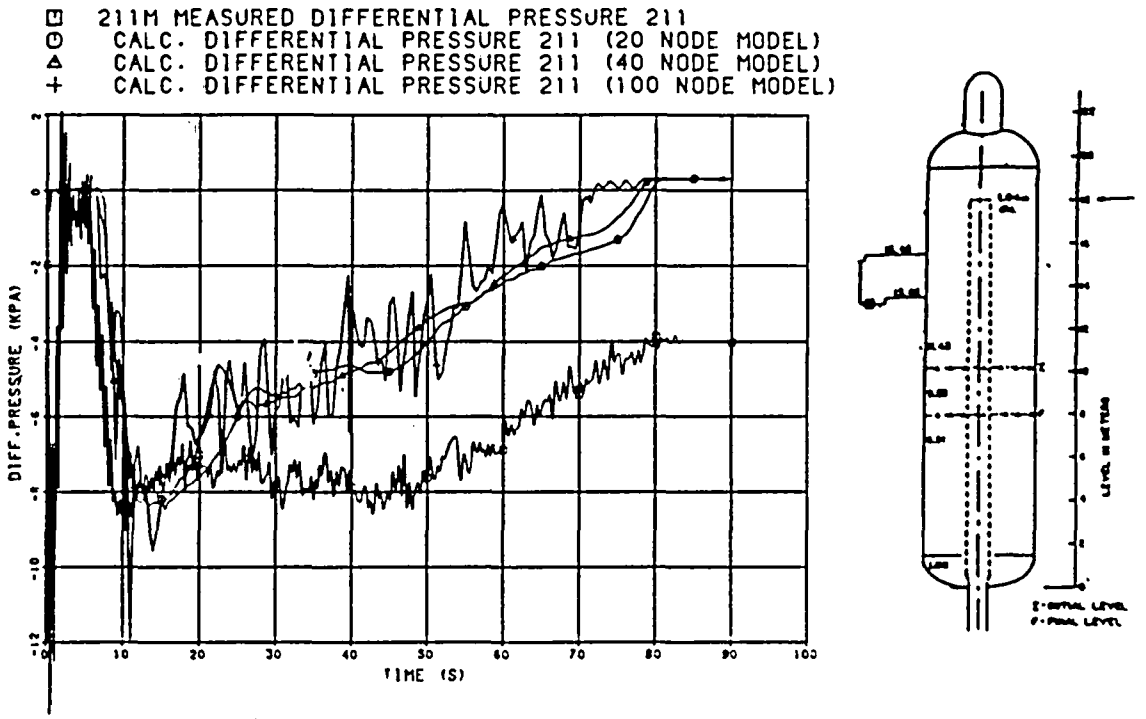

Figure 4-11

Measured and calculated dPs over the 13.46 to 15.45 m elevation.

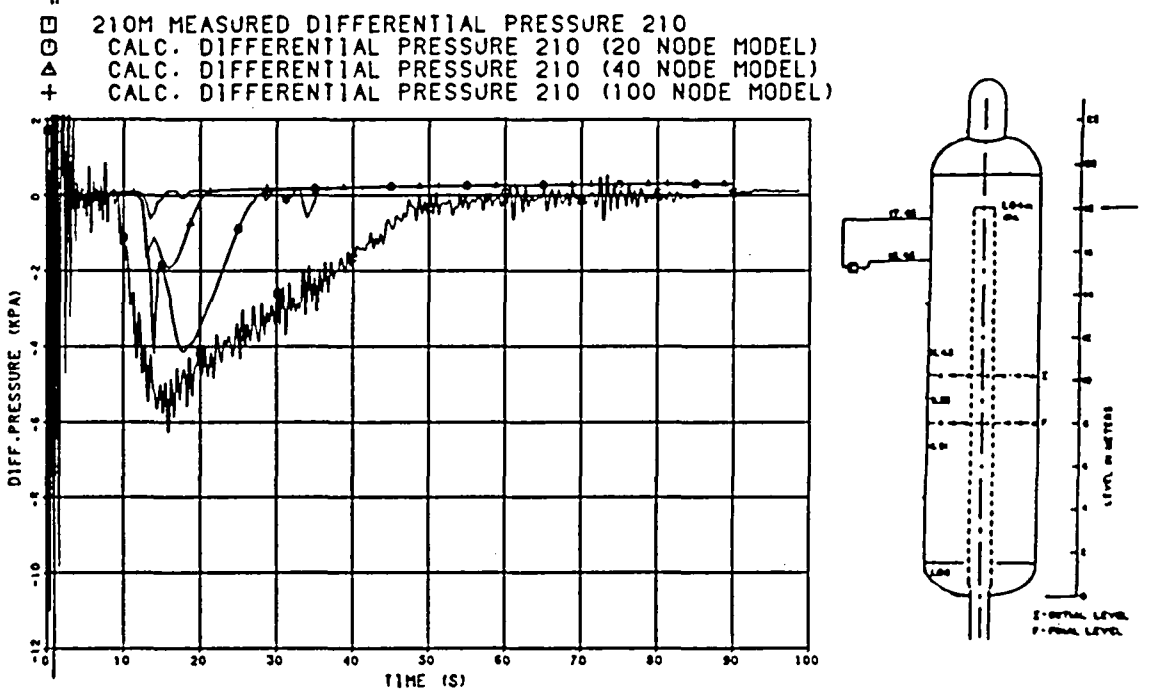

Figure 4-12

Measured and calculated dPs over the 15.45 to 17.45 m elevation.

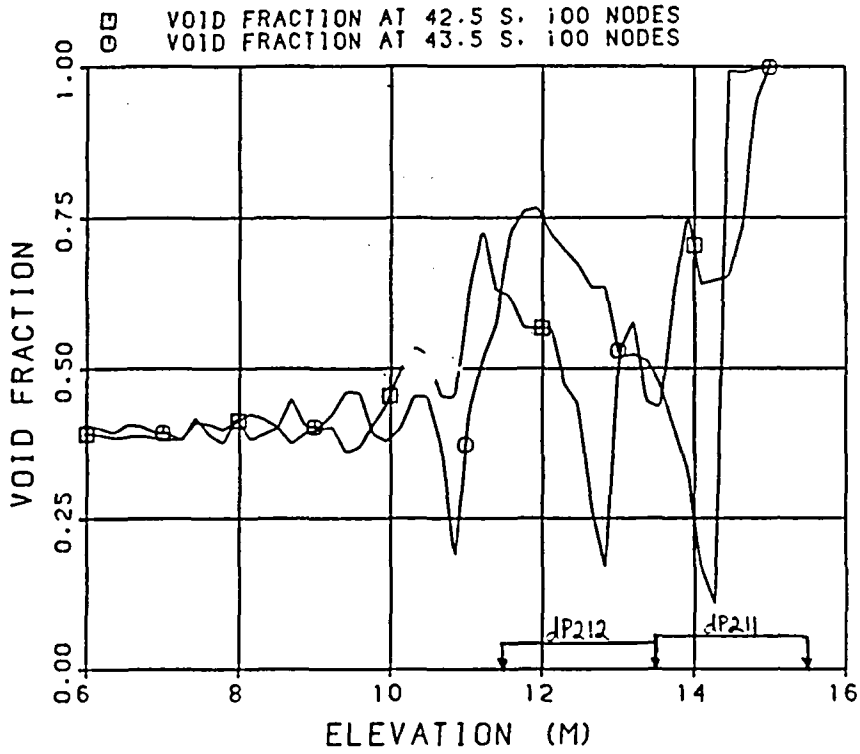

Figure 4-13

Axial void profile for the 100 node simulation.

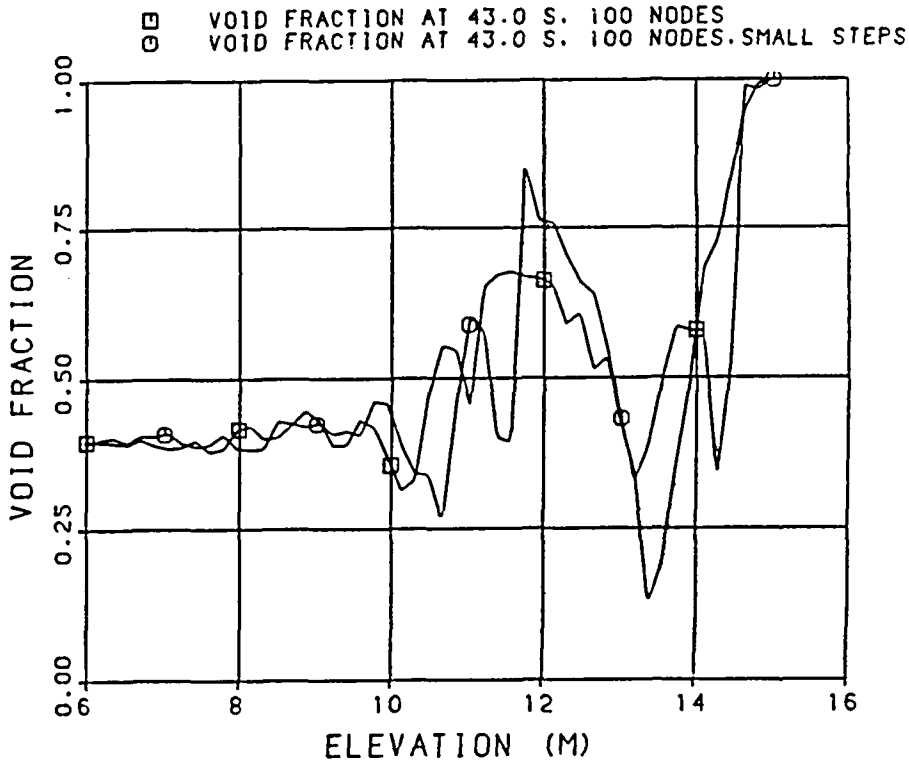

Figure 4-14

Axial void profile for the 100 node simulation.
DTMAX = 0.1 s and DTMAX = 0.05 s.

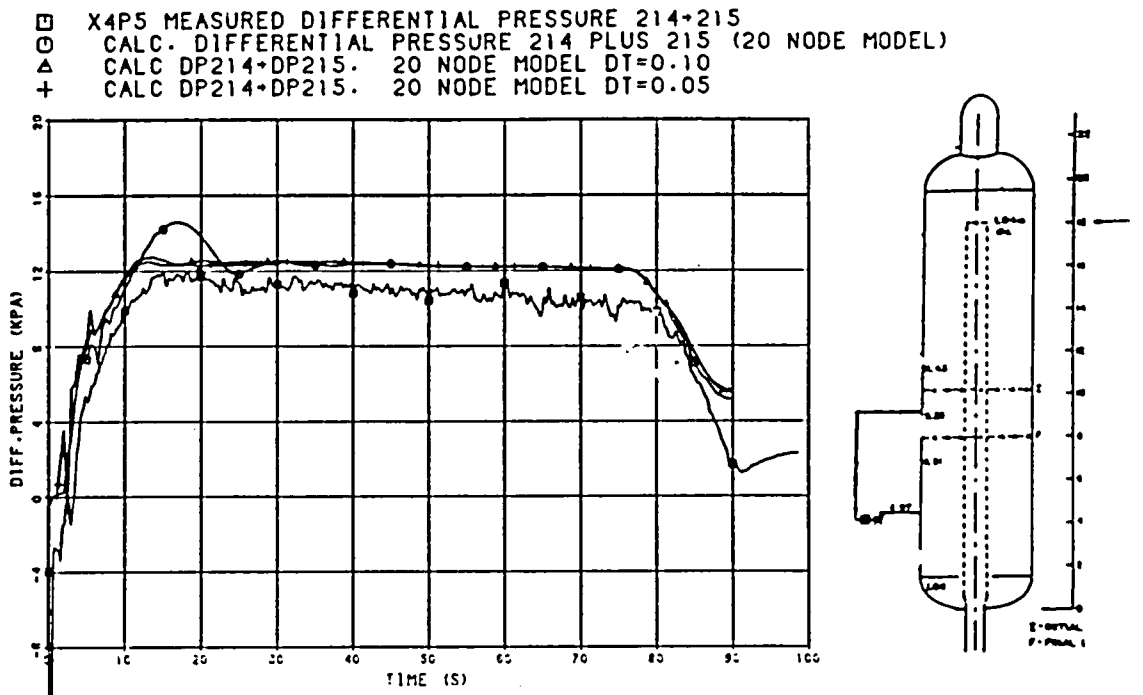

Figure 4-14

Sensitivity of dP214 + dP215 to time step size.

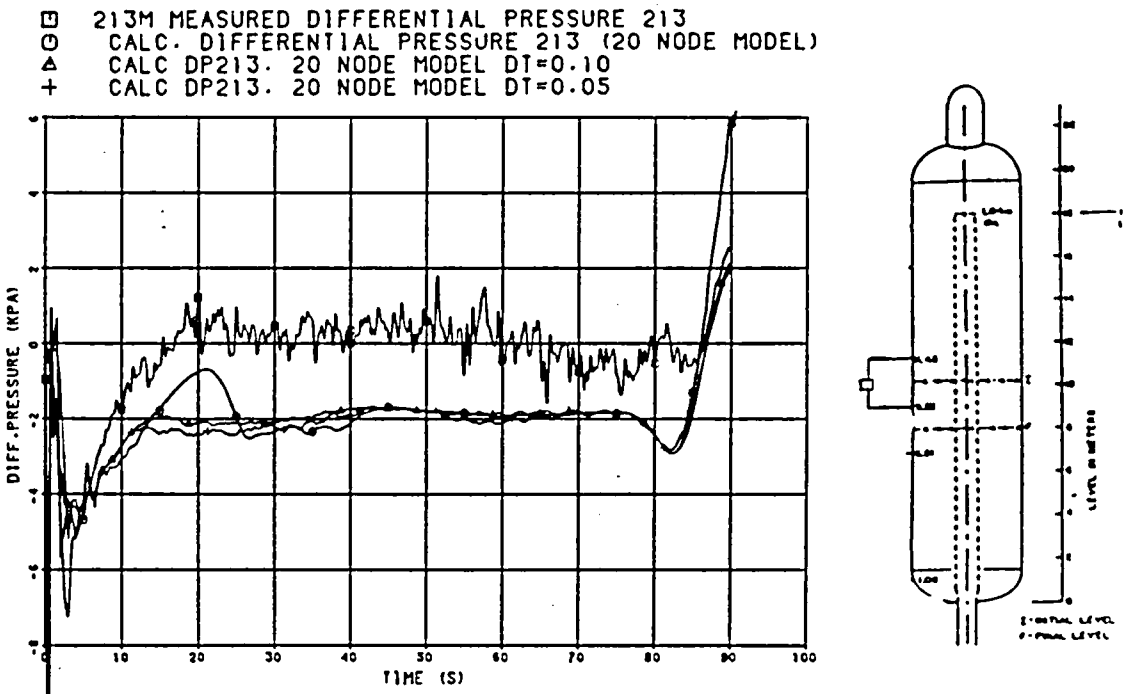

Figure 4-16

Sensitivity of dP213 to time step size.

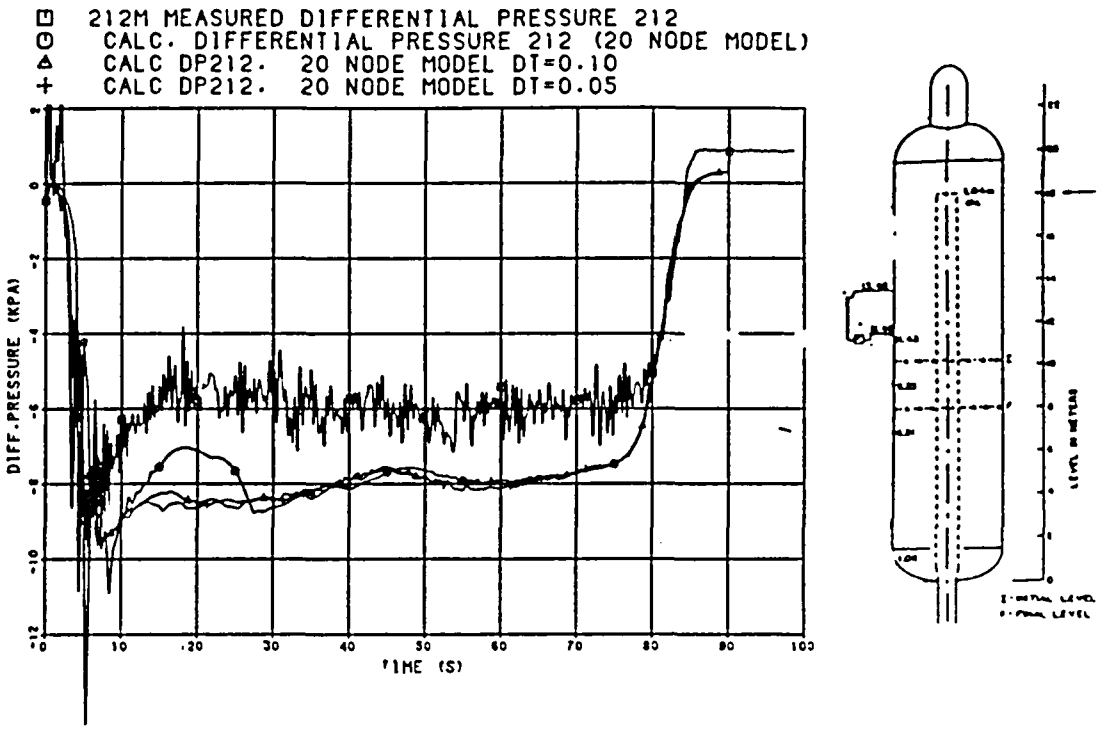

Figure 4-17

Sensitivity of dP212 to time step size.

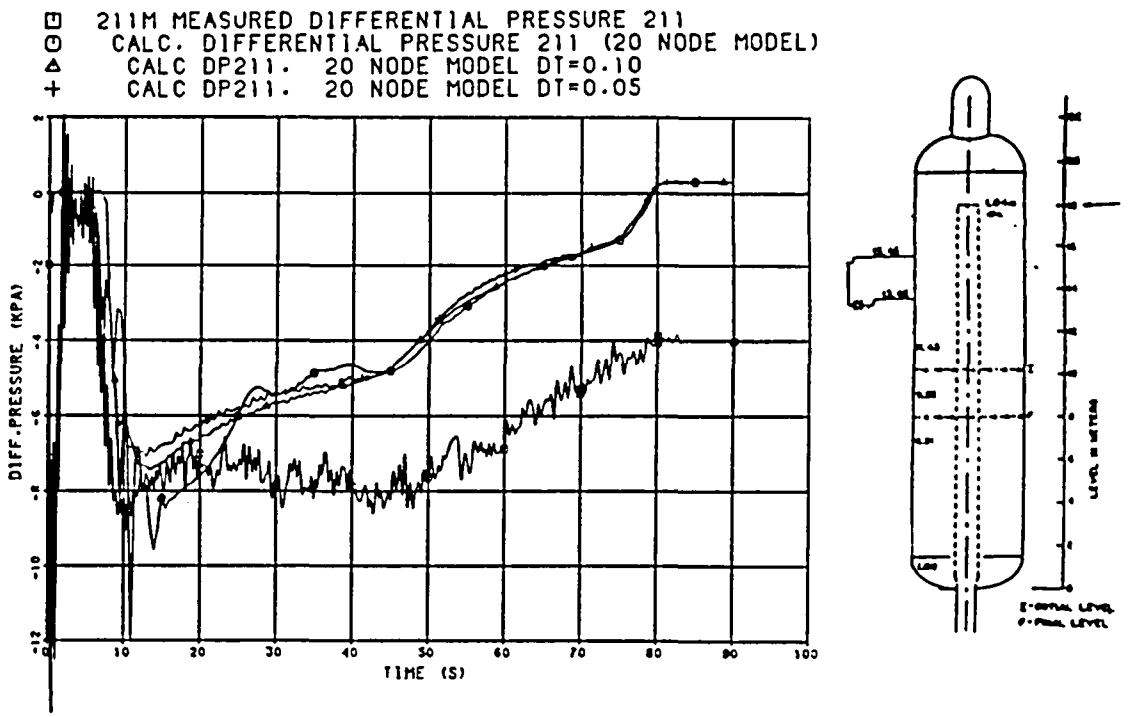

Figure 4-18

Sensitivity of dP211 to time step size.

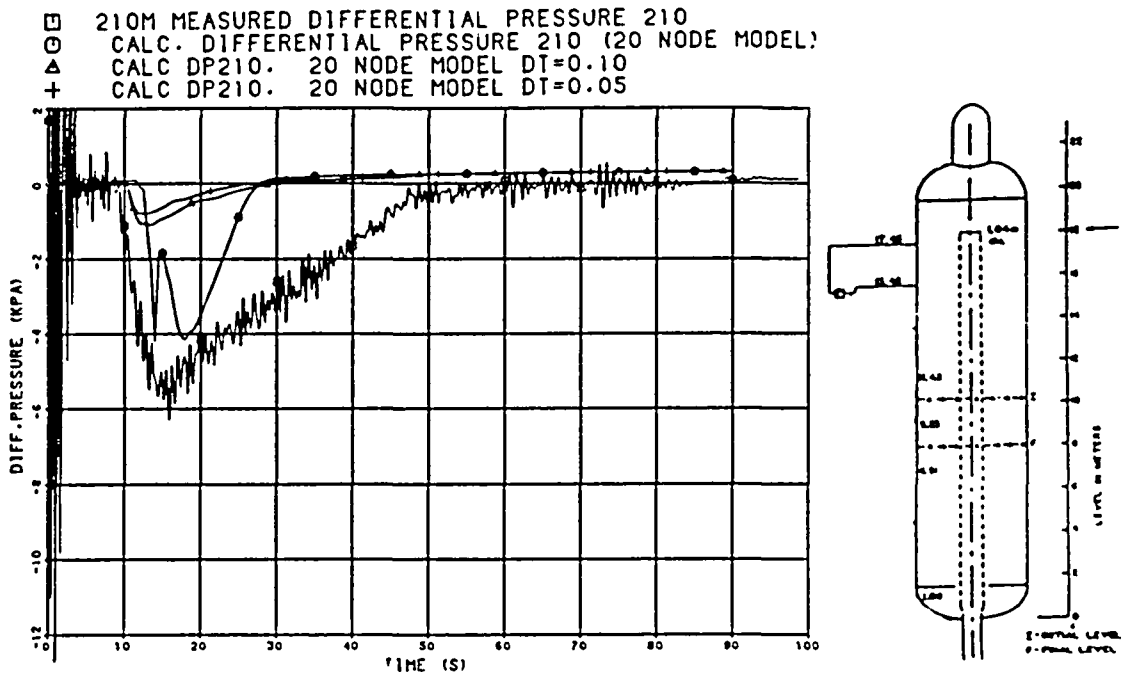

Figure 4-19

Sensitivity of dP210 to time step size.

5. COMPUTATIONAL EFFICIENCY

The computational efficiency of the RELAP5 simulations is summarized in Table 5-1. The CPU times are for a CYBER 180-810 computer.

In general, the simulations used the maximum time step size specified in the input. This time step size was usually slightly smaller than the material Courant limit.

Table 5-1

Run time statistics for JIT 11 simulations.
(ninety second transient)

Case	DTMAX	Actual time steps	CPU(s)	CPU/VOL/DT
20 node	0.01 (t<0.5s) 0.50 (t>0.5s)	257	220	0.04
40 node	0.01 (t<0.5s) 0.25 (t>0.5s)	437	602	0.03
100 node	0.01 (t<0.5s) 0.10 (t>0.5s)	1 135	3 786	0.03

6. CONCLUSIONS

Assessment of RELAP5 against the level swell data obtained from JIT 11 led to the following conclusions:

1. For the 9 to 13 m range RELAP5 calculated a quasi-steady void fraction which was 0.10 to 0.15 lower than measurements indicated.

2. For the 13 to 18 m range RELAP5 calculated a quasi-steady void fraction which was too high. In the base case RELAP calculated the maximum level of the two phase front well but allowed liquid to drain out of the upper region of the vessel faster than it actually did.

3. Nodalization studies demonstrated that the RELAP5 solution did not converge with increasing number of nodes. The 20 node case and the 40 node case gave similar results. The 100 node case, however, exhibited erratic fluctuations in the axial void profile and was sensitive to time step sizes. The behaviour of the 100 node case is believed to be caused by the interphase drag model.

4. The computed results were sensitive to time step size. Time step size had to be reduced considerably below the value allowed by the RELAP5 time step control algorithm in order to obtain converged results during the time when the level was rising. The sensitivity is believed to be caused by the relaxation algorithm in the interphase drag model.

The JIT 11 simulations have shown that the RELAP5 interphase drag model allows the interphase drag force to diminish too rapidly with increasing void fraction for the case of level swell in large vessels. It would, however, be premature to recommend changes in the interphase drag model based upon the results reported here so long as

the model is intended to be used for a variety of geometries (tubes, rod bundles, vessels). Refinements of the interphase drag model should consider separating the treatment of level swell in large vessels from the treatment of flow in ducts.

7. REFERENCES

1. TRAC-PF1/MOD1:
An Advanced Best-Estimate Computer Program for Pressurized Water Reactor Thermal-Hydraulic Analysis.
NUREG/CR-3858.

2. RANSOM, V et al
RELAP5/MOD2 Code Manual.
NUREG/CR-4312.
August 1985.

3. The Marviken Full Scale Jet Impingement Tests.
Facility Description.
MXD-101.
February 1982.

4. The Marviken Full Scale Jet Impingement Tests.
Test 11 Results.
MXD-211.
March 1982.

APPENDIX A

RELAP5 INPUT DECK

```
=RELAP5 INPUT FOR JIT-11 LEVEL SWELL (CASE 1, RUN 2)
*
*
*        MARVIKEN JET IMPINGEMENT TEST (JIT) NO. 11
*        IS USED FOR A LEVEL SWELL CALCULATION WITH
*        RELAP5/MOD2/36.02 AS A PART OF THE ICAAP
*        AGREEMENT.
*
*      STEADY STATE RUN TO GET INITIAL PRESSURES
*     COMPONENTS 902,952,903,953,AND TABLE 210 WILL BE DELETED
*     ON THE RESTART FOR TRANSIENT RUN.
*
100   NEW  STDY-ST
101   RUN
105   10.   20.
*
*         END    DTMIN   DTREQ   FLAGS  MINED  MAJED  RESTART
201      20.0    1.0-6   0.50    00003      1     20      100
*
*============================================================
*       MINOR EDITS
*------------------
301   CNTRLVAR  313
302   CNTRLVAR  101
303   CNTRLVAR  210
304   MFLOWJ    200030000
305   MFLOWJ    951000000
306   TEMPF     100010000
307   TEMPF     100050000
308   TEMPF     100100000
309   TEMPF     100150000
*
311   CNTRLVAR  403
312   CNTRLVAR  405
313   CNTRLVAR  410
314   CNTRLVAR  411
315   CNTRLVAR  412
316   CNTRLVAR  413
317   CNTRLVAR  414
318   CNTRLVAR  415
319   CNTRLVAR  417
*
*============================================================
*       TRIPS
*------------
*
501    TIME     0          GT        NULL      0          100.  L
*
```

```
601        501          AND       501       L
*
*==========================================================
*
*     COMPONENT 100
*     REACTOR VESSEL BELOW TOP OF STANDPIPE
*     LEVELS: 0. - 18.33
*
1000000    VESSLOW      ANNULUS
*
*          NV
1000001    20
*
*          VOLAREA      VOLNO
1000101    0.           20
*
*          LENGTH       VOLNO
1000301    1.23          1
1000302    0.90         20
*
*          VOLUME       VOLNO
1000401     9.22         1
1000402    15.20         2
1000403    17.78         3
1000404    18.194       20
*
*          VANGLE       VOLNO
1000601    90.          20
*
*          WROUGH       HYD-DIA   VOLNO
1000801    0.           4.        20
*
*          VOLFLGS      VOLNO
1001001    00           20
*
*          JUNFLGS      JUNNO
1001101    01000        19
*
*==========================================================
*
*     COMPONENT 200
*     REACTOR VESSEL ABOVE TOP OF STANDPIPE, BELOW SPRAY SHIELD
*     LEVELS: 18.33 - 18.83
*
2000000    VESSMID      BRANCH
*
*          NJ
2000001    3
*
*     VOLAREA   LENGTH    VOLUME  AZI  INCL  ELEV   ROUGH  DIA    FLGS
2000101   0.     0.50      10.79  0.   90.   0.50   0.     0.     00
*
*          FROM         TO          JUNAREA   LOSSF     LOSSR     FLGS
2001101    100010000    200000000   0.        0.        0.        01100
2002101    200010000    300000000   19.6      0.        0.        01100
2003101    200000000    400010000   0.        0.        0.        01100
*
*
*==========================================================
*
```

```
*     COMPONENT 300
*     REACTOR VESSEL ABOVE SPRAY SHIELD
*     LEVELS: 18.83 - 24.618
*
3000000    VESSLOW      ANNULUS
*
*          NV
3000001     3
*
*          VOLAREA      VOLNO
3000101    0.            3
*
*          LENGTH       VOLNO
3000301    1.300         1
3000302    1.334         2
3000303    3.154         3
*
*          VOLUME       VOLNO
3000401    26.52         1
3000402    14.19         2
3000403     6.26         3
*
*          VANGLE       VOLNO
3000601    90.           3
*
*          WROUGH       HYD-DIA   VOLNO
3000801    0.           5.         3
*
*          VOLFLGS      VOLNO
3001001    00            3
*
*          JUNFLGS      JUNNO
3001101    01000         2
*
*=============================================================
*
*     COMPONENT 400
*     STANDPIPE
*     LEVELS: 0. - 18.33
*
4000000    STNDPIPE     PIPE
*
*          NV
4000001     1
*
*          VOLAREA      VOLNO
4000101    0.8210        1
*
*          LENGTH       VOLNO
4000301    18.33         1
*
*          VOLUME       VOLNO
4000401    0.            1
*
*          VANGLE       VOLNO
4000601    90.           1
*
*          WROUGH       HYD-DIA   VOLNO
4000801    0.           5.         1
*
```

```
*          VOLFLGS      VOLNO
4001001    00            1
*
*
*==========================================================
*
*     COMPONENT 901
*     ATMOSPHERE
*
9010000    ATMOSPH      TMDPVOL
*
*     VOLAREA   LENGTH    VOLUME  AZI  INCL  ELEV   ROUGH  DIA    FLGS
9010101  10.    1.         10.    0.   90.   0.50   0.     0.     00
*
*          CW
9010200    2
*
*          TIME          PRESS     QUAL
9010201    0.            0.1E6     1.
*
*==========================================================
*
*     COMPONENT 951
*     NOZZLE FLOW AS FUNCTION OF TIME
*
9510000    NOZZLE       TMDPJUN
*
*          FROM        TO          JUNAREA
9510101    400000000   901000000   0.
*
*          CW
9510200    1            601
*
*          TIME         LIQFLOW   VAPFLOW   ZEROL
9510201    0.           0.        0.        0.
9510202     0.04        0.        824.      0.
9510203     0.06        0.        832.      0.
9510204     0.08        0.        808.      0.
9510205     0.10        0.        647.      0.
9510206     0.16        0.        125.      0.
9510207     0.20        0.        139.      0.
9510208     0.24        0.        349.      0.
9510209     0.28        0.        432.      0.
9510210     0.32        0.        470.      0.
9510211     0.40        0.        432.      0.
9510212     0.46        0.        369.      0.
9510213     0.52        0.        393.      0.
9510214     0.60        0.        411.      0.
9510215     0.70        0.        415.      0.
9510216     0.80        0.        403.      0.
9510217     1.          0.        392.      0.
9510218     1.5         0.        392.      0.
9510219     2.5         0.        401.      0.
9510220     5.          0.        394.      0.
9510221     7.          0.        390.      0.
9510222     9.          0.        375.      0.
9510223    16.          0.        336.      0.
9510224    32.          0.        289.      0.
9510225    50.          0.        228.      0.
9510226    75.          0.        175.      0.
```

```
9510227    78.          0.          113.       0.
9510228    84.          0.            0.       0.
*
*=============================================================
*
*          VOLUME INITIAL CONDITIONS
*          -------------------------
*
*          CW           P           X (OR T)                    VOLNO
1001201    3            5.0E6       533.0          0. 0. 0.      1
1001202    3            5.0E6       533.4          0. 0. 0.      2
1001203    3            5.0E6       533.8          0. 0. 0.      3
1001204    3            5.0E6       534.2          0. 0. 0.      4
1001205    3            5.0E6       534.6          0. 0. 0.      5
1001206    3            5.0E6       535.0          0. 0. 0.      6
1001207    3            5.0E6       535.4          0. 0. 0.      7
1001208    3            5.0E6       535.8          0. 0. 0.      8
1001209    3            5.0E6       536.2          0. 0. 0.      9
1001210    3            5.0E6       536.6          0. 0. 0.     10
1001211    2            5.0E6       0.001          0. 0. 0.     11
1001212    2            5.0E6       1.00           0. 0. 0.     20
*
2000200    2            5.0E6       1.00
*
3001201    2            5.0E6       1.00           0. 0. 0.      3
*
4001201    2            5.0E6       1.00           0. 0. 0.      1
*
*
*=============================================================
*
*          JUNCTION INITIAL CONDITIONS
*          ---------------------------
*
1001301                 0.          0.          0.          19
2001201                 0.          0.          0.
2002201                 0.          0.          0.
2003201                 0.          0.          0.
3001301                 0.          0.          0.          2
*
*=============================================================
*
*          CONTROL VARIABLES
*          -----------------
*
20510100   LIQLEV       SUM         1.0         0.          1
20510101   0.           1.23        VOIDF       100010000
20510102                0.90        VOIDF       100020000
20510103                0.90        VOIDF       100030000
20510104                0.90        VOIDF       100040000
20510105                0.90        VOIDF       100050000
20510106                0.90        VOIDF       100060000
20510107                0.90        VOIDF       100070000
20510108                0.90        VOIDF       100080000
20510109                0.90        VOIDF       100090000
20510110                0.90        VOIDF       100100000
20510111                0.90        VOIDF       100110000
20510112                0.90        VOIDF       100120000
20510113                0.90        VOIDF       100130000
20510114                0.90        VOIDF       100140000
```

```
20510115                0.90      VOIDF     100150000
20510116                0.90      VOIDF     100160000
20510117                0.90      VOIDF     100170000
20510118                0.90      VOIDF     100180000
20510119                0.90      VOIDF     100190000
20510120                0.90      VOIDF     100200000
*
20530100   LEV01   SUM    1.    0.   1
20530101  0.    1.57746 P 100010000    -.57746 P 100020000   *   .000
20530200   LEV02   SUM    1.    0.   1
20530201  0.     .56056 P 100010000     .43944 P 100020000   *  1.083
20530300   LEV03   SUM    1.    0.   1
20530301  0.     .50556 P 100030000     .49444 P 100040000   *  3.025
20530400   LEV04   SUM    1.    0.   1
20530401  0.     .34778 P 100050000     .65222 P 100060000   *  4.967
20530500   LEV05   SUM    1.    0.   1
20530501  0.     .19000 P 100070000     .81000 P 100080000   *  6.909
20530600   LEV06   SUM    1.    0.   1
20530601  0.     .60778 P 100100000     .39222 P 100110000   *  9.233
20530700   LEV07   SUM    1.    0.   1
20530701  0.     .56111 P 100100000     .43889 P 100110000   *  9.275
20530800   LEV08   SUM    1.    0.   1
20530801  0.     .16222 P 100120000     .83778 P 100130000   * 11.434
20530900   LEV09   SUM    1.    0.   1
20530901  0.     .12778 P 100120000     .87222 P 100130000   * 11.465
20531000   LEV10   SUM    1.    0.   1
20531001  0.     .91556 P 100150000     .08444 P 100160000   * 13.456
20531100   LEV11   SUM    1.    0.   1
20531101  0.     .69556 P 100170000     .30444 P 100180000   * 15.454
20531200   LEV12   SUM    1.    0.   1
20531201  0.     .47778 P 100190000     .52222 P 100200000   * 17.450
20531300   LEV13   SUM    1.    0.   1
20531301  0.    -.03966 P 300020000    1.03966 P 300030000   * 23.130
*
20540300  DP203  SUM   1.   0.   1
20540301   10321.  1. CNTRLVAR  313   -1. CNTRLVAR  307
*
20540500  DP205  SUM   1.   0.   1
20540501   71051.  1. CNTRLVAR  307   -1. CNTRLVAR  301
*
20541000  DP210  SUM   1.   0.   1
20541001   497.1   1. CNTRLVAR  312   -1. CNTRLVAR  311
*
20541100  DP211  SUM   1.   0.   1
20541101   497.0   1. CNTRLVAR  311   -1. CNTRLVAR  310
*
20541200  DP212  SUM   1.   0.   1
20541201   495.0   1. CNTRLVAR  310   -1. CNTRLVAR  309
*
20541300  DP213  SUM   1.   0.   1
20541301   7727.   1. CNTRLVAR  308   -1. CNTRLVAR  306
*
20541400  DP214  SUM   1.   0.   1
20541401   17713.  1. CNTRLVAR  306   -1. CNTRLVAR  305
*
20541500  DP215  SUM   1.   0.   1
20541501   14870.  1. CNTRLVAR  305   -1. CNTRLVAR  304
*
20541700  DP217  SUM   1.   0.   1
20541701   14925.  1. CNTRLVAR  303   -1. CNTRLVAR  302
```

```
*
20549900  DF214+215     SUM   1.   0.   1
20549901        0.  1. CNTRLVAR  414    1. CNTRLVAR  415
*
*=============================================================
*
*          STEADY STATE CARDS
*          ------------------
*

*     COMPONENT 902
*     STEADY STATE PRESSURIZER
*
9020000    PRZ          TMDPVOL
*
*     VOLAREA   LENGTH    VOLUME  AZI  INCL  ELEV   ROUGH  DIA    FLGS
9020101 10.     1.        10.     0.   90.   1.     0.     0.     00
*
*          CW
9020200    2
*
*          TIME          PRESS     QUAL
9020201    0.            5.0E6     1.
*
*
*     COMPONENT 952
*     STEADY STATE CONNECTION TO THE PRESSURIZER
*
9520000    PRZLIN       SNGLJUN
*
*          FROM        TO          JUNAREA   LOSSF     LOSSR     FLGS
9520101    300010000   902000000   0.        0.        0.        01100
*
9520201    0           0.          0.        0.
*
*
*
*     COMPONENT 903
*     STEADY STATE LIQUID FILL VOLUME
*
9030000    FILL         TMDPVOL
*
*     VOLAREA   LENGTH    VOLUME  AZI  INCL  ELEV   ROUGH  DIA    FLGS
9030101 10.     1.        10.     0.   90.   1.     0.     0.     00
*
*          CW
9030200    3
*
*          TIME          PRESS     QUAL
9030201    0.            5.0E6     533.
*
*
*     COMPONENT 953
*     STEADY STATE FILL JUNCTION TO OBTAIN THE CORRECT WATER LEVEL
*
9530000    FILLJUN      TMDPJUN
*
*          FROM        TO          JUNAREA
9530101    903000000   100000000   0.
*
```

```
9530200    1           0          CNTRLVAR  210
*
9530201    -10000.      -10000.      0.    0.
9530202       -0.5          0.      0.    0.
9530203        0.5          0.      0.    0.
9530204     10000.       10000.      0.    0.

*
*
*          LIQUID LEVEL CONTROL SYSTEM
20521000   FILLFLOW     SUM     20000.   0.   1
20521001   10.2         -1.     CNTRLVAR   101
*
.
```

NRC FORM 335 (2-84) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

SEE INSTRUCTIONS ON THE REVERSE

1 REPORT NUMBER (Assigned by TIDC, add Vol. No., if any)

NUREG/IA-0006
STUDSVIK/NP-86/97

2 TITLE AND SUBTITLE

ICAP Assessment of RELAP5/MOD2 Against Marviken Jet Impingment Test II Level Swell

3 LEAVE BLANK

4 DATE REPORT COMPLETED

MONTH	YEAR
July	1986

5 AUTHOR(S)

Ö. Rosdahl, D. Caraher

6 DATE REPORT ISSUED

MONTH	YEAR
September	1986

7 PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)

Swedish Nuclear Power Inspectorate
Box 27106
5-102 52 Stockholm, Sweden

8 PROJECT/TASK/WORK UNIT NUMBER

9 FIN OR GRANT NUMBER

10 SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)

Office of Nuclear Regulatory Research
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

11a TYPE OF REPORT

Technical Report

b PERIOD COVERED (Inclusive dates)

12 SUPPLEMENTARY NOTES

13 ABSTRACT (200 words or less)

RELAP5/MOD2 simulations of level swell of saturated liquid in a large (5 m diameter, 22 m high) vessel are reported. For certain nodalizations RELAP5 is shown to predict the measured void fraction profile with fair accuracy. RELAP5 results are shown to be dependent upon nodalization with the accuracy of computed results deteriorating significantly when a large number of nodes is employed.

14 DOCUMENT ANALYSIS - a. KEYWORDS/DESCRIPTORS

RELAP5/MOD2, Marviken Jet Impingment Test, Level Swell, ICAP Code Assessment

b. IDENTIFIERS/OPEN-ENDED TERMS

15 AVAILABILITY STATEMENT

Unlimited

16 SECURITY CLASSIFICATION

(This page)
Unclassified

(This report)
Unclassified

17 NUMBER OF PAGES

18 PRICE

NUREG/IA-0006

ASSESSMENT OF RELAP5/MOD2 AGAINST MARVIKEN JET IMPINGEMENT TEST 11 LEVEL SWELL

SEPTEMBER 1986