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Comparison of COMPARE/RELAP3 Subcompartment Calculations with Battelle-Frankfurt C-Series Test Results

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COMPARISON OF COMPARE/RELAP3 SUBCOMPARTMENT CALCULATIONS

WITH BATTELLE-FRANKFURT C-SERIES TEST RESULTS

by

W. S. Gregory, J. R. Campbell, R. G. Gido, and A. J. Webb

ABSTRACT

This report describes comparison of results from the COMPARE and RELAP3 subcompartment analysis codes with the Battelle-Frankfurt C-Series tests on reactor containment. Comparisons were made for 12 of the 16 tests for which information was available. In the 12 selected tests, inertia was neglected and the 0.6 Moody Multiplier was used to impose the critical flow limit.

Four tests, C5, C10, C13, and C15, were selected for detailed study. Parameter studies varying the Moody Multiplier and entrainment were performed. Test results comparing the use of digitized and nondigitized blowdown data were also obtained. Additional nodalization using COMPARE did not produce large differences when compared to models with fewer nodes.

I. INTRODUCTION

Following a loss-of-coolant accident (LOCA) within a reactor containment, local transient differential pressure loadings will occur on containment internal structures and equipment as the coolant flows from the [illegible] into the containment volume. Internal structures, shielding walls, and equipment within the containment form confined volumes that can become pressurized from the break effluent build-up resulting in flow between these volumes. These confined volumes are commonly referred to as subcompartments. Safety guidelines for nuclear power plants include the requirement that subcompartment analyses be performed to determine localized containment pressure distributions that might result from high-energy line breaks.[1] These pressure distributions will subsequently be used in structural analyses.

The US Nuclear Regulatory Commission (NRC) currently uses the COMPARE[2] and RELAP3 (Mod 68)[3] computer codes to perform such subcompartment analyses. The COMPARE code was specifically developed for this purpose, whereas the RELAP3 code, which is principally a reactor primary loop blowdown analysis code, has been used in lieu of anything else for several years. Both of these codes are recognized by the NRC as possible tools for such application.[1]

Application of the codes requires that criteria be followed to satisfy the guidelines of Ref. 1. In particular, Ref. 1 suggests that critical flow be based on either the Moody[4] critical flow with a multiplier of 0.6, or the homogeneous equilibrium flow model (HEM) (for example, see Ref. 5). These guidelines are based on high-pressure and temperature water blowdown tests (for example, see Ref. 6). Another regulatory guideline is that nodalization (subdivision into fractional volumes) of the subcompartments should be analytically investigated to assure that maximum loading pressure differentials are obtained.

A problem regarding the use of these subcompartment codes has been the lack of experimental verification. This has been due to the lack of test data based on geometries and thermodynamic conditions representative of those for subcompartment LOCA situations. However, the Battelle-Frankfurt C-series tests[7--17] that have recently been run have the potential for providing test results for comparison with subcompartment analysis code calculations. Tests using the Battelle-Frankfurt facility are continuing (D-Series), so further comparisons of calculated and test results can and should be made.

The purpose of this study was to compare the COMPARE and RELAP3 (Mod 68) code-calculated results with the Battelle-Frankfurt C-Series test results. Emphasis was placed on the comparisons of the maximum pressure differences, because these are the parameters of primary interest in the licensing process and the absolute pressures, because these are the best measure of the fundamental validity of code predictions. The regulatory guidelines for modeling were implemented [for example, the 0.6 Moody Multiplier (MM) was used], but parametric runs to investigate the sensitivity of the calculated and test results comparisons were also performed. Parameters of primary interest include

(1) nodalization, (2) Moody critical flow multiplier, (3) use of HEM for critical flow, and (4) entrainment.

At the beginning of this investigation, many of the experimental data were available only in graphical form. Extraction of these data was somewhat tedious, and at times certain simplifying assumptions were made. The data of most concern were the blowdown data--mass flow rate and enthalpy. Digitized blowdown data became available after we completed most of the investigation. Using the digitized data, we have recalculated the results for tests C5, C10, C13, and C15. These tests were selected because they had been studied in detail using the nondigitized data. The results of the analyses based on the digitized data are presented in Sec. VIII. Our purpose in recalculating these results was to ascertain the effect of the digitized blowdown data on the calculated results and to see whether earlier conclusions were invalid.

II. REVIEW OF BATTELLE-FRANKFURT C-SERIES TEST INFORMATION

A. Geometric Description

The Battelle-Frankfurt tests involve pressurized water reactor/boiling water reactor (PWR/BWR) experiments that are being performed in West Germany with a model containment. In these tests, the geometric scaling for the interior subcompartments and vent areas is 1:64 and is based upon a 1200-MW PWR plant, Biblis A. The West Germans believe that the 1:64 geometric scale will allow the time scale of pressure histories to be 1:1, thereby allowing them to extrapolate the model results to a prototype containment. More complete descriptions of the experimental apparatus can be found elsewhere.[18,19]

The model containment is constructed of concrete with nine inner subcompartments (Fig. 1). The nine subcompartments are interconnected by 57 vent ducts that have orifice plates of various sizes. The subcompartments in ascending order of volume are shown in Table I. Subcompartments R7, R8, R5, R6, and R4 are all approximately the same size (41 m^3), whereas R9 is 9 times larger than these, and R1, R2, and R3 are approximately one fourth as large. The volumes of the subcompartments were checked by scaling the available drawings. All volumes were verified except for those of R1 and R3 (off by 5%). The geometry of each subcompartment can be quite complex (for example, see Fig. 14 for subcompartment R3).

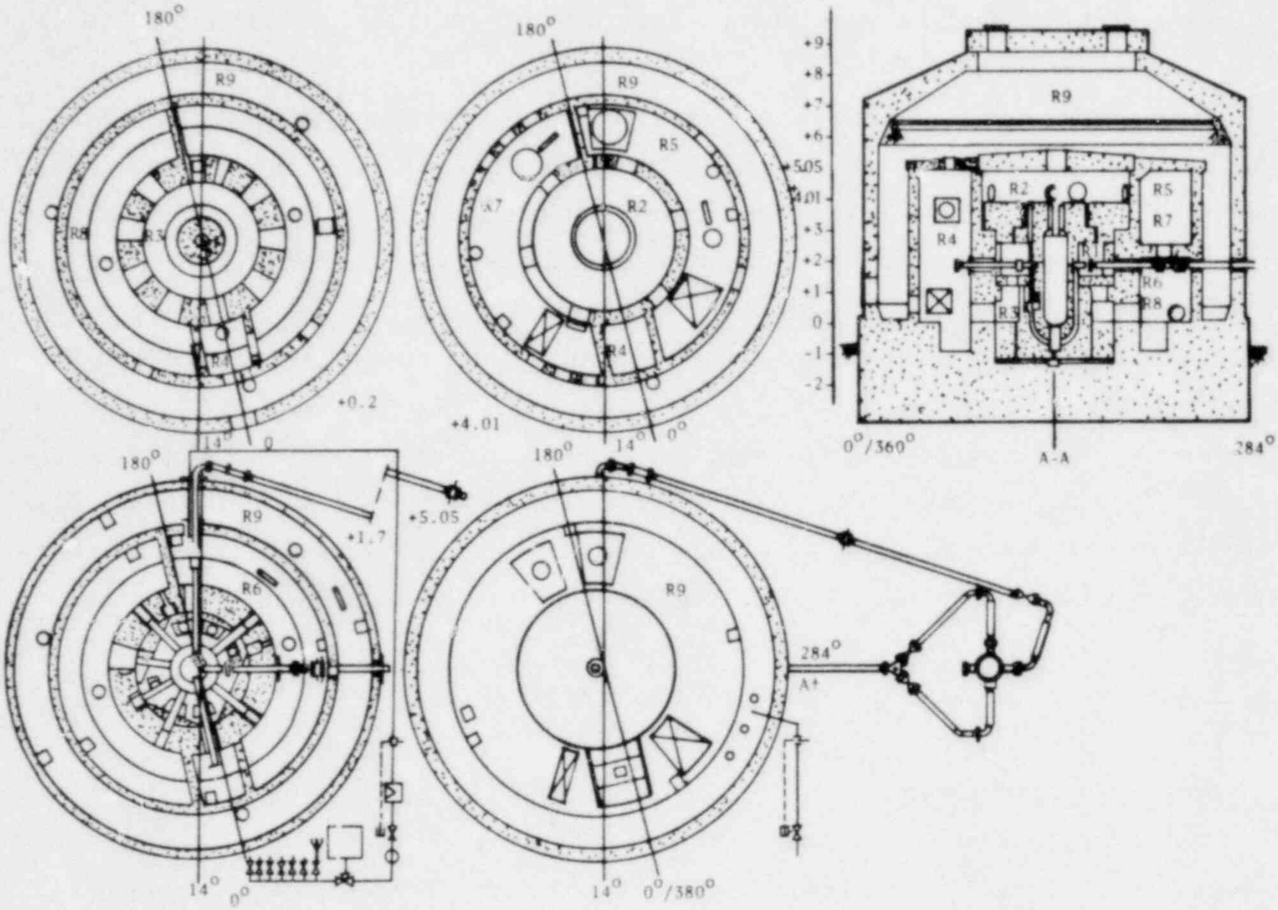

Fig. 1.
Battelle-Frankfurt containment test facility

TABLE I

SUBCOMPARTMENT VOLUMES

Subcompartment	Volume (m^3)
R3	9.95
R1	11.84
R2	17.7
R7	40.4
R8	40.53
R5	41.05
R6	41.26
R4	13.02
R9	367.0

B. C-Series Tests

The C-Series tests were completed by Battelle-Frankfurt in 1976 and were carried out with initial reactor vessel conditions of approximately 140 bar pressure and 290°C temperature. Basic variations in the C-Series tests consisted of variations in the blowdown mass flow rate (single or double-ended break), blowdown location, and connections between the subcompartments. A summary of the C-Series test variations is shown in Table II.

TABLE II

BATTELLE-FRANKFURT C SERIES-TESTS

TEST PARAMETERS	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
I. Subcompartment Connections (See Fig. 2)	Standard	Open 23	Open 23	? DATA NOT AVAILABLE	Open 46 23	Open 54 Closed 55	? DATA NOT AVAILABLE	Standard	Standard	Standard	Closed 4 5 Open 24 25 26 27 Varied 19 14	Closed 4 5 Varied 19 14	Standard	? DATA NOT AVAILABLE	Closed 44 42 41	DATA NOT ANALYZED (Data received too late)
II. Blowdown Characteristics																
A. Location (Subcompartment)	6	6	1	6	6	6	6	10	4	4	2	2	1	1	1	9
B. Single (s) or double (d) break	s	s	s	s	d	d	s	s	s	s	s	s	d	s	d	s
C. Initial blowdown pressure, bar	14.1	12.5	14.0	12.9	12.1	13.2	14.15	14.1	11.9	14.05	14.05	14.1	13.95	13.95	13.95	13.55
D. 2 s Integrated Mass, kg																
(1) Pipeline					549	614							447		552	
(2) Buffer Bottle	522	741	459		447	414			659	666	531	750	354		496	
(3) Total	522	741	459		996	1028			659	666	531	750	801		1048	
III. Reactor Cavity Similarity	NO	NO	YES	?	NO	NO	YES	YES	NO	NO	NO	NO	YES	YES	YES	NO

1. Subcompartment Connections. The connections between the subcompartments are shown in Fig. 2. Fifty-seven connections are shown, although in the C-Series tests only 22 were usually open. Figure 2 also shows the connections that are open and closed for test C1. This combination is referred to as the standard connection arrangement. The wall opening areas, orifice plate diameters, and orifice plate areas for each connection are shown in Table III.

In the C-Series tests, the subcompartments have at least 3 and as many as 10 connections to other subcompartments. The largest connection is between R5 and R6, with the smallest connection extending from R2 to R5 and R7.

The connection area between a crack around R1 and R1 itself in test C8 was not obvious from the available data. Personal communication with T. Kanzlieter at the Battelle-Frankfurt Institute in West Germany revealed that connection to be annular with a width of 75 mm and an inner diameter of 1.45 m.

Examination of the connection variation in test C15 shows that the flow area was reduced by a factor of 2 between the blowdown subcompartment (R1) and the adjacent connected subcompartment (R3). The small volume of R1 and the reduced flow area could cause critical flow to occur in this configuration. Therefore this test was selected for greater study.

TABLE III

CONNECTION DESCRIPTIONS

Connection Number (from Fig. 2)	Compartment Opening Area (m^2)	Orifice Plate Diam (mm)	Orifice Plate Area (m^2)	Remarks
1	1.822	NA[a]	NA	
2	2.247	550	0.238	
3	1.400	NA	NA	
4	0.283	260	0.053	Closed for tests C11 & C12
5	0.105	NA	NA	Closed for tests C11 & C12
6	0.822	NA	NA	
7	2.247	550	0.238	
8	0.275	NA	NA	
9	0.275	NA	NA	
10	0.275	NA	NA	
11	0.275	NA	NA	
12	0.275	NA	NA	
13	0.275	NA	NA	
14	0.283	110	0.0095	Orifice plate removed for tests C11 & C12
15	0.283	NA	NA	
16	0.283	NA	NA	
17	0.283	NA	NA	
18	0.283	NA	NA	
19	0.283	110	0.0095	Orifice plate removed for tests C11 & C12
20	0.880	NA	NA	
21	0.880	NA	NA	
22	0.640	593	0.2762	
23	0.026	NA	NA	Open for test C5
24	0.011	96	0.0724	Open for test C11
25	0.011	96	0.0724	Open for test C11
26	0.011	96	0.0724	Open for test C11
27	0.011	96	0.0724	Open for test C11
28	0.640	593	0.2762	
29	0.360	387	0.118	
30	0.790	1000	0.785	
31	0.890	NA	NA	
32	0.640	NA	NA	
33	0.270	NA	NA	
34	0.270	360	0.102	
35	0.270	NA	NA	
36	0.270	360	0.102	
37	0.312	NA	NA	
38	0.283	NA	NA	
39	0.066	290	0.0660	
40	0.066	290	0.0660	
41	0.066	290	0.0660	Closed for test C15
42	0.066	290	0.0660	Closed for test C15
43	0.066	290	0.0660	
44	0.066	290	0.0660	Closed for test C15
45	0.640	800	0.503	
46	0.050	NA	0.05	Open for tests C5 & C6
47	0.324	360	0.102	
48	0.324	NA	NA	
49	0.324	360	0.102	
50	0.162	NA	NA	
51	0.210	NA	NA	
52	0.283	600	0.283	
53	0.159	NA	NA	
54	3.524	NA	NA	Open for test C6
55	0.817	1020	0.817	
56	0.283	274	0.0590	
57	0.283	387	0.118	

[a]NA - Not available

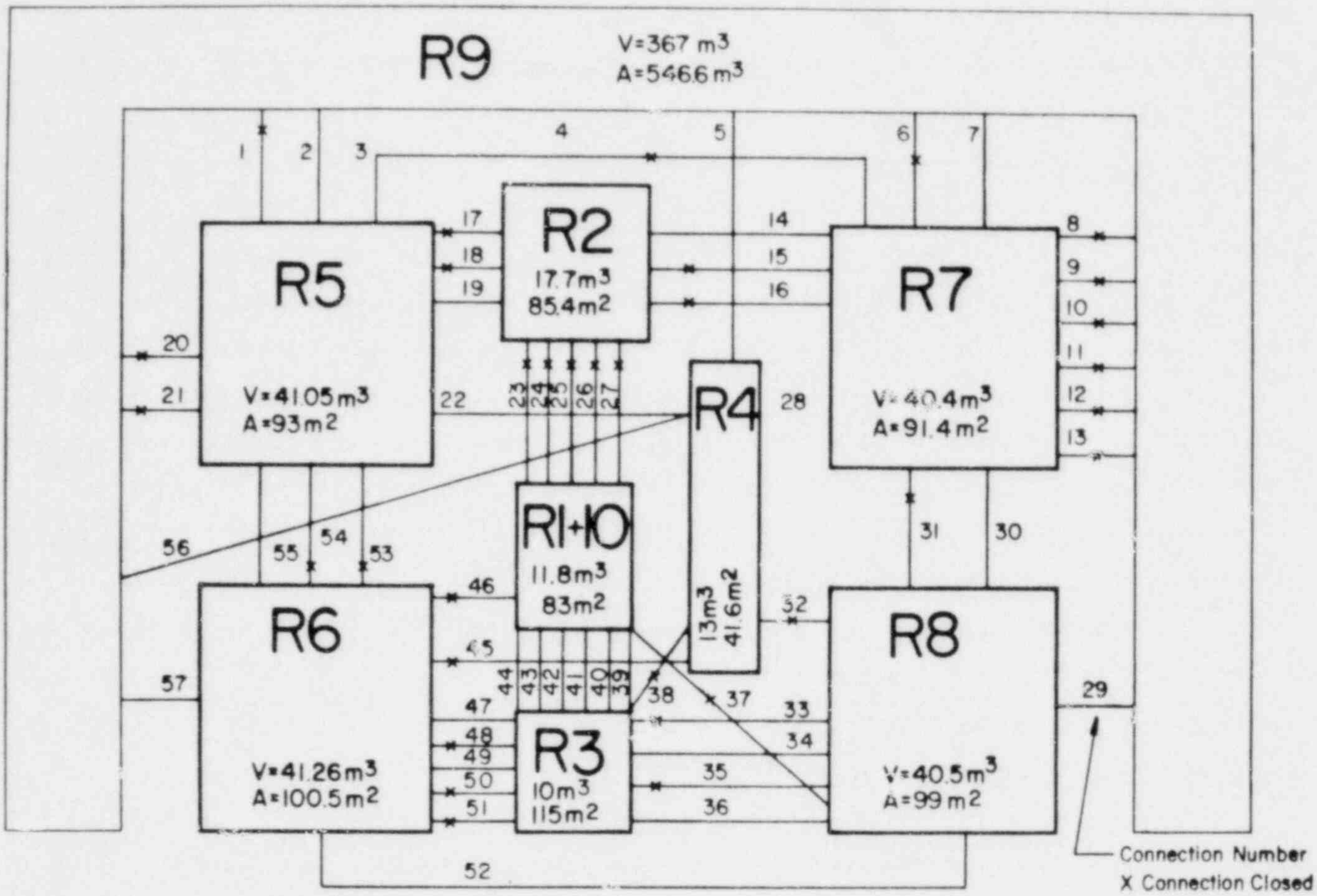

Fig. 2.
Standard connection arrangement and connection numbering system.

The connection change in C6, relative to C5, moves the opening from the breakpoint end to the other end of the subcompartment. This connection change could cause the R6 pressure-time history to be different between tests C5 and C6. Therefore these two tests were studied in greater detail in a nodalization study.

2. Blowdown. In the C-Series tests, break locations were in subcompartments R1, R2, R4, R6, R9, and R10. R10 is a crack around subcompartment R1 as discussed above. Test C8 was performed with the break location in R10. As shown in Table II, tests C3, C7, C8, C13, C14, and C15 offer similarity to reactor cavity blowdowns (break location is in R1 or the crack around R1). Data were not available for tests C7 or C14.

In the C-Series tests, almost all of the break points within the subcompartments were at or near large-orifice connections to adjacent subcompartments.

The only tests where this was not the case were C12 and C15, for which relatively higher pressures in the blowdown subcompartment were observed.

Most of the C-Series tests were performed over a 30- to 40-s period. The total mass blowdown was obtained for the short time ($\leq$ 2 s) by integrating the flow rate data provided. These results are presented in Table II. As shown, the mass flows for tests C5 and C6 and for C9 and C10 were quite close. The data also show agreement for these tests over a 30- to 40-s period. This was not the case for tests C11 and C12. The data show that the blowdown mass flow was within 20 kg over a 30- to 40-s period, but the 2-s integrated blowdown mass (Table II) shows a difference of 219 kg. Any short-time comparative analysis between C11 and C12 would require recognition of this fact. The variance in mass flow rate between tests C3, C13, and C15 should also be recognized along with the connection differences.

Our reason for discussing differences in the tests with regard to blowdown is simply to point out unusual items. The reader should consider these anomalies when making any comparison.

C. Typical Experimental Data

Typical data plots that describe the blowdown are shown in Figs. 3--6. Figure 3 is a plot of the data for the blowdown mass flow rate, and Figs. 4, 5, and 6 show the pressure, temperature, and blowdown density, respectively. The pressure, temperature, and density were used by the experimenters to estimate enthalpy. However, their estimation of enthalpy was not always given, so we had to estimate it for some tests (see Sec. II).

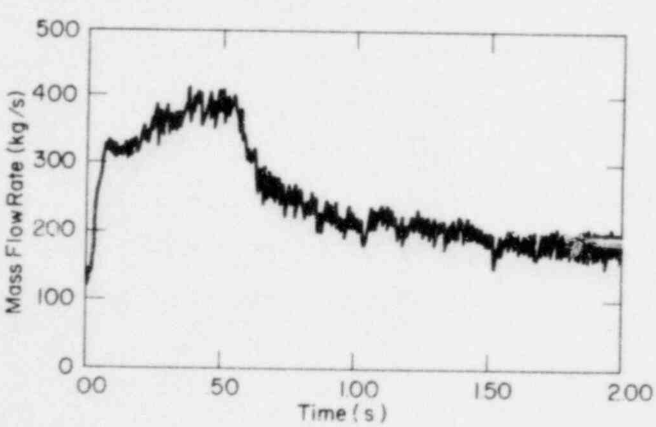

Fig. 3.
Typical blowdown mass flow-rate data.

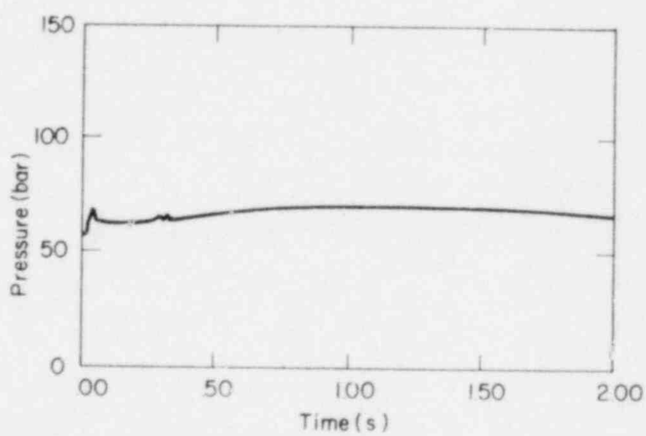

Fig. 4.
Typical blowdown pressure data.

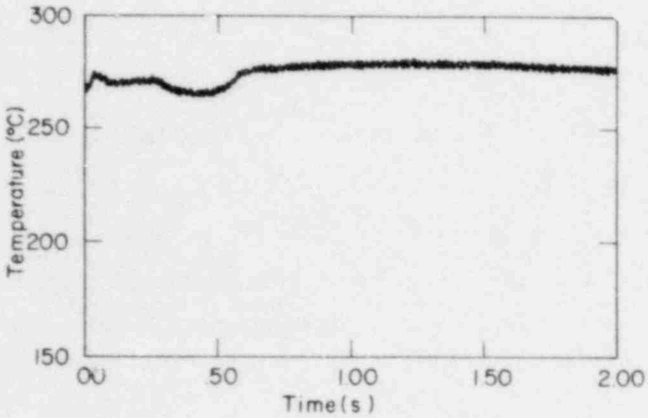

Fig. 5.
Typical blowdown temperature data.

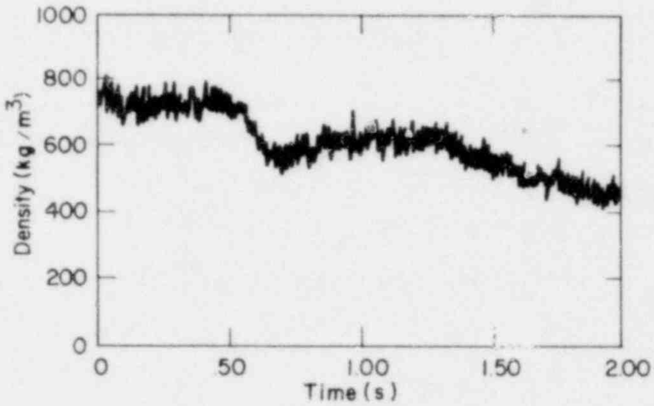

Fig. 6.
Typical blowdown density data.

D. Problem Areas

The most important and perhaps the largest source of error in our analysis of the Battelle-Frankfurt data was in using the blowdown data (Figs. 3--6). The graphical form of the experimental data restricted the accuracy of the input to COMPARE and RELAP3. For example, mass flow rate could not be interpreted more closely than ± 20 kg/s. A variance of 20 ± kg/s alone can cause a 10% error in the input energy rate for both codes.

In Sec. VIII we have attempted to ascertain the effect of using digitized rather than graphical data. The results of this comparison for certain tests are discussed in detail.

Exact location of open and closed connections between subcompartments could not be interpreted from the data provided. This problem was crucial when nodalization of the C-Series tests was performed. Personal communication with T. Kanzlieter at the Battelle-Frankfurt Institute in West Germany solved some of these problems, but he was not able to help in specifying the connection in test C5. Also, comparative test data on the pressure distribution within subcompartment R6 were impossible to obtain because the individual plots were not identified in the graphical data provided.

The graphical form of the test results did not allow easy comparison of code and experimental results. We had to digitize all of the graphical data to generate comparative plots.

III. MODELING PROCEDURE AND ASSUMPTIONS

The purpose of this section is to describe the modeling procedure used in this study. An understanding of the manuals for the codes used is prerequisite to a full understanding of this section. This section will discuss the fundamental subcompartment modeling considerations of (1) volume geometry, (2) initial conditions, (3) blowdown, (4) junction area and critical flow, and (5) junction inertia (L/A) and head losses.

A. Volume Geometry

Information required here is the volume for each subcompartment established by significant restriction to flow when the subcompartment is not nodalized. Nodalization consists of dividing one or more of these subcompartments into fractions of its total volume to investigate possible pressure distributions within the subcompartment. As discussed in Sec. V, the geometric complexity along with inconsistencies in the reported information made the establishment of subcompartment volumes and, in particular, the nodalized volumes subject to error. In any event, the sum of the nodalized volumes for a subcompartment always equalled the total volume of the subcompartment. Volume geometric values used were identical for both codes. The nonnodalized model is referred to as a basic model and was used for all calculations except those identified in Sec. V.

B. Initial Conditions

These were specified in the test reports, and the values of pressure and temperature were taken from the graphical plots at time = 0 for each subcompartment. The pressure was usually close to 1.00 bar, whereas the subcompartment temperatures varied from 15 to 60°C. The relative humidity in each subcompartment was taken as 100%. Several calculations were made varying the initial relative humidity. No significant effects on the results were observed. The COMPARE formulation accounts for a certain amount of air in the containment upon initiation of the test. However, the RELAP3 code has no such provision. Therefore, the alternative procedure suggested in Ref. 1 was used. That is, a homogeneous water-steam mixture at the test initial pressure (1.00 bar) with an equivalent density of that for the model with air was used.

C. Blowdown

Both codes provide for water mass flow rate (M) and energy flow rate (E) in addition to volumes, that is for blowdown. The COMPARE code uses input tables

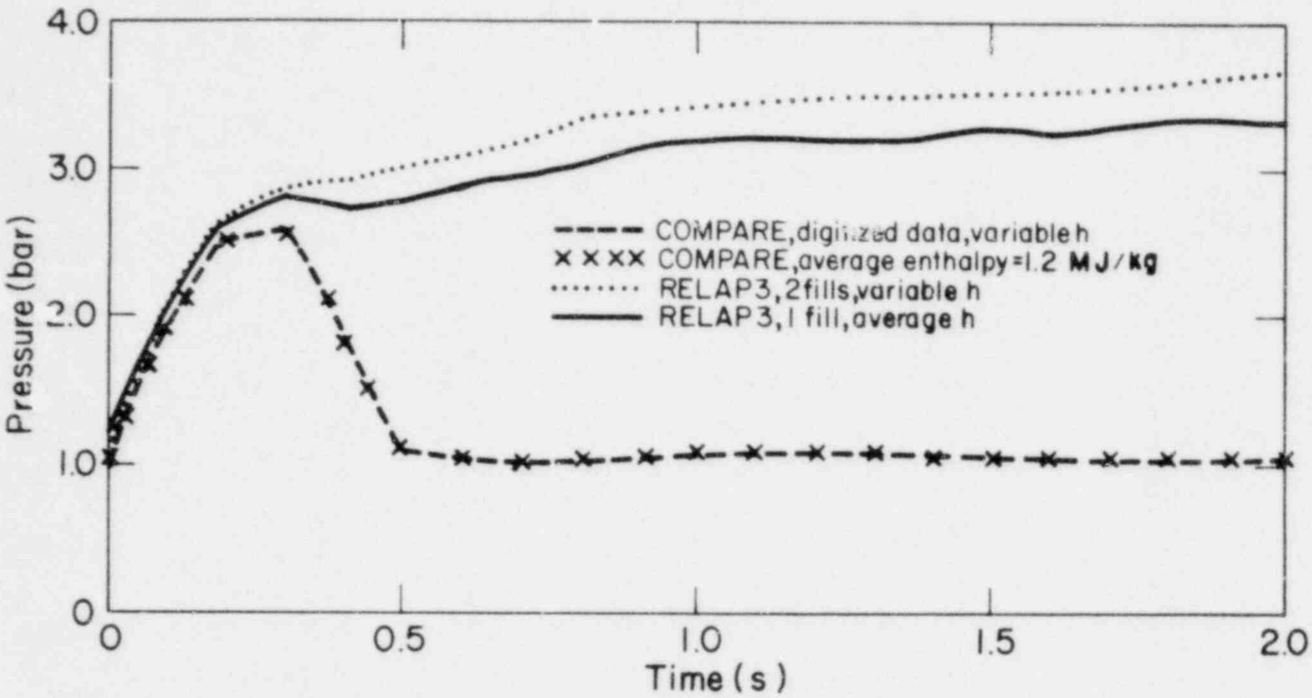

Fig. 7.
R1 pressure vs time for test C3.

of water M and E vs time. RELAP3 blowdown, however, must be represented by fill junctions (20 are available) that represent constant water enthalpy (h) sources with variable mass flow rate.* Unfortunately, digitized test information for M and E or h vs time was available for only four of the tests studied. For all other tests, M information was obtained from test result plots of M vs time. These plots have as much as ± 20 kg/s (± 10%) scatter. Most calculations were performed with a constant h of 1.20 MJ/kg (518 Btu/lbm) assumed. This assumption was determined to be reasonable on the basis of calculations performed for test C3 where enthalpy values were available (see Fig. 7). This figure shows essentially identical results with the variable h and the constant h. Checks were made for all tests to assure that their blowdown h's were reasonably close to the assumed constant value. These checks were based on blowdown source pipe pressure, temperature, and density measurements.

D. Junction Area and Critical Flow

For nonnodalized calculations, the minimum flow area (usually an orifice) between subcompartments was used (see Sec. II). Nodalized calculations used

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*A scheme was developed to represent any h within an arbitrary range by using the range extreme h's and appropriate fractions of the total flow to produce the total flow and h desired.

the area that represented the plane of connection between the nodes into which a subcompartment had been divided as well as the orifice areas. The basic critical flow model used was that of 0.6 x Moody (see Ref. 1). This was accomplished in the COMPARE code by means of the MM input parameters. However, in the RELAP3 code, a reduction of the flow area to 0.60 of the actual flow area was used to impose the critical flow limit. This reduced area for the RELAP3 code was not used in the inertia or L/A discussed below where the actual area was used. Variations of the MM were studied (see Sec. VII). In addition, the use of the homogeneous equilibrium critical flow model was investigated (see Sec. VI). The variations from the base case were made with the COMPARE code only.

E. Junction Inertia (L/A) and Head Losses

Inertia in the form of a L/A term was based on actual geometry (see Sec. V). Inertia was not considered in both codes for the basic model and was used only in the nodalized COMPARE model. This representation included the geometric L/A caused by openings in the concrete walls because the orifice plates were attached to one side of the wall. Head losses for the nonnodalized calculations were those for flow through an orifice, that is, 0.5 inlet and 1.0 exit. However, nodalized calculations introduce the further consideration of friction head losses, that is, fL/De. These head losses were based on a Blasius friction factor of 0.02 used in the Darcy equation, $\Delta P = fL/De\ (G^2/2\rho)$. Flow losses between nodalized volumes of a subcompartment were usually totally made up of such head losses. For the COMPARE code, friction losses were always accounted for by inclusion in the entrance loss coefficient and not in the exit loss coefficient for the orifices. Friction head losses through the wall openings were also accounted for.

IV. COMPARISON OF COMPARE AND RELAP3 WITH TEST DATA

A. Tests Chosen for Comparison

We believed that we could not pick several of the C-Series tests for analysis in some depth without investigating all available tests. For this reason, we performed a basic analysis of as many of the tests as possible. Both absolute pressure and pressure difference were evaluated using the basic model for 12 of the 16 C-Series tests. Data were not available for tests C4, C7, and

C14. Also, data for test C16 were not received in time for analysis. Nodalization, possible inertia, and other specific effects were neglected in these basic model analyses, and only short times ($\leq$ 2 s) were considered in determining absolute pressure and pressure differentials. The specific effects were studied selectively (see Sec. VII). Comparison of all of the tests analyzed with COMPARE and RELAP3 can be found in Appendix A in the summary and plots of absolute pressure differences.

Code comparison with tests C5, C10, C13, and C15 only will be illustrated in greater detail here. These tests were selected for the following reasons.

1. Tests C13 and C15 have reactor cavity type blowdowns.
2. The experimental data are fairly complete in these tests.
3. Test C5 had digitized mass flow rate and enthalpy data available in a then recent publication.[17]
4. All exhibit high mass flow rates.
5. The possibility of critical flow exists for all of the tests except C5.

B. Plots of COMPARE and RELAP3 Results for all Subcompartments

The absolute pressures predicted by COMPARE and RELAP3 for each subcompartment are plotted in Appendix A for the selected tests.

C. Absolute Pressure Comparisons of COMPARE, RELAP3, and Tests

Comparisons of the results predicted by COMPARE and RELAP3 with the test data are illustrated in Table IV for specific times and locations. Table IV shows the maximum absolute pressure (at 2 s) for the blowdown subcompartments and the containment (R9). Intermediate absolute pressure comparisons for the blowdown subcompartments are also illustrated using an arbitrary time of 0.2 s.

Comparative plots of the code results with the experimental data for absolute pressure are shown in Appendix A.

D. Pressure Difference Comparisons of COMPARE, RELAP3, and Tests

Table V contains pressure difference comparisons at 0.2 s. The time of 0.2 s was chosen because much of the early data indicate that maximum pressure differences occurred near this time. Table VI contains maximum pressure difference comparisons observed during the first 2 seconds. Both Tables V and VI illustrate the blowdown-containment, R4-R6, and R1-R4 pressure differences. Subcompartment R4 was used as a reference for direct measurement of pressure differentials in the C-Series tests. Note that the test blowdown-containment

TABLE IV

COMPARE/RELAP3/TEST DATA ABSOLUTE PRESSURE (BAR) COMPARISON IN FIRST 2 s

	Test (Blowdown Location) C5 (R6)	C10 (R4)	C13 (R1)	C15 (R1)
1. Maximum Absolute Pressure in Blowdown Subcompartment				
A. Test	2.25	2.10	3.60	6.00
B. COMPARE	2.49	2.27	4.37	8.20
C. RELAP3	[illegible]	2.58	6.80	10.67
2. Absolute Pressure in Blowdown Subcompartment at 0.2 s				
A. Test	1.60	2.10	2.60	4.00
B. COMPARE	1.73	2.21	3.44	5.11
C. RELAP3	1.69	1.71	3.38	4.29
3. Maximum Absolute Pressure in Subcompartment R9				
A. Test	1.90	1.65	1.75	1.75
B. COMPARE	2.27	1.85	1.90	1.96
C. RELAP3	1.94	1.50	1.63	1.67

TABLE V

COMPARE/RELAP3/TEST DATA PRESSURE DIFFERENTIALS (BAR) AT 0.2 s

	Test (Blowdown Location) C5 (R6)	C10 (R4)	C13 (R1)	C15 (R1)
1. Blowdown/Containment Subcompartments				
A. Test Data (calculated)	0.50	1.00	2.10	3.20
B. COMPARE	0.63	1.15	2.41	4.10
C. RELAP3	0.63	0.68	2.35	3.26
2. R4 - R6 Subcompartments				
A. Test Data (measured)	-.55	0.75	-0.04	-0.04
B. COMPARE	-.43	1.04	-0.04	-0.02
C. RELAP3	-0.5.	0.66	-0.01	-0.01
3. R1 - R4 Subcompartments				
A. Test Data (measured)	0.23	-0.80	2.30	3.30
B. COMPARE	0.06	-1.06	2.36	4.05
C. RELAP3	0.06	-0.66	2.35	3.25

pressure differential in Table V was calculated from measured absolute pressures. However, this was not done in Table VI because of the difficulty in searching through the data for maximum pressure differentials. The COMPARE and RELAP3 values shown in Table VI were produced from numerical output at every 0.1 s, whereas the actual calculation time step is usually two orders of magnitude smaller.

TABLE VI

COMPARE/RELAP3/TEST MAXIMUM PRESSURE DIFFERENTIALS

Test	C5		C10		C13		C15	
1. Blowdown Location	R6		R4		R3		R1	
	Pressure (bar)	Time (s)	Pressure (bar)	Time (s)	Pressure (bar)	Time (s)	Pressure (bar)	Time (s)
2. Blowdown - R9								
A. Test	Not measured		1.25	0.2	Not measured		Not measured	
B. COMPARE	0.74	0.6	1.15	0.2	3.05	0.9	6.57	1.0
C. RELAP3	1.11	0.7	1.06	1.4	5.34	1.4	9.01	2.0
3. R4 - R6								
A. Test (measured)	-0.55	0.2	0.95	0.2	-0.04	2.0	-0.05	0.3
B. COMPARE	-0.47	0.1	1.04	0.2	-0.05	0.9	-0.06	1.1
C. RELAP3	-0.76	0.6	0.96	1.3	-0.10	1.7	-0.08	1.0
4. R1 - R4								
A. Test (measured)	0.52	0.3	-1.00	0.1	2.20	2.0	5.00	1.0
B. COMPARE	0.10	0.5	-1.06	0.2	2.82	0.8	6.32	1.0
C. RELAP3	0.16	1.2	-0.96	1.0	5.16	1.4	8.74	1.8

Comparative pressure differential plots for the four tests are shown in Figs. 8--11. These plots are only for pressure differentials between subcompartments R4 and R6. In addition, Appendix B contains a comparison of measured and COMPARE-calculated R4-R6 pressure differences for tests C1, C6, C11, and C12.

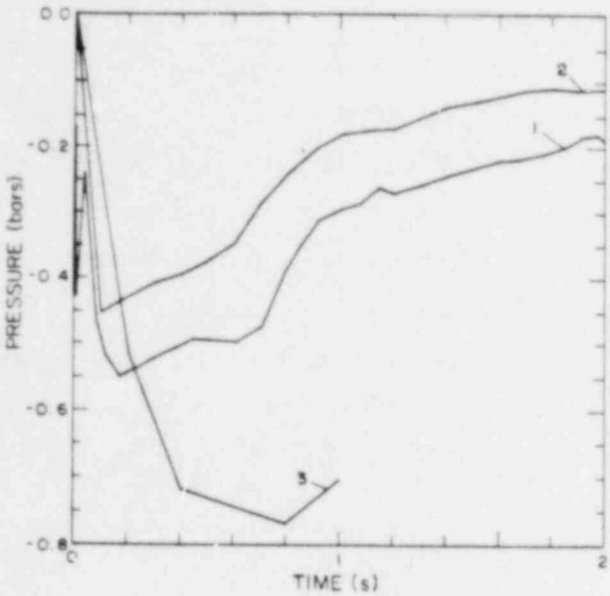


Fig. 8.
Pressure difference comparisons for test C5. Plot (1) is the test result, plot (2) is the COMPARE prediction, and plot (3) is the RELAP3 prediction.

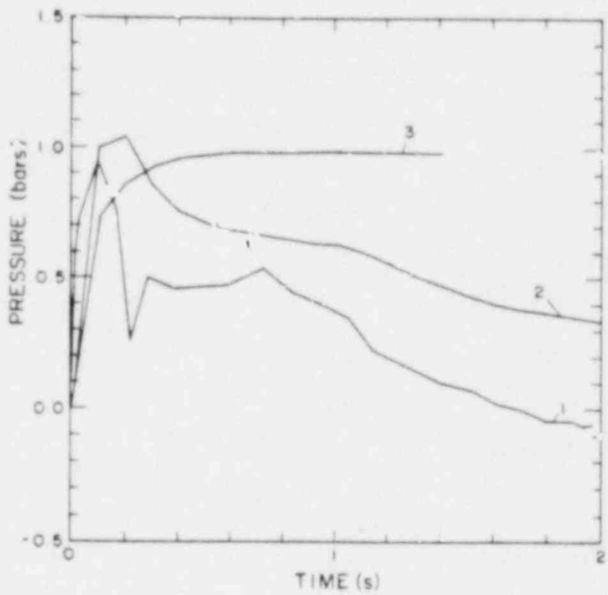


Fig. 9.
Pressure difference comparisons for test C10. Plot (1) is the test result, plot (2) is the COMPARE prediction, and plot (3) is the RELAP3 prediction.

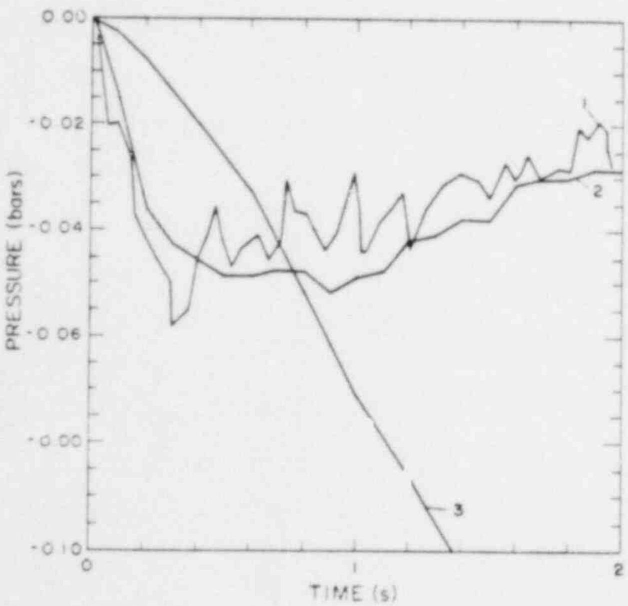


Fig. 10.
Pressure difference comparisons for test C13. Plot (1) is the test result, plot (2) is the COMPARE prediction, and plot (3) is the RELAP3 prediction.

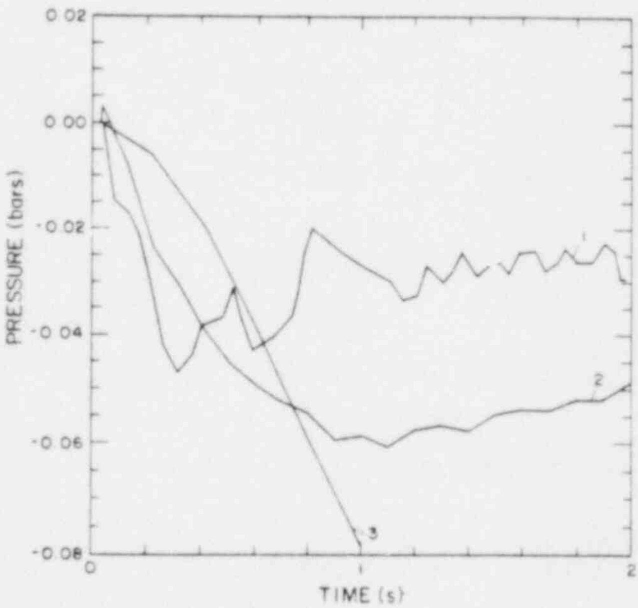


Fig. 11.
Pressure difference comparisons for test C15. Plot (1) is the test result, plot (2) is the COMPARE prediction, and plot (3) is the RELAP3 prediction.

E. Discussion of COMPARE, RELAP3, and Test Comparison

1. Absolute Pressure. Absolute pressures calculated by RELAP3 at the end of 2 s always tended to be higher than both COMPARE and the test data for the blowdown subcompartments. However, at 2 s the RELAP3 pressures were generally lower than both COMPARE values and the test data for the containment subcompartment (R9). The only exception was test C5. On the other hand, COMPARE was always higher than the test data for both the blowdown and containment subcompartments. At 0.2 s in the blowdown subcompartments, the absolute pressure predicted by COMPARE was always higher than the test data, whereas RELAP3 was slightly lower in one of the tests.

2. Pressure Differences. The maximum pressure differences predicted by COMPARE and RELAP3 are generally higher than the test data. An exception to this was test C5 for both codes, possibly because digitized data were available for test C5. COMPARE was lower for R4-R6 and R1-R4, whereas RELAP3 was lower for only R1-R4. RELAP3 generally gave larger maximum pressure differentials than COMPARE when the differential involved the blowdown subcompartment.

The R4-R6 plots indicate that COMPARE follows the experimental data quite well. This was also indicated in Table VI, where the time of maximum pressure difference compares well with the test data. The only exception was test C15. However, the RELAP3 results did not follow the R4-R6 test data; furthermore, the maximum times were not close. The time for maximum pressure differential tended to be later for RELAP3 than for the test data or COMPARE. The exception to this was test C13.

V. NODALIZATION EFFECTS USING COMPARE

A. Subcompartment Isometric Views

The drawing shown in Fig. 1 was used to generate isometric views of each subcompartment volume (Figs. 12--20). Location of the subcompartment connections was mandatory before proper nodalization could be done. The isometric views show the relative location of the standard connection used in tests C1, C8, C9, C10, and C13.

B. Subcompartment Nodalization

All of the subcompartments were subdivided into at least two parts (R9) and into as many as 20 parts (R3). A total of 56 volumes with 75 connections resulted. For comparison, the basic nonnodalized model had 9 subcompartments

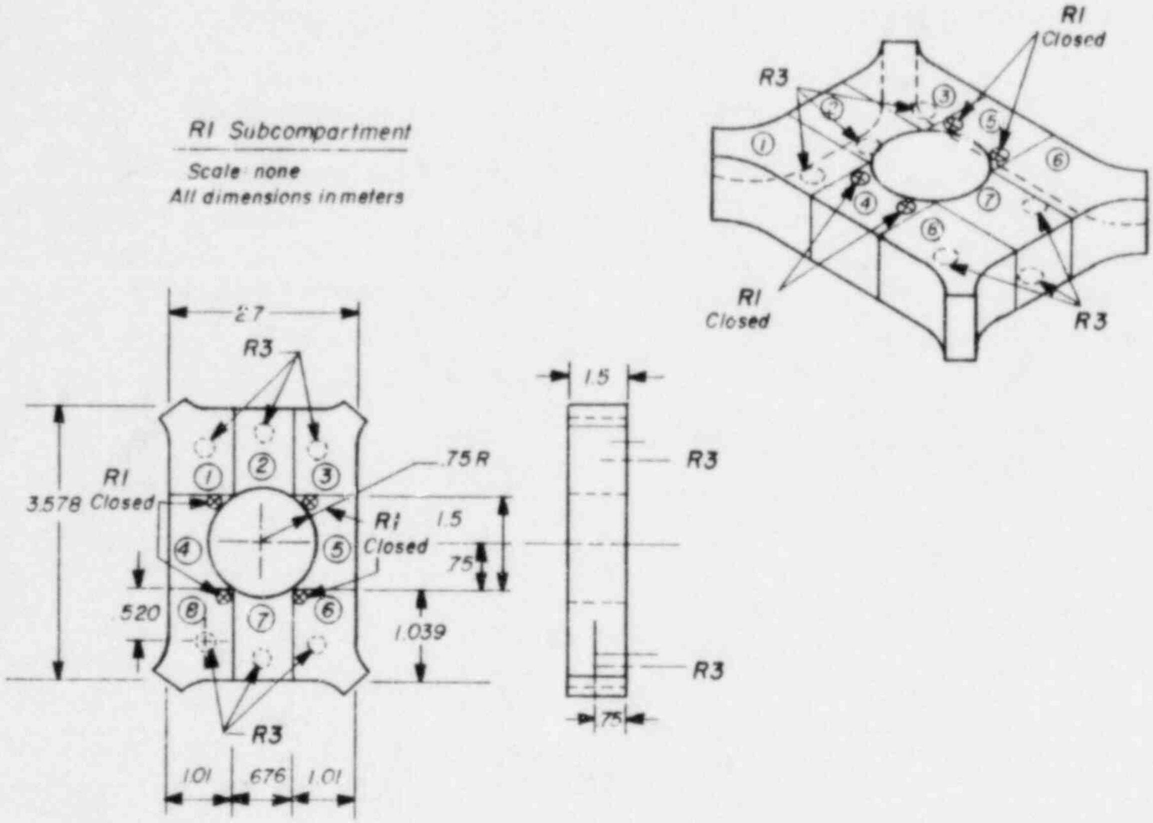


Fig. 12.
Isometric view and dimensional drawings of subcompartment Rl.

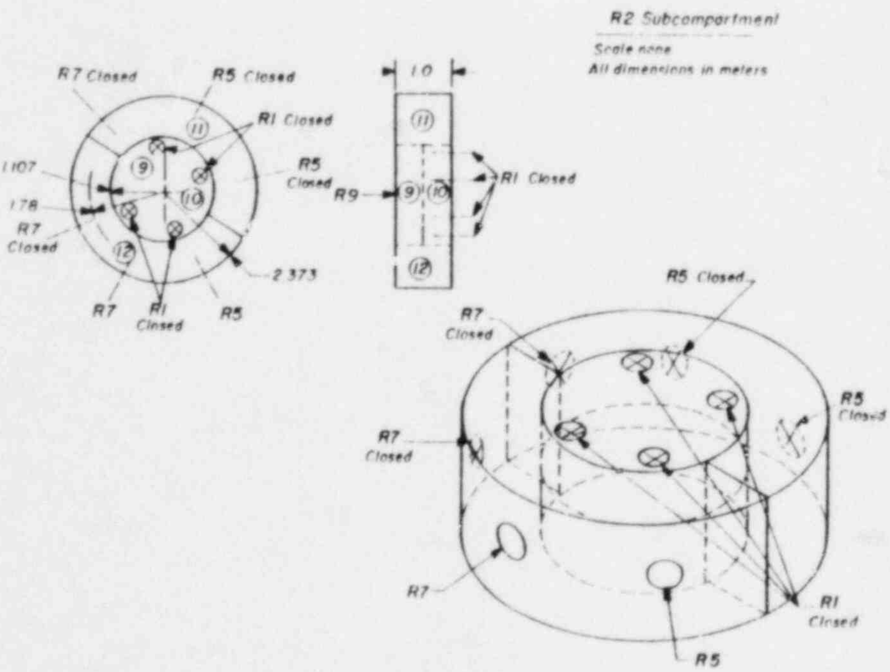


Fig. 13.
Isometric view and dimensional drawings of subcompartment R2.

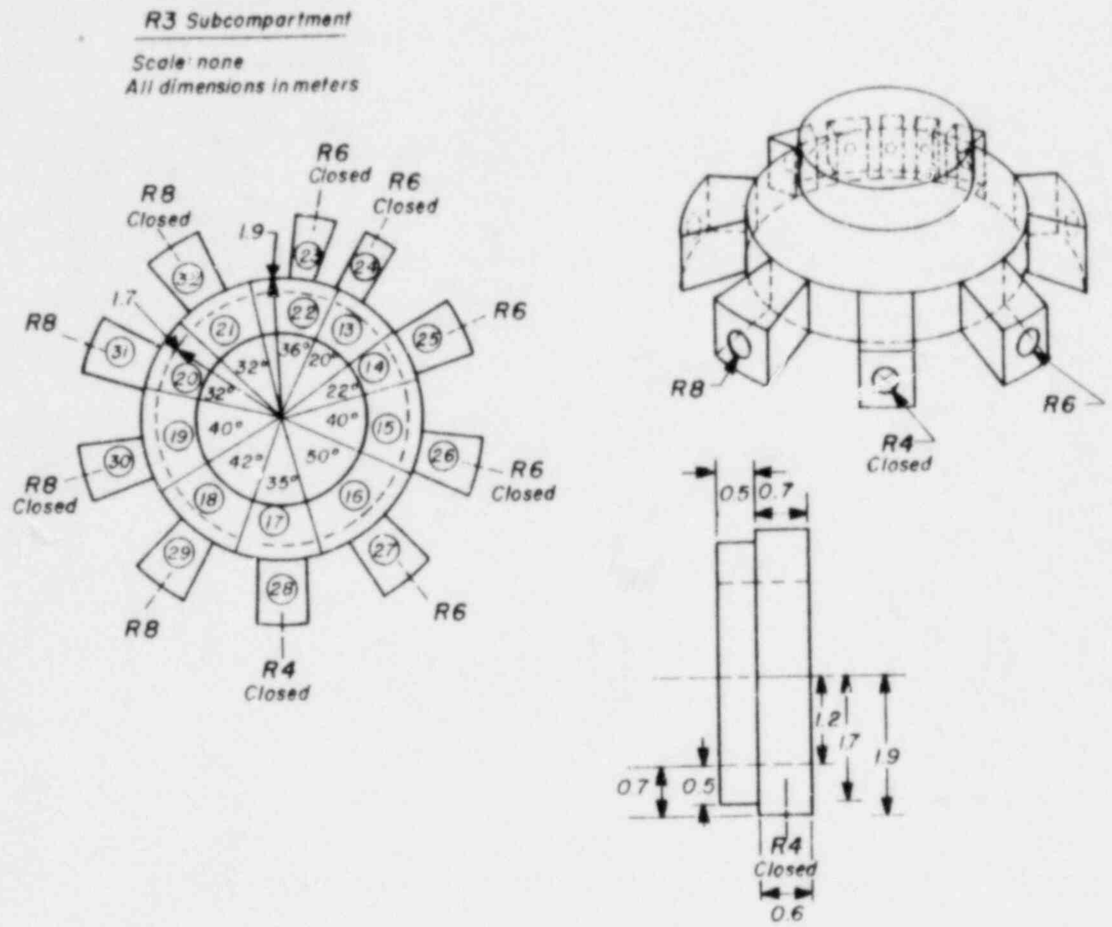


Fig. 14.
Isometric view and dimensional drawings of subcompartment R3.

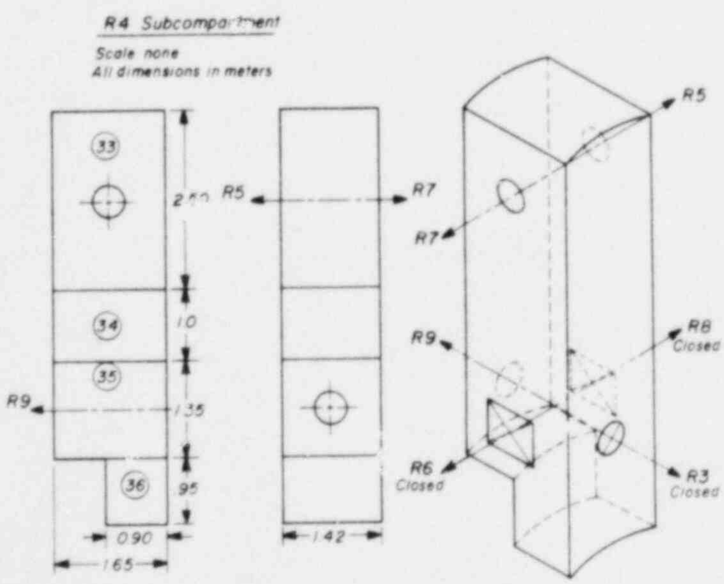


Fig. 15.
Isometric view and dimensional drawings of subcompartment R4.

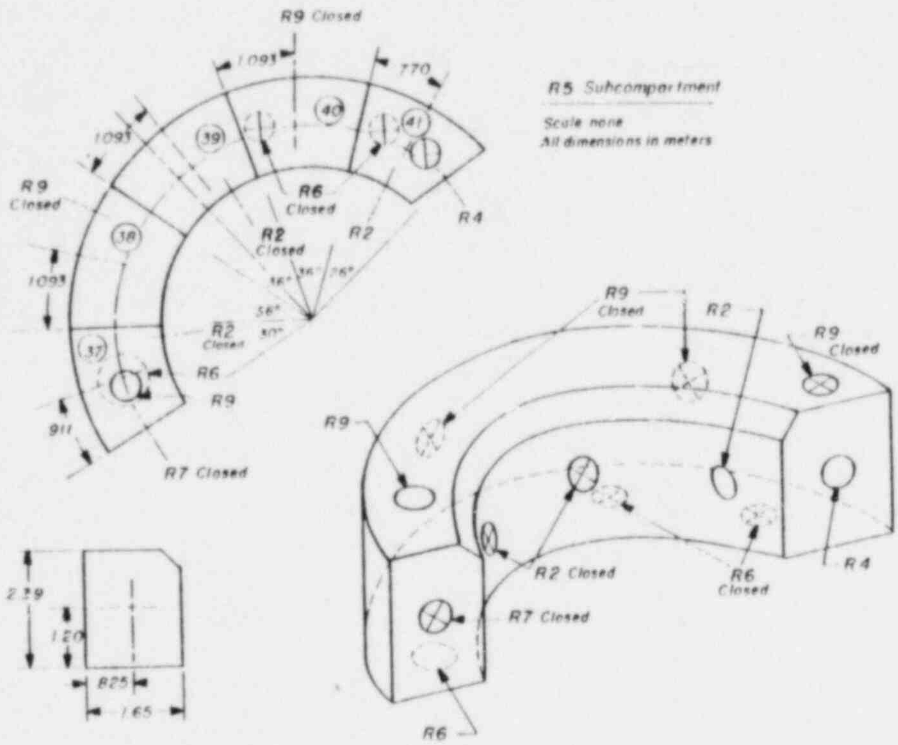


Fig. 16.
Isometric view and dimensional drawings of subcompartment R9.

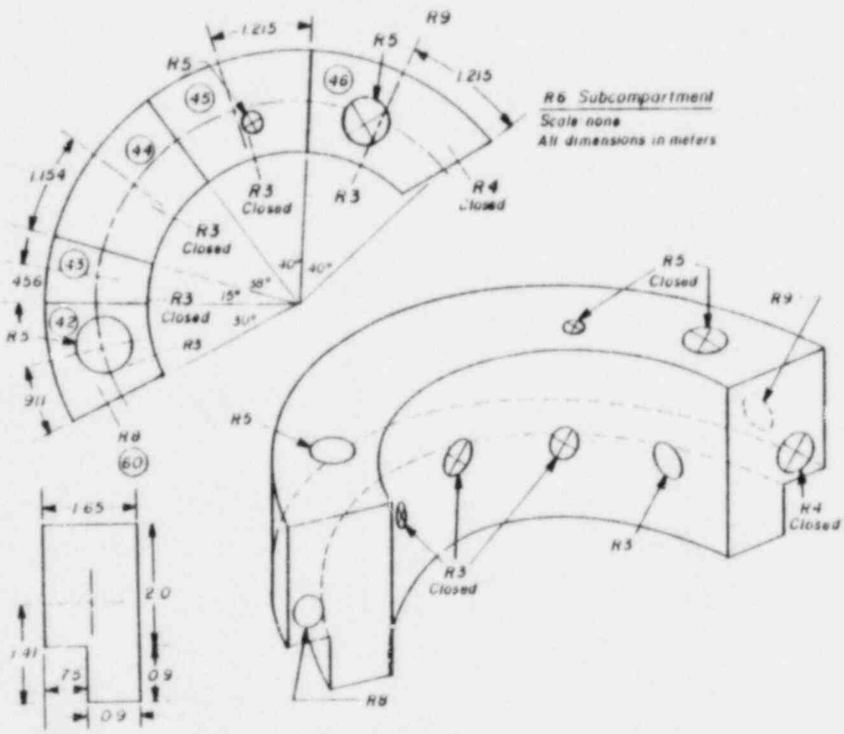


Fig. 17.
Isometric view and dimensional drawings of subcompartment R6.

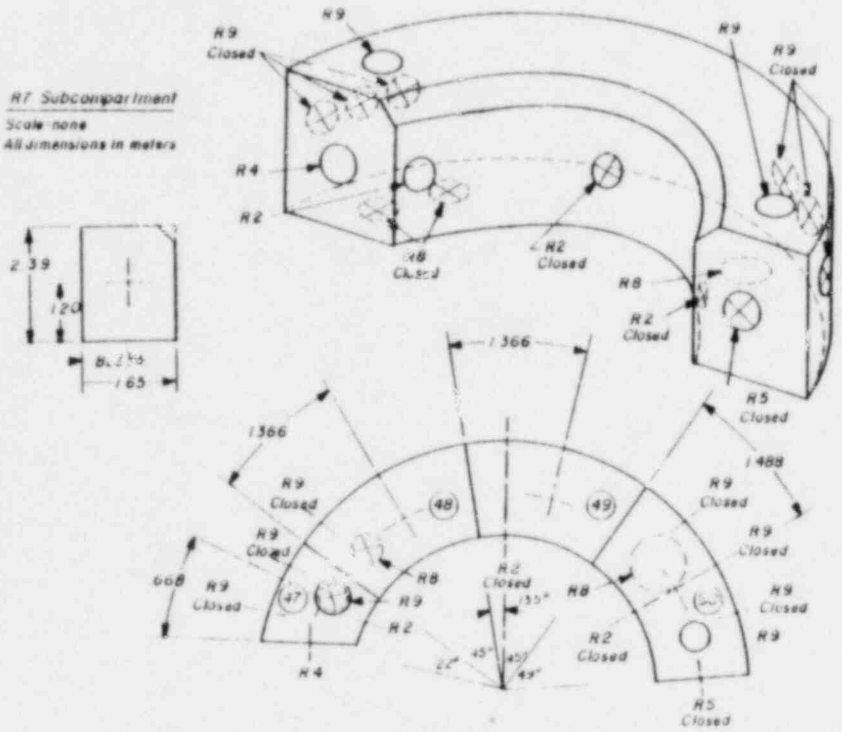


Fig. 18.
Isometric view and dimensional drawings of subcompartment R7.

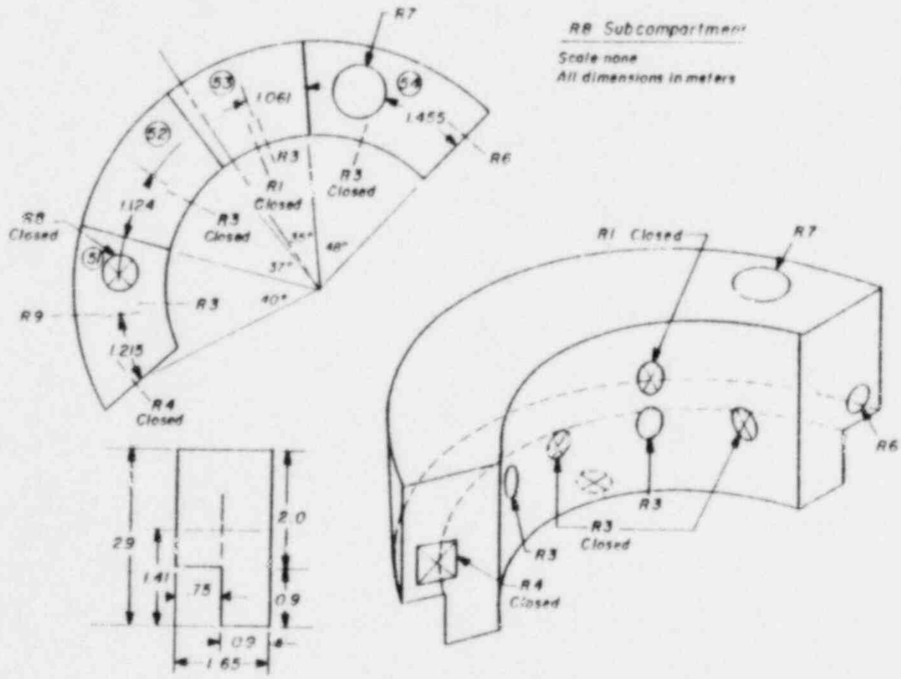


Fig. 19.
Isometric view and dimensional drawings of subcompartment R8.

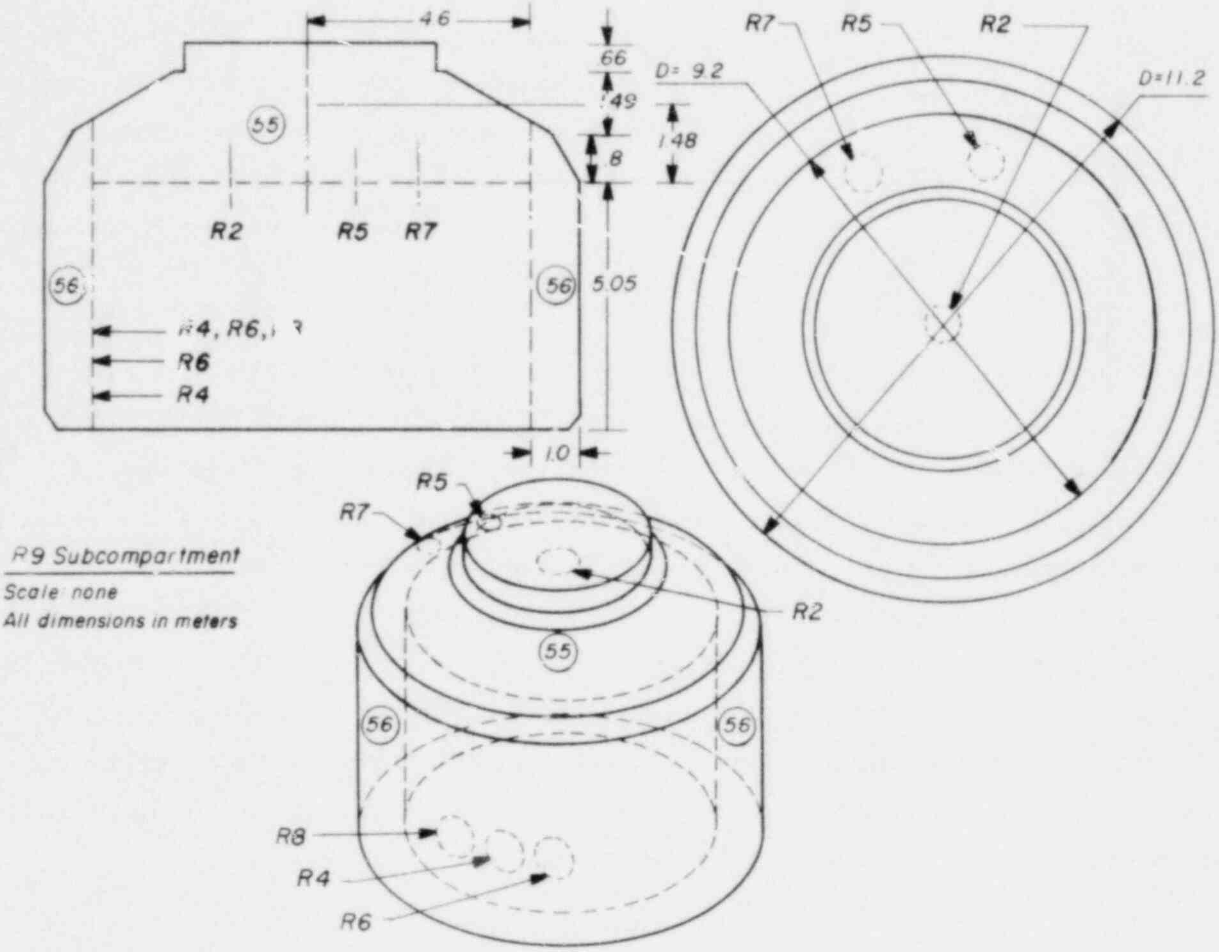


Fig. 20.
Isometric view and dimensional drawings of subcompartment R9.

and 22 connections. The nodalization of each subcompartment is shown in Figs. 12--20, where node numbers are circled. Table VII contains the calculated volume for each node.

The connections between subcompartments (for the standard connection), cross-sectional area, and the inertia terms are contained in Table VIII.

C. Tests Selected for Nodalization Studies

Tests C5, C6, C13, and C15 were selected for nodalization studies. The bases for using C5, C13, and C15 were essentially the same as described in

TABLE VII

VOLUME OF NODES

Node	Volume (m^3)	Node	Volume (m^3)	Node	Volume (m^3)
1	1.574	22	0.705	43	3.710
2	1.054	23	0.168	44	9.400
3	1.574	24	0.168	45	9.850
4	1.712	25	0.259	46	9.850
5	1.712	26	0.259	47	5.380
6	1.574	27	0.259	48	1.105
7	1.054	28	0.259	49	1.105
8	1.574	29	0.259	50	1.201
9	2.213	30	0.259	51	9.870
10	2.213	31	0.259	52	9.140
11	6.632	32	0.259	53	8.650
12	6.632	33	5.780	54	1.186
13	0.588	34	2.310	55	132.260
14	0.431	35	3.120	56	235.160
15	0.783	36	1.190		
16	0.979	37	7.362		
17	0.685	38	8.872		
18	0.823	39	8.872		
19	0.783	40	8.872		
20	0.626	41	6.382		
21	0.626	42	7.410		

previous sections. Test C6 was included because an orifice connection to R5 near the break point was closed and another orifice was opened at the opposite end of the blowdown subcompartment (R6). Subcompartment R6 was examined to determine the effect on the pressure gradient in R6 of moving this connection.

D. Comparison of Nodalized, Nonnodalized, and Test Data

Table IX contains absolute pressure and pressure difference results at selected locations and times for both nodalized and nonnodalized models using COMPARE. The absolute pressure for the nodalized results shown in Table IX was the highest pressure observed in the subcompartment. The test data are also listed for comparison.

E. Discussion of Nodalization Effects

The essential conclusion regarding nodalization in the C-Series tests is that there is little or no change in the results through nodalization. The pressures in the blowdown volumes are the same, although there is a slight change in the other volumes (R4 in Table IX).

TABLE VIII

CONNECTIONS, CROSS-SECTIONAL AREA, AND INERTIA TERMS

Connection Number	Nodes 1	Nodes 2	L/A (m^{-1})	A (m^2)	Connection Number	Nodes 1	Nodes 2	L/A (m^{-1})	A (m^2)	Connection Number	Nodes 1	Nodes 2	L/A (m^{-1})	A (m^2)
1	1	22	3.000	0.066	26	29	51	0.880	0.102	51	33	34	0.758	2.310
2	2	13	3.640	0.066	27	31	53	0.900	0.102	52	34	35	0.509	2.310
3	3	15	2.910	0.066	28	13	14	0.769	0.704	53	35	36	0.669	1.260
4	6	17	3.020	0.066	29	13	24	1.650	0.210	54	37	42	3.382	0.817
5	7	18	2.810	0.066	30	14	15	1.134	0.740	55	37	55	1.626	0.238
6	8	19	2.910	0.066	31	14	25	1.204	0.360	56	37	38	0.496	4.040
7	1	2	0.541	1.559	32	15	16	1.645	0.740	57	38	39	0.541	4.040
8	1	4	0.894	1.515	33	15	26	0.984	0.360	58	39	40	0.541	4.040
9	2	3	0.541	1.599	34	16	17	1.553	0.740	59	40	41	0.466	4.040
10	3	5	0.894	1.515	35	16	27	0.930	0.360	60	42	54	1.804	0.283
11	5	6	0.894	1.515	36	17	18	1.407	0.740	61	46	56	1.354	0.118
12	6	7	0.541	1.559	37	17	28	2.297	0.283	62	42	43	0.328	4.170
13	4	8	0.894	1.515	38	18	19	1.499	0.740	63	43	44	0.386	4.170
14	7	8	[illegible]	1.559	39	18	29	[illegible]	0.330	64	44	45	0.568	4.170
15	[illegible]	41	1.540	0.010	40	19	20	1.316	0.740	65	45	46	0.583	4.170
16	[illegible]	47	1.580	0.010	41	19	30	1.039	0.330	66	50	54	2.464	0.785
17	[illegible]	[illegible]	0.113	4.426	42	20	21	1.170	0.740	67	50	55	1.075	0.238
18	9	11	0.850	1.865	43	20	31	1.106	0.330	68	47	48	0.496	4.040
19	9	12	0.850	1.865	44	21	22	1.243	0.740	69	48	49	0.661	4.040
20	10	[illegible]	0.850	1.865	45	21	32	1.106	0.330	70	49	50	0.699	4.040
21	10	12	0.850	1.865	46	13	22	1.024	0.740	71	51	56	0.588	0.118
22	11	12	4.715	2.372	47	22	23	1.352	0.240	72	51	52	0.561	4.170
23	9	55	3.140	0.053	48	33	41	0.834	0.276	73	52	53	[illegible]	4.170
24	25	44	0.834	0.102	49	33	47	0.804	0.276	74	53	54	[illegible]	4.170
25	27	46	0.828	0.102	50	35	56	1.500	0.059	75	55	56	0.325	23.120

TABLE IX

COMPARISON OF NODALIZED AND NONNODALIZED COMPARE RESULTS WITH TEST DATA

Parameter	C5 (R6)	C10 (R4)	C13 (R1)	C15 (R1)
	Test (Blowdown Location)			
1. Absolute Pressure in Blowdown Subcompartment at 0.2 s, bar				
A. Test Data	1.60	1.75	2.80	4.10
B. Nonnodalized COMPARE	1.73	1.74	3.44	5.11
C. Nodalized RELAP3	1.72	1.76	3.40	5.08
2. Absolute Pressure in R4 at 0.2 s, bar				
A. Test Data	1.10	1.26	1.05	1.10
B. Nonnodalized COMPARE	1.30	1.28	1.09	1.06
C. Nodalized RELAP3	1.30	1.29	1.13	1.11
3. R - R4 Pressure Difference at 0.2 s, bar				
A. Test Data	1.23	----	2.30	3.25
B. Nonnodalized COMPARE	0.06	0.01	2.36	4.05
C. Nodalized RELAP3	0.07	0.01	2.27	3.93
4. R4 - R6 Pressure Difference at 0.2 s, bar				
A. Test Data	-0.55	-0.55	-0.04	-0.03
B. Nonnodalized COMPARE	-0.43	-0.46	-0.04	[illegible]
C. Nodalized RELAP3	-0.42	-0.43	-0.04	-0.02

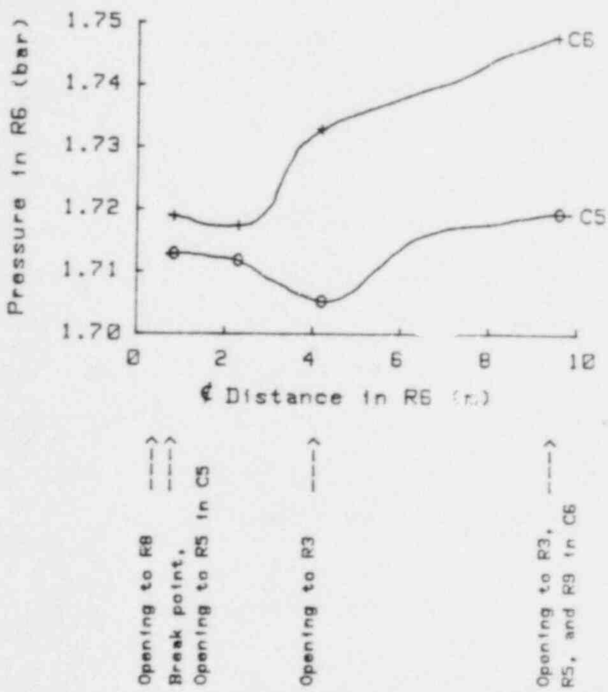


Fig. 21.
Pressure distribution at 0.2 s in R6 for tests C5 and C6.

Figure 21 is a plot of the pressure distribution in R6 for tests C5 and C6. Movement of the large opening to R5 away from the break point, as was done in C6, causes a definite pressure gradient to be created within the subcompartment. Connection of the compartments in series could yield differences between nonnodalized and nodalized results. This is indicated in Table VIII by tests C13 and C15. With the blowdown in R1, the major flow reaches R4 by passing through R3, R6, and R5. As shown in Table VIII, there is a slight difference between the nonnodalized and nodalized results for R4 in tests C13 and C15.

VI. HOMOGENEOUS EQUILIBRIUM MODEL

A. Methodology

The maximum critical flow between subcompartments has a direct influence on the pressures predicted within the various subcompartments. To determine this relation, experiment C15 was simulated using a COMPARE code altered so that critical flow was based on the HEM[5] rather than the Moody model.[4] This was accomplished by circumventing subroutine Moody in the code. The results of this simulation are shown in Figs. 22--24.

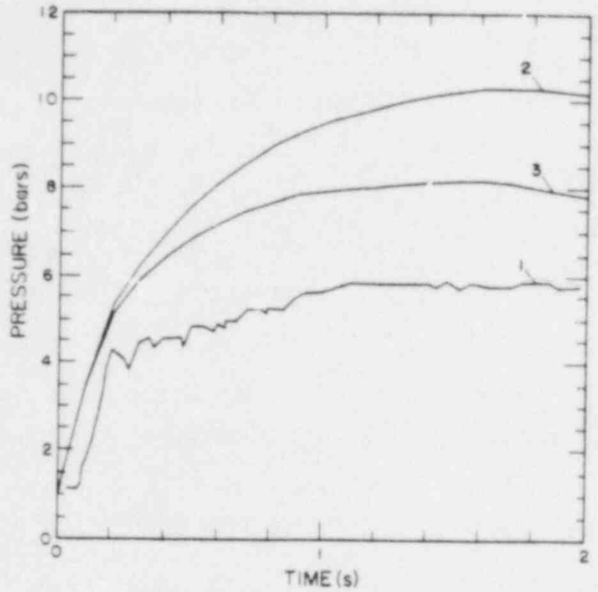


Fig. 22.
Pressure in subcompartment R1 in test C15 using the homogeneous equilibrium model (HEM) in the COMPARE code. Plot (1) is the test result, plot (2) is the Moody model, and plot (3) is the HEM.

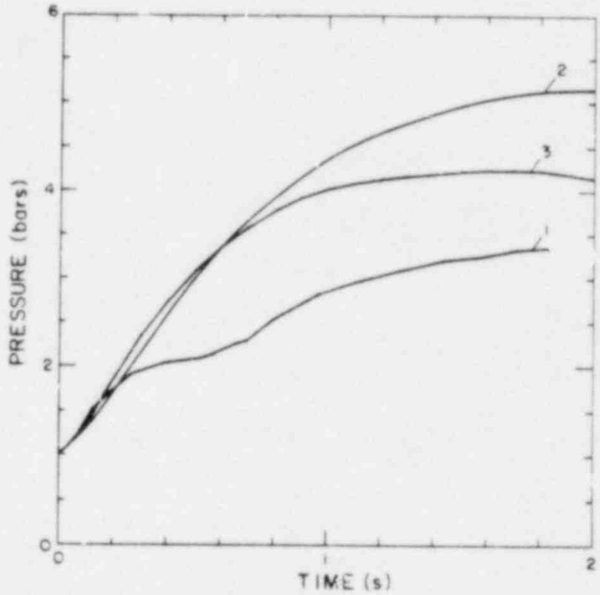
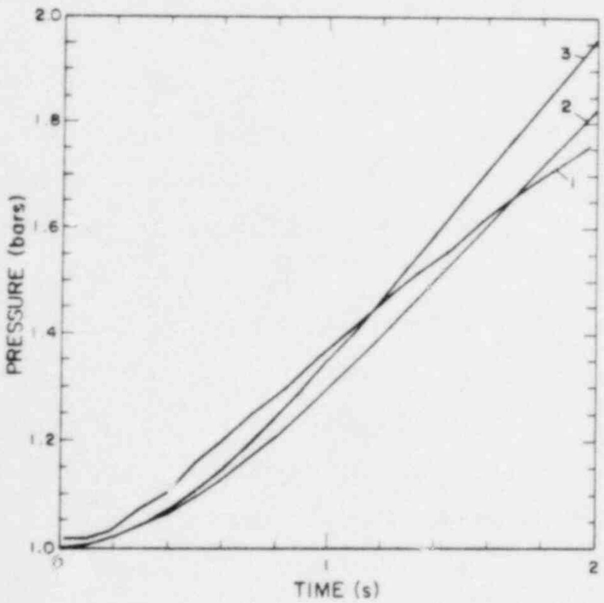


Fig. 23.
Pressure in subcompartment R3 in test C15 using the homogeneous equilibrium model (HEM) in the COMPARE code. Plot (1) is the test result, plot (2) is the Moody model, and plot (3) is the HEM.



B. Discussion of Results

The effect of the HEM on pressure trends is different for the various subcompartments and appears to be a function of distance from and connections to the blowdown subcompartment (R1). This effect on pressure for the blowdown subcompartment is a uniform decrease in the

Fig. 24.
Pressure in subcompartment R9 in test C15 using the homogeneous equilibrium model (HEM) in the COMPARE code. Plot (1) is the test result, plot (2) is the Moody model, and plot (3) is the HEM.

pressure for the entire simulation period as shown in Fig. 22. HEM can thus be seen to bring the simulated pressures closer to the experimental results for this subcompartment.

The effect of the HEM on the pressures in subcompartment R3, which is directly connected to the blowdown subcompartment, is different from the effect on the blowdown subcompartment. As may be seen in Fig. 23, the pressures for the HEM are also closer to the experimental pressures. However, the HEM results in increased pressures for the first 0.6 s of simulation.

For the outer containment (R9), the pressures are close for all three cases, as shown in Fig. 24. However, the effective trend of the HEM is reversed from that for the blowdown subcompartment (that is, the pressures are increased by the HEM). Where the HEM underpredicts experimental pressures for the first 1.15 s, the Moody calculation underpredicts pressures for the initial 1.70 s.

VII. PARAMETER STUDIES

A. Moody Multiplier (MM) Effects

1. Methodology. Another somewhat arbitrary consideration that affects the pressures predicted for the various subcompartments is the MM correction for two-phase flow through the connections. Therefore a parametric study varying the MM was made. For this study, tests C5, C10, C13, and C15 were chosen for reasons stated in previous sections.

The MM for the blowdown subcompartment connections (designated BMM) was fixed at 0.4, 0.6, 0.8, and 1.0, while the MM for the other connection (designated OMM) was varied over the same range of values. The comparison of the experimental results with the calculated results produced Figs. C1--C48, which are summarized in Table X. Representative subcompartments were chosen for the comparisons to be the blowdown (subcompartment R1, R6, or R4), the outer containment (R9), and a subcompartment adjacent to the break (R3, R4, or R5).

2. Discussion of Results. Some general conclusions can be drawn from analysis of these figures. In general, the pressures in the blowdown subcompartments seem to be fairly insensitive to the OMM, but the trend is toward increasing sensitivity with increasing BMM. Also, the pressure in the blowdown volume is inversely related to both BMM and OMM. This is also true for the other subcompartments. Finally, the trend is toward decreasing sensitivity to

TABLE X

SUMMARY TABLE OF MOODY MULTIPLIER STUDY FIGURES

Blow-down Moody Mult.	Description of Subcompartment	C5 Fig. No.	Sub-compartment No.	C10 Fig. No.	Sub-compartment No.	C13 Fig No.	Sub-compartment No.	C15 Fig. No.	Sub-compartment No.
0.4	← Blowdown → Sub-compartment	C-1	6	C-13	4	C-25	1	C-37	1
0.6		C-2	↓	C-14	↓	C-26	↓	C-38	↓
0.8		C-3	↓	C-15	↓	C-27	↓	C-39	↓
1.0		C-4	↓	C-16	↓	C-28	↓	C-40	↓
0.4	← Adjacent→ to Blowdown	C-5	4	C-17	5	C-29	3	C-41	3
0.6		C-6	↓	C-18	↓	C-30	↓	C-42	↓
0.8		C-7	↓	C-19	↓	C-31	↓	C-43	↓
1.0		C-8	↓	C-20	↓	C-32	↓	C-44	↓
0.4	← Outer → Con-tainment	C-9	9	C-21	9	C-33	9	C-45	9
0.6		C-10	↓	C-22	↓	C-34	↓	C-46	↓
0.8		C-11	↓	C-23	↓	C-35	↓	C-47	↓
1.0		C-12	↓	C-24	↓	C-36	↓	C-48	↓

the MM as the distance from the blowdown subcompartment is increased. The outer containment is the subcompartment that is the most insensitive to variation of the BMM and OMM.

Qualitatively, the MM that yields pressures closest to experimental tests is for BMM and OMM equal to 0.8 in contrast to the default of 0.6.

B. Entrainment Effects

1. Methodology. Another factor that is not taken into account in the COMPARE code is the possibility of less than complete entrainment of liquid water within the various subcompartments. This can easily be included in the code by varying the entrainment in the junctions between the subcompartments.

To demonstrate the definition of entrainment use, consider a junction from an upstream source subcompartment whose mass is 60% air, 30% steam, and 10% liquid water. If the total flow calculated for this junction is 1000 kg/s and the entrainment is 1.0, there will be a liquid water mass flow rate of 100 kg/s. If the entrainment is 0.5, there will be a liquid water mass flow rate of only 50 kg/s and a total mass flow rate of 950 kg/s.

As in the case of the MM, it is reasonable to vary the entrainment values for the junctions from the blowdown subcompartment (BEN) independently of the other junctions (OEN). Again C5, C10, C13, and C15 were chosen as representative tests, and the same blowdown, adjacent to blowdown, and outer containment subcompartments were chosen for application of the entrainment variation. The entrainment for the junctions connecting the blowdown subcompartment to the

TABLE XI

SUMMARY TABLE OF ENTRAINMENT STUDY FIGURES

Blowdown Entrainment Value	Description of Subcompartment	Sub-compartment No.	Fig. No. for C5	Sub-compartment No.	Fig. No. for C10	Sub-compartment No.	Fig. No. for C13	Sub-compartment No.	Fig. No. for C15
0.5	Breakdown Subcompartment	6	D-1	4	D-13	1	D-25	1	D-37
0.7			D-2		D-14		D-26		D-38
0.9			D-3		D-15		D-27		D-39
1.0			D-4		D-16		D-28		D-40
0.5	Subcompartment Adjacent to Blowdown	4	D-5	5	D-17	3	D-29	3	D-41
0.7			D-6		D-18		D-30		D-42
0.9			D-7		D-19		D-31		D-43
1.0			D-8		D-20		D-32		D-44
0.5	Outer Containment	9	D-9	9	D-21	9	D-33	9	D-45
0.7			D-10		D-22		D-34		D-46
0.9			D-11		D-23		D-35		D-47
1.0			D-12		D-24		D-36		D-48

rest of the subcompartments was chosen as 0.5, 0.7, 0.9, and 1.0, and entrainment in the other junctions was 0.2, 0.4, and 0.6. The comparison of the experimental results with the calculated results produced Figs. D-1--D-48, which are summarized in Table XI.

2. Discussion of Results. From these results we can see that the pressure in the blowdown subcompartment decreases with increasing BEN and increasing OEN. The pressure in the subcompartment adjacent to the blowdown decreases with increasing OEN and with decreasing BEN, and the pressure in the outer containment decreases with decreasing BEN and OEN.

In summary, the pressures in the blowdown subcompartments are inversely related to BEN and OEN; in the adjacent subcompartment the pressures are inversely related to OEN and directly related to BEN, and the pressures in the outer containment are directly related to BEN and OEN. The most accurate results for the pressure are given by the lowest BEN (0.5) and the highest OEN (0.6).

VIII. TEST RESULTS AND COMPARISON USING DIGITIZED AND NONDIGITIZED BLOWDOWN DATA

At the beginning of this investigation, many of the experimental data were available only in graphical form. Extraction of these data was somewhat tedious, and at times certain simplifying assumptions were made. The data of

TABLE XII

PRESSURES (BAR) USING DIGITIZED DATA

	Tests - (Blowdown Location)			
	C5 (R4)	C10 (R4)	C13 (R1)	C15 (R1)
1. Blowdown room at 0.2 s				
A. Test	1.70	2.10	2.60	4.00
B. COMPARE	1.75	2.43	3.04	5.83
2. Maximum in blowdown room in first 2 s				
A. Test	2.25	2.10	3.60	6.00
B. COMPARE	2.43	2.41	4.36	9.05
3. Maximum in room 9 in first 2 s				
A. Test	1.90	1.65	1.75	1.75
B. COMPARE	2.28	1.93	1.96	2.08

most concern were the blowdown data--mass flow rate and enthalpy. After we had completed most of the investigation, digitized blowdown data became available. Using the digitized data, we recalculated the results for tests C5, C10, C13, and C15. These tests were selected because they were studied in detail in the original studies using the nondigitized data. The results of the analyses based on the digitized data are presented in the sections below. Our purpose in recalculating these tests was to ascertain the effect of the digitized blowdown data on the calculated results and to see whether earlier conclusions were invalid in any way.

A. Selection of Tests for Comparison

We selected tests C5, C10, C13, and C15 for recalculation using digitized blowdown data from a recent USNRC publication.[20] These tests were chosen because they were studied earlier in great detail. The models used for these calculations were exactly the same as those described in Sec. III. Only the COMPARE code is used in recalculation because the effect of using digitized blowdown data should be about the same using either COMPARE or RELAP3.

B. Results Using Digitized Data

Pressure values from COMPARE results and test data for the blowdown rooms and R9 are tabulated in Table XII. These pressure values are for times of 0.2 s and the maximum within the first 2 s. Also shown in Figs. 25--28 are the digitized blowdown pressure vs time plots for COMPARE and the test data.

Pressure difference results are presented in Tables XIII and XIV. Table XIII contains pressure difference values for COMPARE and test data at a time of 0.2 s. The pressure differences are between the blowdown rooms and R9 or R4. R4 was taken as a reference measurement location for many of the tests. Plots of the pressure difference values vs time are shown in Figs. 29--32.

C. Comparison of COMPARE Results With and Without Digitized Blowdown Data

We have compared the COMPARE results for tests C5, C10, C13, and C15 using both assumed and recently available digitized data. Our approach and procedure for obtaining the blowdown data in the absence of digitized data is discussed in Sec. II. The mass flow rate was taken from graphical data, whereas the enthalpy was assumed to be 1.2 MJ/kg (518 btu/lbm).

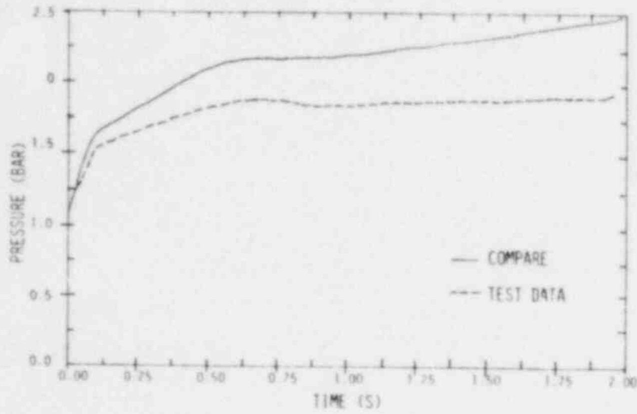


Fig. 25.
Battelle-Frankfurt test C5 subcompartment R6 pressure.

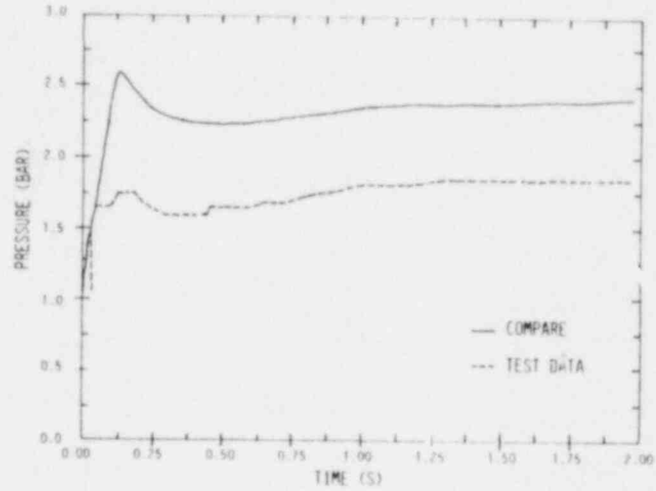


Fig. 26.
Battelle-Frankfurt test C10 subcompartment R4 pressure.

A comparison of the COMPARE results with and without digitized blowdown data is shown in Figs. 33--36. Also shown in these plots are the test data results. The general effect of using the digitized data is an increase in the separation between the COMPARE calculations and the test results. That is, the digitized data give higher subcompartment pressures than our earlier calculations.

We believe that the higher pressures obtained using the digitized data are partially accounted for by the larger enthalpy given with the digitized data.

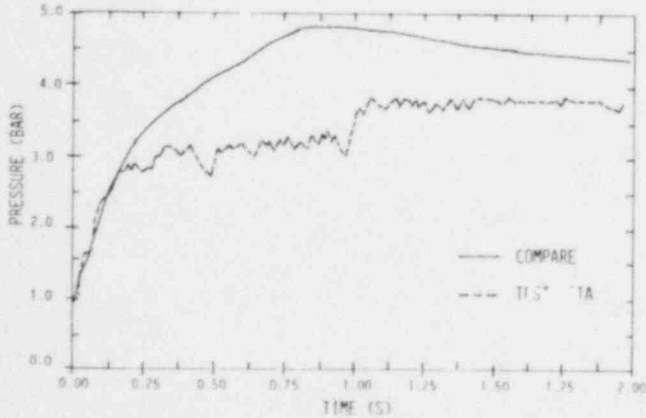


Fig. 27.
Battelle-Frankfurt test C13 subcompartment R1 pressure.

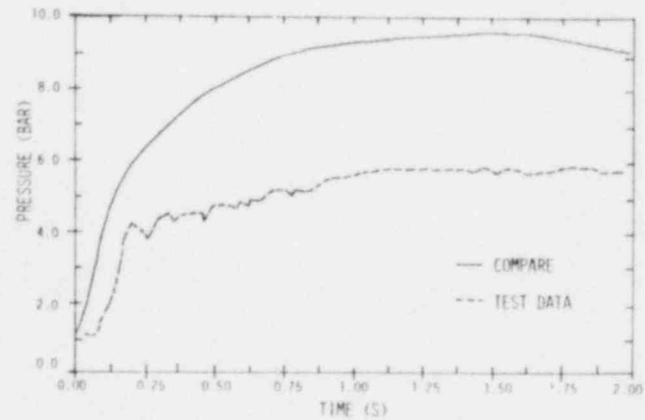


Fig. 28.
Battelle-Frankfurt test C15 subcompartment R1 pressure.

TABLE XIII

PRESSURES DIFFERENCES (BAR) AT 0.2 s USING DIGITIZED DATA

	Tests - (Blowdown Location) C5 (R6)	C10 (R4)	C13 (R1)	C15 (R1)
1. Blowdown - R9				
A. Test	0.50	1.00	2.10	3.20
B. COMPARE	0.65	1.37	2.02	4.80
2. R4 - R6				
A. Test	-0.55	0.75	-0.04	-0.04
B. COMPARE	-0.44	1.24	-0.03	-0.03
3. R1 - R4				
A. Test	0.23	-0.80	2.30	3.30
B. COMPARE	0.06	-1.26	1.97	4.76

TABLE XIV

MAXIMUM PRESSURE DIFFERENCE (BAR)[a] USING DIGITIZED DATA

	Test - (Blowdown Location) C5 (R6)	C10 (R4)	C13 (R1)	C15 (R1)
1. Blowdown - R9				
A. Test	0.56	0.67	2.20	4.40
B. COMPARE	0.79	1.55	3.51	7.94
2. R4 - R6				
A. Test	-0.55	0.95	-0.04	-0.05
B. COMPARE	-0.47	1.47	-0.06	-0.08
3. R1 - R4				
A. Test	0.25	-1.00	2.20	5.00
B. COMPARE	0.11	-1.49	3.24	7.62

[a]Times of occurrence approximately the same.

The digitized enthalpies are approximately 10% higher than the previously assumed values.

However, because the pressure differences indicate a slightly larger difference (15%--20%) than that explained by the enthalpy differences (10%), we examined the mass flow-rate data. Table XV shows a comparison of the integrated mass flow for the digitized and nondigitized data. Integrations from 0 to 0.2 s and from 0 to 2 s are shown. The values shown in Table XV of the digitized and nondigitized mass flow rates are close. The only exception is C13 for the 0--0.2 s interval. This explains why the nondigitized pressures were higher between 0 and 0.2 s as shown in Fig. 35. However, in general, the only difference seems to be due to the higher enthalpies given in the digitized data.

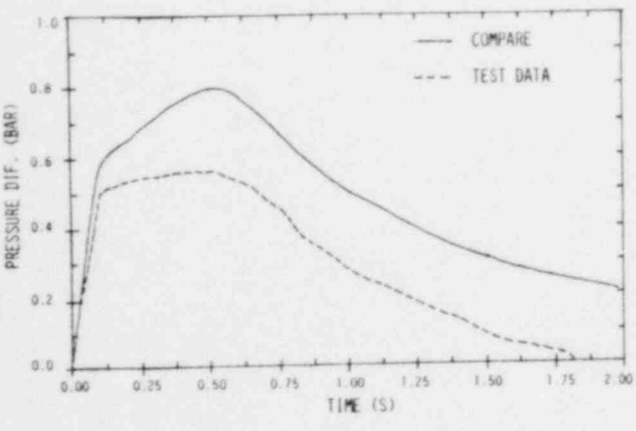


Fig. 29.
Battelle-Frankfurt test C5 for subcompartment R6 to R9 pressure difference.

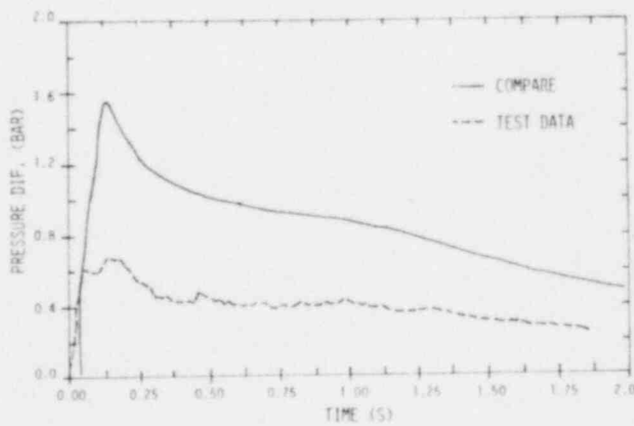


Fig. 30.
Battelle-Frankfurt test C10 for subcompartment R4 to R9 pressure difference.

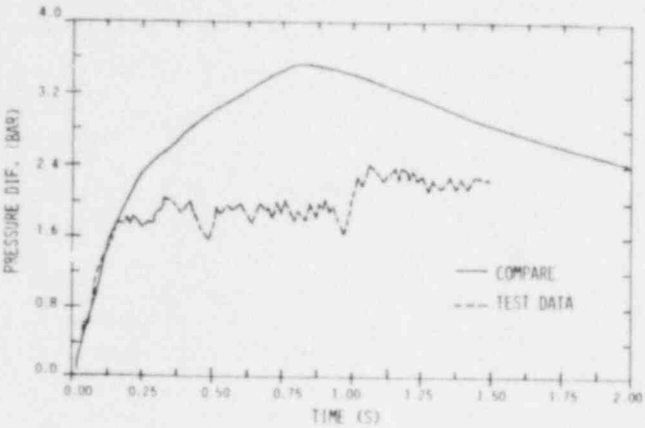


Fig. 31.
Battelle-Frankfurt test C3 for subcompartment R1 to R9 pressure difference.

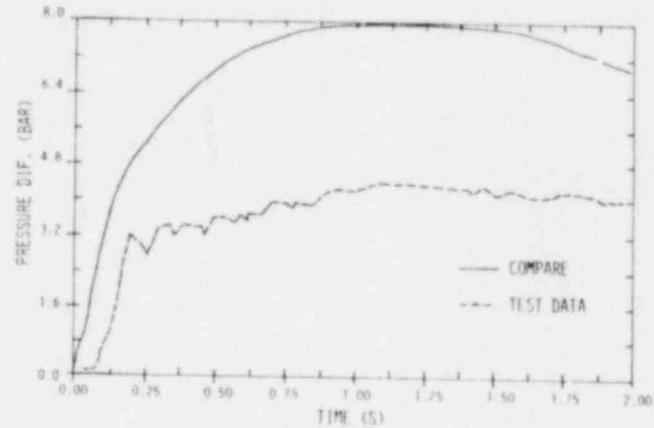


Fig. 32.
Battelle-Frankfurt test C15 for subcompartment R1 to R9 pressure difference.

We believe that, in general the conclusions drawn on the basis of nondigitized blowdown data are still valid.

IX. SUMMARY

Results calculated with the COMPARE and RELAP3 subcompartment analysis codes have been compared with the Battelle-Frankfurt C-Series test results.

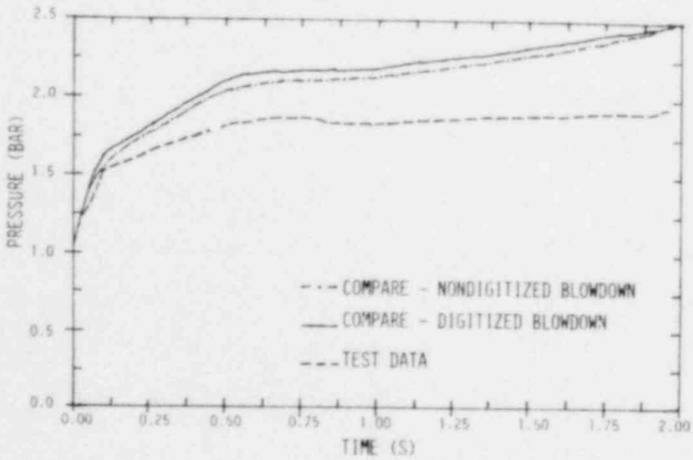


Fig. 33.
Test C5 pressure in R6 using digitized and nondigitized blowdown data with comparison to test data.

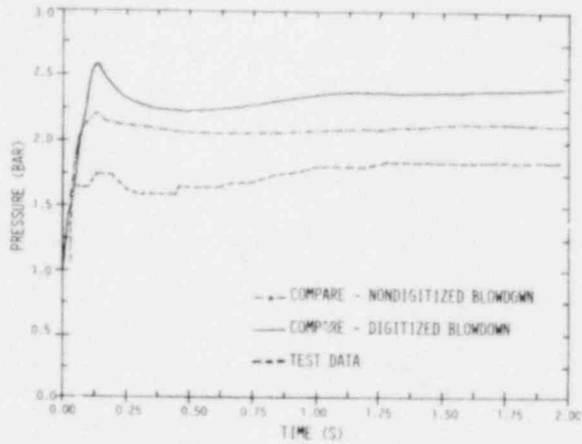


Fig. 34.
Test C10 pressure in R4 using digitized and nondigitized blowdown data with comparison to test data.

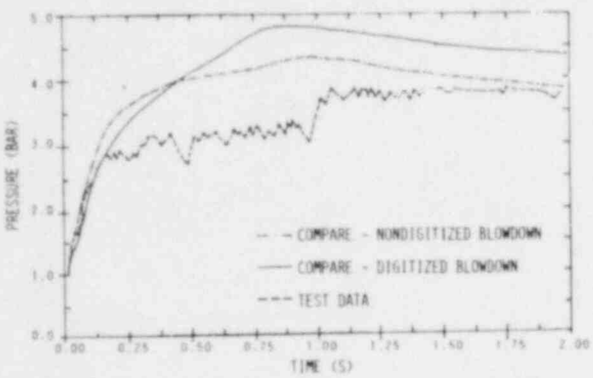


Fig. 35.
Test C13 pressure in R1 using digitized and nondigitized blowdown data with comparison to test data.

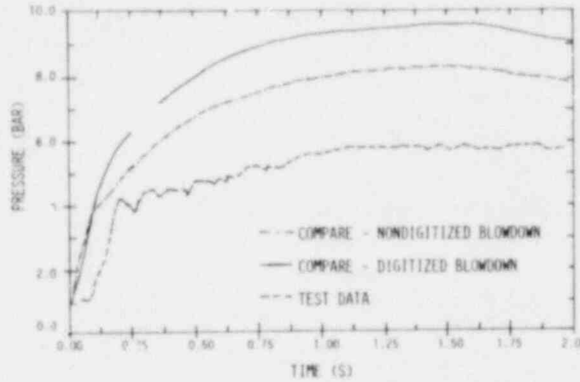


Fig. 36.
Test C15 pressure in R1 using digitized and nondigitized blowdown data with comparison to test data.

The comparisons have been made for 12 of the 16 tests for which information was available. Table XVI contains a summary of the 12 tests analyzed. The table identifies those tests where critical flow can be expected. All of the C-Series tests except C1, C2, and C5 indicated potential for critical flow from COMPARE results or the test data. The C-Series tests that offer reactor cavity similiarity are also identified in Table XVI. These are C3, C7, C8, C13, C14, and C15.

All of the 12 tests were analyzed using a basic model for COMPARE and RELAP3. Possible inertia was neglected, and the 0.6 MM was used to impose the critical flow limit.

Table XVI concentrates on comparisons at an arbitrary 0.2 s for absolute pressure comparisons. Absolute pressures in the blowdown and containment subcompartments are presented. Maximum pressure differentials are presented for blowdown-R9, R4-R6, and R1-R4 subcompartments.

Additional parameter studies were performed using the COMPARE code. Results from variation in nodalization, MM, and entrainment were compared with the test data for tests C5, C10, C13, and C15. The homogeneous equilibrium model was also evaluated for test C15.

A comparison of the use of digitized and nondigitized blowdown data was included in Sec. VIII. The principal difference in the results seems

TABLE XV

INTEGRATED MASS FLOW AT 0.2 s AND 2 s FOR THE DIGITIZED AND NON-DIGITIZED DATA

	0—0.2 s		0—2 s	
Test	Digitized Mass Flow (kg)	Nondigitized Mass Flow (kg)	Digitized Mass Flow (kg)	Nondigitized Mass Flow (kg)
C5	115	125	913	996
C10	85	81	678	666
C13	69	98	755	801
C15	121	172	1020	1018

TABLE XVI

SHORT TIME (≤ 2 s) SUMMARY OF BATTELLE-FRANKFURT C-SERIES TESTS

TEST PARAMETERS	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	
I. Compartment Connections[a]	Standard	Open 25	Open 23	Data not available	Open 46 23	Open 54 Closed 55	Data not available	Standard	Standard	Standard	Closed 4 5 Open 34 25 26 27 Varied 19 14	Closed 4 5 Varied 15 1	Standard	Data not available	Closed 44 42 41	
II. Blowdown Characteristics																
A. Location (compartment)	6	6	1	6	6	6	6	10	4	4	2	2	1	1	1	9
B. Single (s) or double (d) break	s	s	s	s	d	d	s	s	s	s	s	s	d	s	d	s
C. Initial blowdown pressure, bar	141	125	140	129	121	132	141.5	141	119	140.5	140.5	140.5	141	139.5	135.5	135.5
D. 2 s integrated mass, kg																
1) Pipeline	---	---	---		549	614			---	---	---	---	447		522	
2) Buffer Bottle	522	741	459		447	414			659	666	551	750	354		496	
3) Total	522	741	459		996	1028		121.19	659	666	551	750	801		1018	
III. Critical Flow (from blowdown volume)																
A. Experimental Data[b]	NA[c]	NA	NA		Yes	Yes			Yes	Yes	Yes	Yes	Yes		Yes	
B. COMPARE Results	No	No	Yes		No	Yes			Yes	Yes	Yes	Yes	Yes	Yes	Yes	
IV. Reactor Cavity Similarity	No	No	Yes	?	No	No	Yes	Yes	No	No	No	No	Yes	Yes	Yes	No
V. Maximum Absolute Pressure in Blowdown Compartments, bar																
A. Experimental Data	1.80[d]	1.70[d]	1.90[d]	DATA NOT ANALYZED	2.25	1.80		1.44	1.75	2.00	2.10	1.80	3.80		5.80	DATA NOT ANALYZED
B. COMPARE	1.69	2.03	2.68		2.49	2.82		1.38	2.34	2.27	2.01	2.62	4.37		8.20	
C. RELAP3	1.92	2.31	3.61		2.95	2.89			3.25	2.58	2.71	7.28	6.80		10.67	
D. COMPARE (nodalized)					2.16								4.35			
VI. Maximum Absolute Pressure in Compartment 9, bar																
A. Experimental Data	NA	NA	NA		2.00	2.00		NA	1.65	1.65	1.50	1.75	1.75		1.75	
B. COMPARE	1.59	1.95	1.14		2.27	2.27		1.17	1.83	1.85	1.68	1.89	1.90		1.96	
C. RELAP3	1.58	1.73	1.45		1.94	1.89			1.63	1.50	1.50	1.52	1.63		1.67	
D. COMPARE (nodalized)													1.47			
VII. Absolute Pressure in Blowdown Compartments at 0.2 s, bar																
A. Experimental Data	1.00[d]	2.30[d]	1.90[d]		1.60	1.80		1.25	1.75	2.00	2.10	1.80	2.80		4.00	
B. COMPARE	1.37	1.60	2.63		1.73	1.74		1.38	2.04	2.21	2.01	2.30	3.44		3.11	
C. RELAP3	1.40	1.54	2.55		1.69	1.73		---	2.15	1.71	2.10	3.11	3.38		4.29	
D. COMPARE (nodalized)					1.71	1.72							3.40			
VIII. Break - Containment Compartment (9) Pressure Difference at 0.2 s, bars																
A. Experimental Data	NA	NA	NA		0.50	0.60		NA	0.67	0.95	1.10	0.70	1.76		2.95	
B. COMPARE	0.32	0.52			0.63	0.67		-0.04	0.99	1.15	0.97	1.26	2.41		4.10	
C. RELAP3	0.34	0.49			0.63	0.65		---	1.13	0.68	1.08	2.09	2.35		3.26	
D. COMPARE (nodalized)					0.65	0.68										
IX. Maximum Pressure Difference Between Compartments 4 and 6 Bars																
A. Experimental Data	NA	NA	NA		-0.55	-0.55		-0.01	NA	0.90	NA	-0.01	-0.04		-0.05	
B. COMPARE	0.24	0.39	0.03		0.47	0.51		0.00	0.92	1.20	0.02	0.05	0.05		0.06	
C. RELAP3	0.26	0.51	0.03		0.82	0.20		----	1.50	0.96	0.02	0.04	0.10		0.12	
D. COMPARE (nodalized)													-0.03			

[a] A standard connection is that used for test C1 and shown in Fig. 2.

[b] Critical flow in experimental data is assumed possible if ratio of downstream pressure to upstream pressure >0.5.

[c] NA - Not available.

[d] Order of magnitude error is assumed in data. Value is assumed.

to be due to the 10% higher enthalpy in the digitized data. The mass flows were very close.

X. CONCLUSIONS AND RECOMMENDATIONS

A. Use of Subcompartment Codes

1. COMPARE. The COMPARE/test results comparison indicates that the COMPARE code

TABLE XVI CONT

SHORT TIME ($\leq$ 2 s) SUMMARY OF BATTELLE-FRANKFURT C-SERIES TESTS

TEST PARAMETERS	C1		C2		C3		C4	C5		C6		C7	C8	C9		C10		C11		C12		C13		C14	C15		
	Pressure (bar)	Time (s)	Pressure (bar)	Time (s)	Pressure (bar)	Time (s)		Pressure (bar)	Time (s)	Pressure (bar)	Time (s)			Pressure (bar)	Time (s)	Pressure (bar)	Time (s)	Pressure (bar)	Time (s)	Pressure (bar)	Time (s)	Pressure (bar)	Time (s)		Pressure (bar)	Time (s)	
X. Maximum Pressure Difference R1-R4, and Time of Occurrence																											
A. Test	--	--	--	--	--	--		0.3	0.5	--	--			-0.6	0.2	-1.0	0.1	-0.1	0.1	0.1	0.1	2.2	2.0		5.0	1.0	
B. COMPARE	-0.0	2.0	0.0	0.7	1.6	0.2		0.1	0.5	0.3	0.6			0.9	0.2	-1.1	0.2	0.0	0.1	-0.0	0.9	2.8	0.8		6.3	1.0	
C. RELAP3	0.1	0.8	0.1	1.4	2.1	1.4		0.2	1.2	0.1	1.9			-1.5	1.0	-1.0	1.0	-0.0	0.9	-0.0	0.9	5.2	1.4		8.7	1.8	
XI. Maximum Pressure Difference R4-R6, and Time of Occurrence																											
A. Test	--	--	--	--	--	--		-0.6	0.2	-0.6	0.2			--	--	-1.0	0.2	0.0	0.1	0.0	0.1	-0.0	2.0		-0.1	0.3	
B. COMPARE	-0.2	0.2	-0.4	0.2	-0.0	0.3		-0.5	0.1	-0.5	0.1			0.9	0.2	1.3	0.2	0.0	0.2	0.3	0.2	-0.1	0.9		-0.1	1.1	
C. RELAP3	-0.3	0.8	-0.5	1.2	-0.0	1.5		-0.8	0.6	-0.7	0.8			1.5	0.9	1.0	1.2	0.0	1.1	0.1	1.1	-0.1	0.2		-0.1	2.0	
XII. Maximum Pressure Difference Blowdown - R9, and Time of Occurrence																											
A. Test	--	--	--	--	--	--		--	--	--	--			--	--	1.3	0.2	--	--	--	--	--	--		--	--	
B. COMPARE	0.3	0.2	0.5	0.2	1.6	0.3		0.7	0.6	0.7	0.6			1.0	0.2	1.2	0.2	1.0	0.2	1.1	1.1	3.1	0.9		6.0	1.0	
C. RELAP3	0.4	0.3	0.7	0.6	2.2	1.4		1.1	0.7	1.0	0.7			1.7	1.1	1.1	1.4	1.3	1.1	1.5	1.1	5.1	1.4		9.0	2.0	

- calculated blowdown compartment pressure greater than measured (Table IV),
- calculated blowdown/main compartment pressure differences higher than measured (Table V),
- calculated blowdown/adjacent compartment maximum pressure differences higher than measured (see Table VI, tests C13 and C15), and
- calculated times for maximum pressure difference generally in agreement with tests except for C13 (see Table VI, tests C5, C10, and C15).

2. RELAP3. The RELAP3/test results comparison indicates that the RELAP3 code

- calculated blowdown subcompartment pressure higher than that measured and higher than that calculated by the COMPARE code (Table IV),
- calculated blowdown/main subcompartment pressure differences higher than measured (Table V),
- calculated blowdown/adjacent subcompartment maximum pressure differences higher than measured (Table VI, tests C13 and C15), and
- calculated times for maximum pressure differentials generally later than measured and also later than those calculated using the COMPARE code (Table VI).

B. Is COMPARE Conservative?

The comparisons presented show that the COMPARE-calculated maximum pressures for subcompartments near the break are higher than those measured. As stated in Ref. 1 (NRC Guidelines), the calculation of high pressure is desirable for conservatism. This is a simple and convenient measure of conservatism and should be used with caution. Another basis for conservatism might be more complicated. For example, the force on a particular wall from a pressure difference might be of interest. For such a situation, an evaluation of the calculated conservatism would be more involved.

C. Parametric Studies

The parametric studies using the COMPARE code indicated that

- nodalization has little or no effect,
- use of the HEM critical flow model produced absolute pressure results that were, in general, closer to the test results than those obtained using 0.6 x Moody critical flow model,
- a MM of 0.8 for all subcompartments yielded results that were closer to the test data than any other value of MM, and
- a decrease of entrainment in the blowdown subcompartment and an increase in entrainment in the other subcompartments gave results closer to the test data.

D. Digitized vs Nondigitized Blowdown Data Comparison

We believe that the use of nondigitized data does not invalidate any of the conclusions stated above. In general, use of the digitized blowdown data will give higher subcompartment pressures.

E. C-Series Tests as an Experimental Data-Based Problem

We believe that the C-Series tests do not offer optimum conditions for an experimental data-based problem for the following reasons.

1. The complex connections and the location of orifices near the break point make nodalization difficult to evaluate.
2. The two C-Series (C7, C14) tests that offer similarities to reactor cavity blowdowns were not made available for analysis.
3. Specific locations of open or closed connections between compartments are not adequately described (for example, which of the three connections between R1 and R3 are closed in C15).
4. All of the graphical test results had to be redigitized before comparisons could be made.

We recommend that any subsequent tests also be evaluated for their potential use in development of an experimental data-based problem. If, however, only C-Series tests can be considered, we would recommend C5, C10, C13, and C15 as candidate tests for the reasons stated in Sec. IV. Regardless of which tests are used, we recommend that

- digitized blowdown data be obtained,
- digitized test results be provided, and
- a first-hand or on-site observation be made of the experimental apparatus to clarify many of the geometric and connection details needed for a thorough and reliable analysis.

These items would provide a better basis for selecting a single test from the C-Series, as well as from any subsequent Battelle-Frankfurt tests.

F. Future Experimental Needs and Comparisons

The Battelle-Frankfurt tests offer the best available experimental data necessary for support of analytical subcompartment code development. However, our investigations using the Battelle-Frankfurt data have revealed test deficiencies in

- resolution of several geometric flow and connection details,
- use of the complex subcompartment geometry for nodalization studies,
- complete identification of all blowdown fluid properties, and
- the lack of digitized blowdown and measurement information for the tests.

We believe that a feasibility study should be performed that would provide the following.

1. The feasibility of designing an experimental program that would provide capability for isolation of parameters that affect analytical code results. Isolation of air, containment, inertia, geometry, and heat-transfer effects could unmask the combined effect of these processes.
2. Identification of geometries that are conducive to nodalization and evaluation of inertia effects.
3. Requirements for evaluation of critical flow and the associated variables (air, entrainment).
4. An evaluation of the instrumentation necessary to measure both fluid properties and dynamics, including an estimation of the error involved in all of the measurements.

5. A conceptual design with associated costs for a facility that would accomplish items 1--4, if feasibility is shown.

ACKNOWLEDGEMENT

We would like to thank the Nuclear Regulatory Commission (NRC) and the Battelle-Frankfurt group for providing reports on the C-Series tests. Conversations with T. F. Kanzleiter (Battelle-Institute) proved essential in the nodalization studies, particularly for test C15. P. W. Barownowski's (NRC) guidance in emphasizing and clarifying the essential NRC goals in the study were appreciated. S. W. Brown (NRC) provided useful and constructive comments based upon his examination of test C5. W. Jensen (NRC) provided data outlining connection details for tests C1--C6. In addition, we would like to express our appreciation to J. B. Payne and K. H. Duerre of LASL for their help in implementing COMPARE and RELAP3 on LASL's CDC machines.

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APPENDIX A

ABSOLUTE PRESSURES IN THE BATTELLE-FRANKFURT TEST FACILITY SUBCOMPARTMENTS FOR TESTS C1, C2, C3, C5, C6, C9, C10, C11, C12, C13, and C15

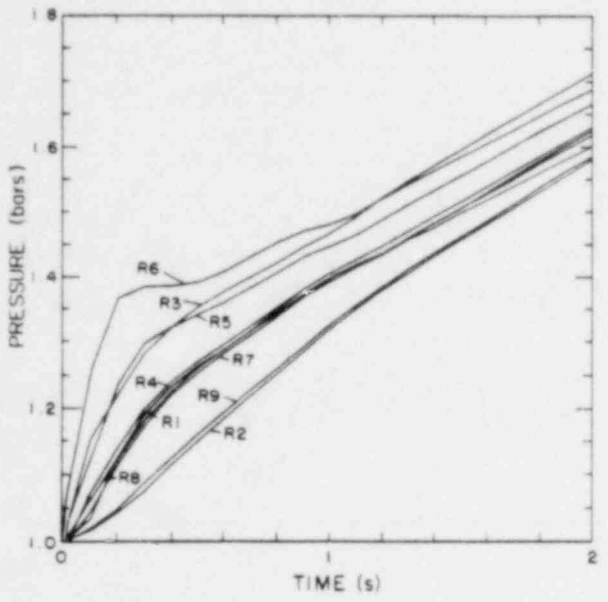


Fig. A-1. Test C1--Absolute pressure comparison in all subcompartments as predicted by COMPARE.

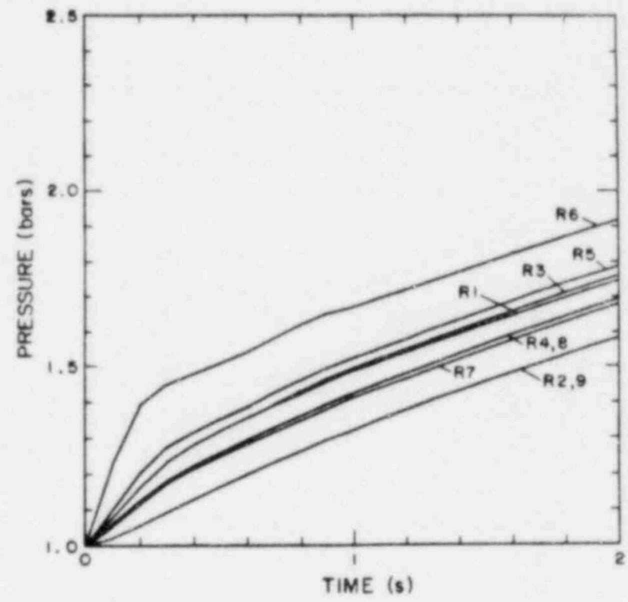


Fig. A-2. Test C1--Absolute pressure comparison in all subcompartments as predicted by RELAP3.

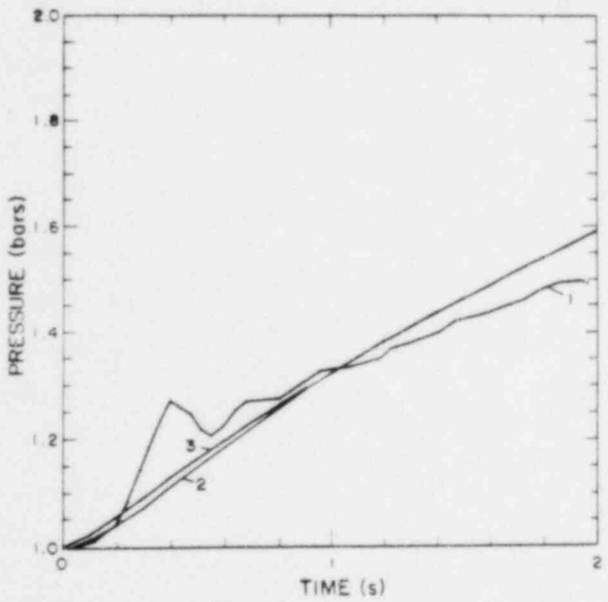


Fig. A-3. Test C1--Absolute pressure comparison in subcompartment R2 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

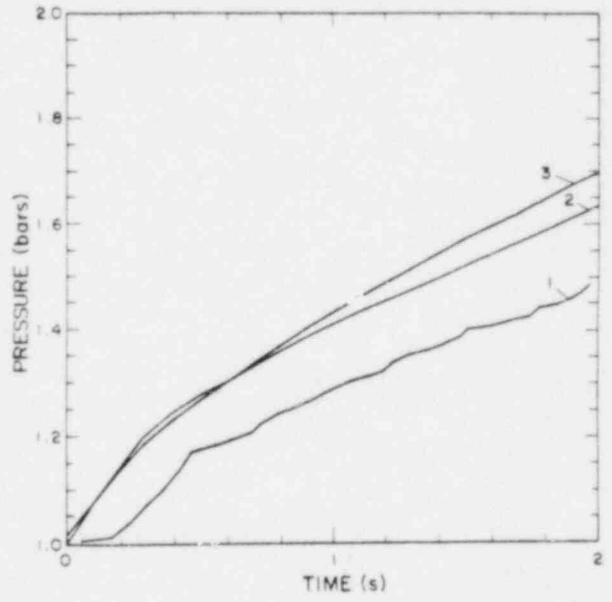


Fig. A-4. Test C1--Absolute pressure comparison in subcompartment R4 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

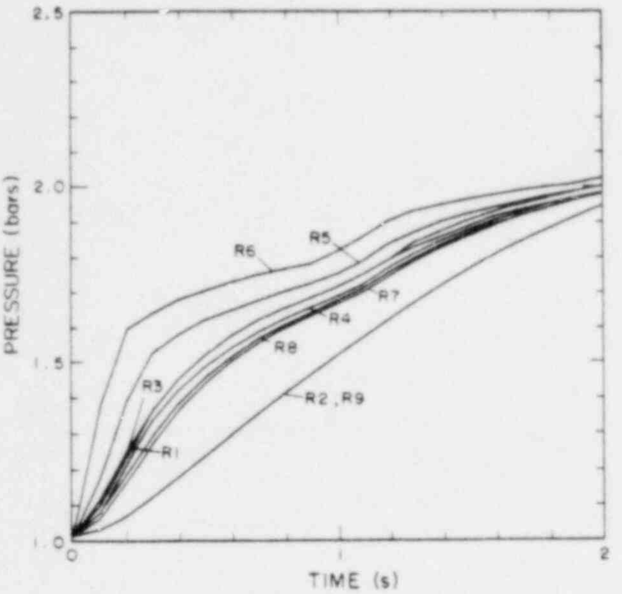


Fig. A-5. Test C2--Absolute pressure in all subcompartments as predicted by COMPARE.

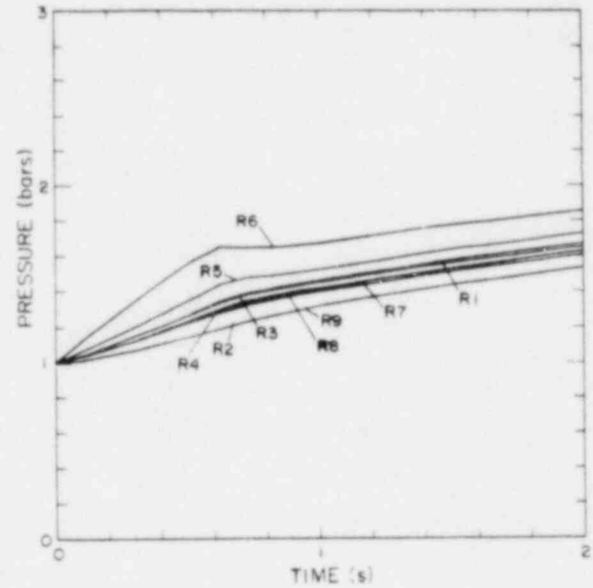


Fig. A-6. Test C2--Absolute pressure in all subcompartments as predicted by RELAP3 (1 Fill).

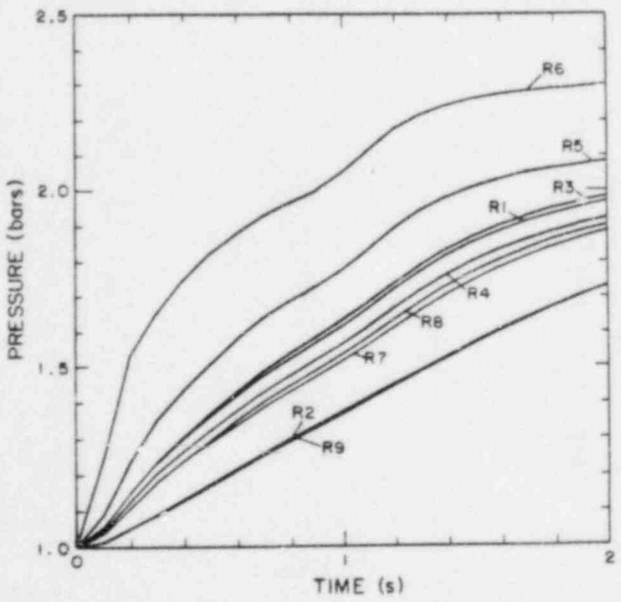


Fig. A-7. Test C2--Absolute pressure in all subcompartments as predicted by RELAP3 (2 Fill).

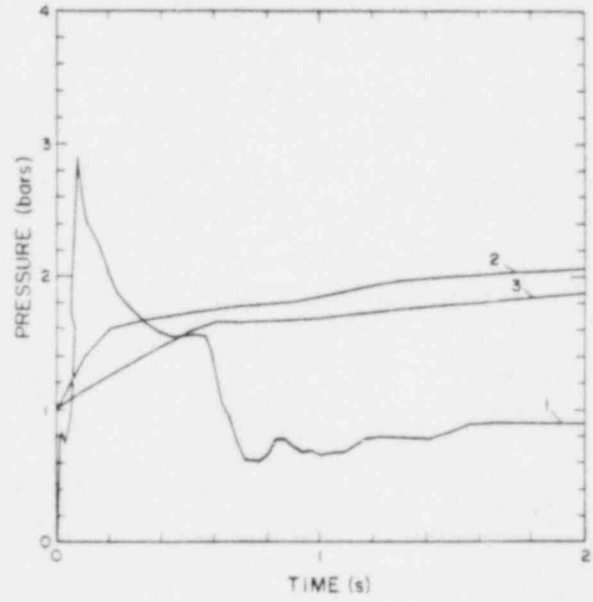


Fig. A-8. Test C2 --Absolute pressure comparison in subcompartment R6 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

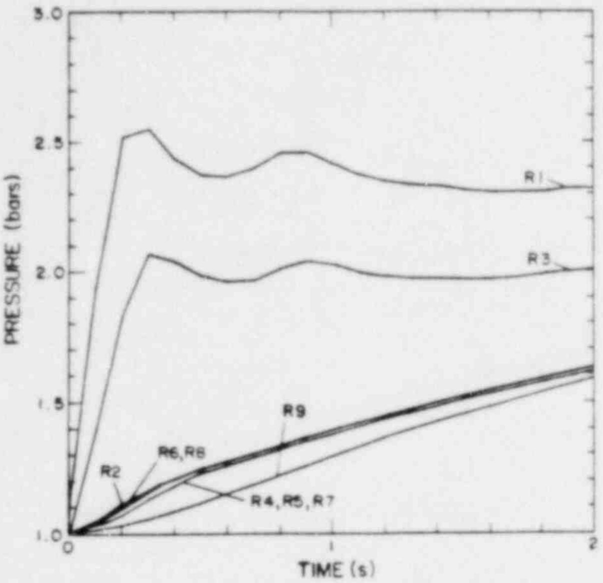


Fig. A-9. Test C3--Absolute pressure comparison in all subcompartments as predicted by COMPARE (average enthalpy).

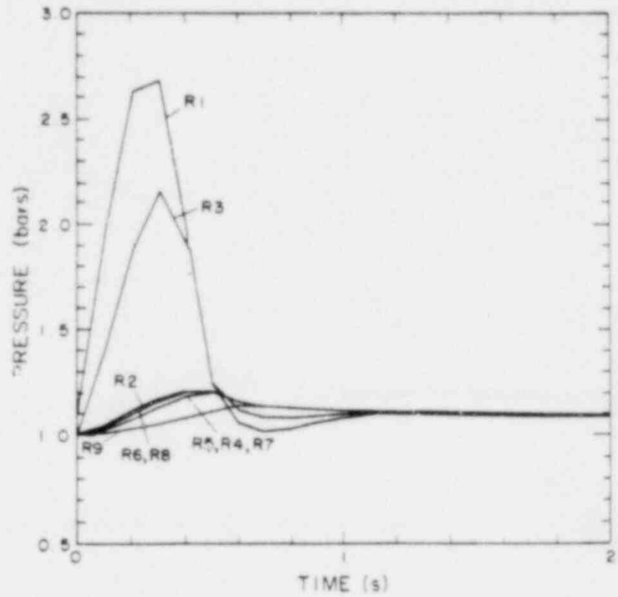


Fig. A-10. Test C3--Absolute pressure comparison in all subcompartments as predicted by COMPARE.

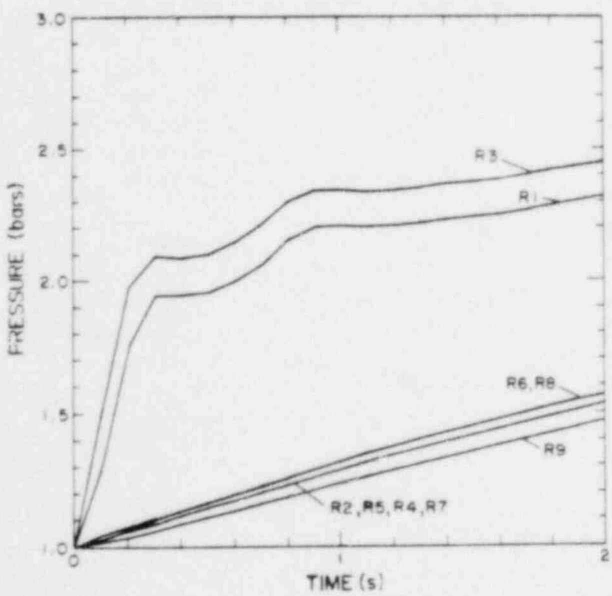


Fig. A-11. Test C3--Absolute pressure comparison in all subcompartments as predicted by RELAP3 (1 Fill).

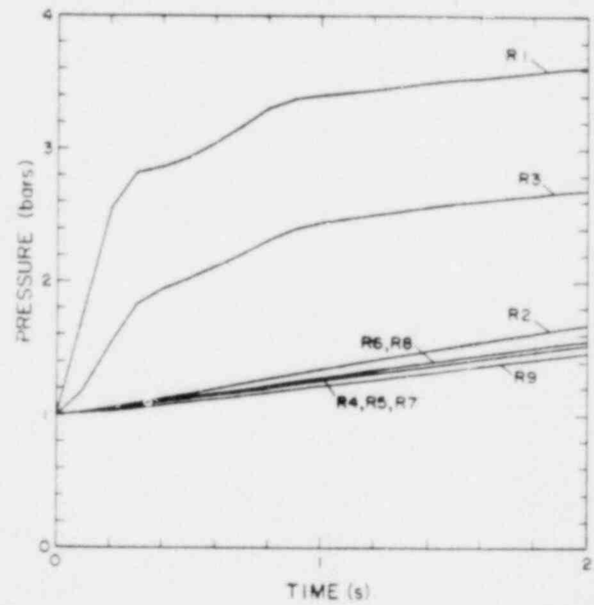


Fig. A-12. Test C3-- Absolute pressure comparison in all subcompartments as predicted by RELAP3 (2 Fill).

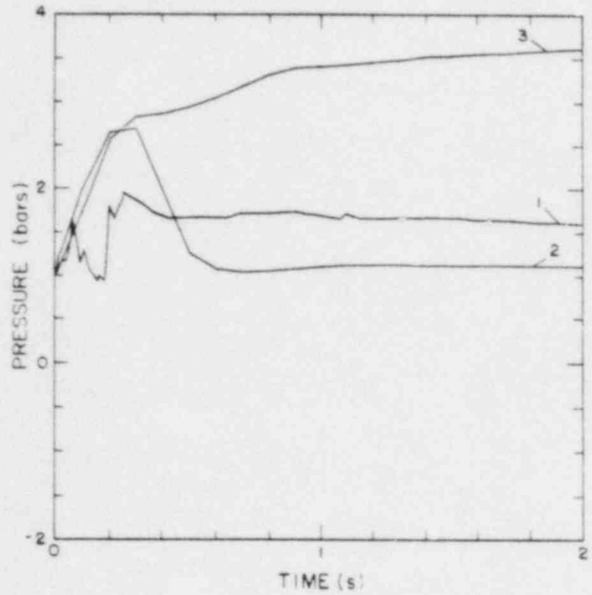


Fig. A-13. Test C3--Absolute pressure comparison in subcompartment R1 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

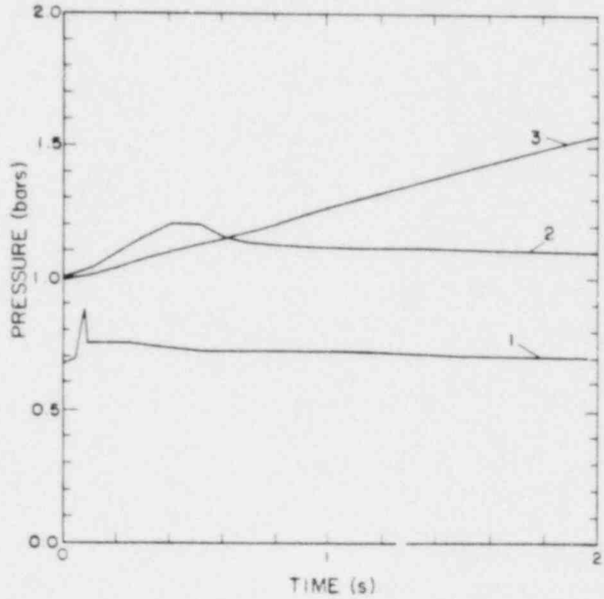


Fig. A-14. Test C3--Absolute pressure comparison in subcompartment R6 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

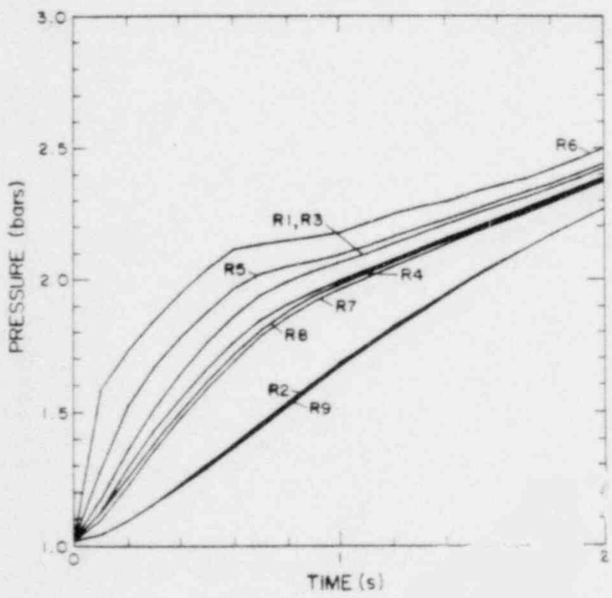


Fig. A-15. Test C5--Absolute pressure comparison in all subcompartments as predicted by COMPARE.

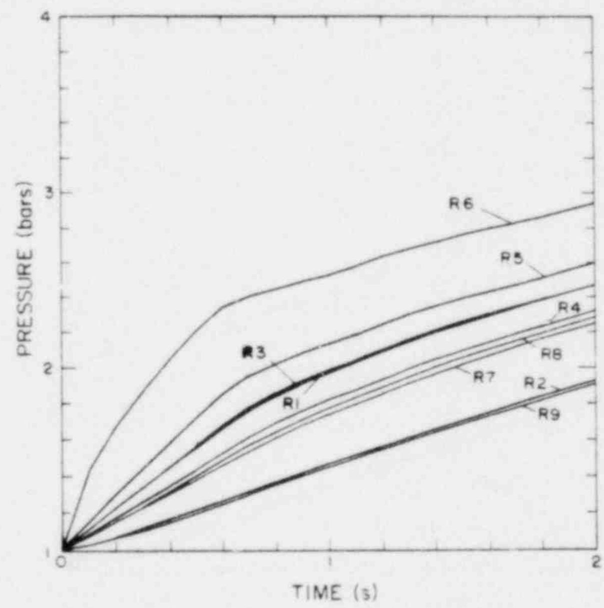


Fig. A-16. Test C5--Absolute pressure comparison in all subcompartments as predicted by RELAP3.

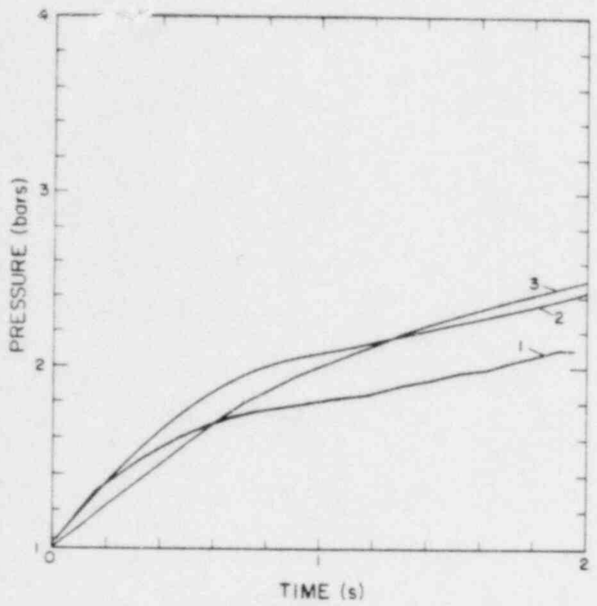


Fig. A-17. Test C5--Absolute pressure comparison in subcompartment R1 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

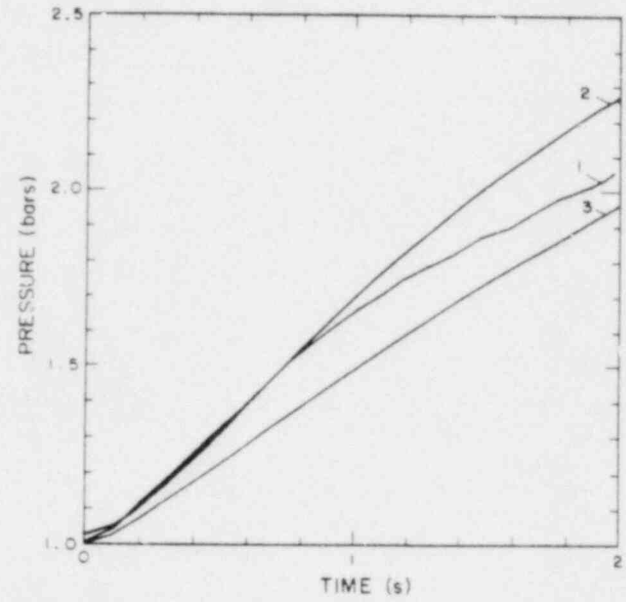


Fig. A-18. Test C5--Absolute pressure comparison in subcompartment R2 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

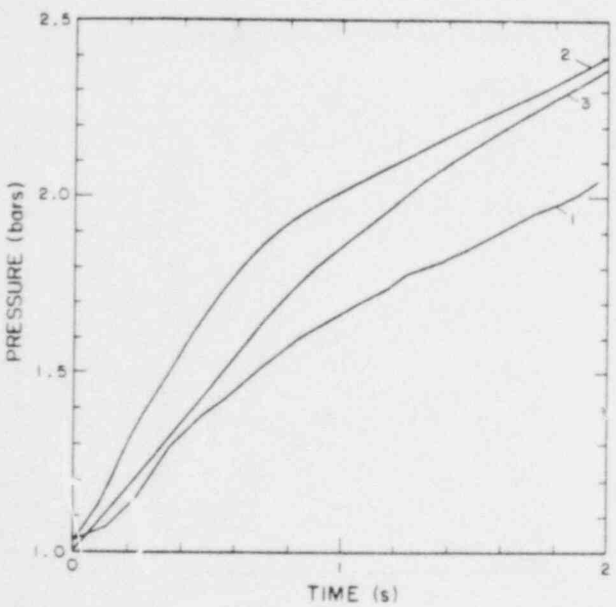


Fig. A-19. Test C5--Absolute pressure comparison in subcompartment R4 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

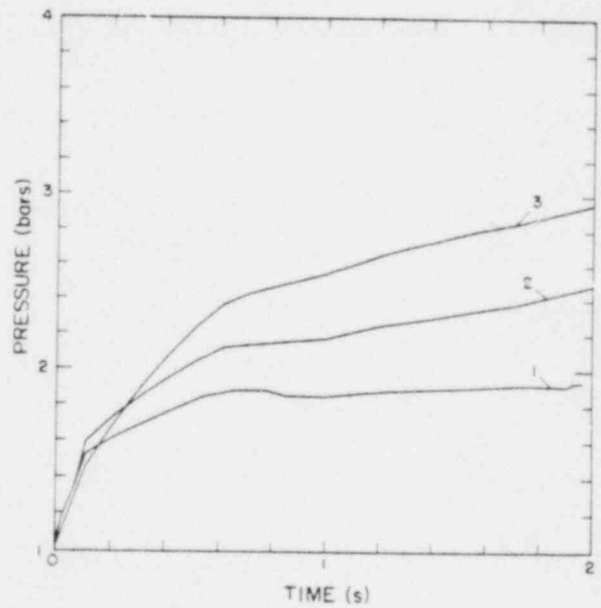


Fig. A-20. Test C5--Absolute pressure comparison in subcompartment R6 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

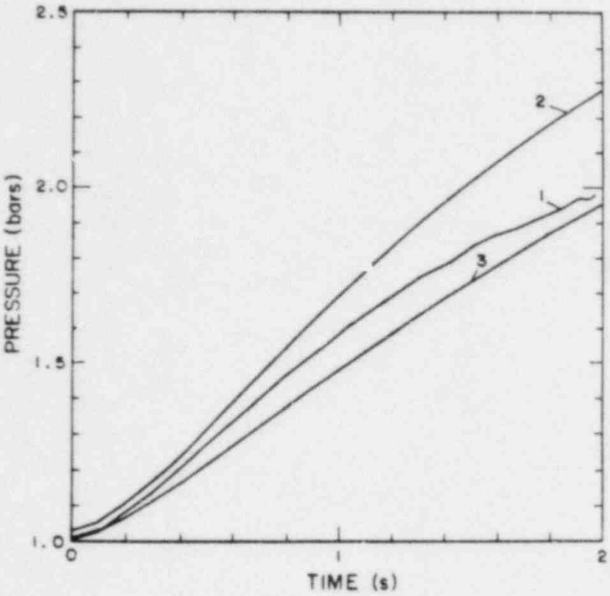


Fig. A-21. Test C5--Absolute pressure comparison in subcompartment R9 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

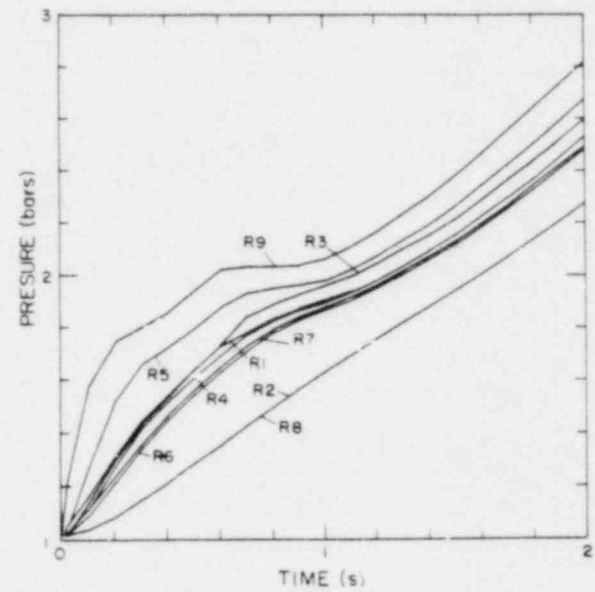


Fig. A-22. Test C6--Absolute pressure comparison in all subcompartments as predicted by COMPARE.

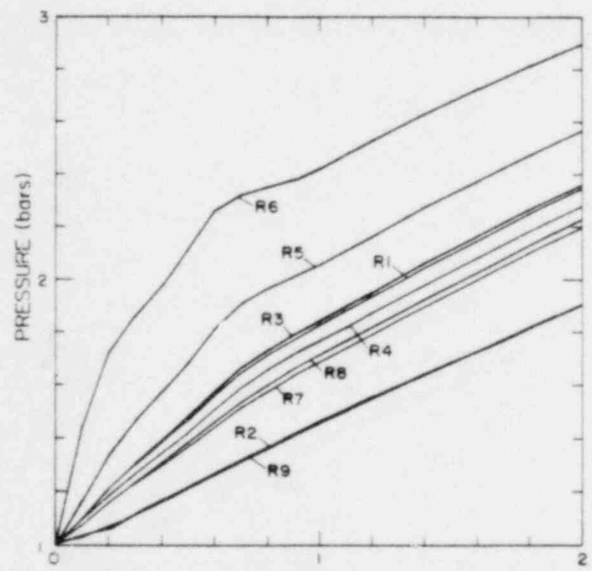


Fig. A-23. Test C6--Absolute pressure comparison in all subcompartments as predicted by RELAP3.

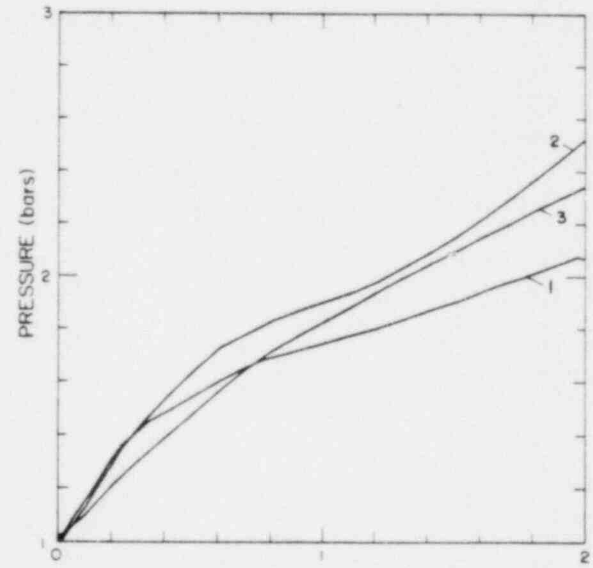


Fig. A-24. Test C6--Absolute pressure comparison in subcompartment R1 for TEST (1), and as predicted by COMPARE (2), and RELAP3 (3).

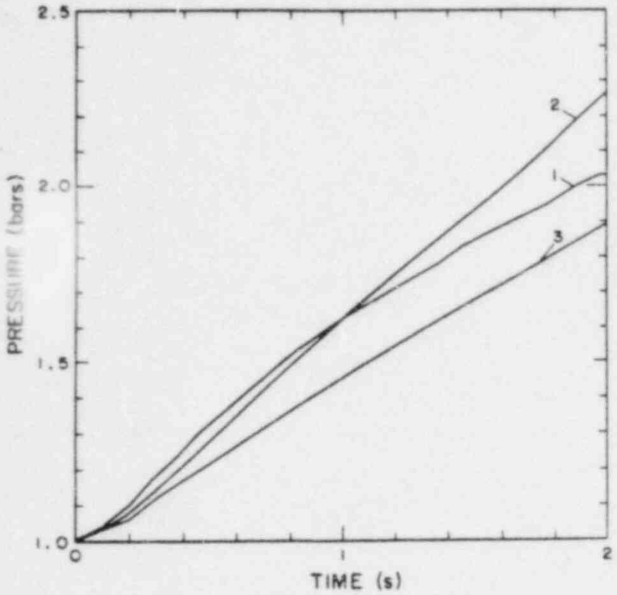


Fig. A-25. Test C6--Absolute pressure comparison in subcompartment R2 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

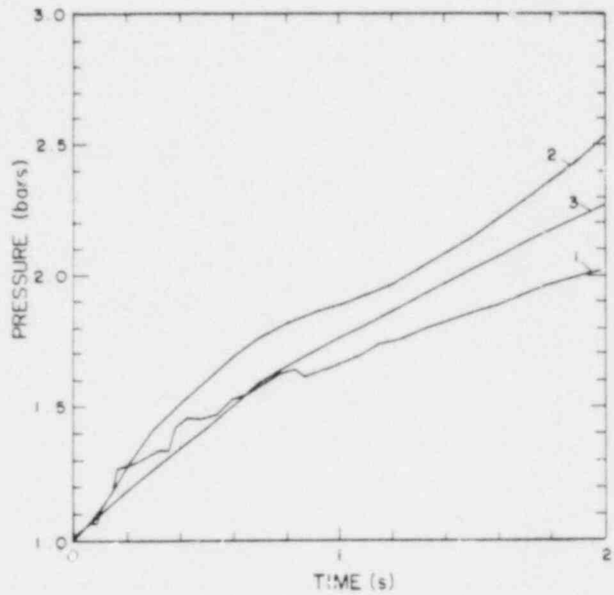


Fig. A-26. Test C6--Absolute pressure comparison in subcompartment R4 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

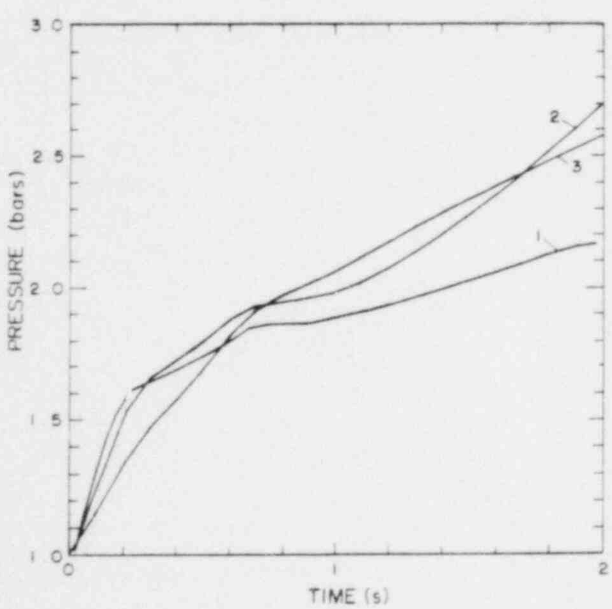


Fig. A-27. Test C6--Absolute pressure comparison in subcompartment R5 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

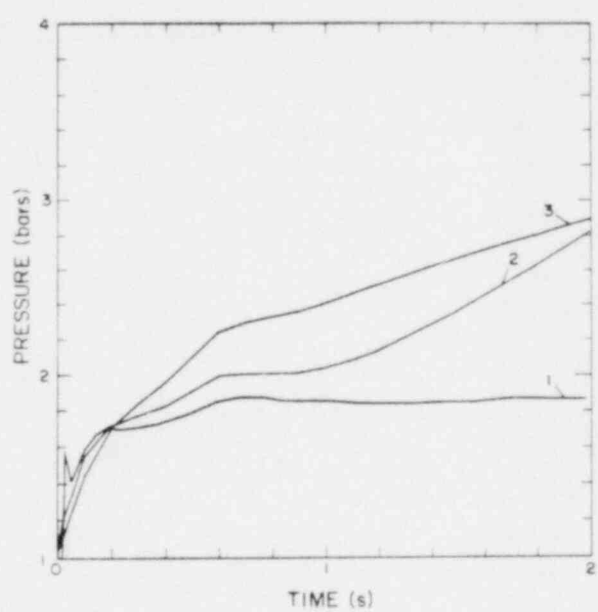


Fig. A-28. Test C6--Absolute pressure comparison in subcompartment R6 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

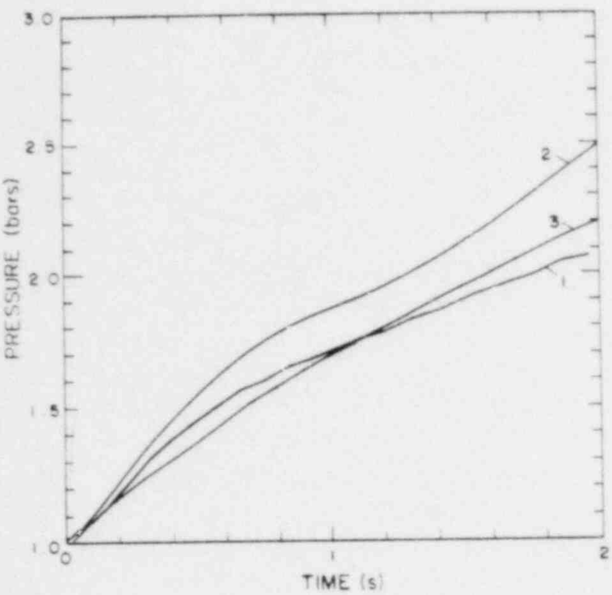


Fig. A-29. Test C6--Absolute pressure comparison in subcompartment R7 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

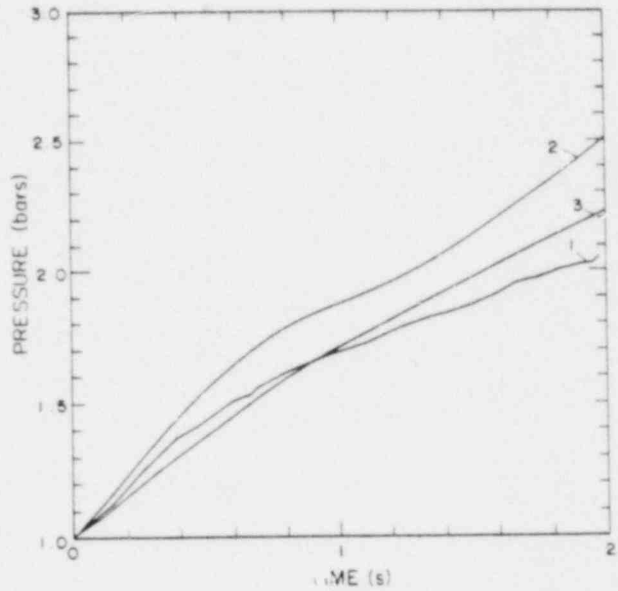


Fig. A-30. Test C6--Absolute pressure comparison in subcompartment R8 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

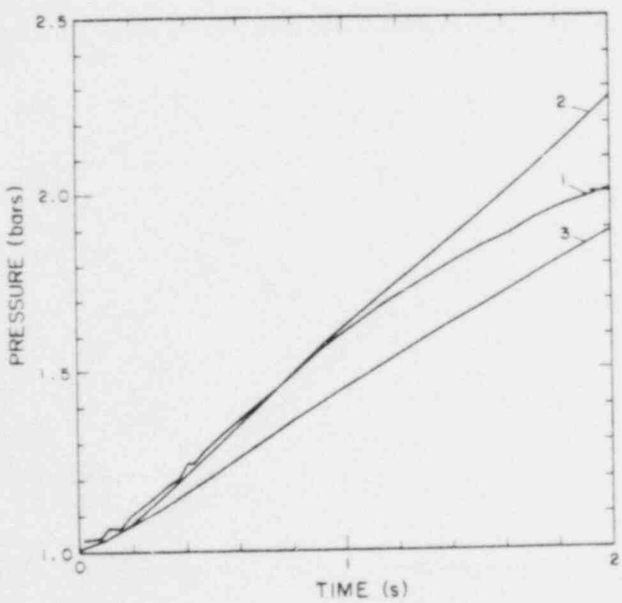


Fig. A-31. Test C6--Absolute pressure comparison in subcompartment R9 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

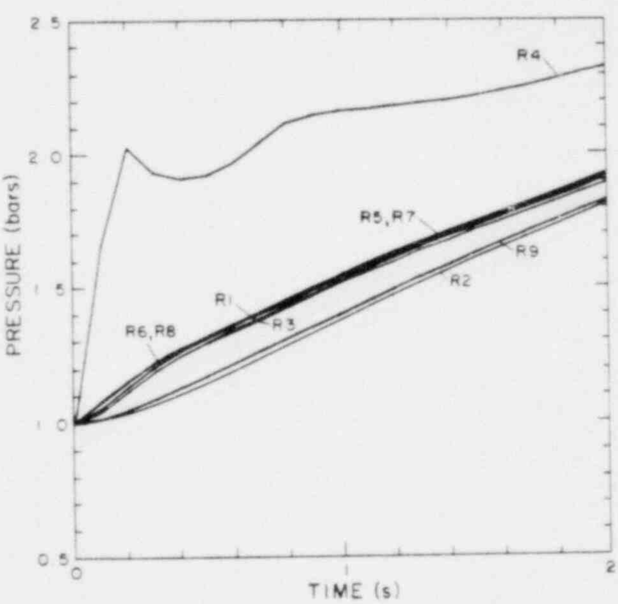


Fig. A-32. Test C9--Absolute pressure comparison in all subcompartments as predicted by COMPARE.

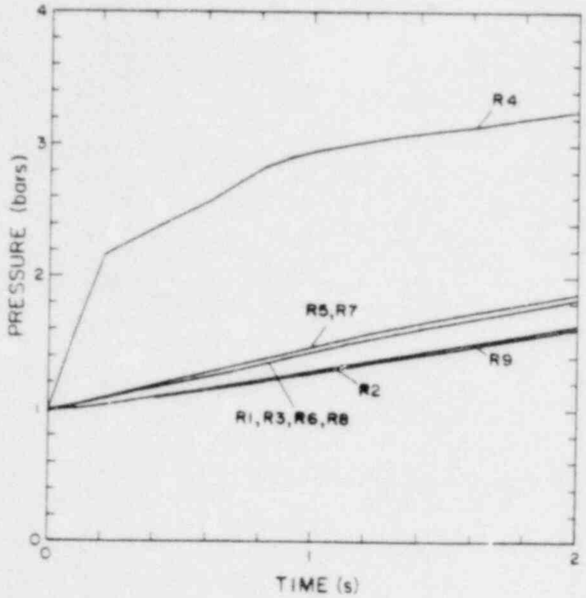


Fig. A-33. Test C9--Absolute pressure comparison in all subcompartments as predicted by RELAP3.

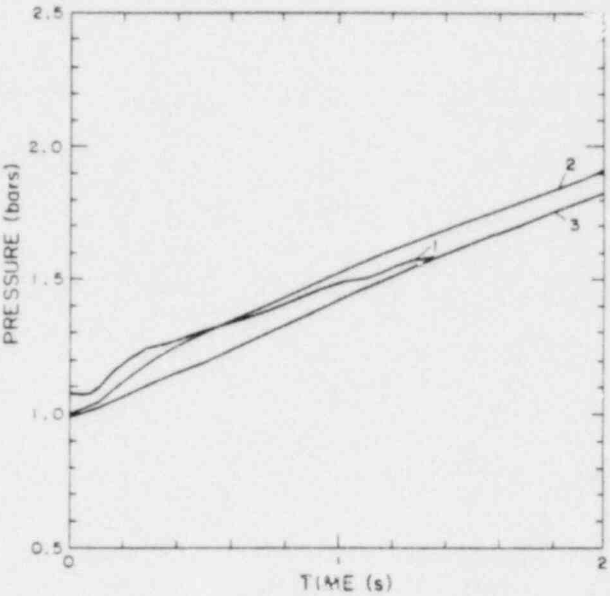


Fig. A-34. Test C9--Absolute pressure comparison in subcompartment R1 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

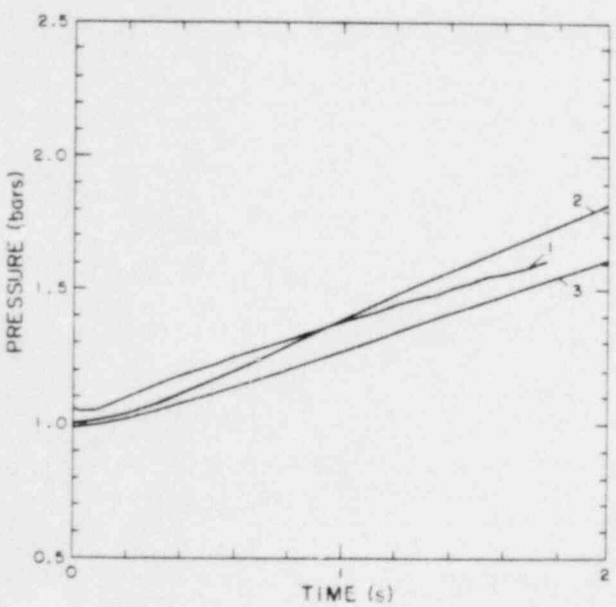


Fig. A-35. Test C9--Absolute pressure comparison in subcompartment R2 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

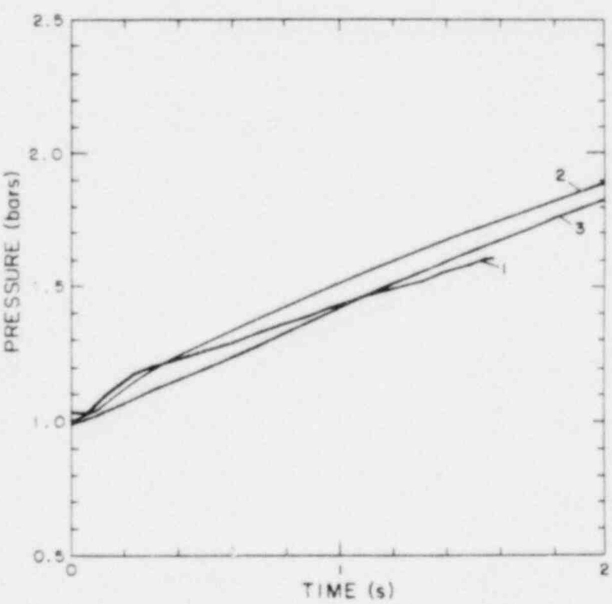


Fig. A-36. Test C9--Absolute pressure comparison in subcompartment R3 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

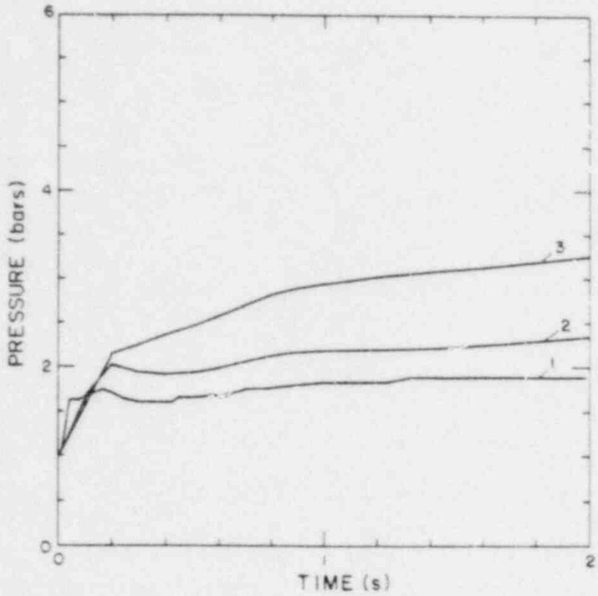


Fig. A-37. Test C9--Absolute pressure comparison in subcompartment R5 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

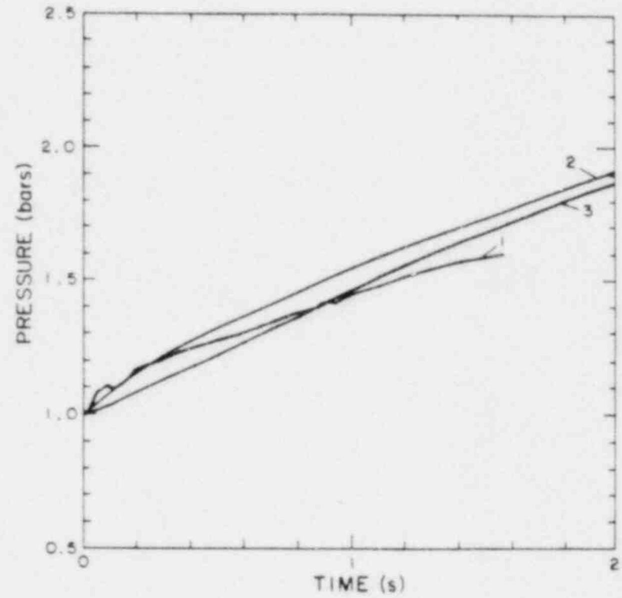


Fig. A-38. Test C9--Absolute pressure comparison in subcompartment R4 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

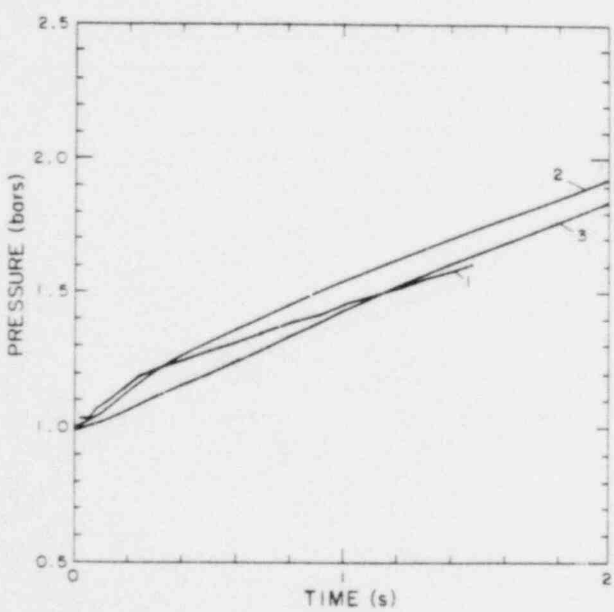


Fig. A-39. Test C9--Absolute pressure comparison in subcompartment R6 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

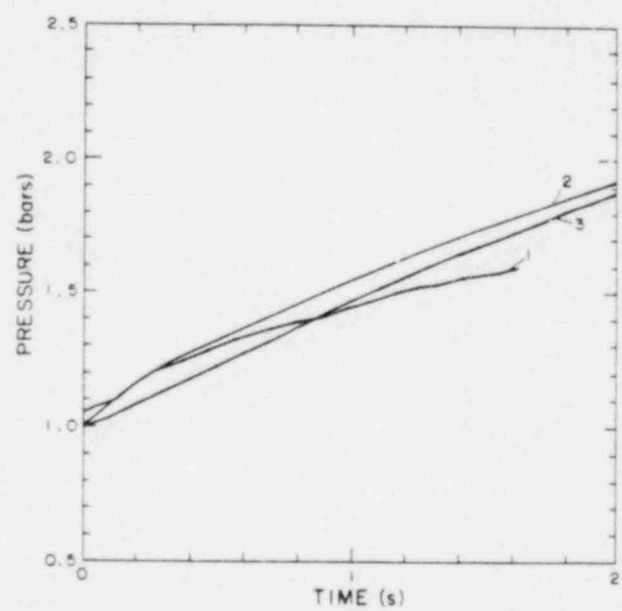


Fig. A-40. Test C9--Absolute pressure comparison in subcompartment R7 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

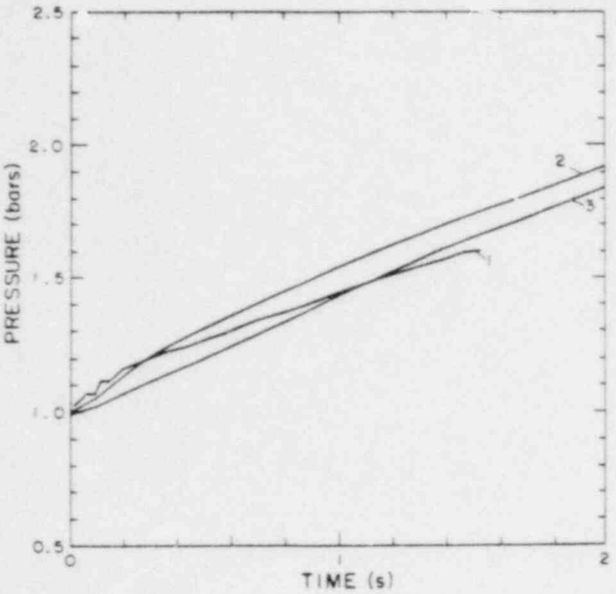


Fig. A-41. Test C9--Absolute pressure comparison in subcompartment R8 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

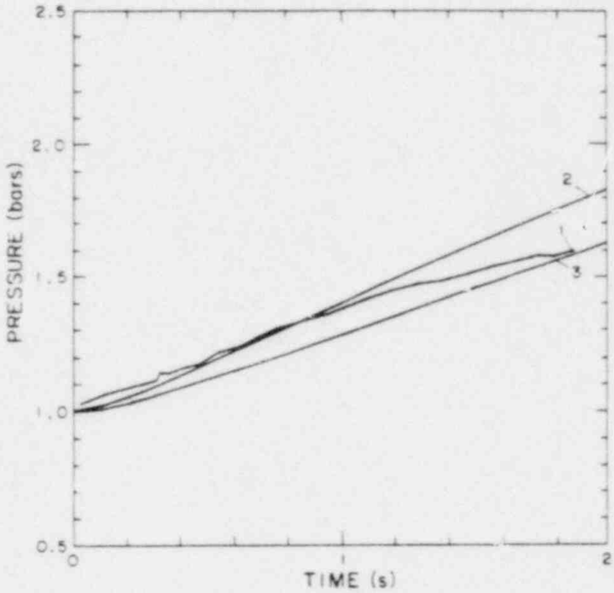


Fig. A-42. Test C9--Absolute pressure comparison in subcompartment R9 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

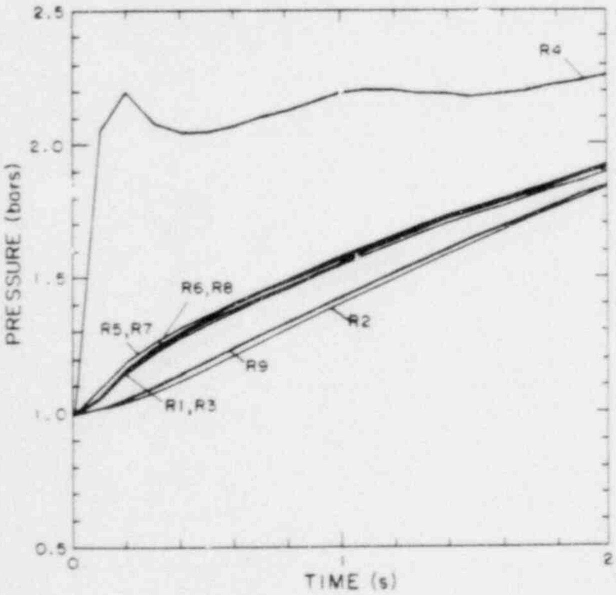


Fig. A-43. Test C10--Absolute pressure comparison in all subcompartments as predicted by COMPARE.

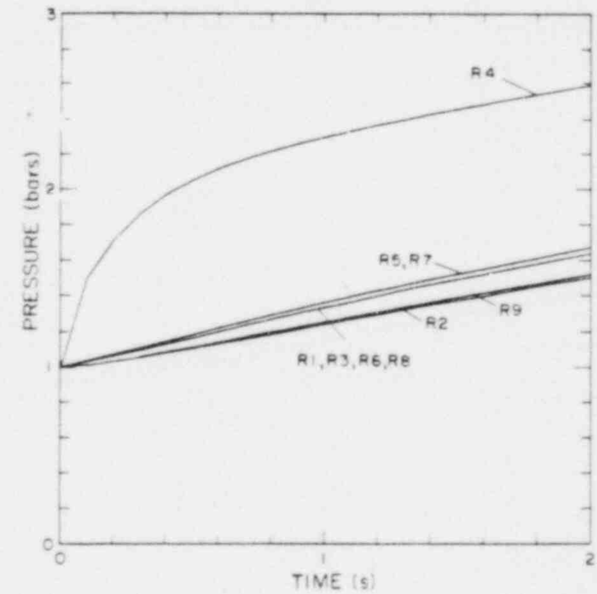


Fig. A-44. Test C10--Absolute pressure comparison in all subcompartments as predicted by RELAP3.

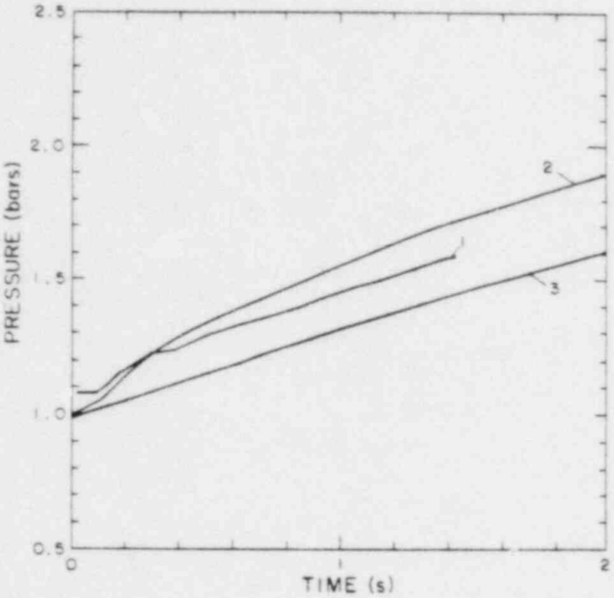


Fig. A-45. Test C10--Absolute pressure comparison in subcompartment R1 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

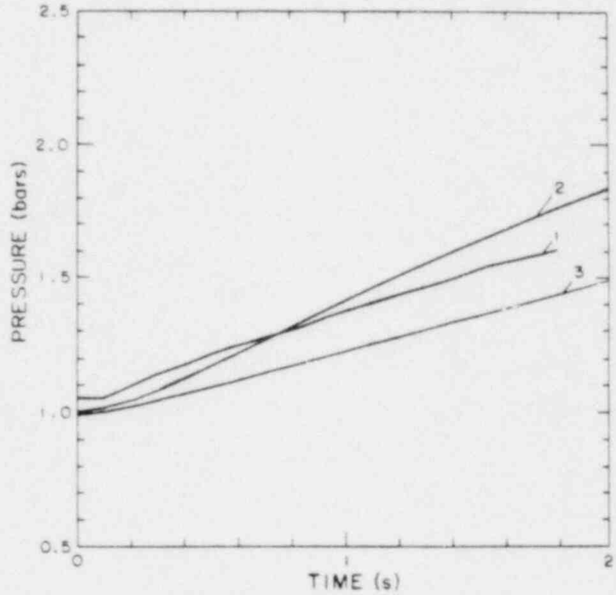


Fig. A-46. Test C10--Absolute pressure comparison in subcompartment R2 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

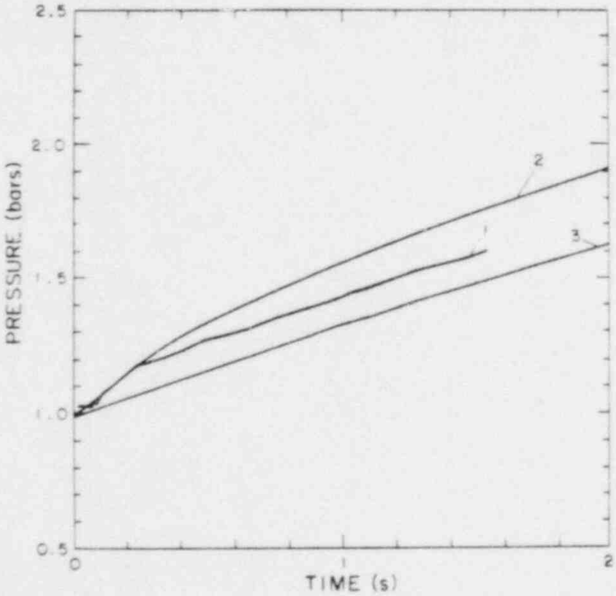


Fig. A-47. Test C10--Absolute pressure comparison in subcompartment R3 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

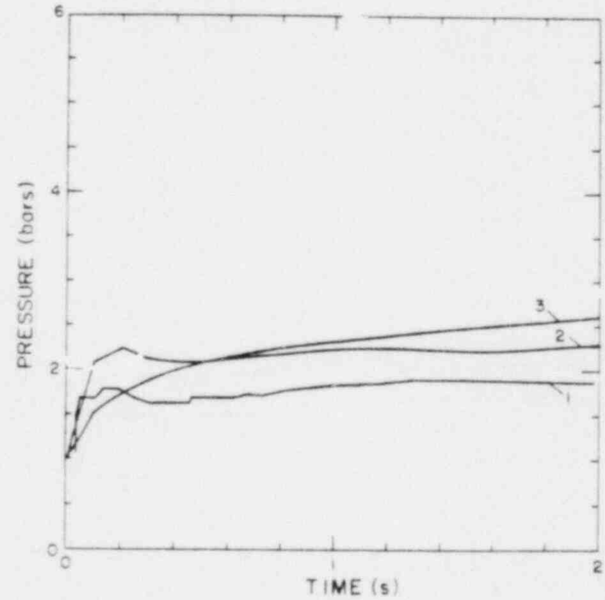


Fig. A-48. Test C10--Absolute pressure comparison in subcompartment R4 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

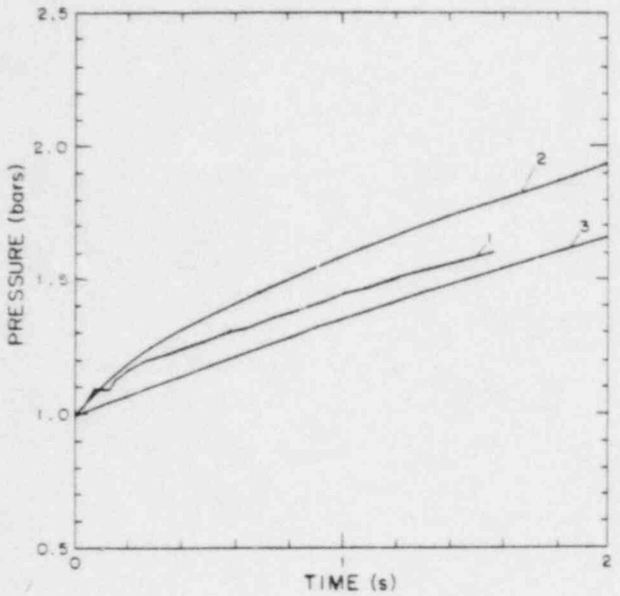


Fig. A-49. Test C10--Absolute pressure comparison in subcompartment R5 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

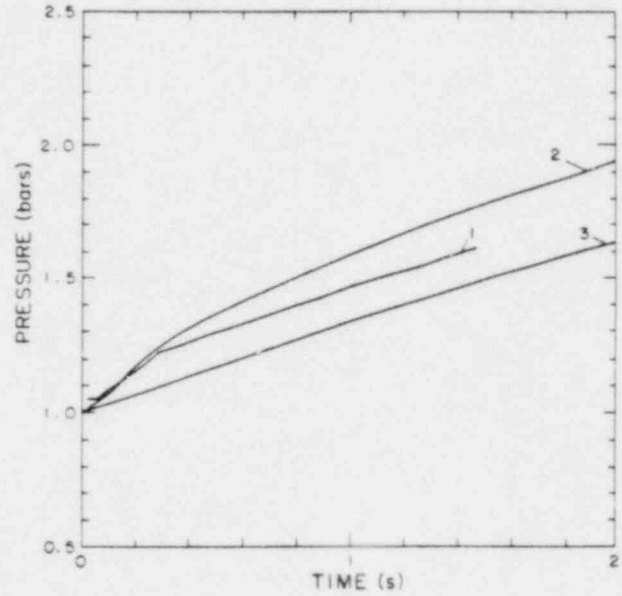


Fig. A-50. Test C10--Absolute pressure comparison in subcompartment R6 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

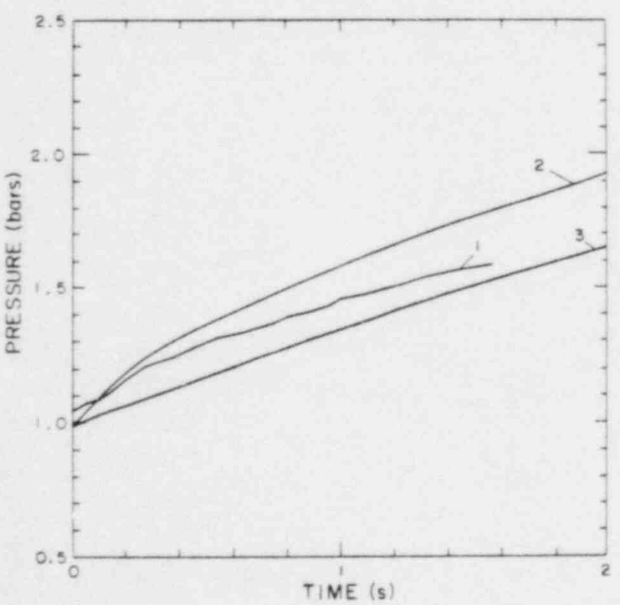


Fig. A-51. Test C10--Absolute pressure comparison in subcompartment R7 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

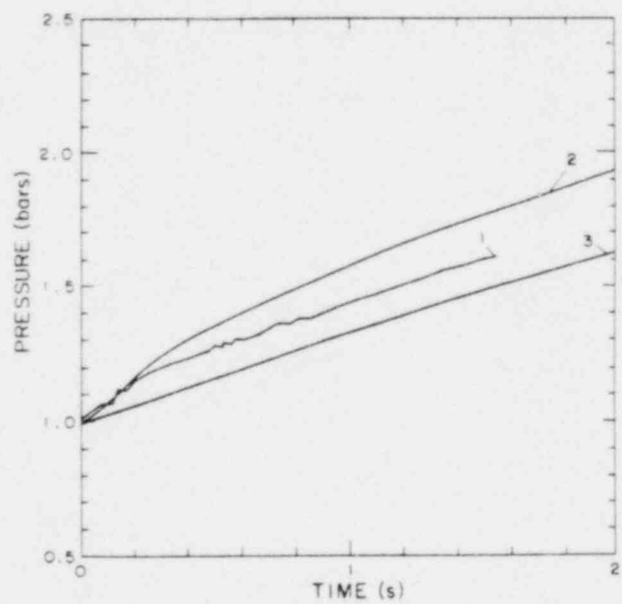


Fig. A-52. Test C10--Absolute pressure comparison in subcompartment R8 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

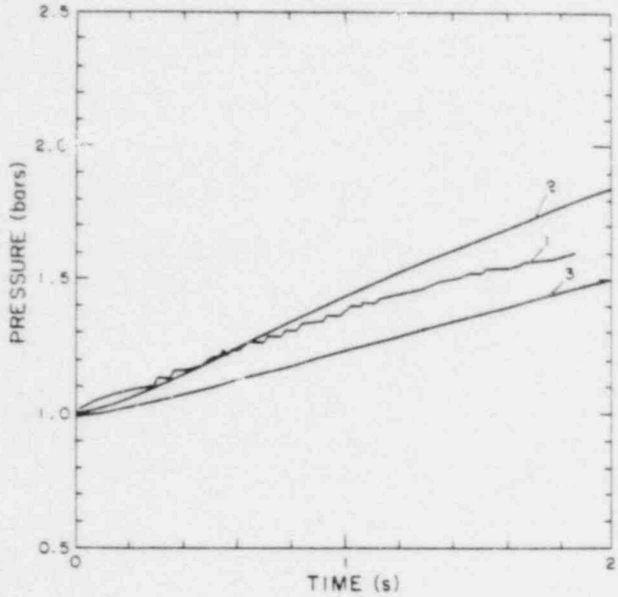


Fig. A-53. Test C10--Absolute pressure comparison in subcompartment R9 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3)

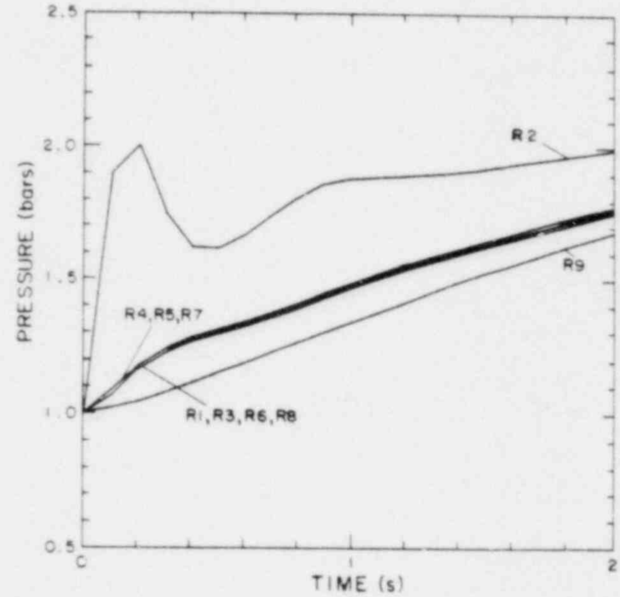


Fig. A-54. Test C11--Absolute pressure comparison in all subcompartments as predicted by COMPARE.

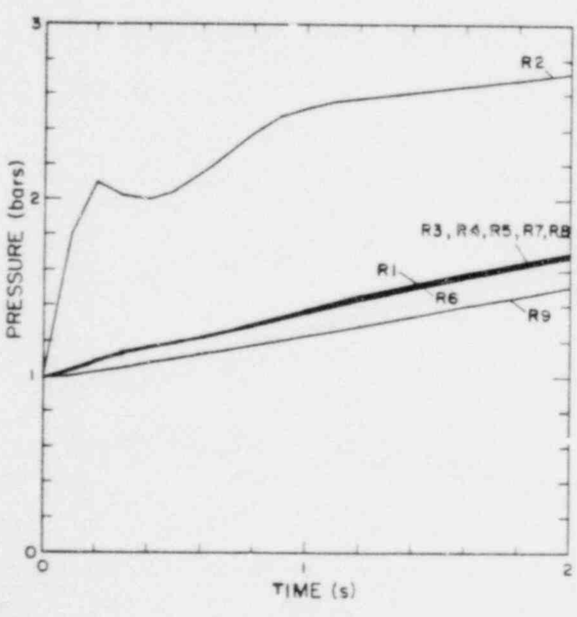


Fig. A-55. Test C11--Absolute pressure comparison in all subcompartments as predicted by RELAP3.

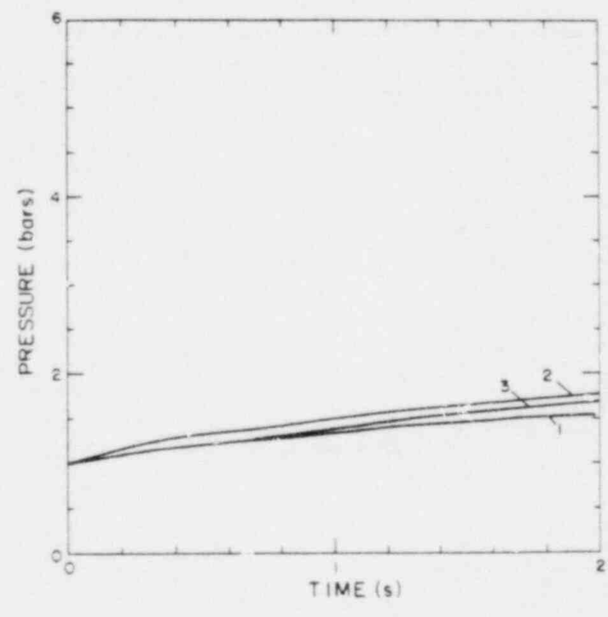


Fig. A-56. Test C11--Absolute pressure comparison in subcompartment R1 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

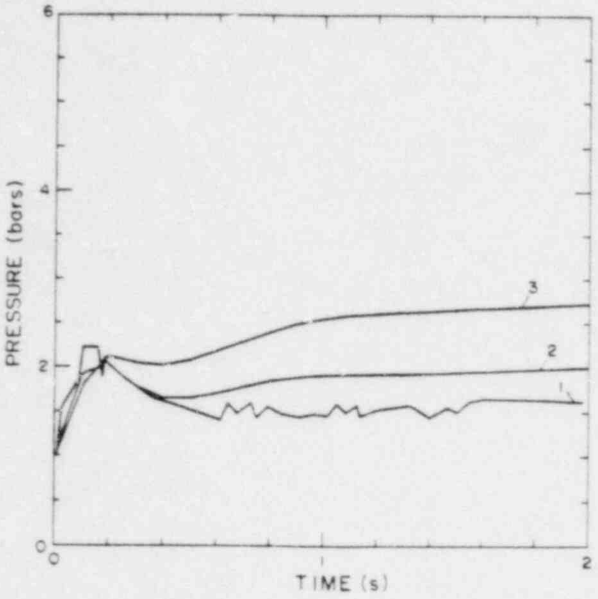


Fig. A-57. Test C11--Absolute pressure comparison in subcompartment R2 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

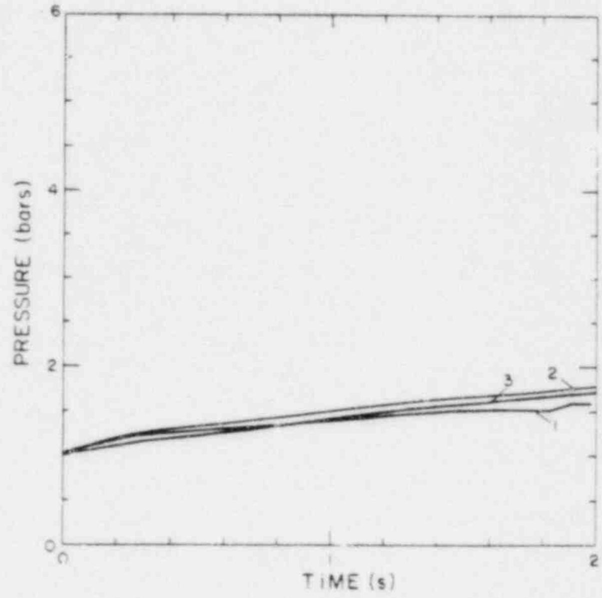


Fig. A-58. Test C11--Absolute pressure comparison in subcompartment R5 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

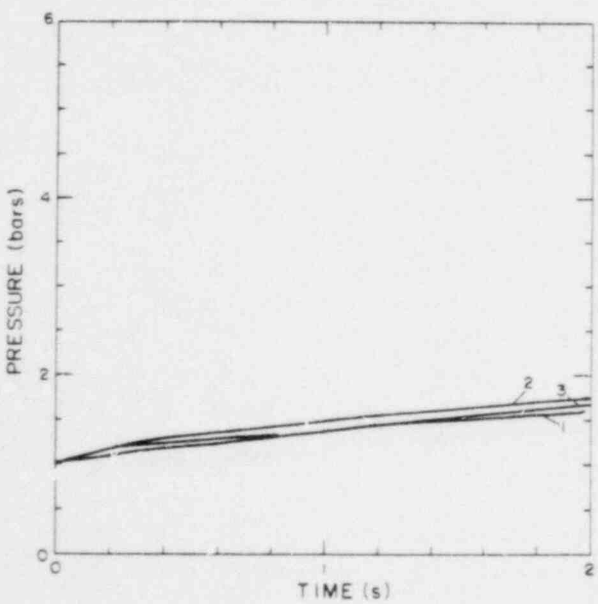


Fig. A-59. Test C11--Absolute pressure comparison in subcompartment R6 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

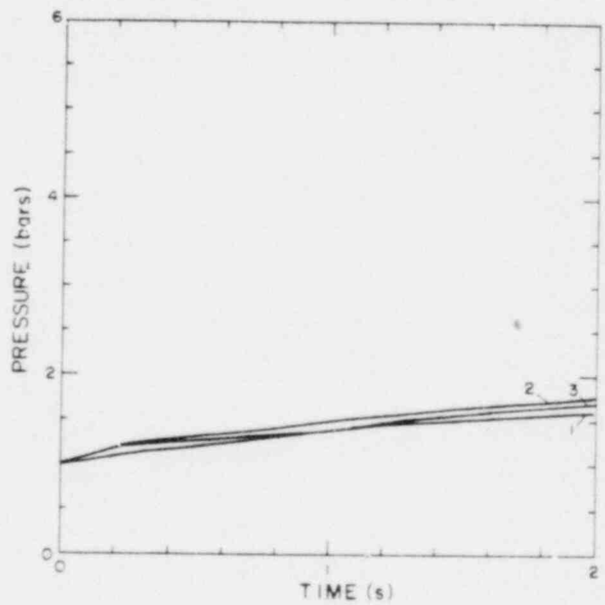


Fig. A-60. Test C11--Absolute pressure comparison in subcompartment R7 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

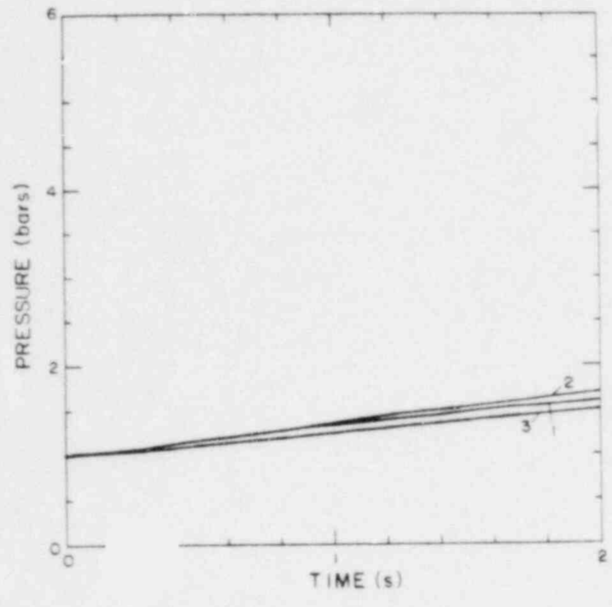


Fig. A-61. Test C11--Absolute pressure comparison in subcompartment R9 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

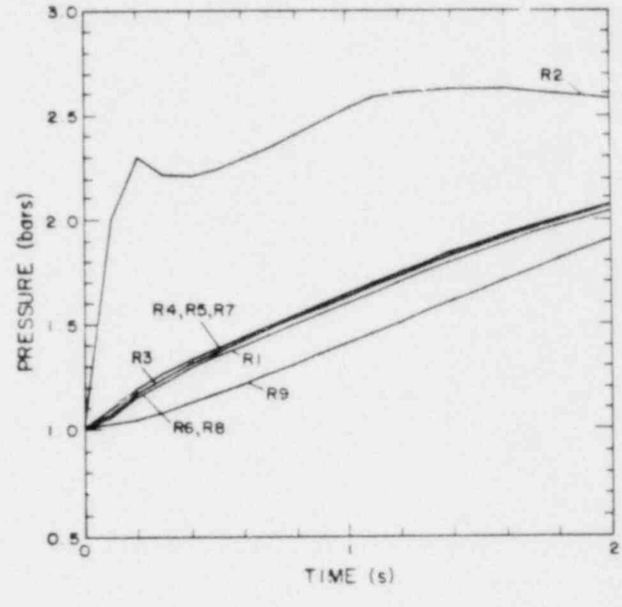


Fig. A-62. Test C12--Absolute pressure comparison in all subcompartments as predicted by COMPARE.

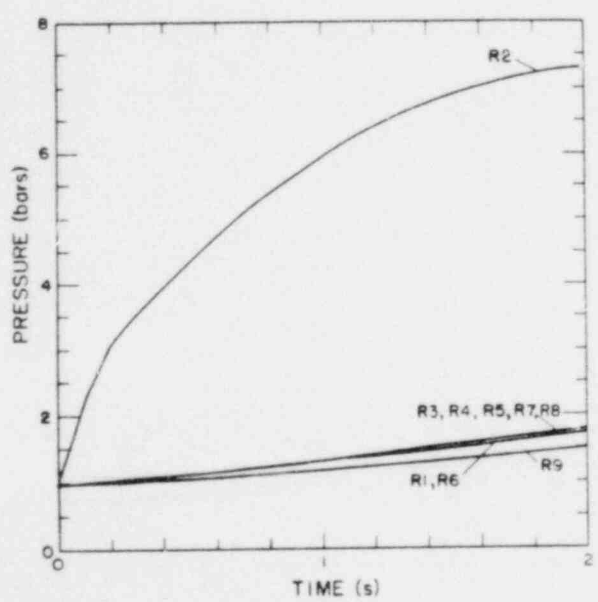


Fig. A-63. Test C12--Absolute pressure comparison in all subcompartments as predicted by RELAP3.

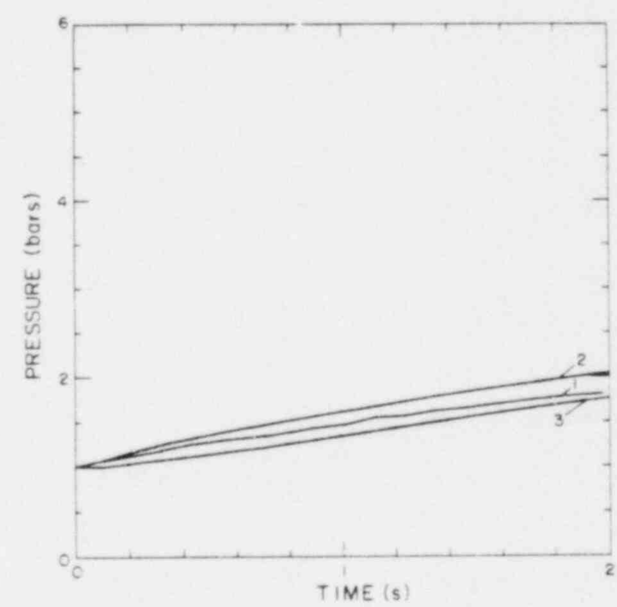


Fig. A-64. Test C12--Absolute pressure comparison in subcompartment R1 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

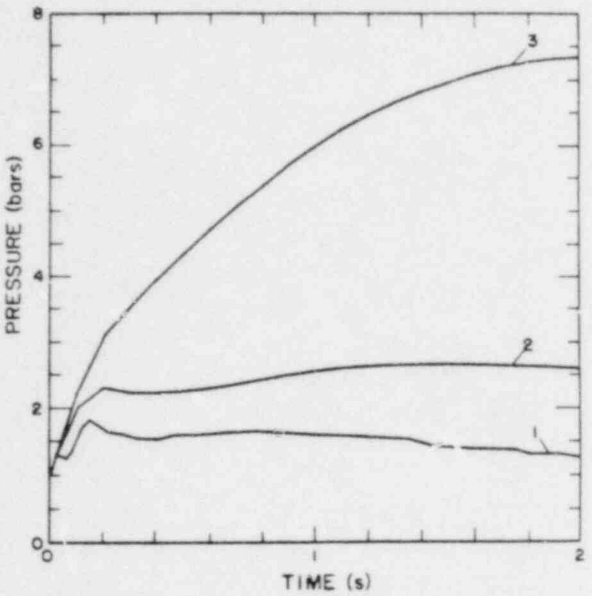


Fig. A-65. Test C12--Absolute pressure comparison in subcompartment R2 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

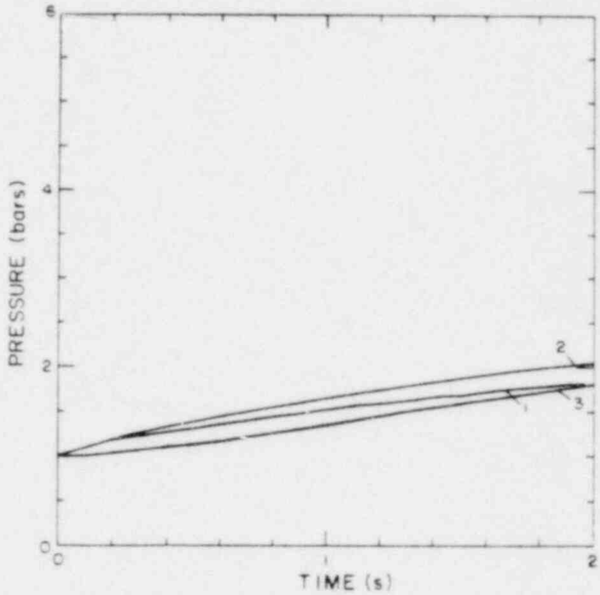


Fig. A-66. Test C12--Absolute pressure comparison in subcompartment R5 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

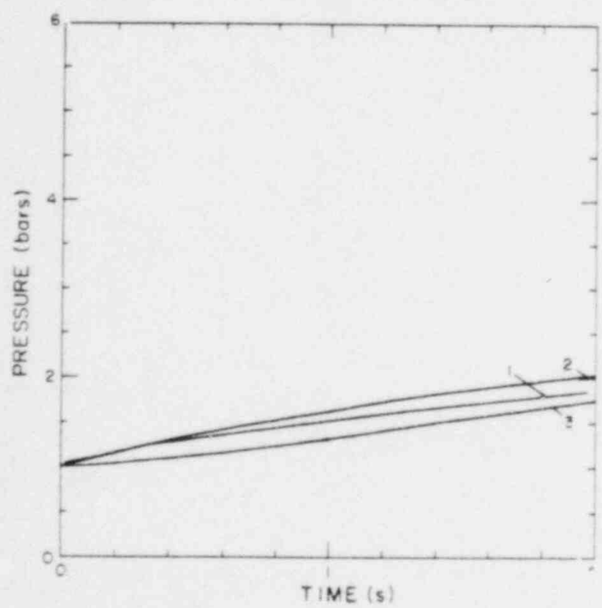


Fig. A-67. Test C12--Absolute pressure comparison in subcompartment R6 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

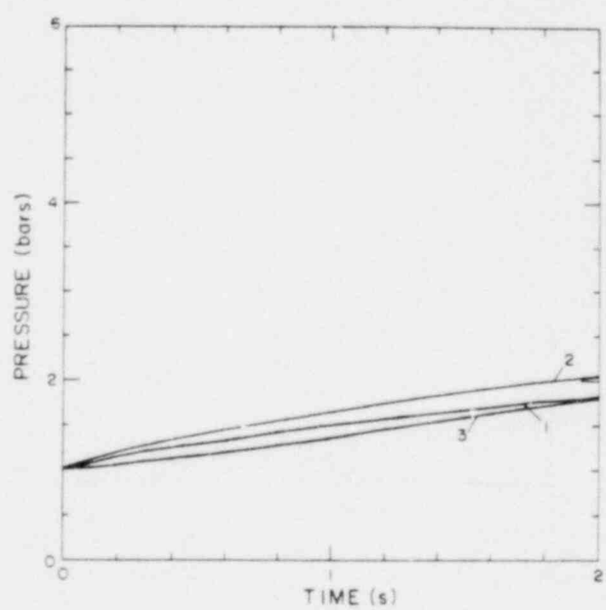


Fig. A-68. Test C12--Absolute pressure comparison in subcompartment R7 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

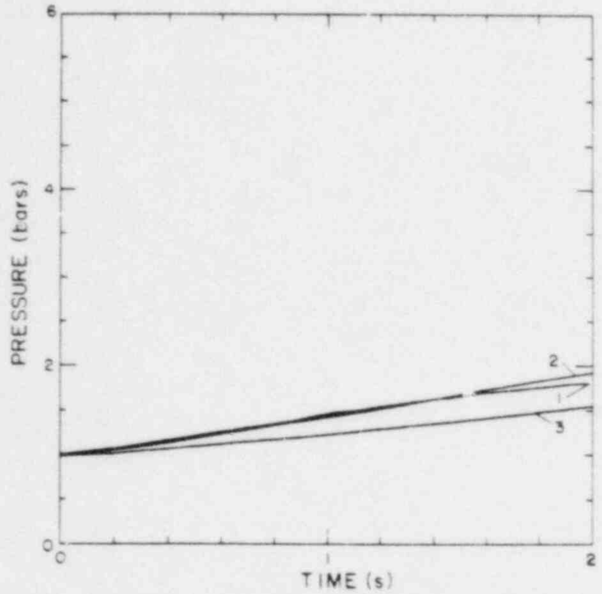


Fig. A-69. Test C12--Absolute pressure comparison in subcompartment R9 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

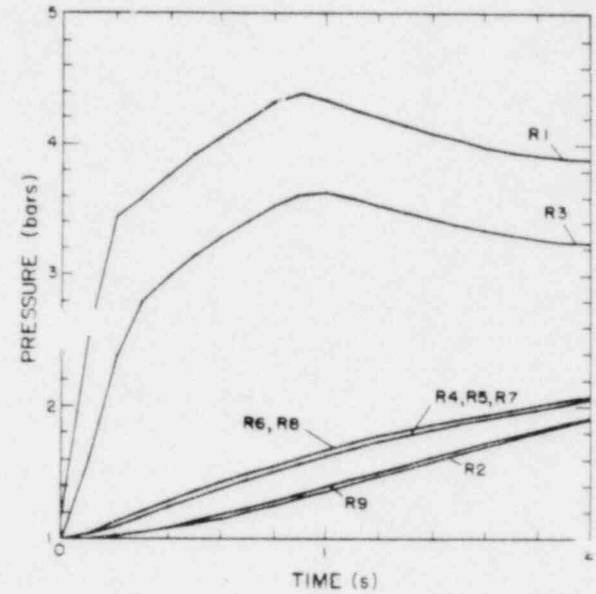


Fig. A-70. Test C13--Absolute pressure comparison in all subcompartments as predicted by COMPARE.

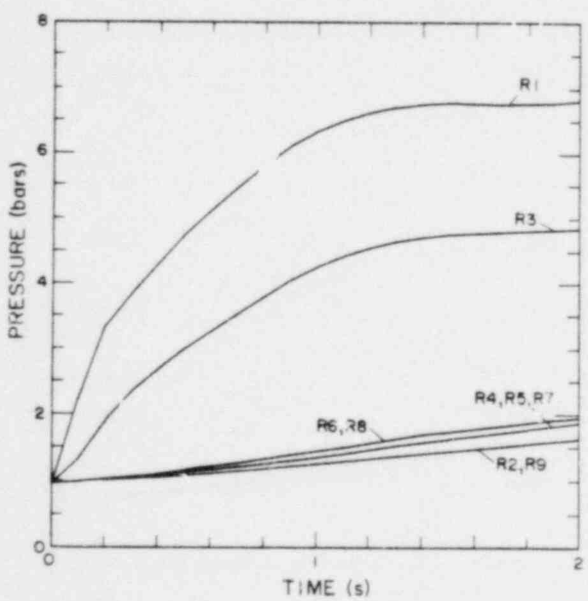


Fig. A-71. Test C13--Absolute pressure comparison in all subcompartments as predicted by RELAP3.

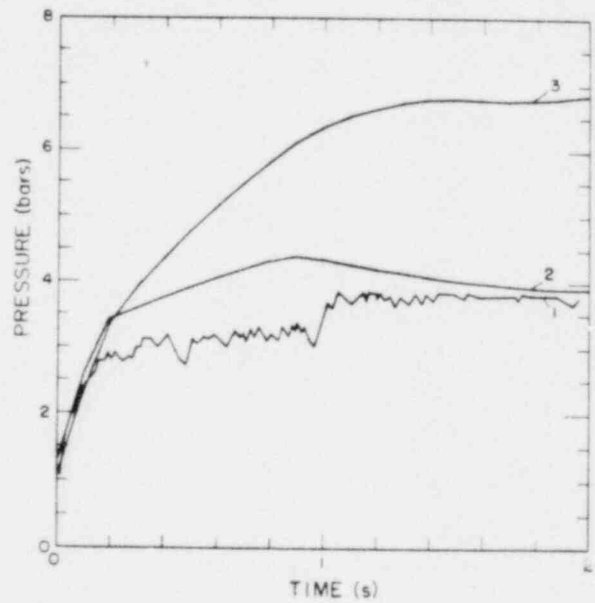


Fig. A-72. Test C13--Absolute pressure comparison in subcompartment R1 for TEST (1), and as predicted by C__PARE (2) and RELAP3 (3).

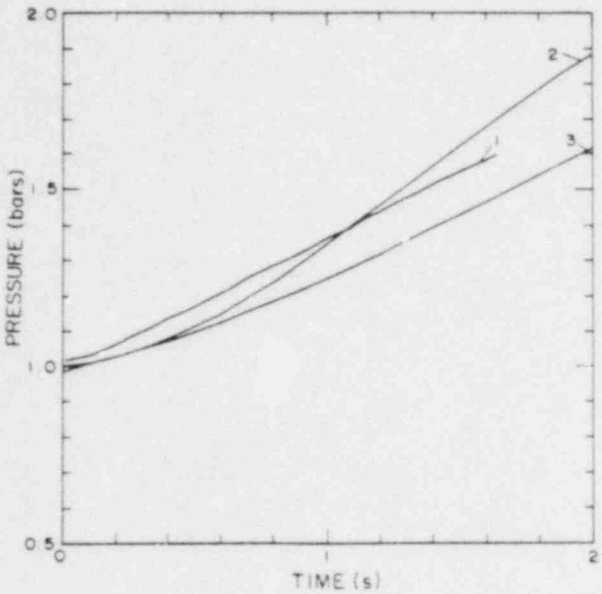


Fig. A-73. Test C13--Absolute pressure comparison in subcompartment R2 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

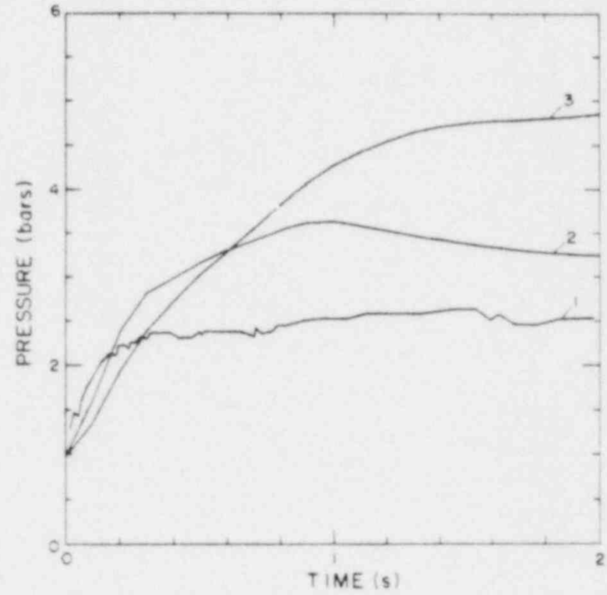


Fig. A-74. Test C13--Absolute pressure comparison in subcompartment R3 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

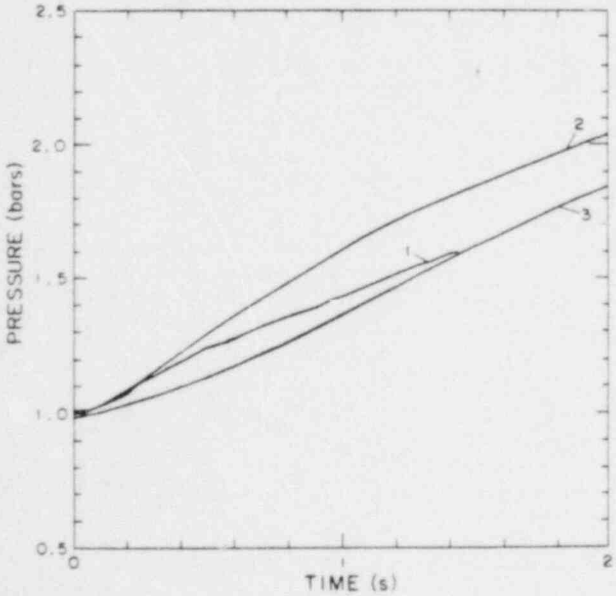


Fig. A-75. Test C13--Absolute pressure comparison in subcompartment R4 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

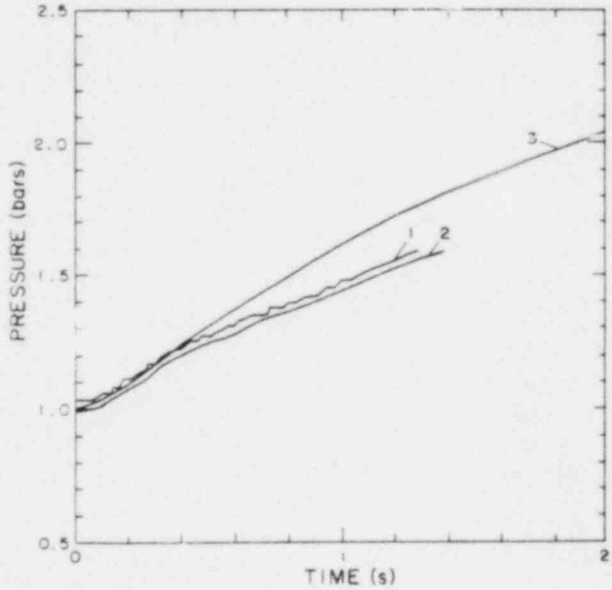


Fig. A-76. Test C13--Absolute pressure comparison in subcompartment R5 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

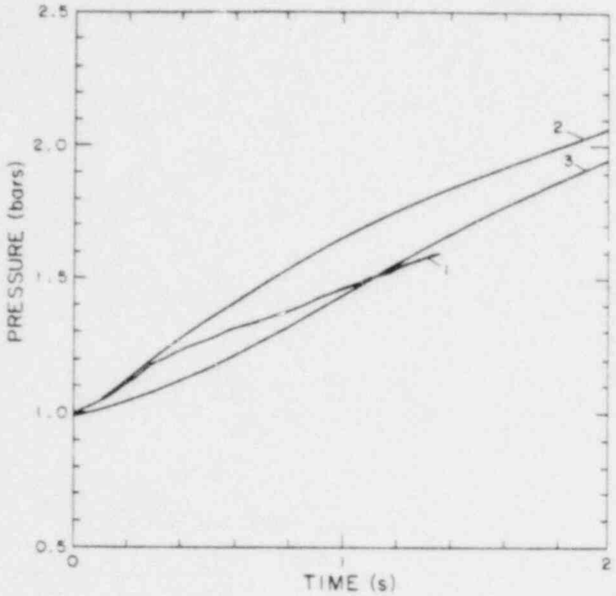


Fig. A-77. Test C13--Absolute pressure comparison in subcompartment R6 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

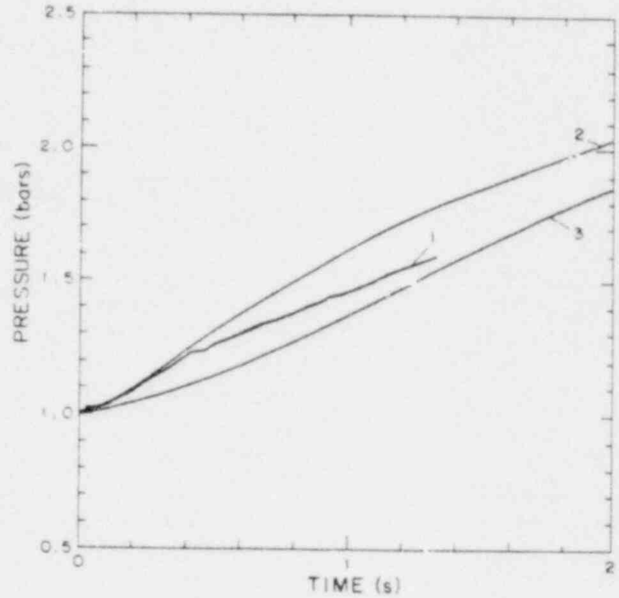


Fig. A-78. Test C13--Absolute pressure comparison in subcompartment R7 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

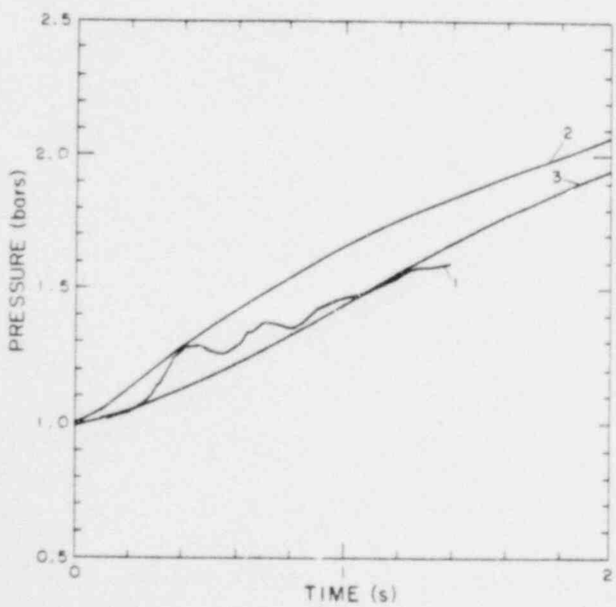


Fig. A-79. Test C13--Absolute pressure comparison in subcompartment R8 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

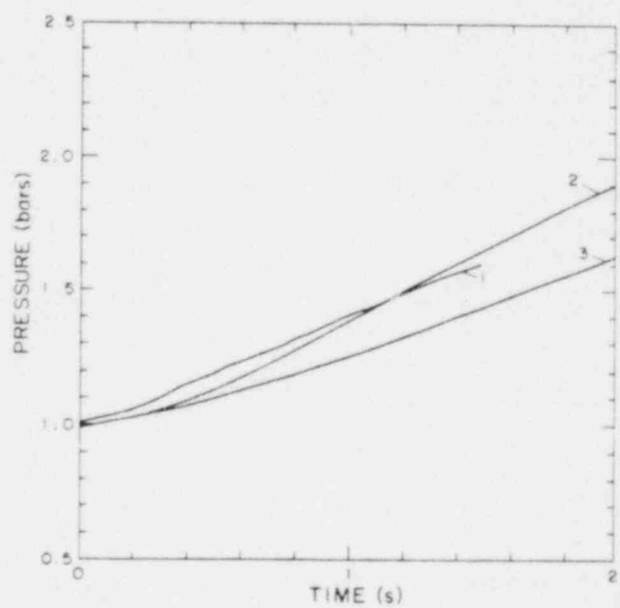


Fig. A-80. Test C13--Absolute pressure comparison in subcompartment R9 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

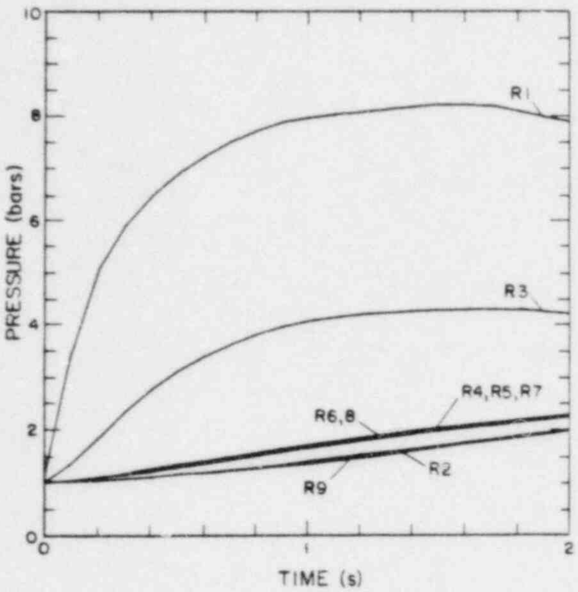


Fig. A-81. Test C15--Absolute pressure comparison in all subcompartments as predicted by COMPARE.

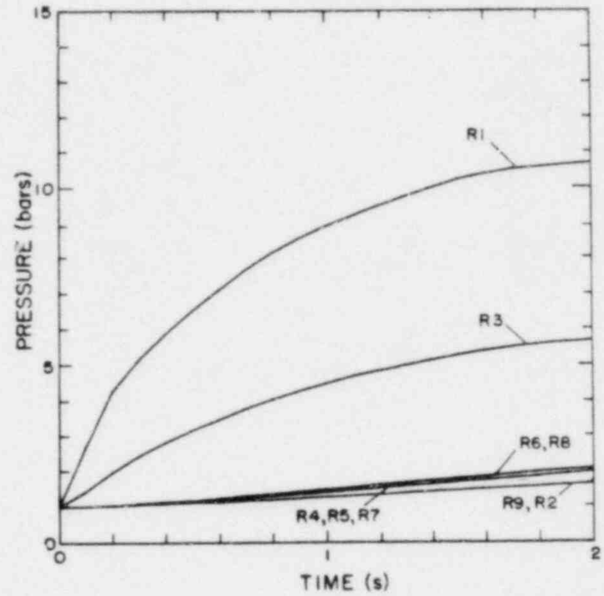


Fig. A-82. Test C15--Absolute pressure comparison in all subcompartments as predicted by RELAP3.

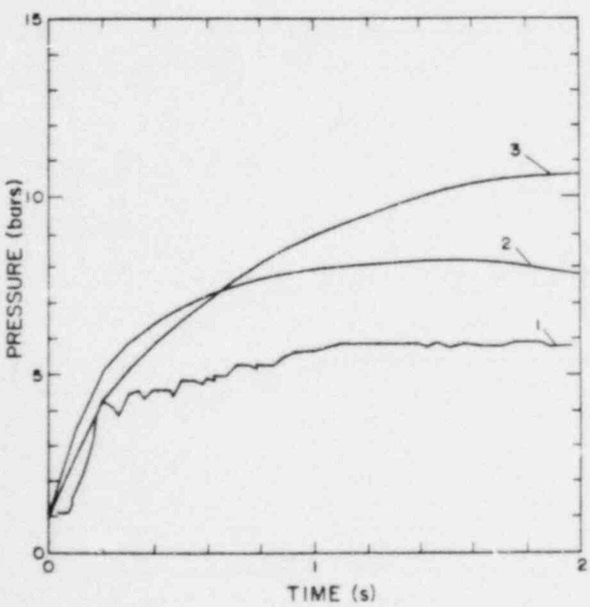


Fig. A-83. Test C15--Absolute pressure comparison in subcompartment R1 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

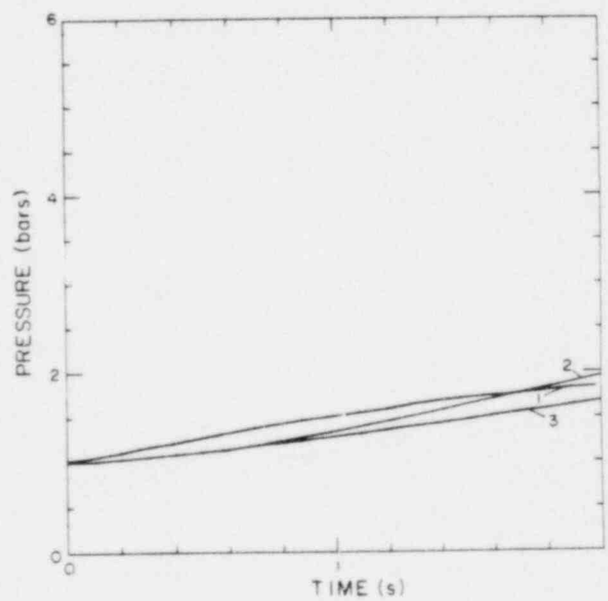


Fig. A-84. Test C15--Absolute pressure comparison in subcompartment R2 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

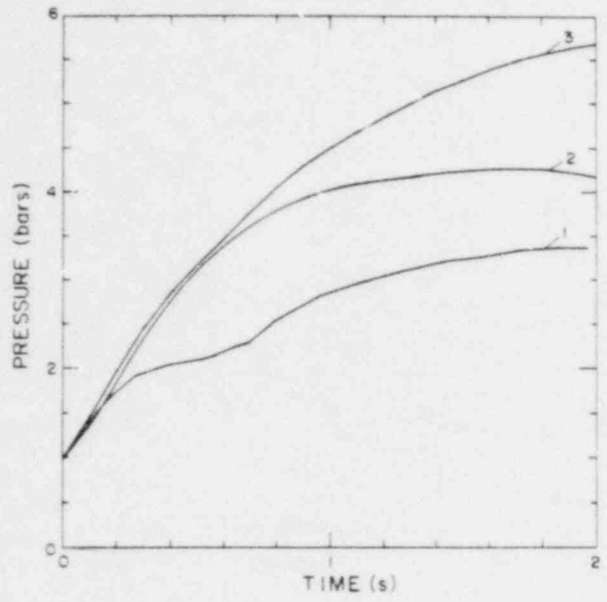


Fig. A-85. Test C15--Absolute pressure comparison in subcompartment R3 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

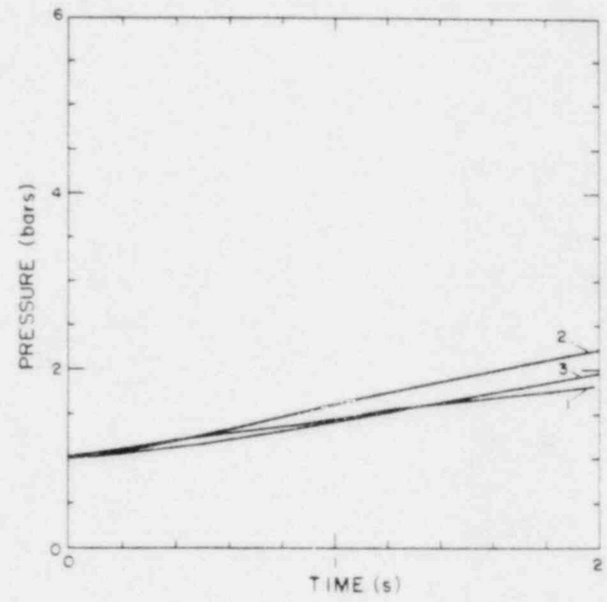


Fig. A-86. Test C15--Absolute pressure comparison in subcompartment R4 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

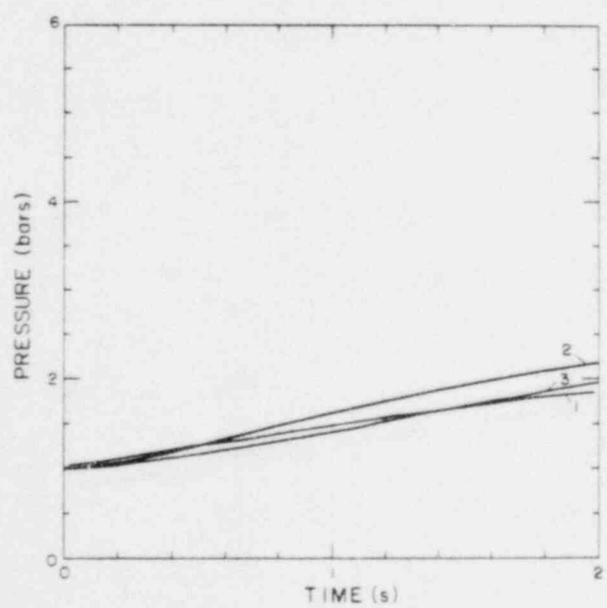


Fig. A-87. Test C15--Absolute pressure comparison in subcompartment R5 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

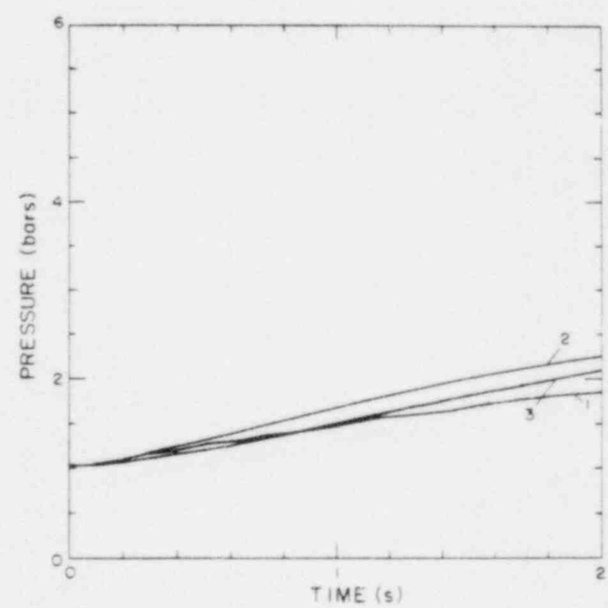


Fig. A-88. Test C15--Absolute pressure comparison in subcompartment R6 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

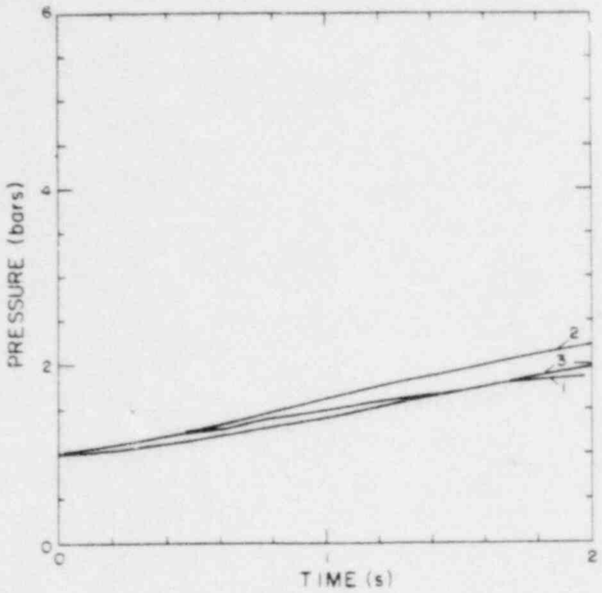


Fig. A-89. Test C15--Absolute pressure comparison in subcompartment R7 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

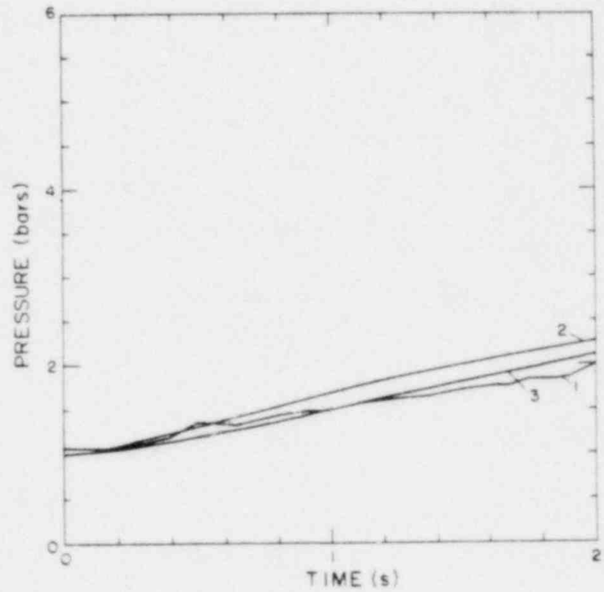


Fig. A-90. Test C15--Absolute pressure comparison in subcompartment R8 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

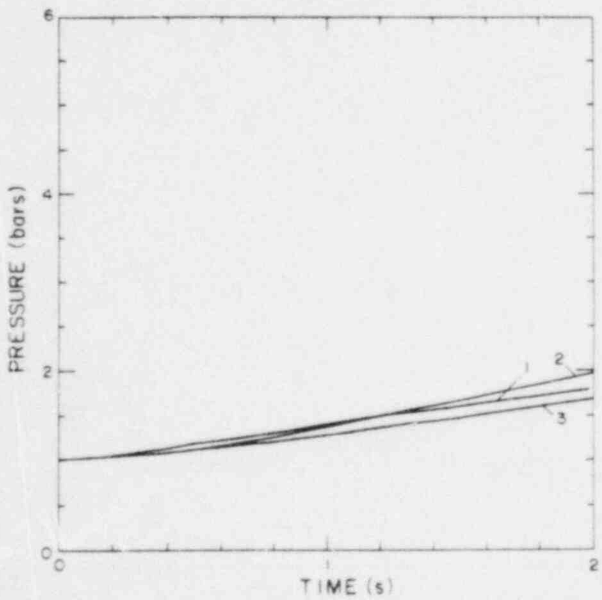


Fig. A-91. Test C15--Absolute pressure comparison in subcompartment R9 for TEST (1), and as predicted by COMPARE (2) and RELAP3 (3).

APPENDIX B

PRESSURE DIFFERENCES BETWEEN SUBCOMPARTMENTS 4 AND 6

FOR TESTS C1, C5, C6, C10, C11, C12, C13, AND C15

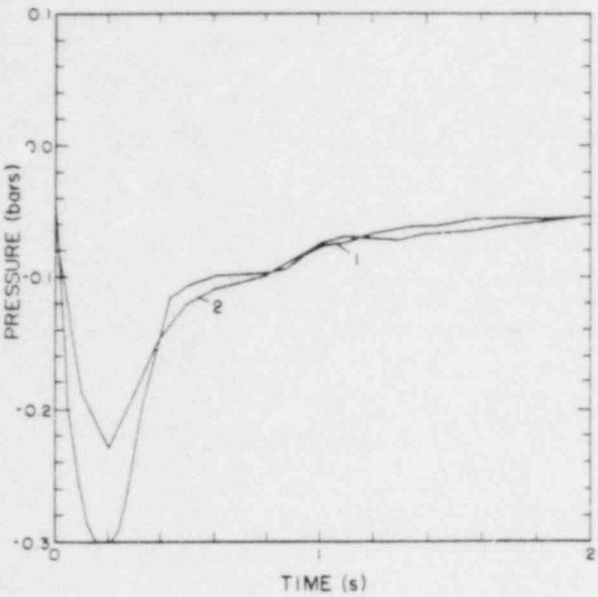


Fig. B-1. Test C1--Pressure difference comparison between subcompartments R4 and R6 for TEST (1) and as predicted by COMPARE(2).

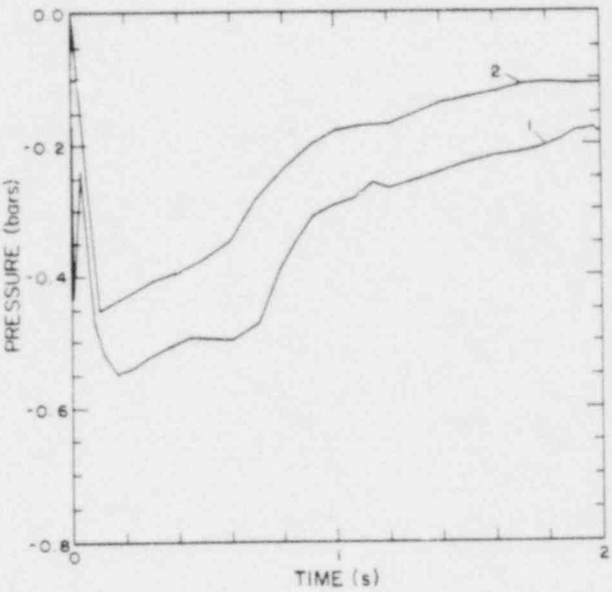


Fig. B-2. Test C5--Pressure difference comparison between subcompartments R4 and R6 for TEST (1) and as predicted by COMPARE (2).

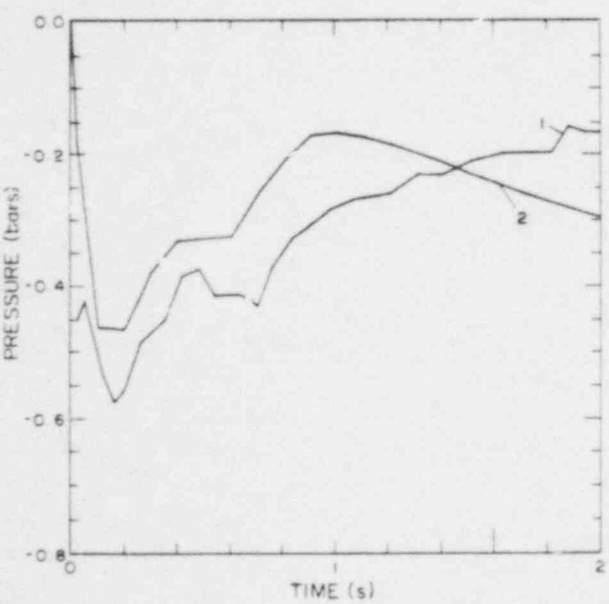


Fig. B-3. Test C6--Pressure difference comparison between subcompartments R4 and R6 for TEST (1) and as predicted by COMPARE(2).

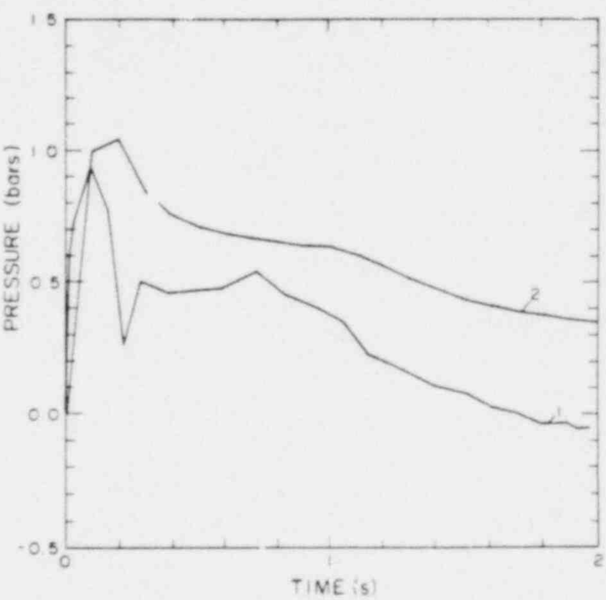


Fig. B-4. Test C10--Pressure difference comparison between subcompartments R4 and R6 for TEST (1) and as predicted by COMPARE (2).

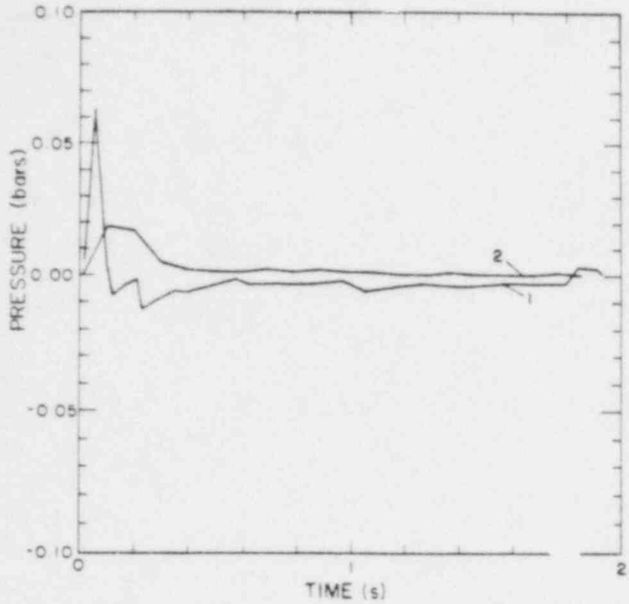


Fig. B-5. Test C11--Pressure difference comparison between subcompartments R4 and R6 for TEST (1) and as predicted by COMPARE(2).

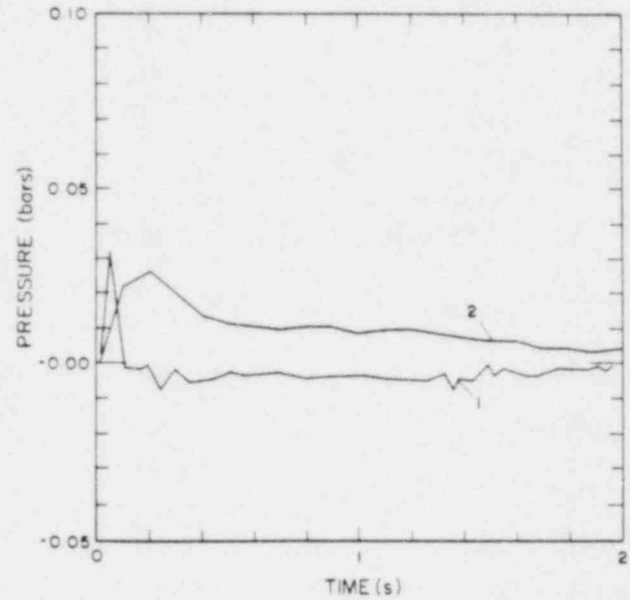


Fig. B-6. Test C12--Pressure difference comparison between subcompartments R4 and R6 for TEST (1) and as predicted by COMPARE (2).

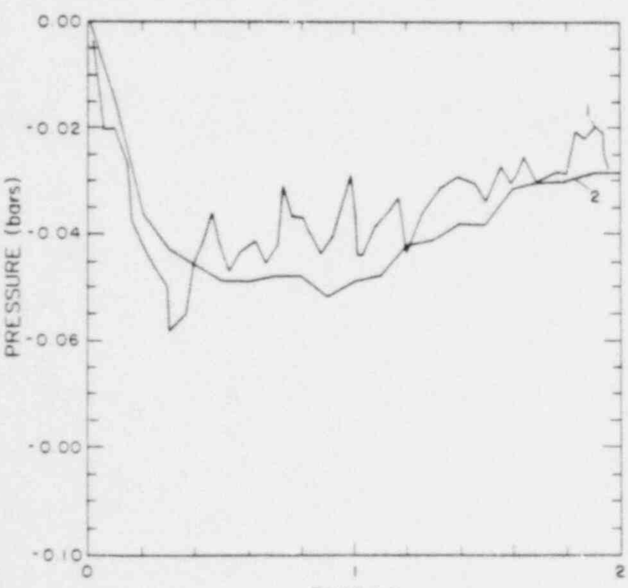


Fig. B-7. Test C13--Pressure difference comparison between subcompartments R4 and R6 for TEST (1) and as predicted by COMPARE(2).

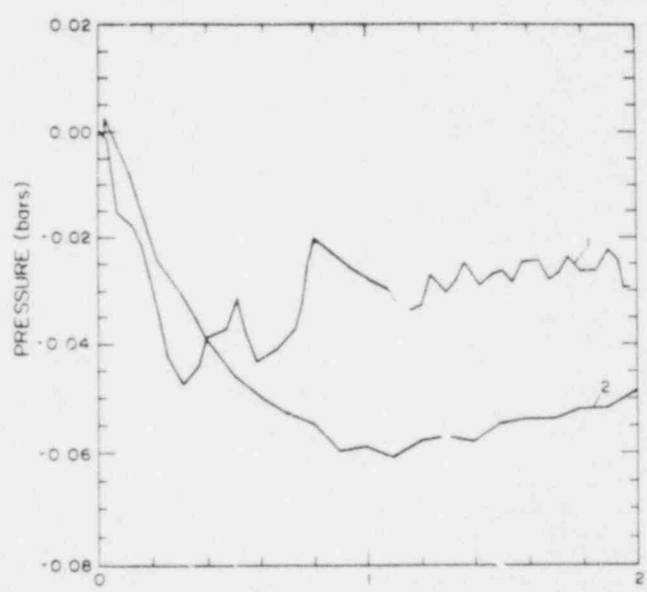


Fig. B-8. Test C15--Pressure difference comparison between subcompartments R4 and R6 for TEST (1) and as predicted by COMPARE (2).

APPENDIX C

THE EFFECTS OF VARYING THE MOODY MULTIPLIERS FOR TESTS C5, C10, C13, AND C15

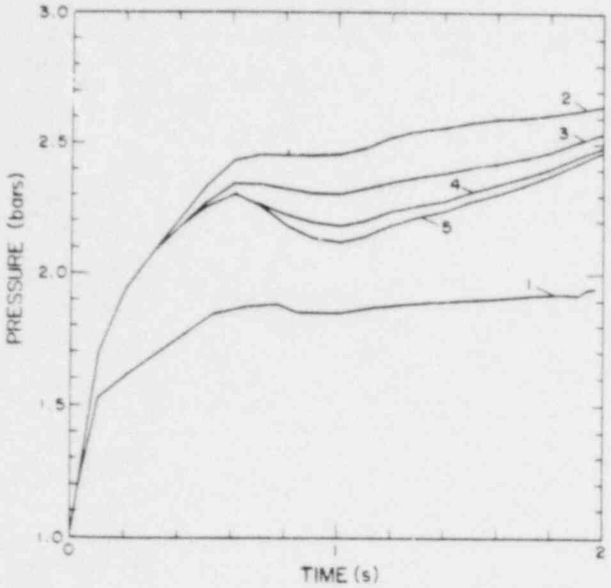


Fig. C-1. Test C5--Absolute pressure in subcompartment R6 for BMM=0.4 and OMM values listed below.

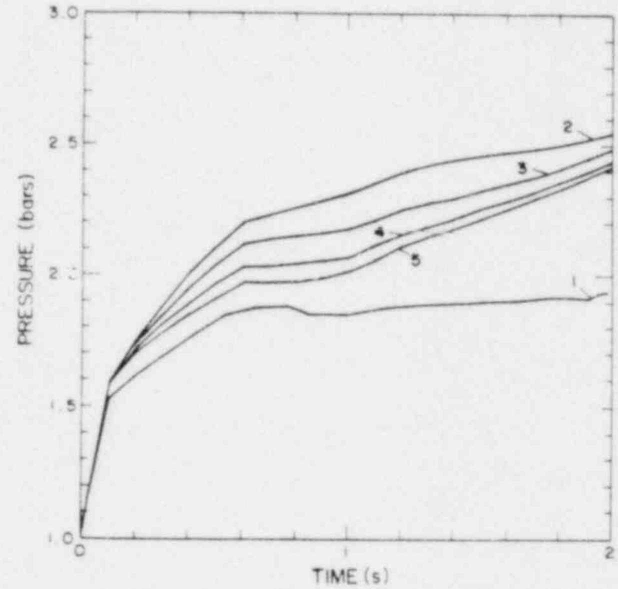


Fig. C-2. Test C5--Absolute pressure in subcompartment R6 for BMM=0.6 and OMM values listed below.

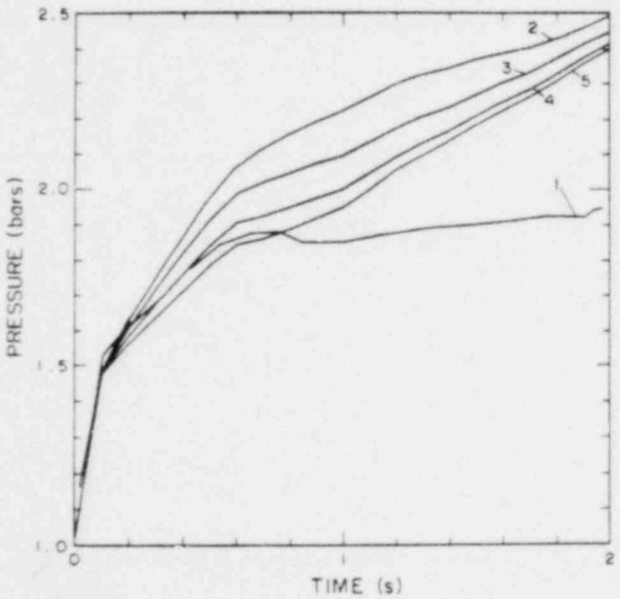


Fig. C-3. Test C5--Absolute pressure in subcompartment R6 for BMM=0.8 and OMM values listed below.

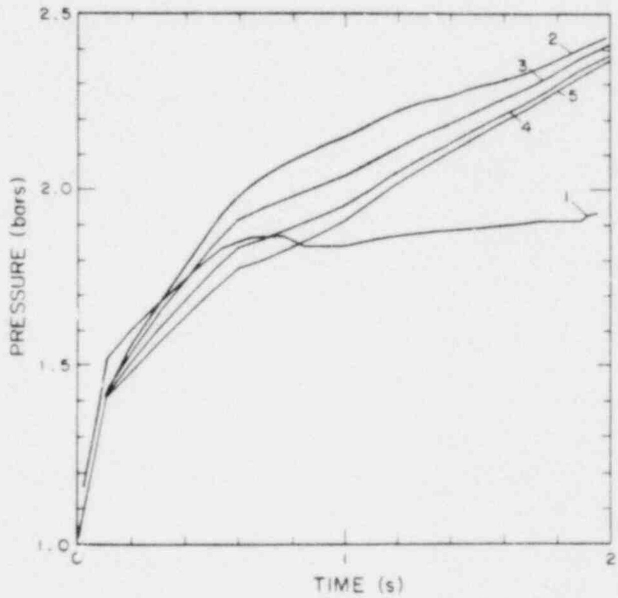


Fig. C-4. Test C5--Absolute pressure in subcompartment R6 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

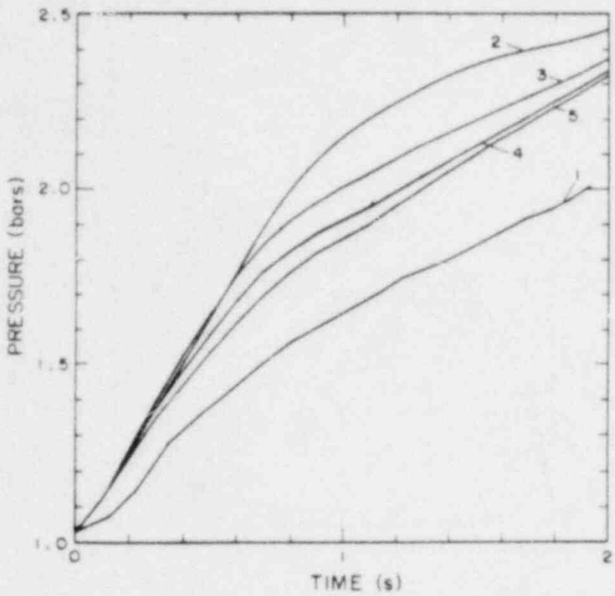


Fig. C-5. Test C5--Absolute pressure in subcompartment R4 for BMM=0.4 and OMM values listed below.

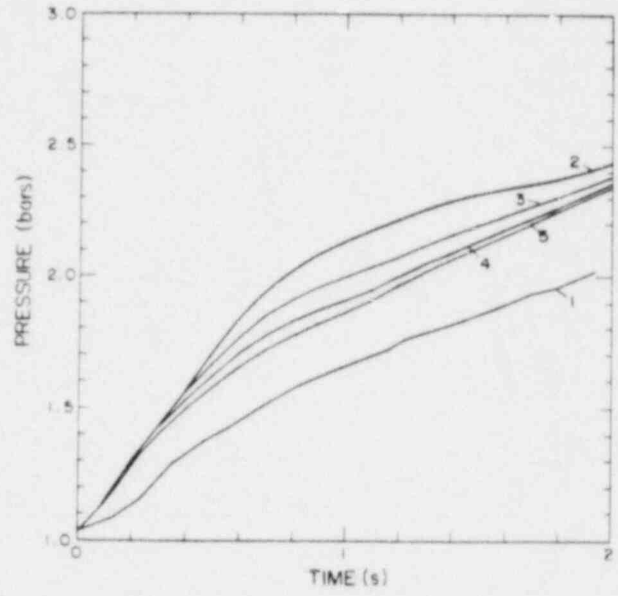


Fig. C-6. Test C5--Absolute pressure in subcompartment R4 for BMM=0.6 and OMM values listed below.

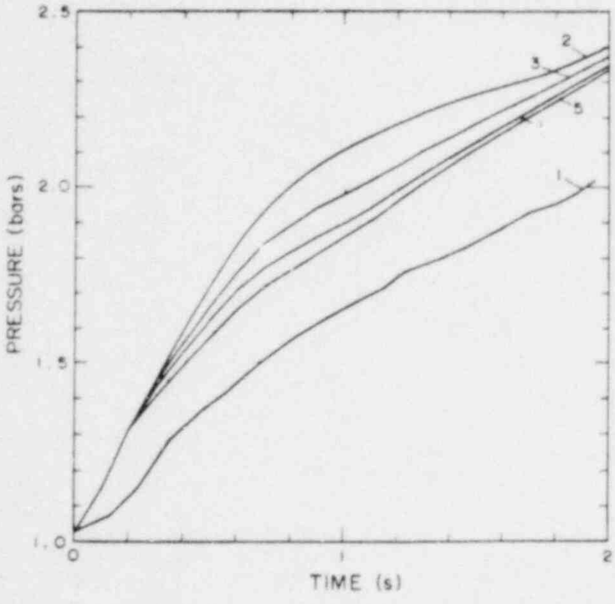


Fig. C-7. Test C5--Absolute pressure in subcompartment R4 for BMM=0.8 and OMM values listed below.

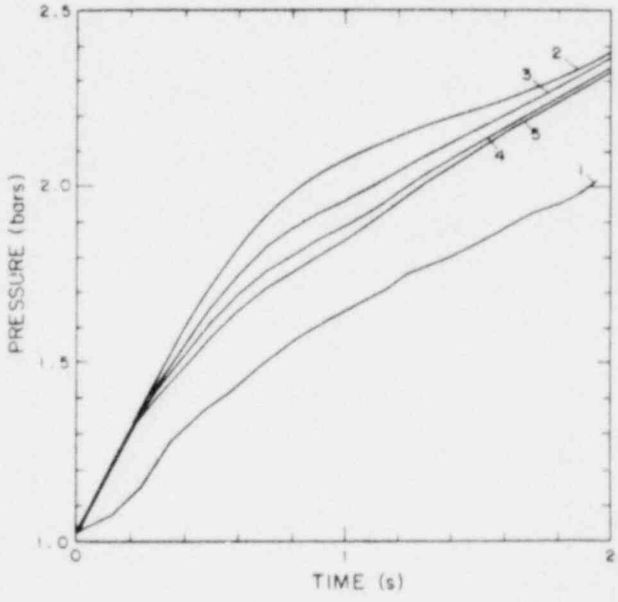


Fig. C-8. Test C5--Absolute pressure in subcompartment R4 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

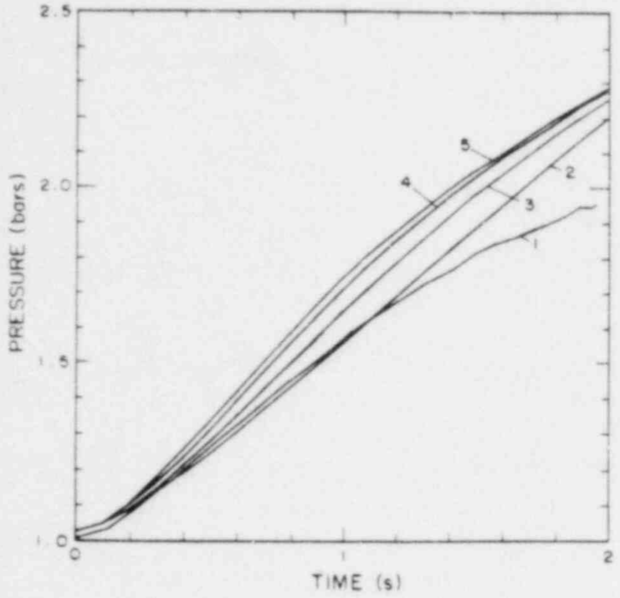


Fig. C-9. Test C5--Absolute pressure in subcompartment R9 for BMM=0.4 and OMM values listed below.

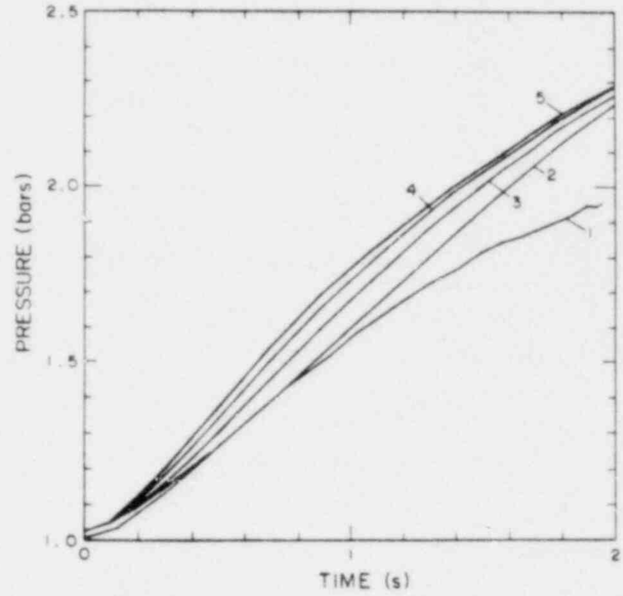


Fig. C-10. Test C5--Absolute pressure in subcompartment R9 for BMM=0.6 and OMM values listed below.

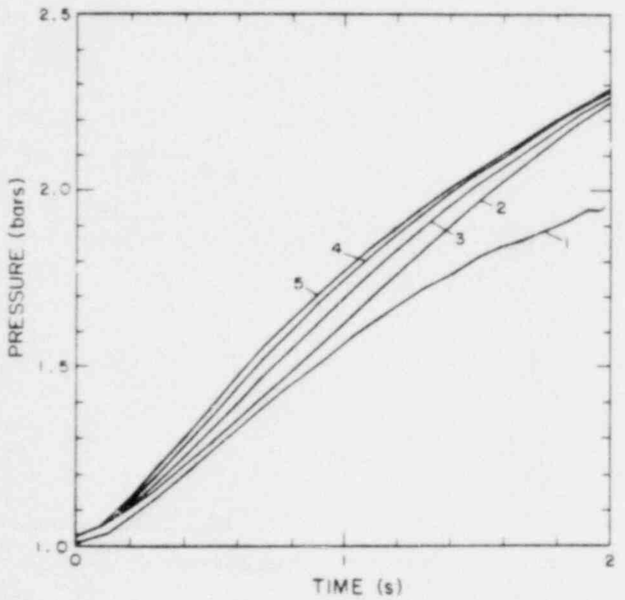


Fig. C-11. Test C5--Absolute pressure in subcompartment R9 for BMM=0.8 and OMM values listed below.

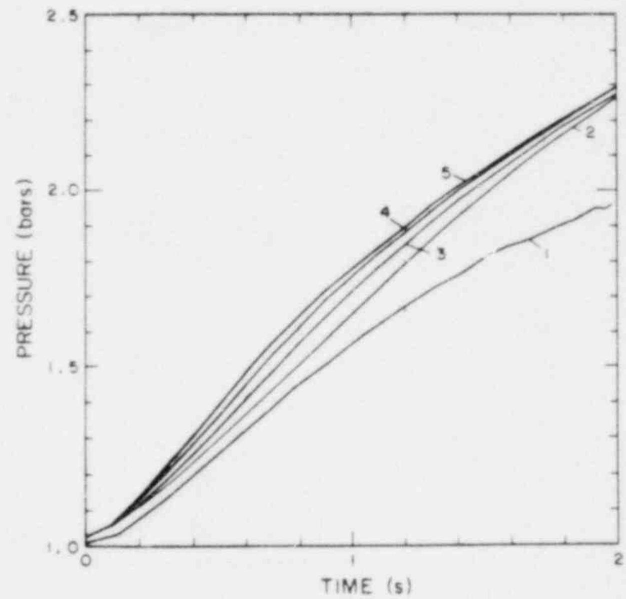


Fig. C-12. Test C5--Absolute pressure in subcompartment R9 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

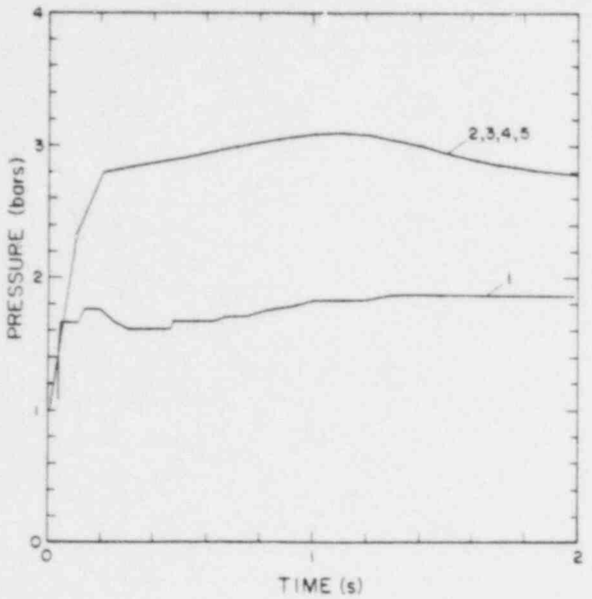


Fig. C-13. Test C10--Absolute pressure in subcompartment R4 for BMM=0.4 and OMM values listed below.

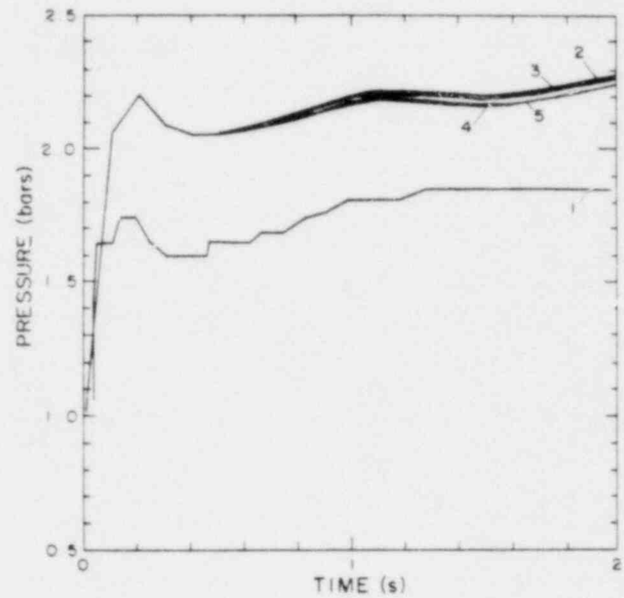


Fig. C-14. Test C10--Absolute pressure in subcompartment R4 for BMM=0.6 and OMM values listed below.

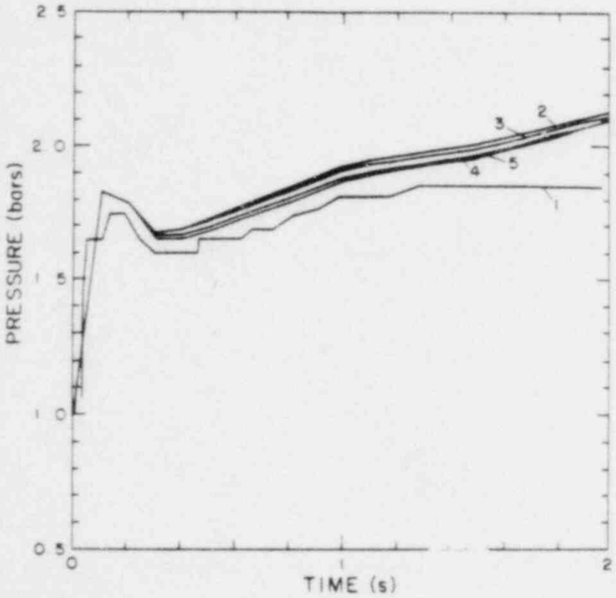


Fig. C-15. Test C10--Absolute pressure in subcompartment R4 for BMM=0.8 and OMM values listed below.

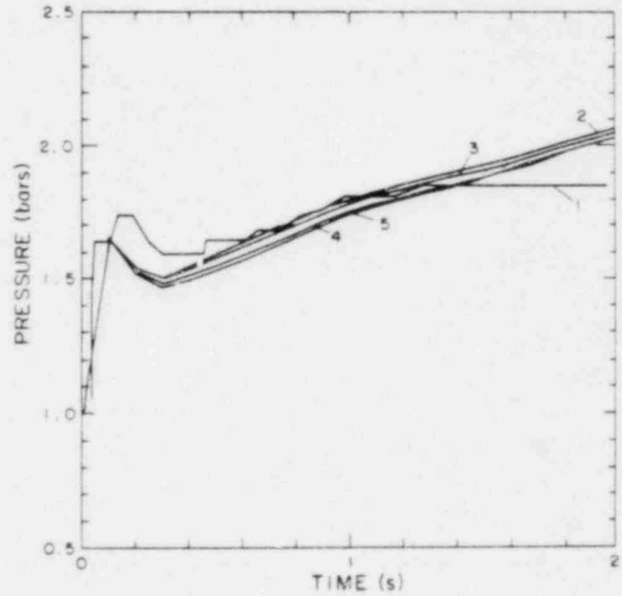


Fig. C-16. Test C10--Absolute pressure in subcompartment R4 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

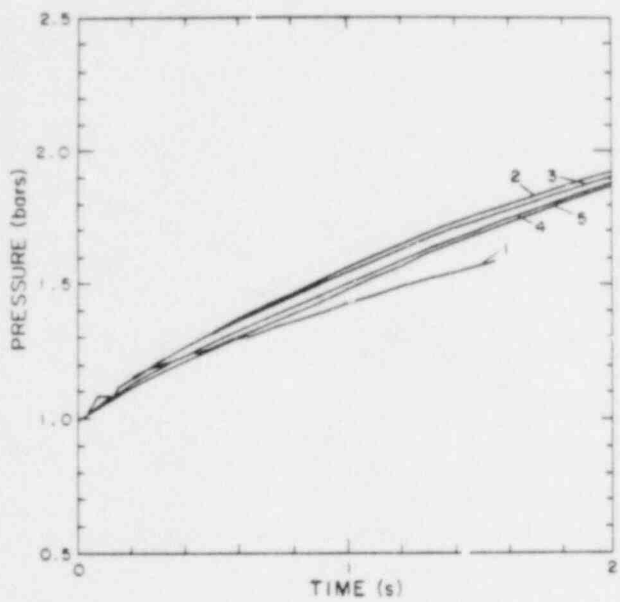


Fig. C-17. Test C10--Absolute pressure in subcompartment R5 for BMM=0.4 and OMM values listed below.

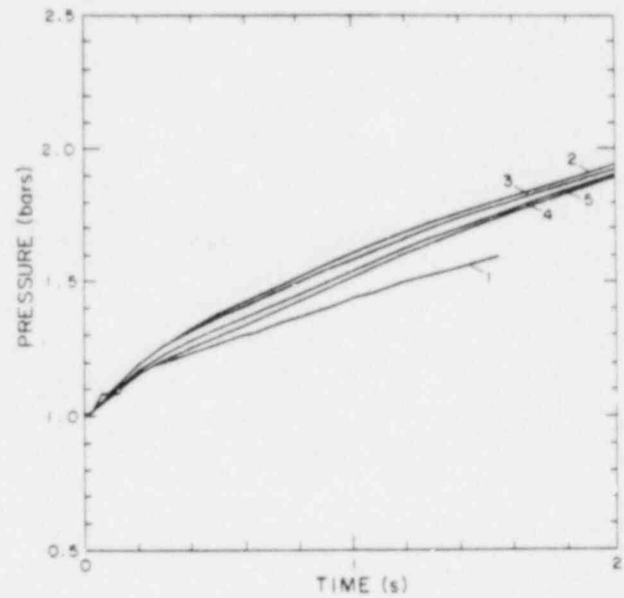


Fig. C-18. Test C10--Absolute pressure in subcompartment R5 for BMM=0.6 and OMM values listed below.

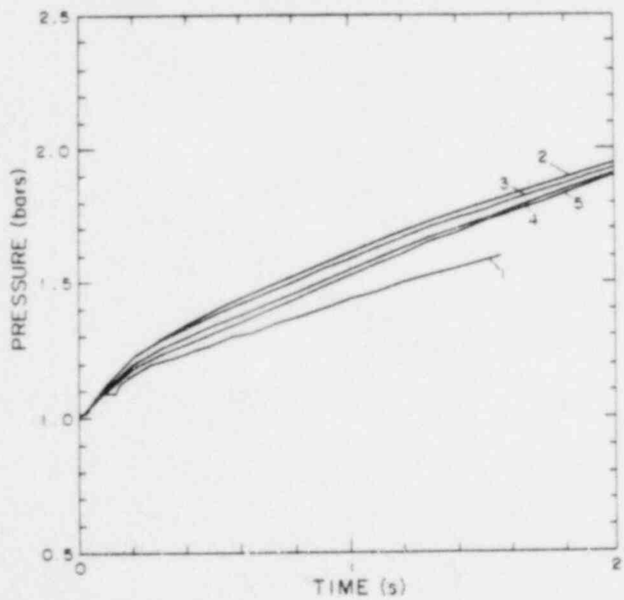


Fig. C-19. Test C10--Absolute pressure in subcompartment R5 for BMM=0.8 and OMM values listed below.

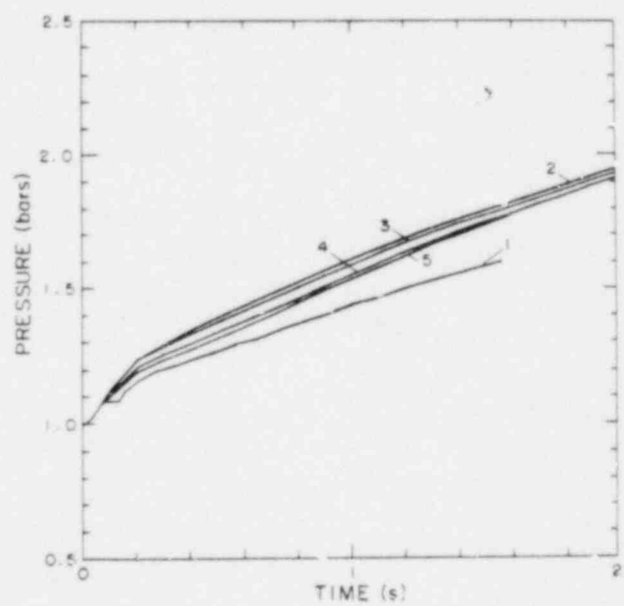


Fig. C-20. Test C10--Absolute pressure in subcompartment R5 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

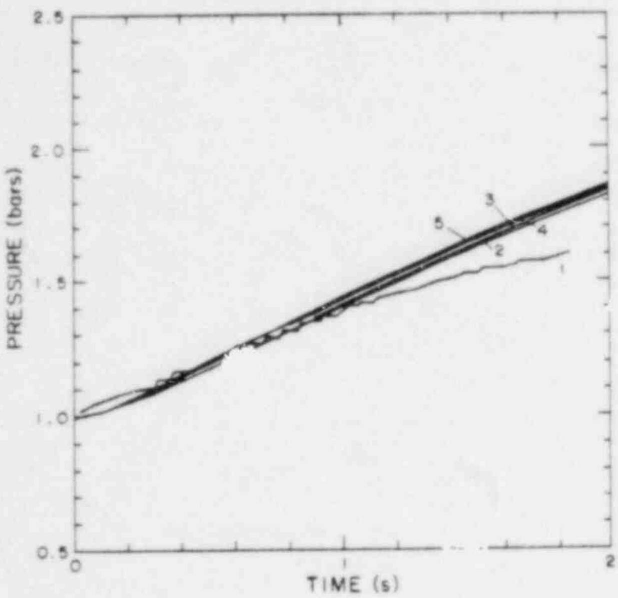


Fig. C-21. Test C10--Absolute pressure in subcompartment R9 for BMM=0.4 and OMM values listed below.

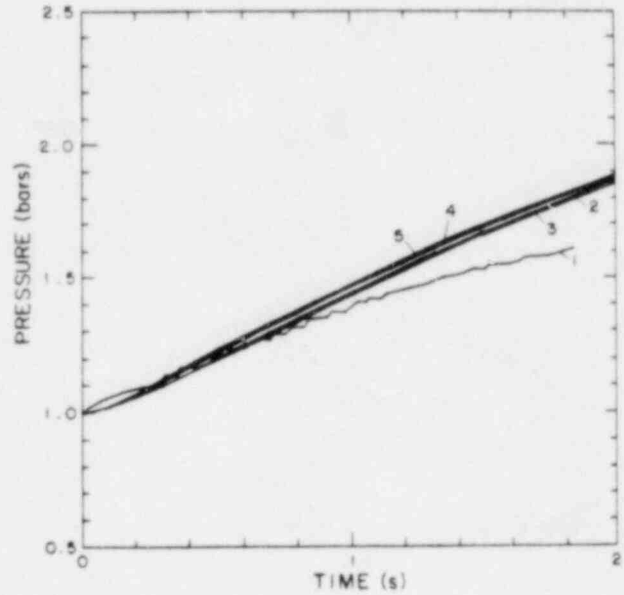


Fig. C-22. Test C10--Absolute pressure in subcompartment R9 for BMM=0.6 and OMM values listed below.

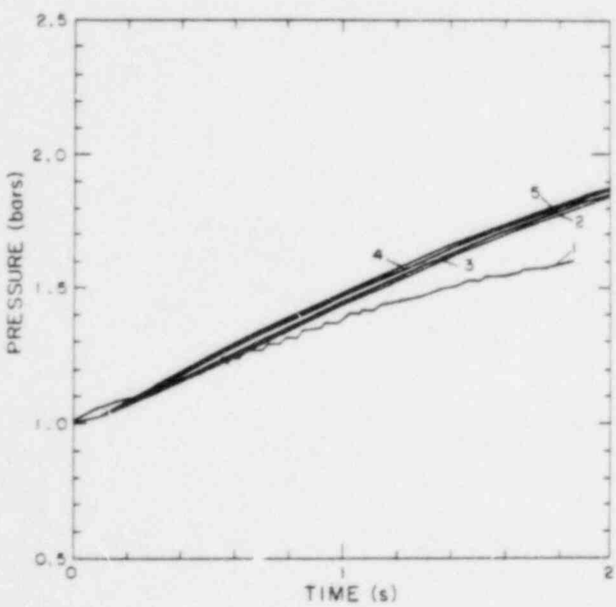


Fig. C-23. Test C10--Absolute pressure in subcompartment R9 for BMM=0.8 and OMM values listed below.

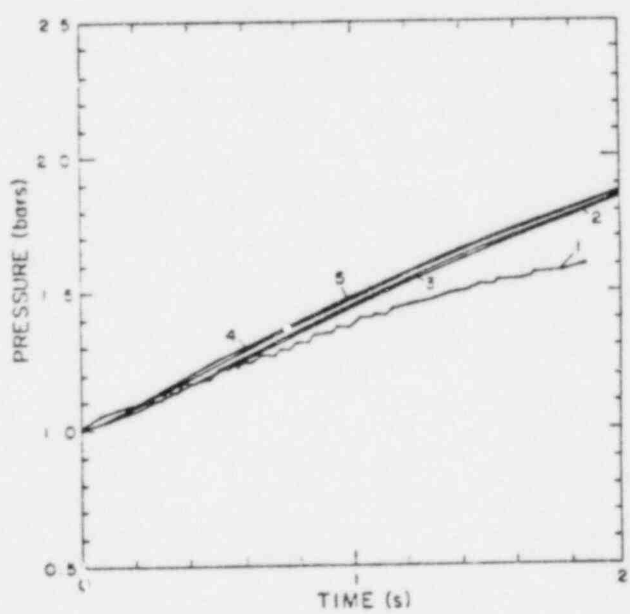


Fig. C-24. Test C10--Absolute pressure in subcompartment R9 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

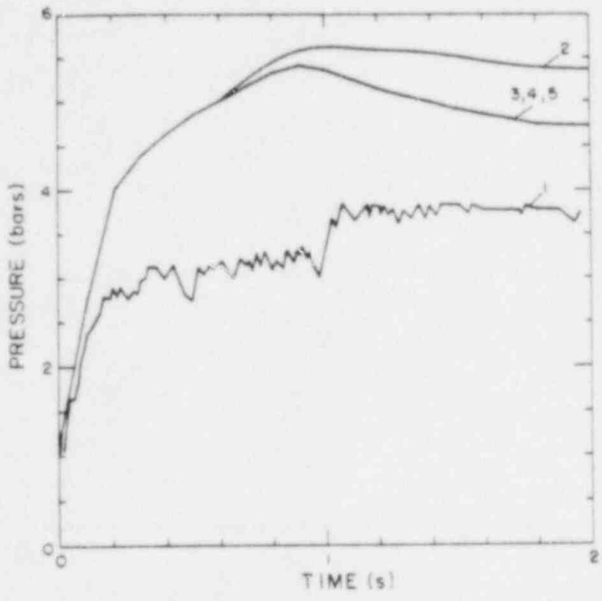


Fig. C-25. Test C13--Absolute pressure in subcompartment R1 for BMM=0.4 and OMM values listed below.

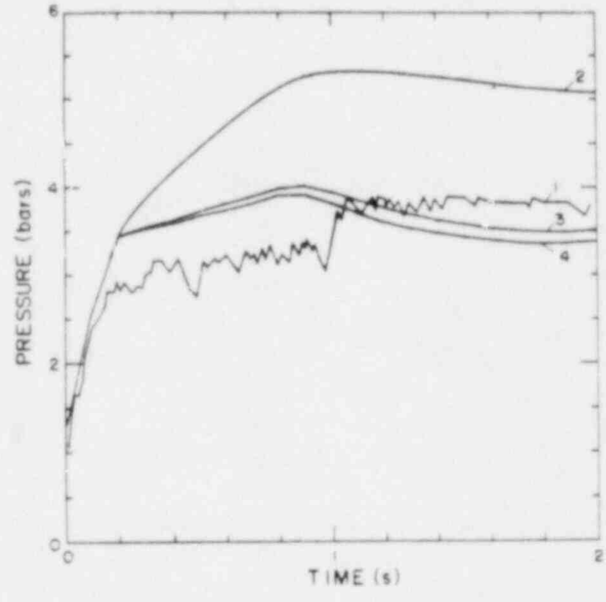


Fig. C-26. Test C13--Absolute pressure in subcompartment R1 for BMM=0.6 and OMM values listed below.

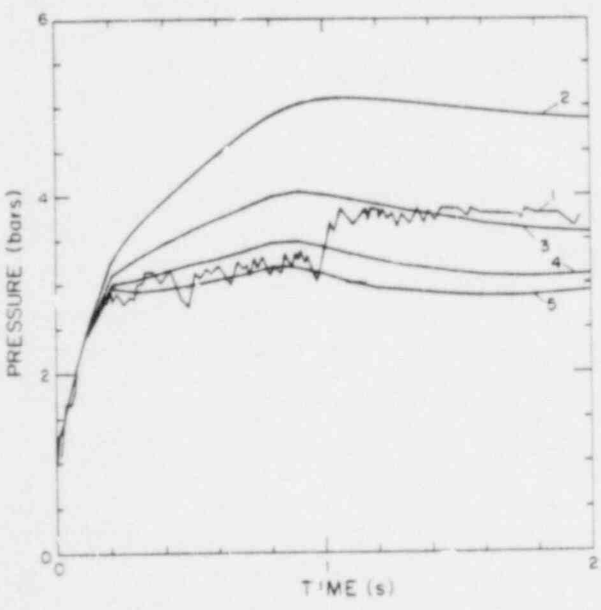


Fig. C-27. Test C13-Absolute pressure in subcompartment R1 for BMM=0.8 and OMM values listed below.

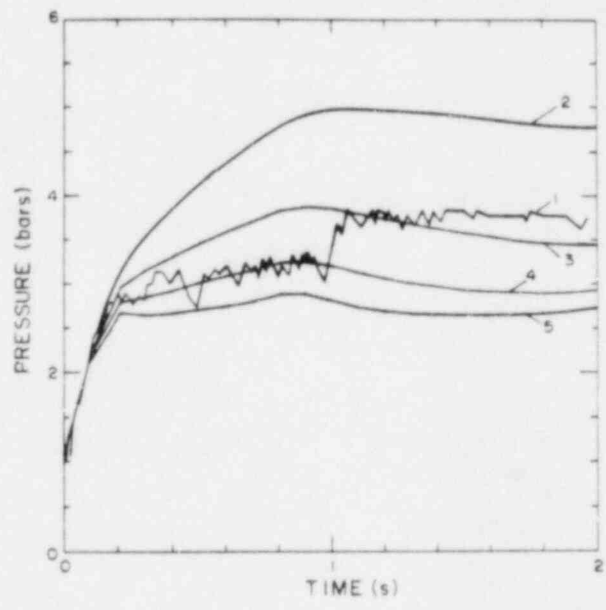


Fig. C-28. Test C13--Absolute pressure in subcompartment R1 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; Fig. C-26: (1) TEST, (2)OMM=0.4, (3)OMM=0.8, (4)OMM=1.0; other figures: (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

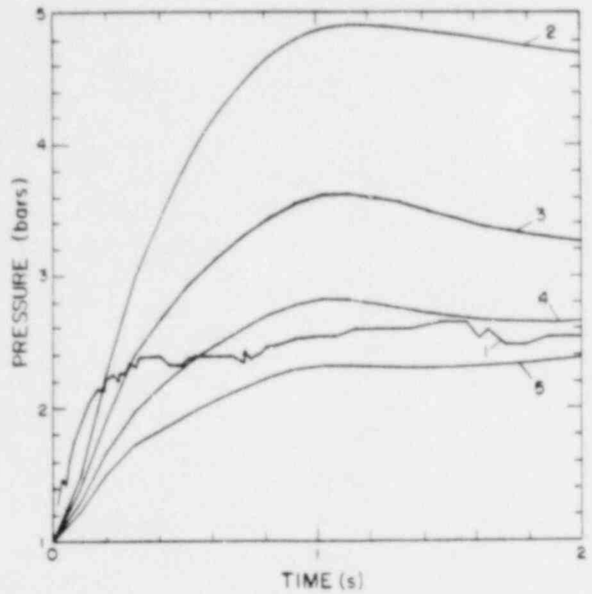


Fig. C-29. Test C13--Absolute pressure in subcompartment R3 for BMM=0.4 and OMM values listed below.

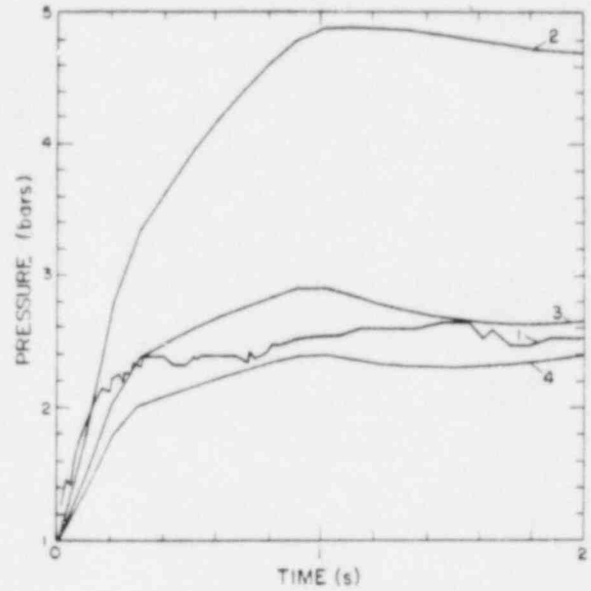


Fig. C-30. Test C13--Absolute pressure in subcompartment R3 for BMM=0.6 and OMM values listed below.

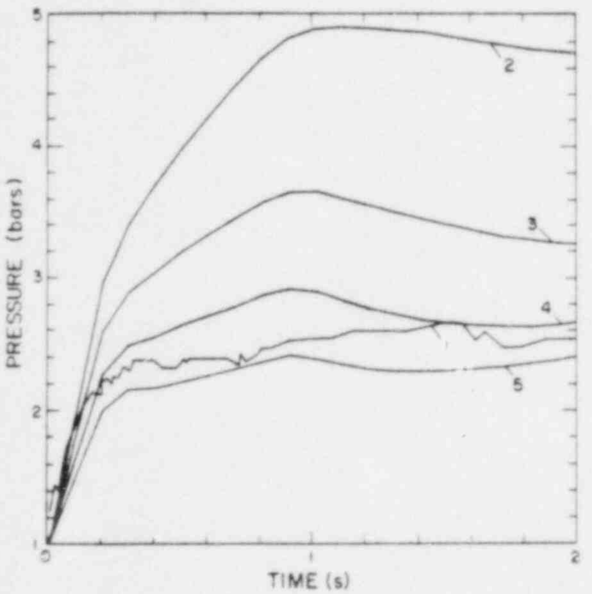


Fig. C-31. Test C13--Absolute pressure in subcompartment R3 for BMM=0.8 and OMM values listed below.

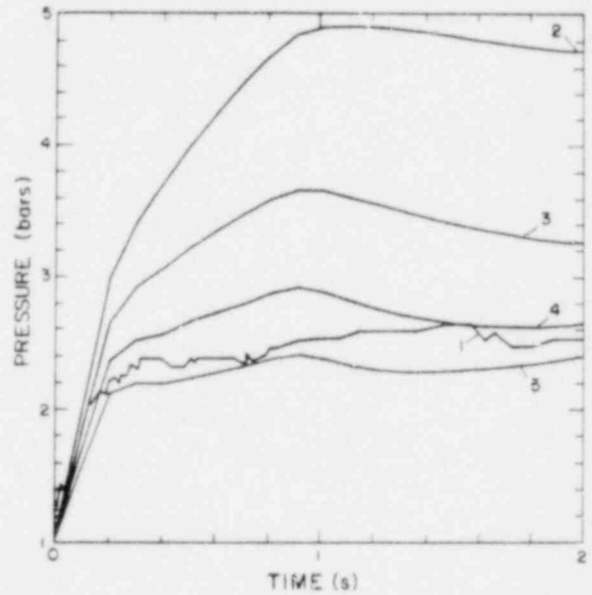


Fig. C-32. Test C13--Absolute pressure in subcompartment R3 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multipliers, OMM=Other Room Moody Multipliers; Fig. C-30: (1)TEST, (2)OMM=0.4, (3)OMM=0.8, (4)OMM=1.0; other figures: (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

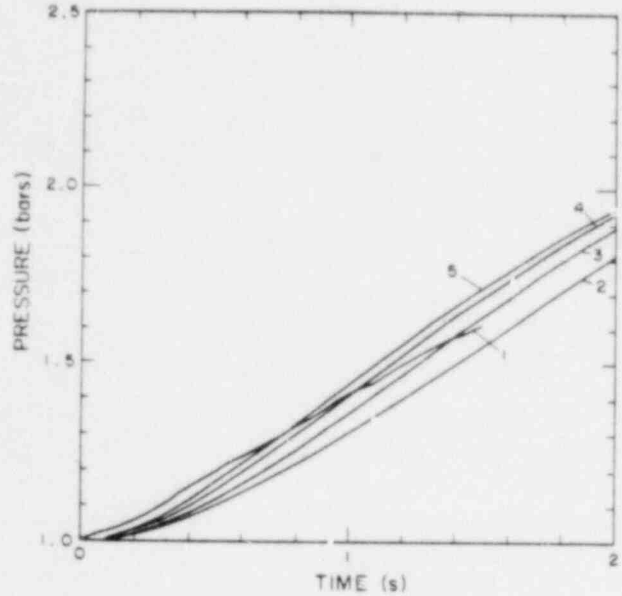


Fig. C-33. Test C13--Absolute pressure in subcompartment R9 for BMM=0.4 and OMM values listed below.

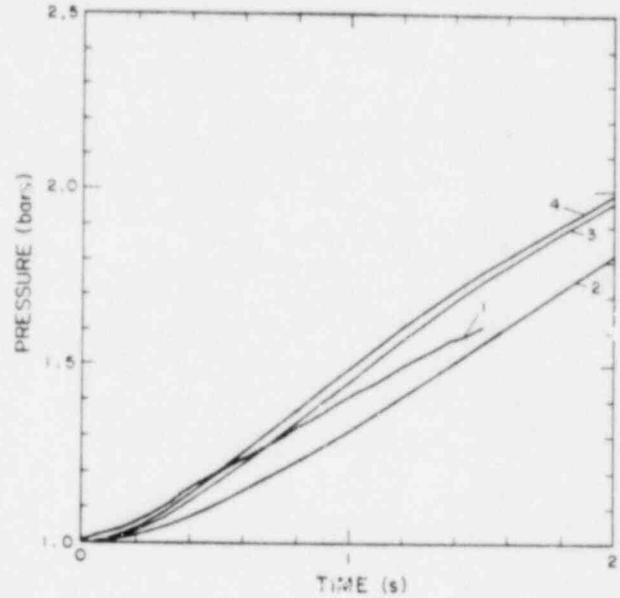


Fig. C-34. Test C13--Absolute pressure in subcompartment R9 for BMM=0.6 and OMM values listed below.

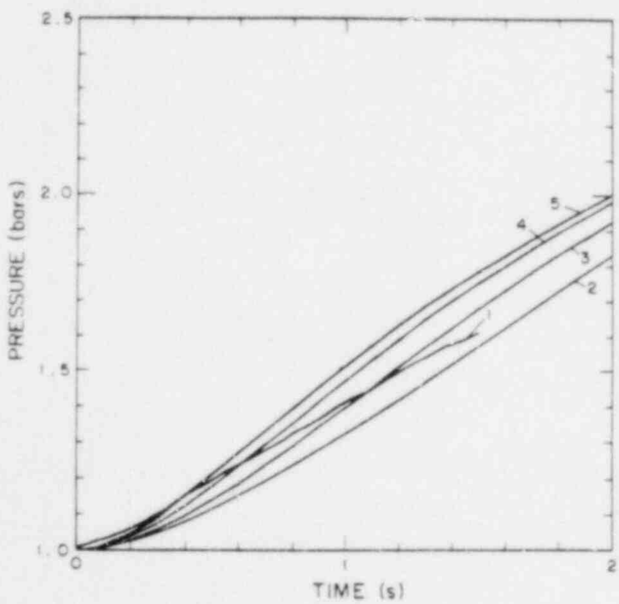


Fig. C-35. Test C13--Absolute pressure in subcompartment R9 for BMM=0.8 and OMM values listed below.

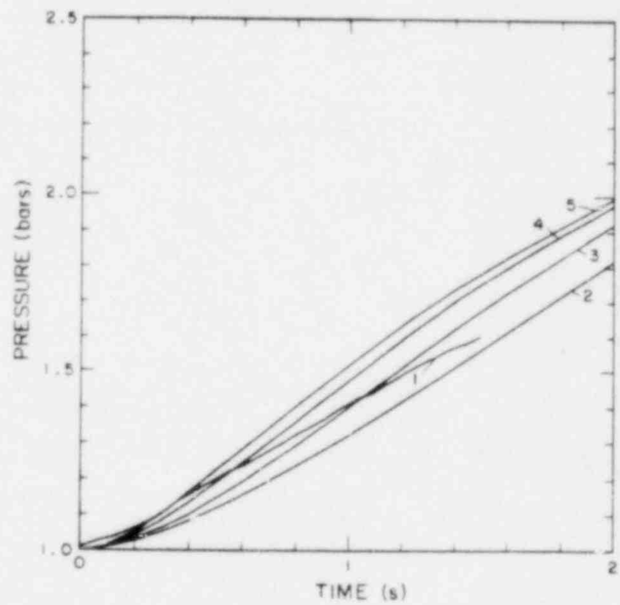


Fig. C-36. Test C13--Absolute pressure in subcompartment R9 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; Fig. C-34: (1) TEST, (2)OMM=0.4, (3)OMM=0.8, (4)OMM=1.0; other figures: (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

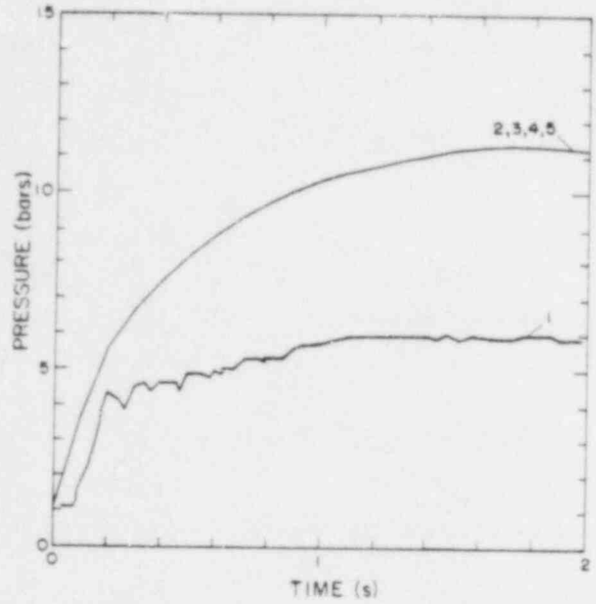


Fig. C-37. Test C15--Absolute pressure in subcompartment R1 for BMM=0.4 and OMM values listed below.

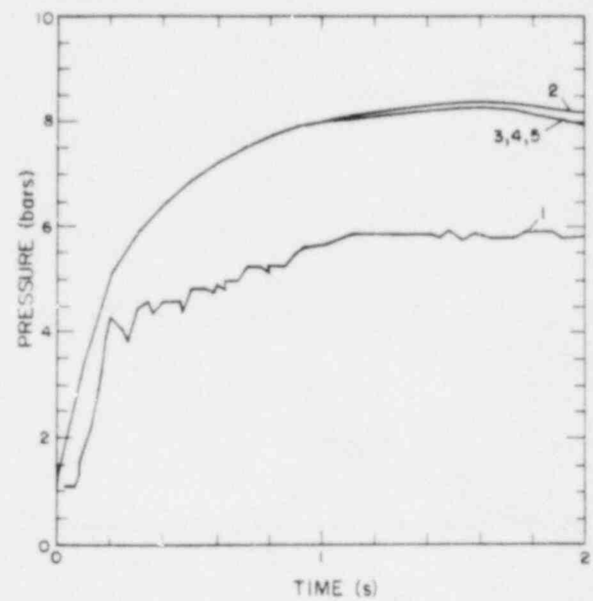


Fig. C-38. Test C15--Absolute pressure in subcompartment R1 for BMM=0.6 and OMM values listed below.

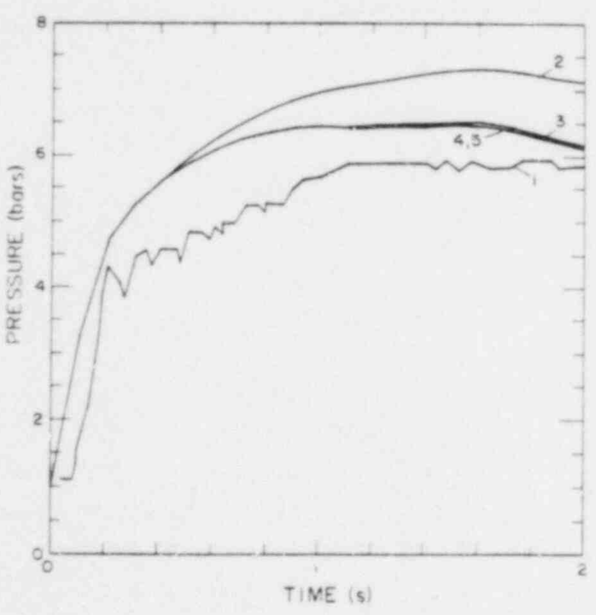


Fig. C-39. Test C15--Absolute pressure in subcompartment R1 for BMM=0.8 and OMM values listed below.

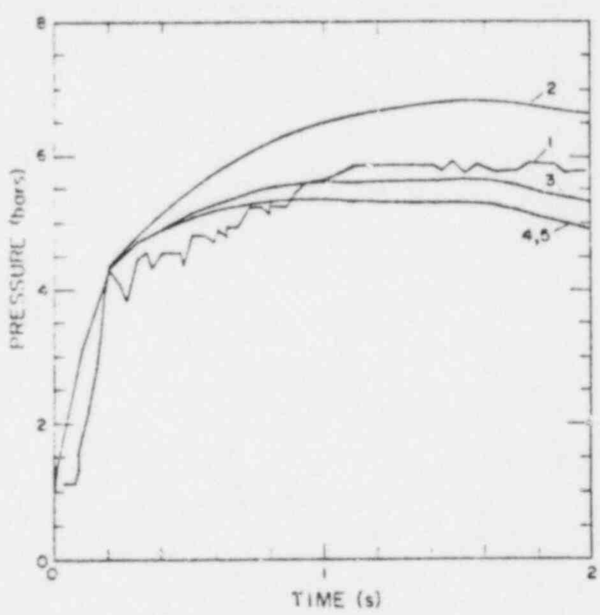


Fig. C-40. Test C15--Absolute pressure in subcompartment R1 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

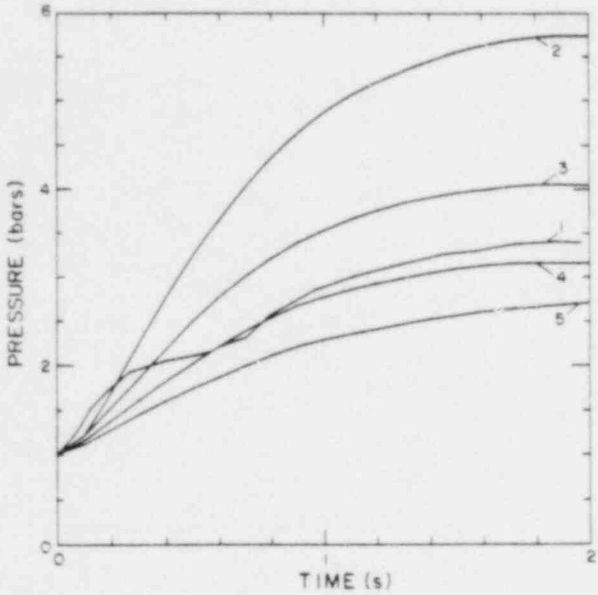


Fig. C-41. Test C15--Absolute pressure in subcompartment R3 for BMM=0.4 and OMM values listed below.

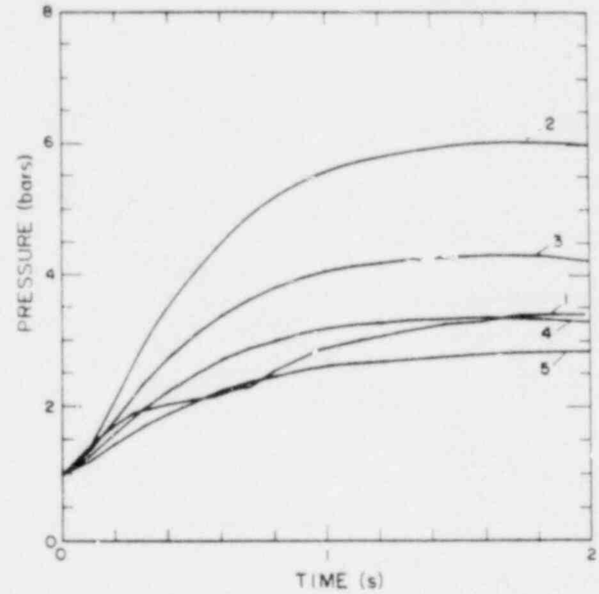


Fig. C-42. Test C15--Absolute pressure in subcompartment R3 for BMM=0.6 and OMM values listed below.

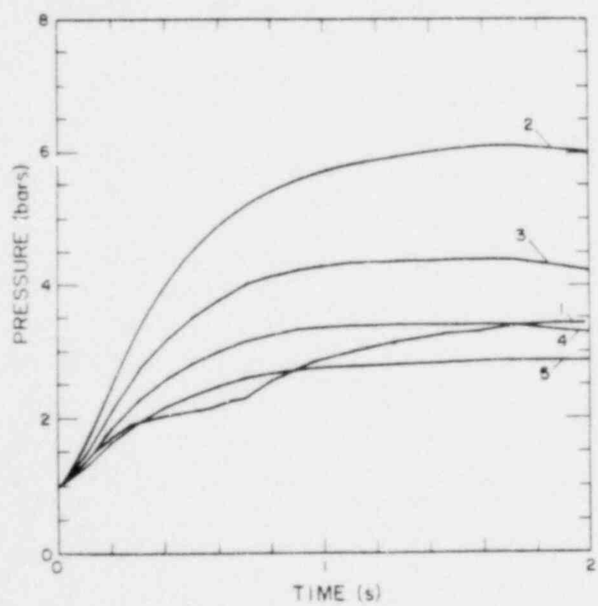


Fig. C-43. Test C15--Absolute pressure in subcompartment R3 for BMM=0.8 and OMM values listed below.

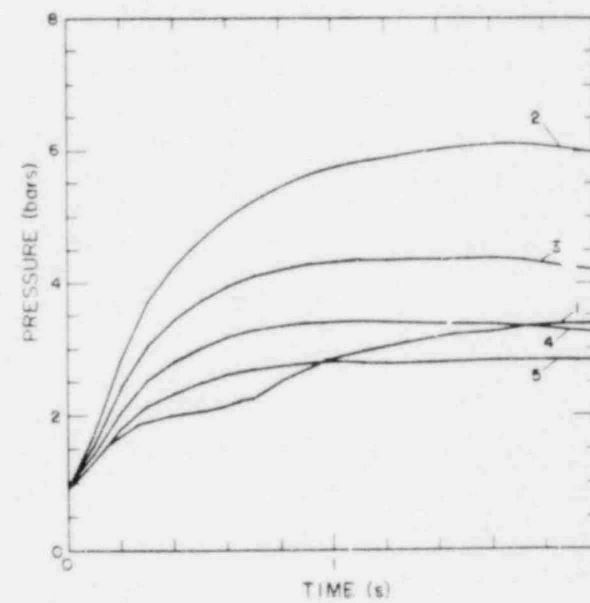


Fig. C-44. Test C15--Absolute pressure in subcompartment R3 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

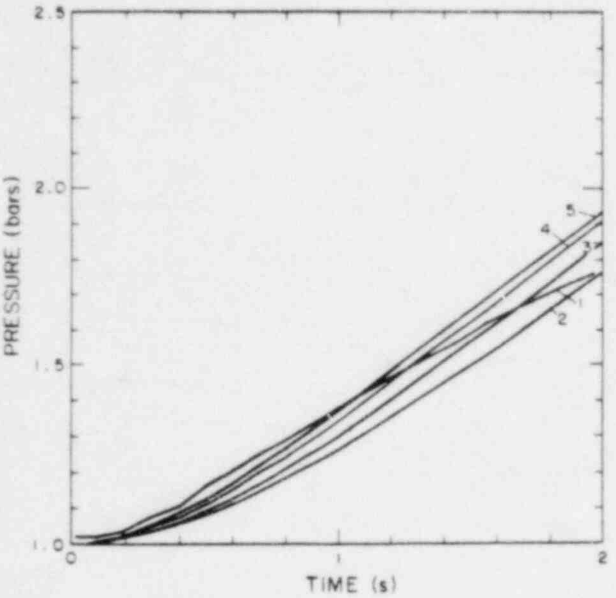


Fig. C-45. Test C15--Absolute pressure in subcompartment R9 for BMM=0.4 and OMM values listed below.

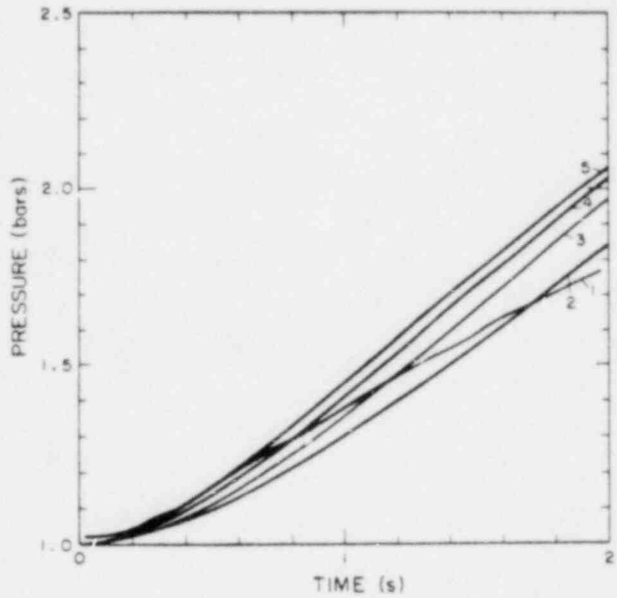


Fig. C-46. Test C15--Absolute pressure in subcompartment R9 for BMM=0.6 and OMM values listed below.

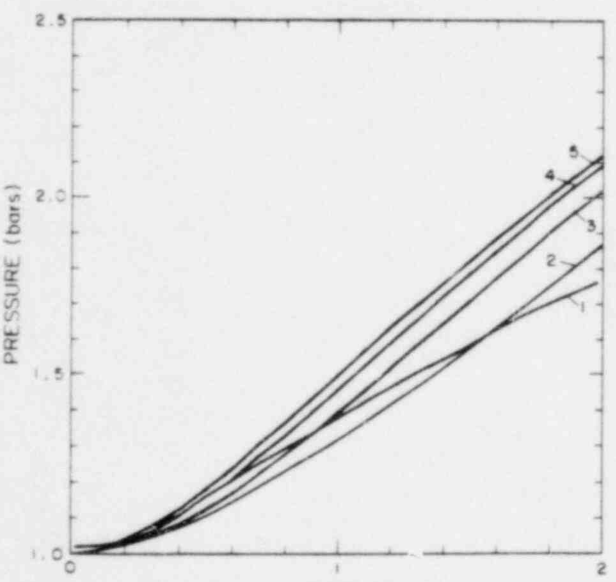


Fig. C-47. Test C15--Absolute pressure in subcompartment R9 for BMM=0.8 and OMM values listed below.

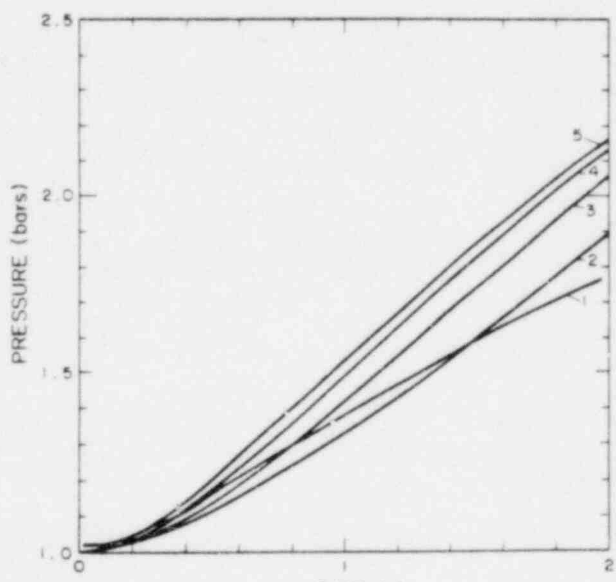


Fig. C-48. Test C15--Absolute pressure in subcompartment R9 for BMM=1.0 and OMM values listed below.

Note: BMM=Blowdown Room Moody Multiplier, OMM=Other Room Moody Multipliers; (1)TEST, (2)OMM=0.4, (3)OMM=0.6, (4)OMM=0.8, and (5)OMM=1.0.

APPENDIX D

THE EFFECTS OF VARYING ENTRAINMENT IN TESTS C5, C13, AND C15

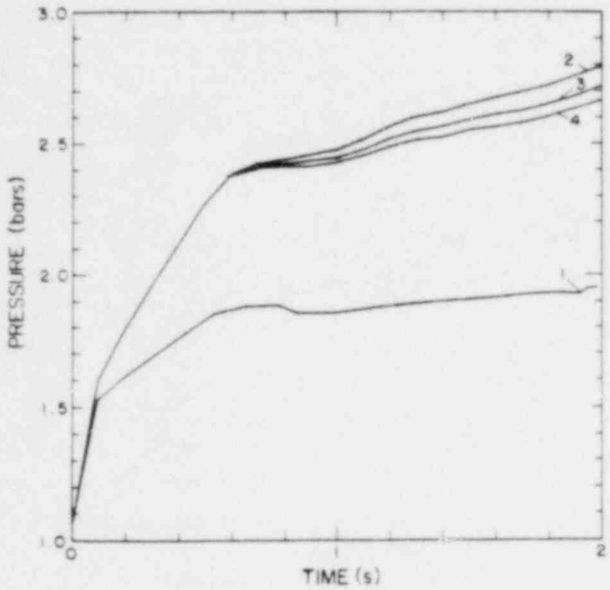


Fig. D-1. Test C5--Absolute pressure in subcompartment R6 for BEN=0.5 and OEN values listed below.

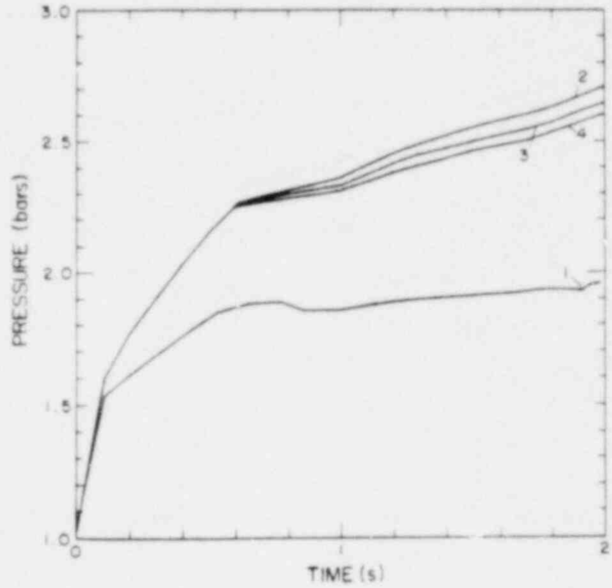


Fig. D-2. Test C5--Absolute pressure in subcompartment R6 for BEN=0.7 and OEN values listed below.

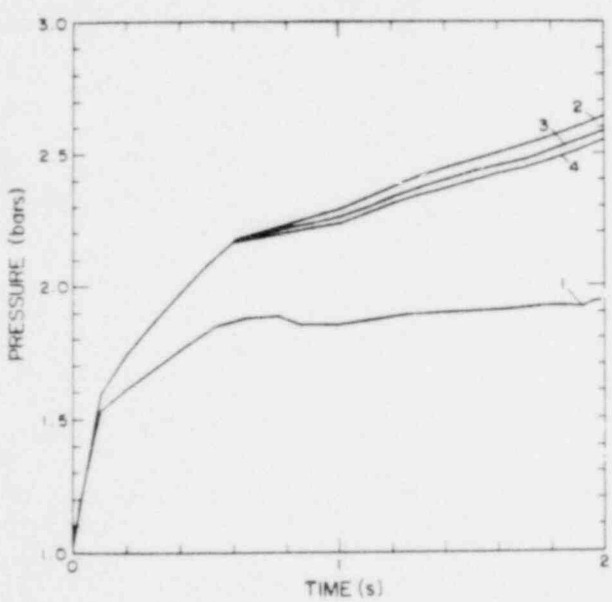


Fig. D-3. Test C5--Absolute pressure in subcompartment R6 for BEN=0.9 and OEN values listed below.

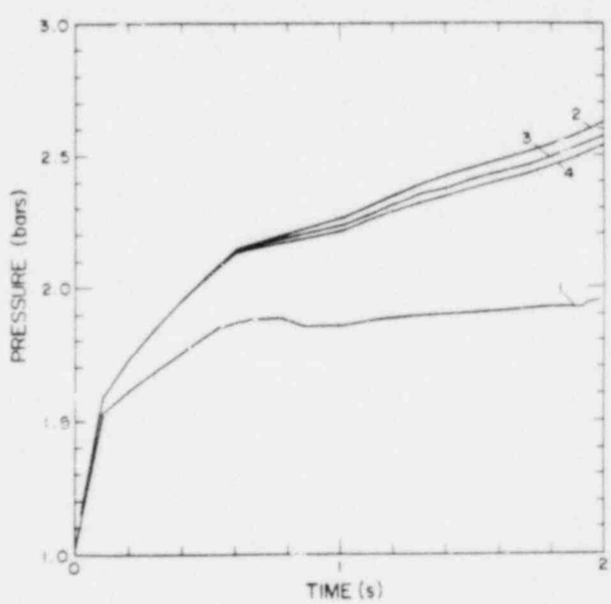


Fig. D-4. Test C5--Absolute pressure in subcompartment R6 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

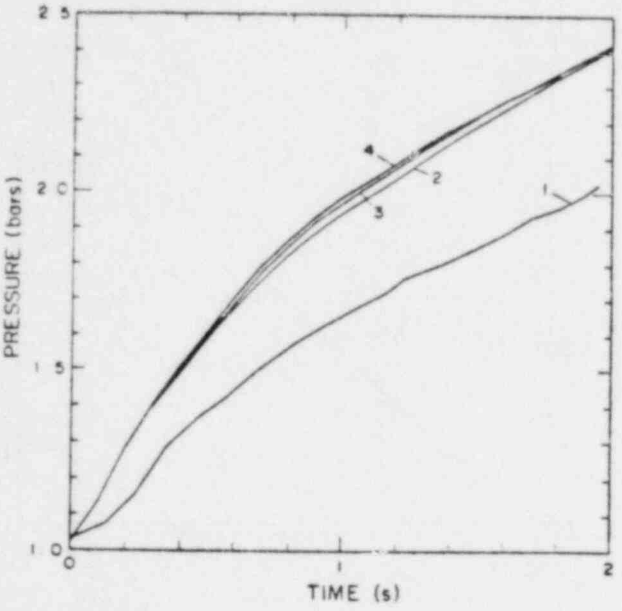


Fig. D-5. Test C5--Absolute pressure in subcompartment R4 for BEN=0.5 and OEN values listed below.

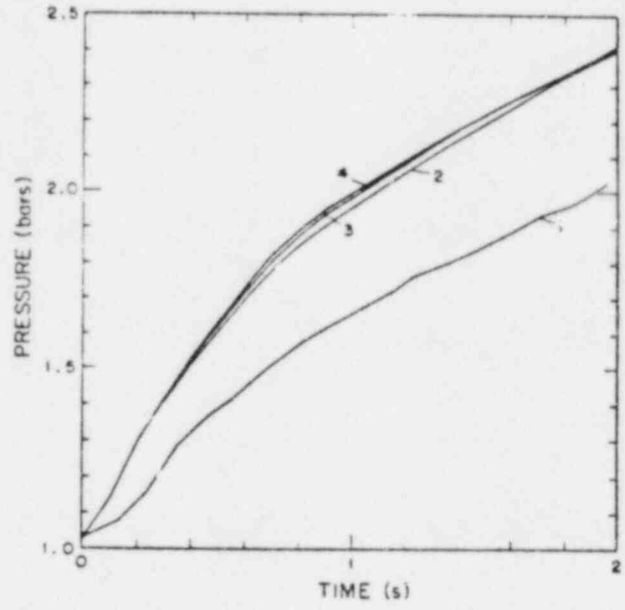


Fig. D-6. Test C5--Absolute pressure in subcompartment R4 for BEN=0.7 and OEN values listed below.

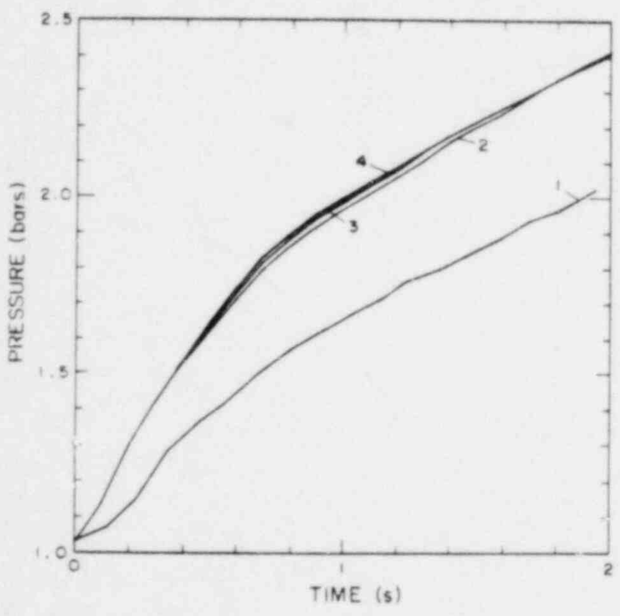


Fig. D-7. Test C5--Absolute pressure in subcompartment R4 for BEN=0.9 and OEN values listed below.

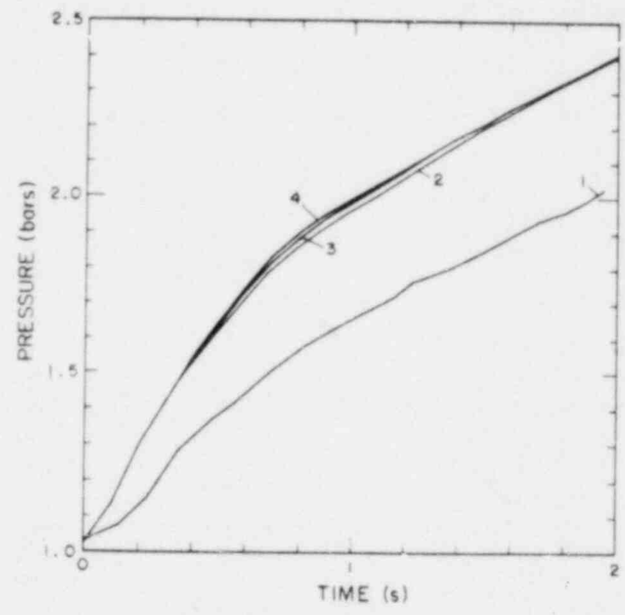


Fig. D-8. Test C5--Absolute pressure in subcompartment R4 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

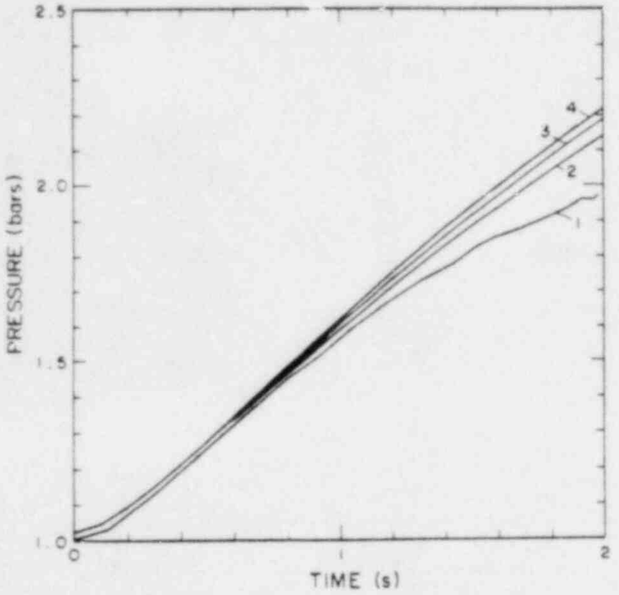


Fig. D-9. Test C5--Absolute pressure in subcompartment R9 for BEN=0.5 and OEN values listed below.

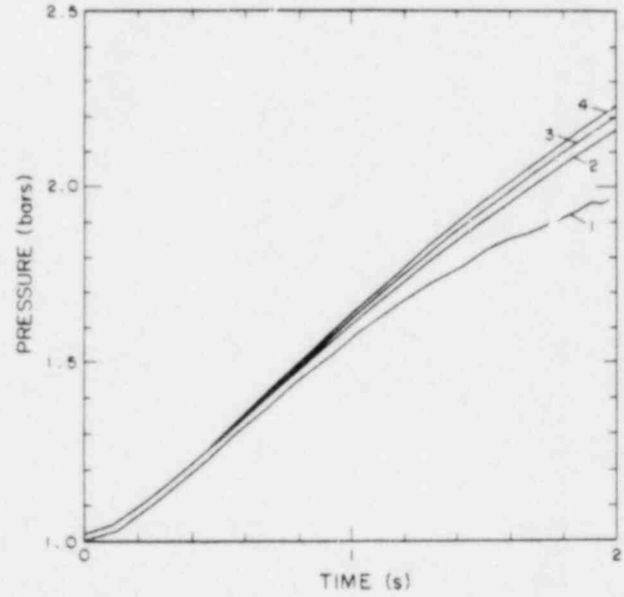


Fig. D-10. Test C5--Absolute pressure in subcompartment R9 for BEN=0.7 and OEN values listed below.

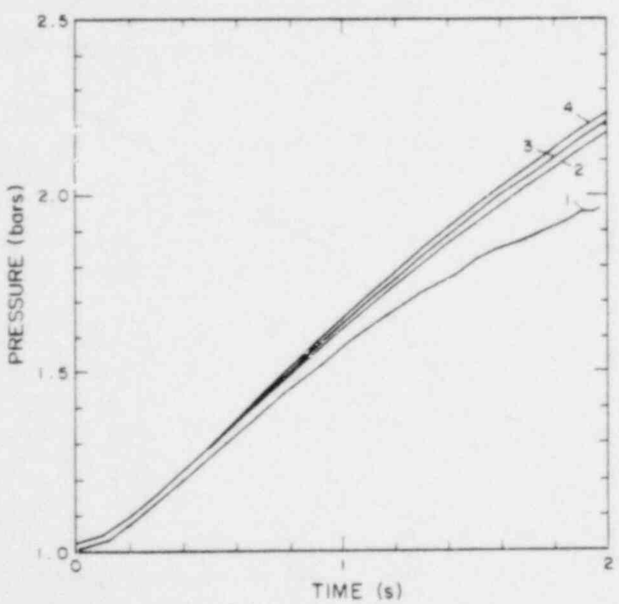


Fig. D-11. Test C5--Absolute pressure in subcompartment R9 for BEN=0.9 and OEN values listed below.

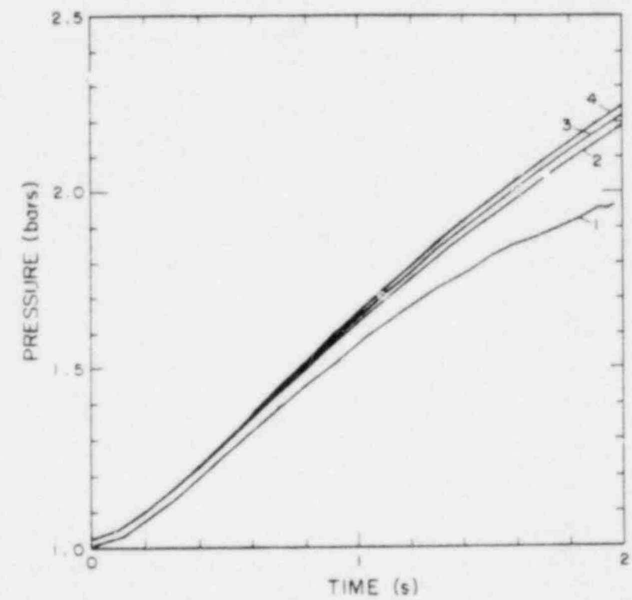


Fig. D-12. Test C5--Absolute pressure in subcompartment R9 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

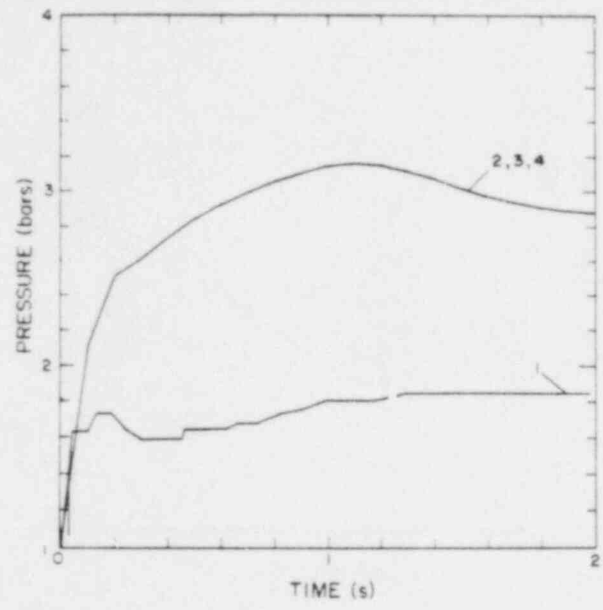


Fig. D-13. Test C10--Absolute pressure in subcompartment R4 for BEN=0.5 and OEN values listed below.

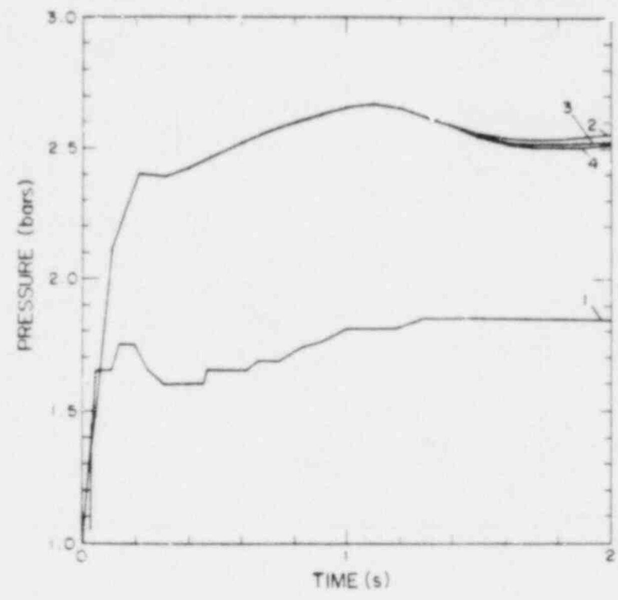


Fig. D-14. Test C10--Absolute pressure in subcompartment R4 for BEN=0.7 and OEN values listed below.

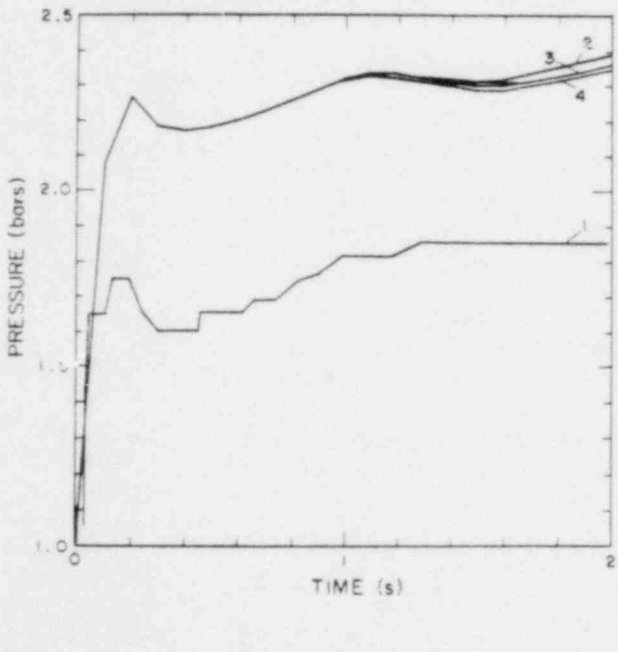


Fig. D-15. Test C10--Absolute pressure in subcompartment R4 for BEN=0.9 and OEN values listed below.

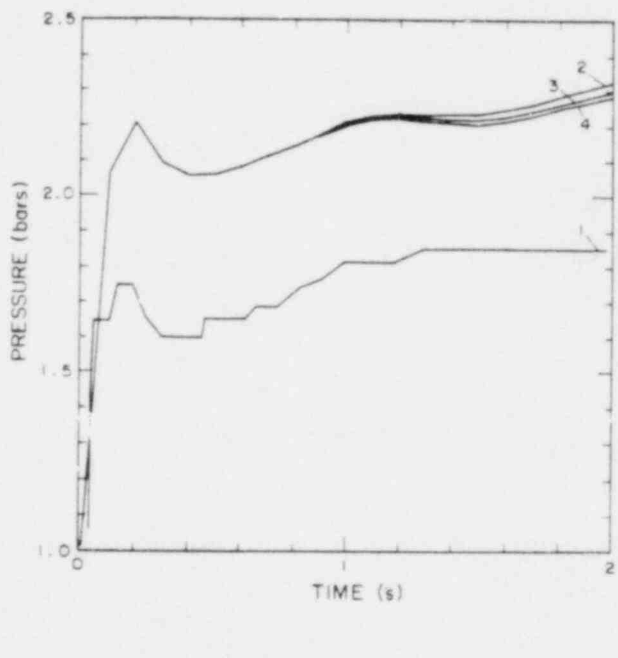


Fig. D-16. Test C10--Absolute pressure in subcompartment R4 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

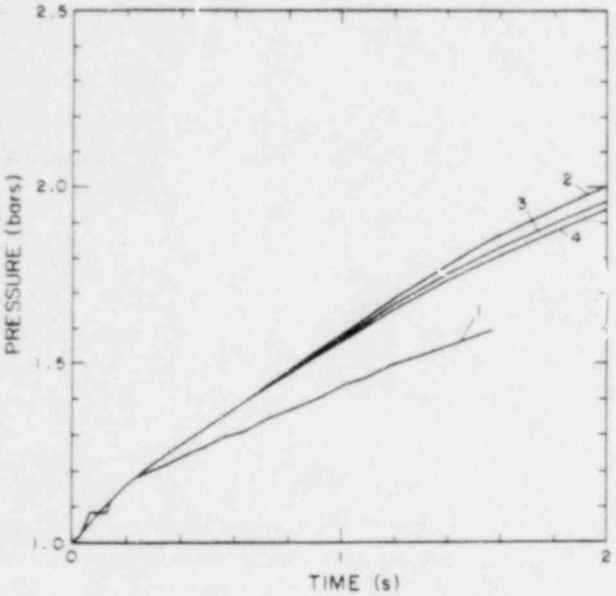


Fig. D-17. Test C10--Absolute pressure in subcompartment R5 for BEN=0.5 and OEN values listed below.

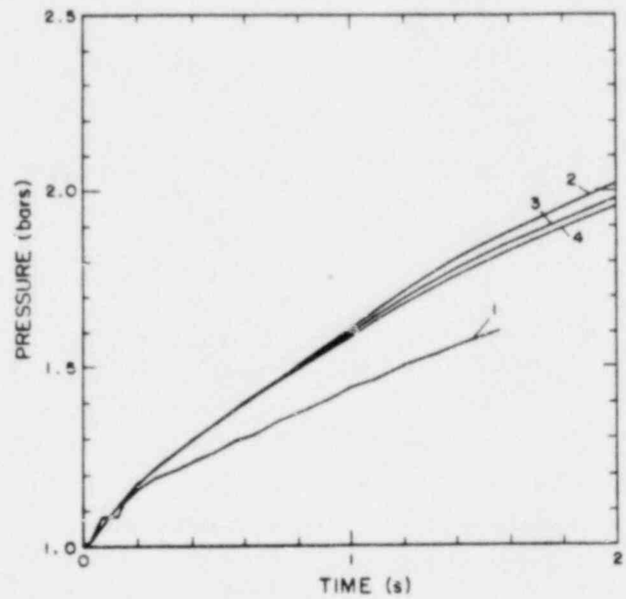


Fig. D-18. Test C10--Absolute pressure in subcompartment R5 for BEN=0.7 and OEN values listed below.

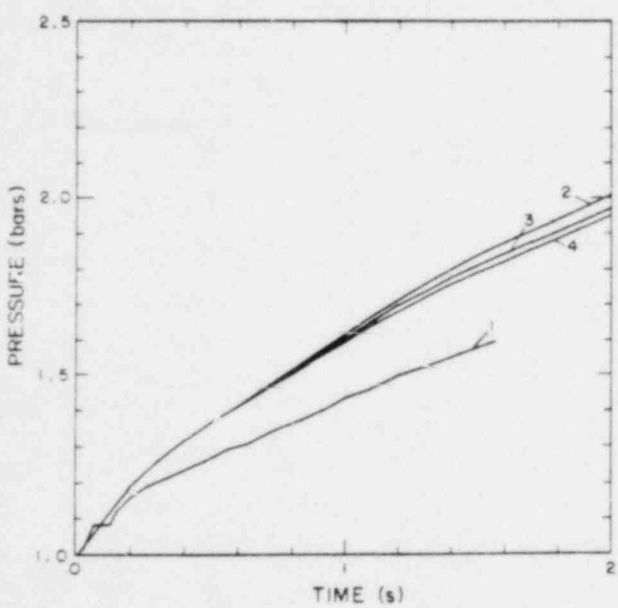


Fig. D-19. Test C10--Absolute pressure in subcompartment R5 for BEN=0.9 and OEN values listed below.

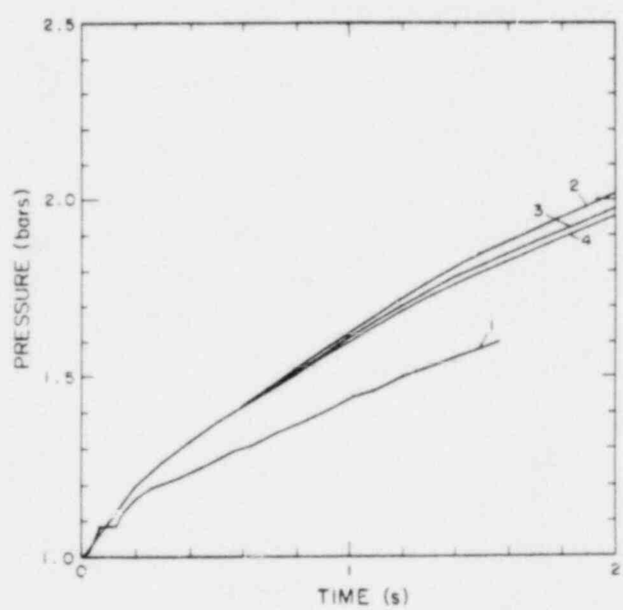


Fig. D-20. Test C10--Absolute pressure in subcompartment R5 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

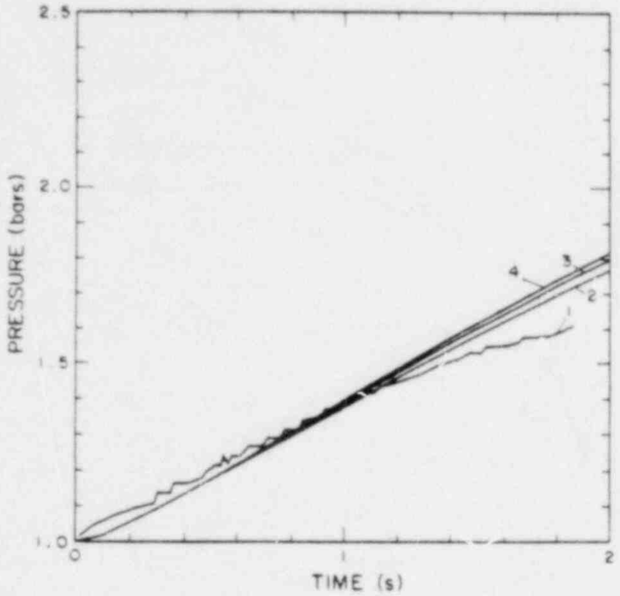


Fig. D-21. Test C10--Absolute pressure in subcompartment R9 for BEN=0.5 and OEN values listed below.

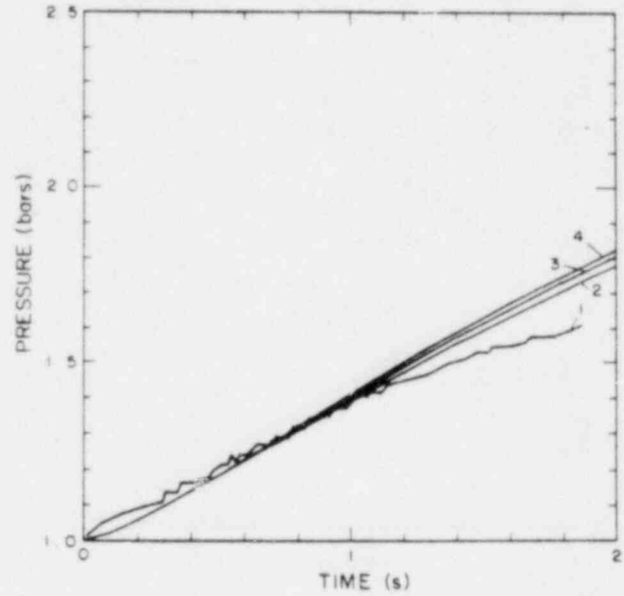


Fig. D-22. Test C10--Absolute pressure in subcompartment R9 for BEN=0.7 and OEN values listed below

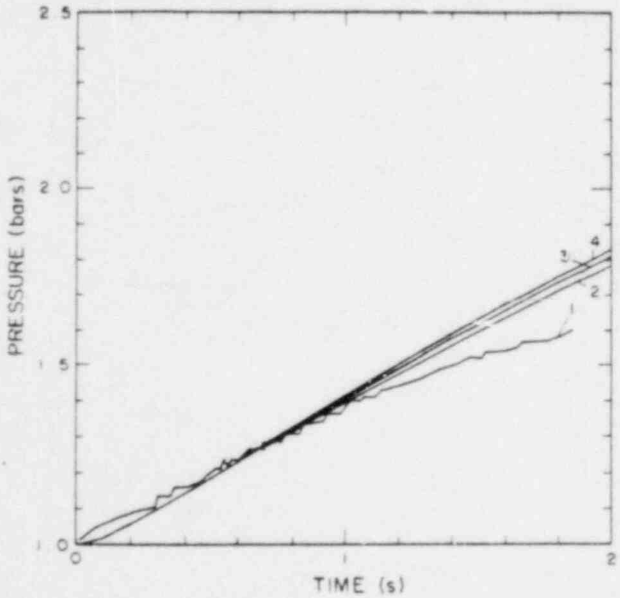


Fig. D-23. Test C10--Absolute pressure in subcompartment R9 for BEN=0.9 and OEN values listed below.

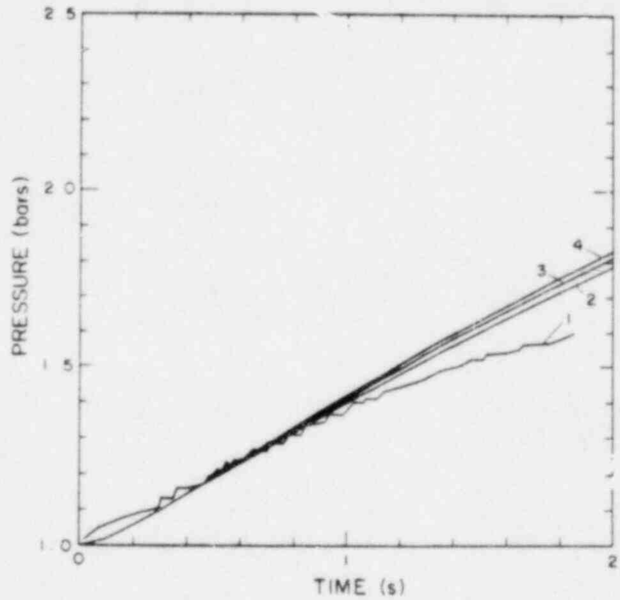


Fig. D-24. Test C10--Absolute pressure in subcompartment R9 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

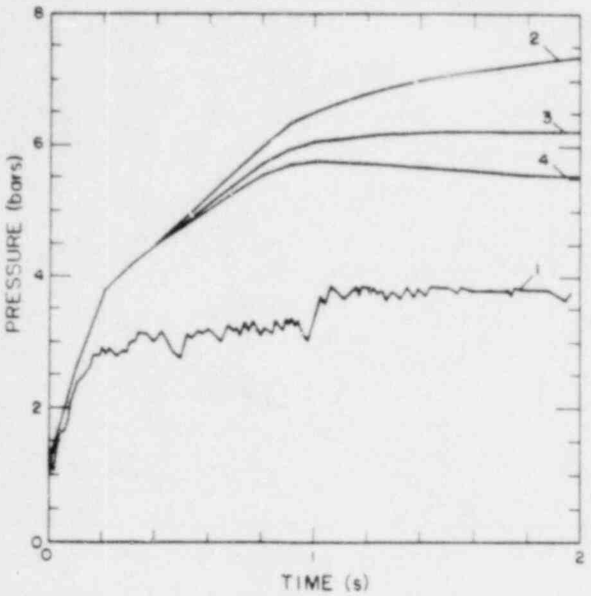


Fig. D-25. Test C13--Absolute pressure in subcompartment R1 for BEN=0.5 and OEN values listed below.

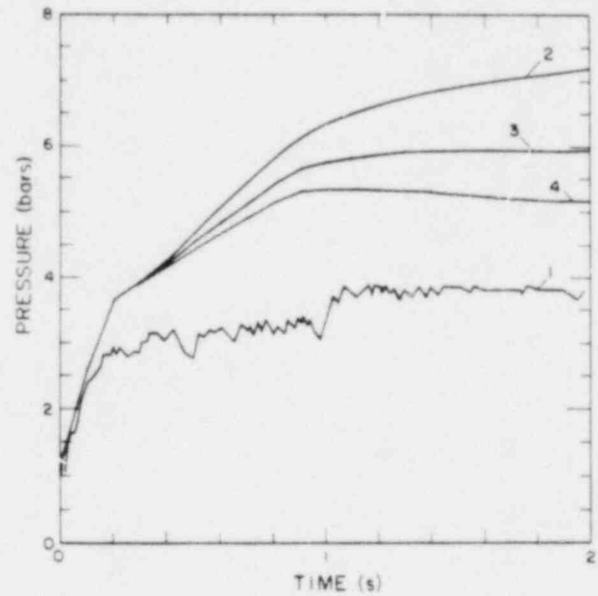


Fig. D-26. Test C13--Absolute pressure in subcompartment R1 for BEN=0.7 and OEN values listed below.

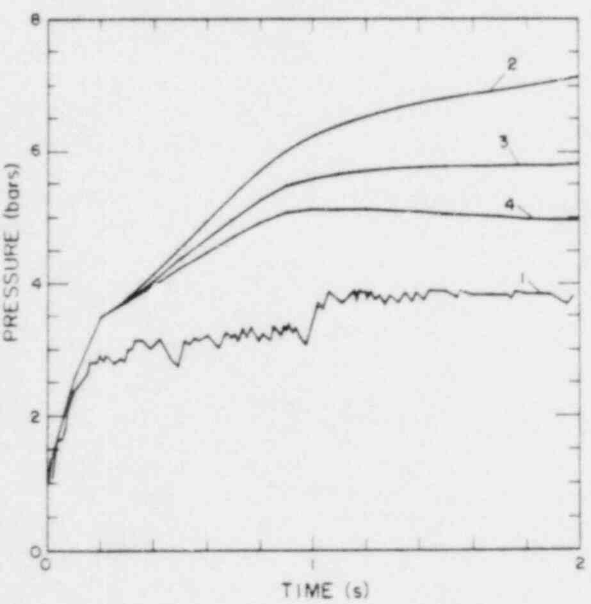


Fig. D-27. Test C13--Absolute pressure in subcompartment R1 for BEN=0.9 and OEN values listed below.

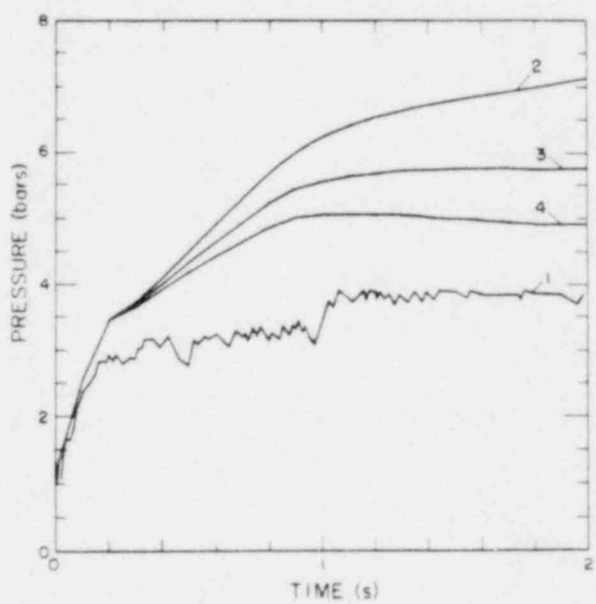


Fig. D-28. Test C13--Absolute pressure in subcompartment R1 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

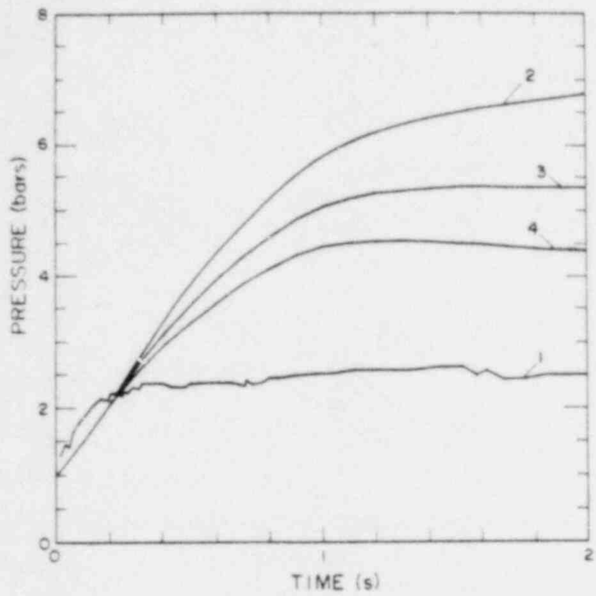


Fig. D-29. Test C13--Absolute pressure in subcompartment R3 for BEN=0.5 and OEN values listed below.

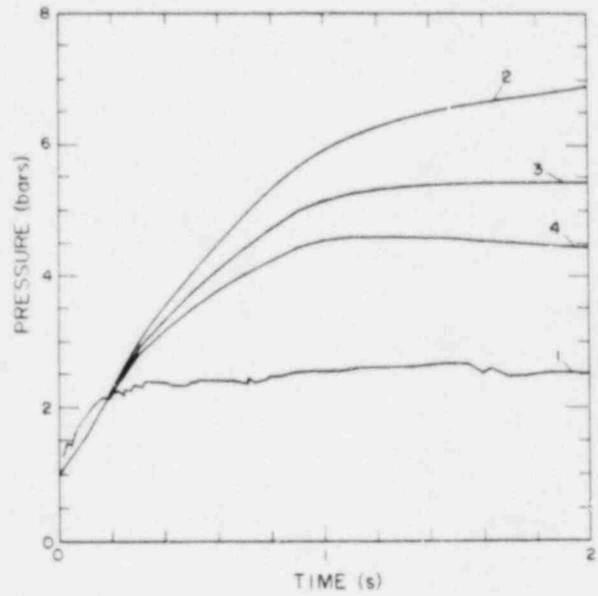


Fig. D-30. Test C13--Absolute pressure in subcompartment R3 for BEN=0.7 and OEN values listed below.

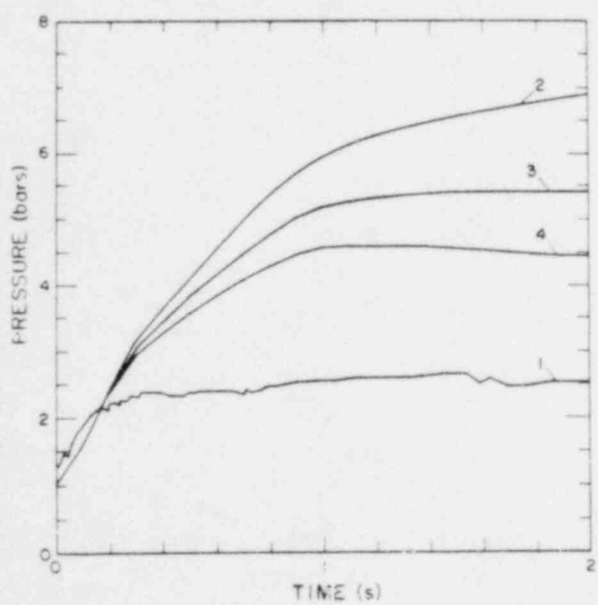


Fig. D-31. Test C13--Absolute pressure in subcompartment R3 for BEN=0.9 and OEN values listed below.

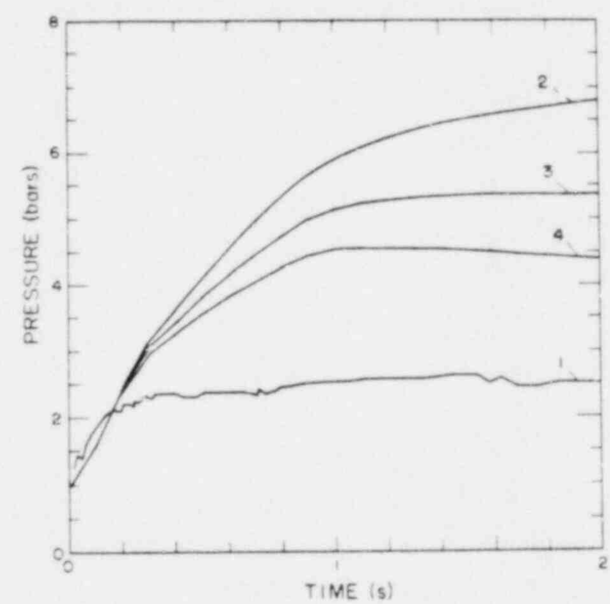


Fig. D-32. Test C13--Absolute pressure in subcompartment R3 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

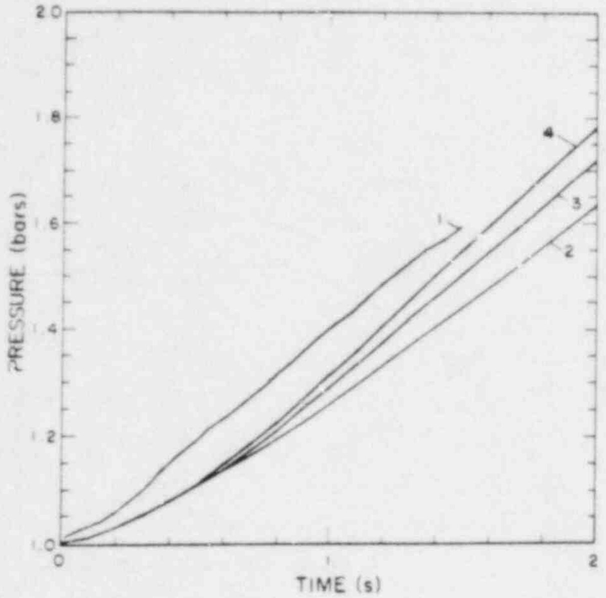
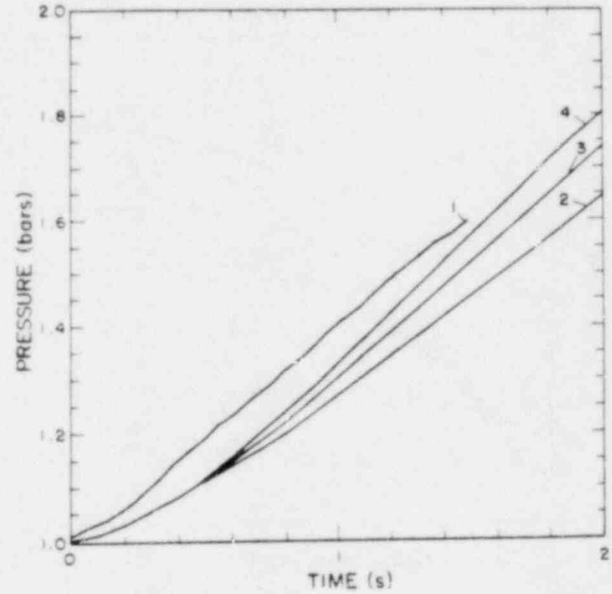


Fig. D-33. Test C13--Absolute pressure in subcompartment R9 for BEN=0.5 and OEN values listed below.



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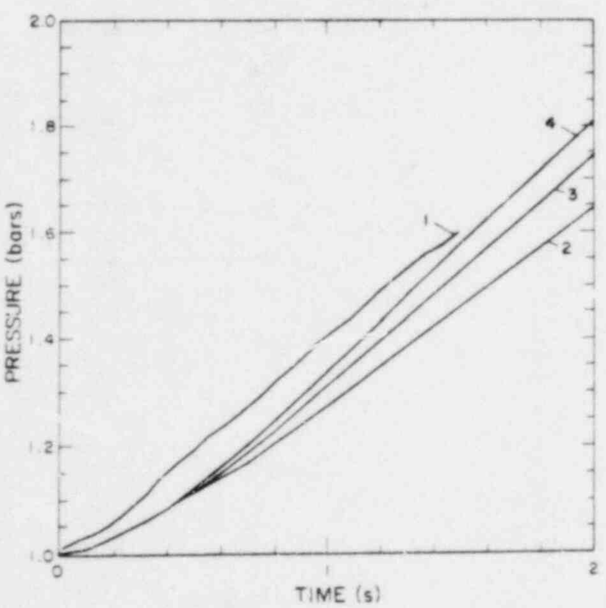

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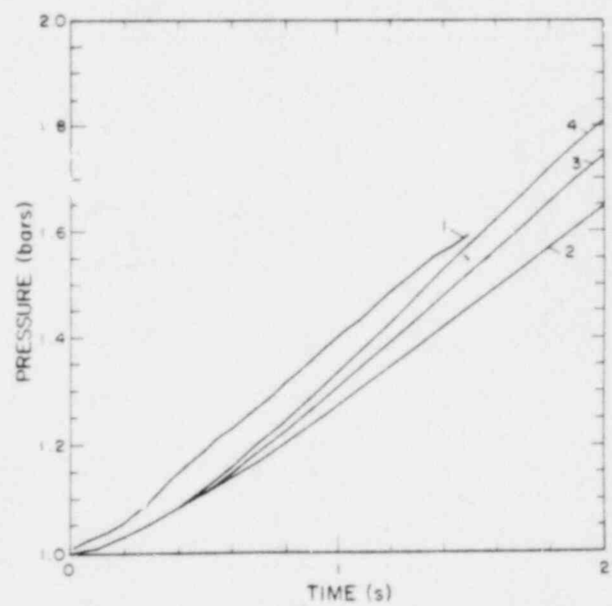

Fig. D-36. Test C13--Absolute pressure in subcompartment R9 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

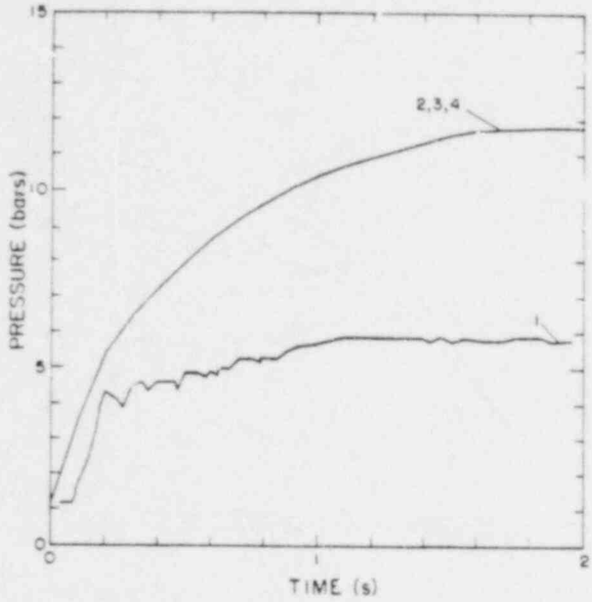

Fig. D-37. Test C15--Absolute pressure in subcompartment R1 for BEN=0.5 and OEN values listed below.

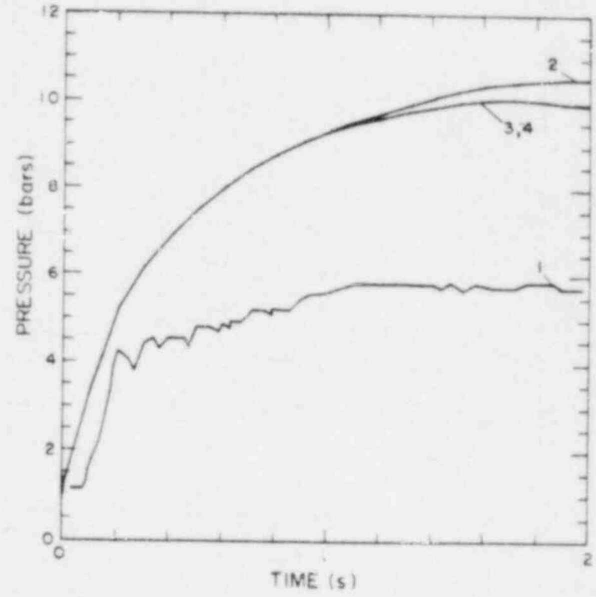

Fig. D-38. Test C15--Absolute pressure in subcompartment R1 for BEN=0.7 and OEN values listed below.

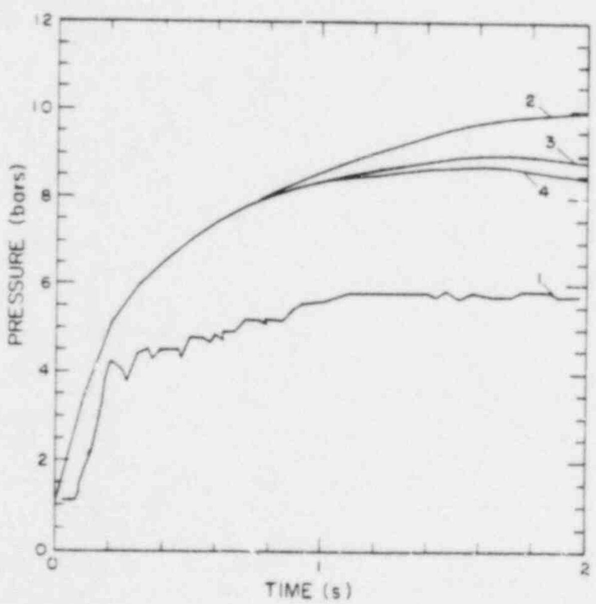

Fig. D-39. Test C15--Absolute pressure in subcompartment R1 for BEN=0.9 and OEN values listed below.

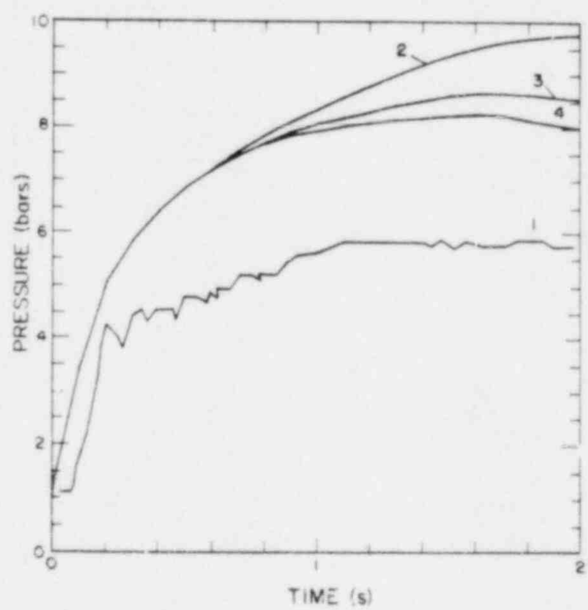

Fig. D-40. Test C15--Absolute pressure in subcompartment R1 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

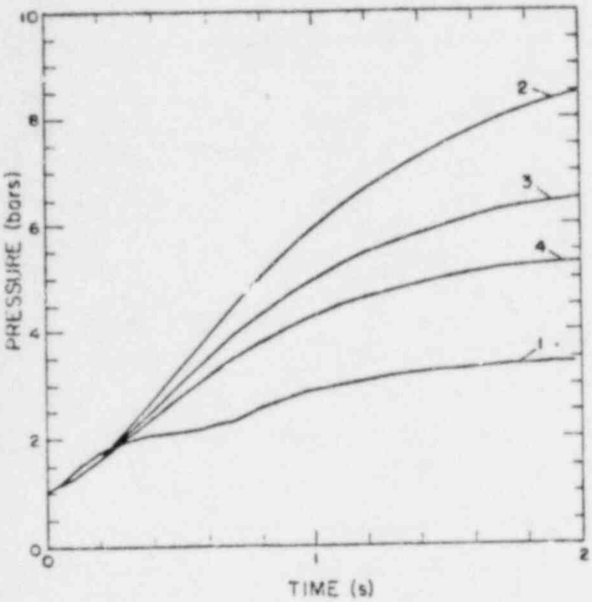

Fig. D-41. Test C15--Absolute pressure in subcompartment R3 for BEN=0.5 and OEN values listed below.

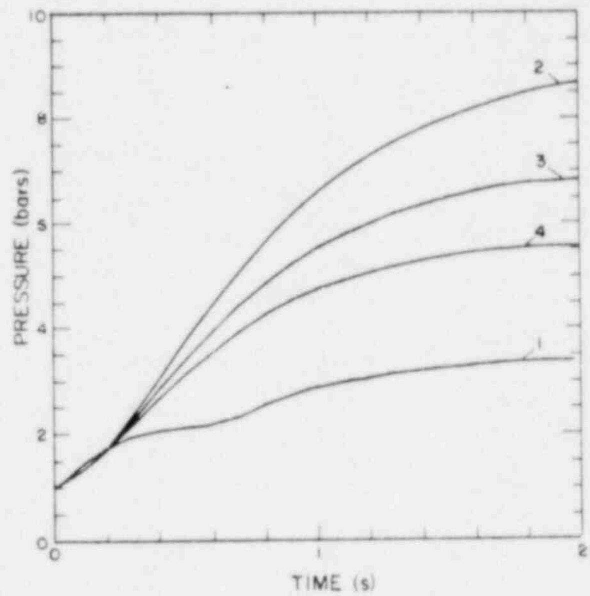

Fig. D-42. Test C15--Absolute pressure in subcompartment R3 for BEN=0.7 and OEN values listed below.

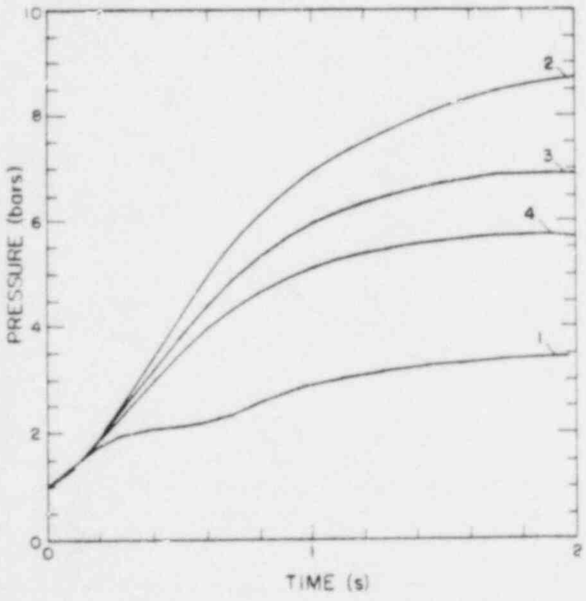

Fig. D-43. Test C15--Absolute pressure in subcompartment R3 for BEN=0.9 and OEN values listed below.

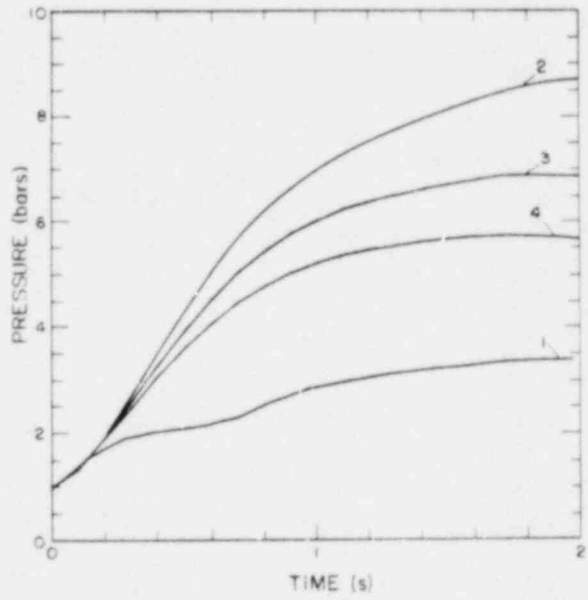

Fig. D-44. Test C15--Absolute pressure in subcompartment R3 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment, OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

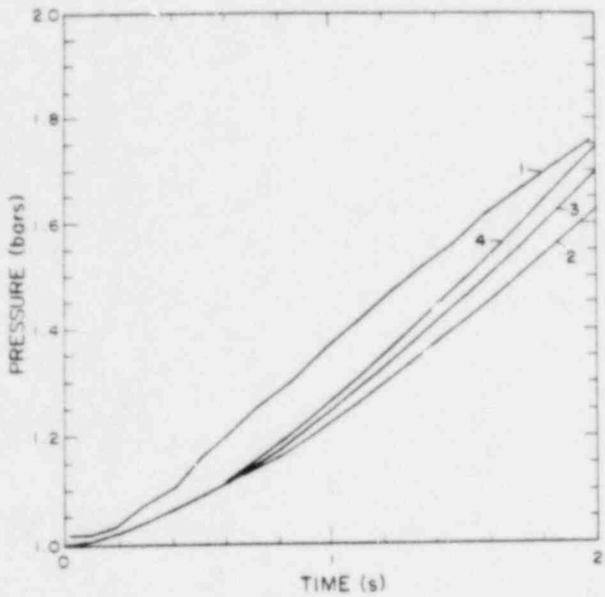

Fig. D-45. Test C15--Absolute pressure in subcompartment R9 for BEN=0.5 and OEN values listed below.

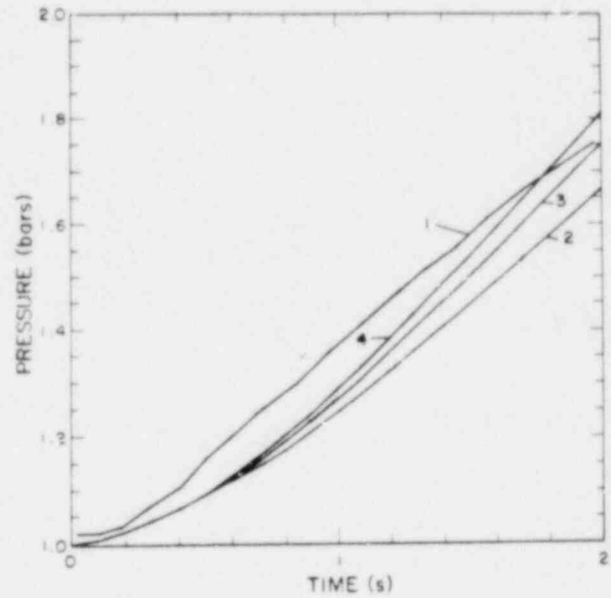

Fig. D-46. Test C15--Absolute pressure in subcompartment R9 for BEN=0.7 and OEN values listed below.

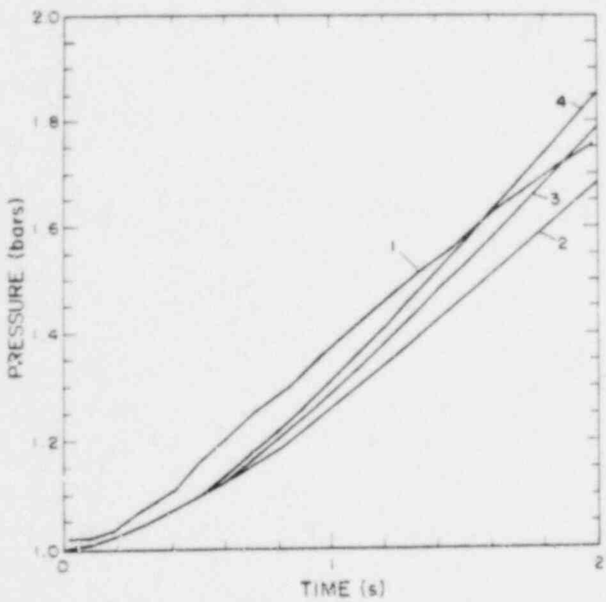

Fig. D-47. Test C15--Absolute pressure in subcompartment R9 for BEN=0.9 and OEN values listed below.

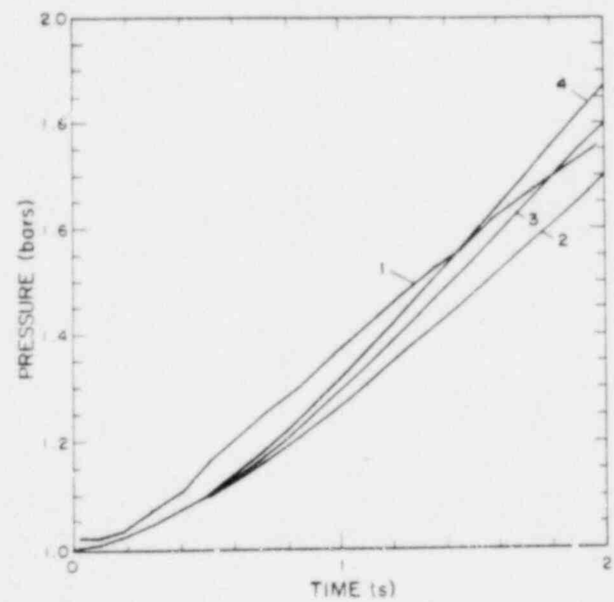

Fig. D-48. Test C15--Absolute pressure in subcompartment R9 for BEN=1.0 and OEN values listed below.

Note: BEN=Blowdown Room Entrainment OEN=Other Room Entrainment; (1)TEST, (2)OEN=0.2, (3)OEN=0.4, (4)OEN=0.6.

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16. ABSTRACT (200 words or less)

This report describes comparison of results from the COMPARE and RELAP3 subcompartment analysis codes with the Battelle-Frankfurt C-Series tests on reactor containment. Comparisons were made for 12 of the 16 tests for which information was available. In the 12 selected tests, inertia was neglected and the 0.6 Moody Multiplier was used to impose the critical flow limit.

Four tests, C5, C10, C13 and C15, were selected for detailed study. Parameter studies varying the Moody Multiplier and entrainment were performed. Test results comparing the use of digitized and nondigitized blowdown data were also obtained. Additional nodalization using COMPARE did not produce large differences when compared to models with fewer nodes.

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