FORM TI-12
07/1999

B-T-3271

AN ASSESSMENT OF RELAP5-3D USING THE EDWARDS-O'BRIEN BLOWDOWN PROBLEM

E. T. Tomlinson, D. L. Aumiller

U.S. Department of Energy Contract DE-AC11-98PN38206

BETTIS ATOMIC POWER LABORATORY WEST MIFFLIN, PENNSYLVANIA 15122-0079

Operated for the U.S. Department of Energy
by Bechtel Bettis, Inc.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

1999 RELAP5 International Users Seminar
Park City, Utah
July 28-30, 1999

B-T-3271

AN ASSESSMENT OF RELAP5-3D USING THE EDWARDS-O'BRIEN BLOWDOWN PROBLEM

E.T. Tomlinson
D.L. Aumiller

Bechtel Bettis, Inc.
Bettis Atomic Laboratory
P.O. Box 79
West Mifflin, PA 15122-0079

Abstract

The RELAP5-3D (version bt) computer code was used to assess the United States Nuclear Regulatory Commission's Standard Problem 1 (Edwards-O'Brien Blowdown Test). The RELAP5-3D standard installation problem based on the Edwards-O'Brien Blowdown Test was modified to model the appropriate initial conditions and to represent the proper location of the instruments present in the experiment. The results obtained using the modified model are significantly different from the original calculation indicating the need to model accurately the experimental conditions if an accurate assessment of the calculational model is to be obtained.

Introduction

An important part of any computer code development effort is performing an assessment of the program's ability to predict measured data accurately. To aid in the assessment process, a series of standard problems based on experimental data has been established. One such problem, Standard Problem 1, is based on the Edwards-O'Brien Blowdown Test. [1]

Description of the Test

The Edwards-O'Brien experiments consisted of fluid depressurization studies in a straight pipe 4.096 m (13.44 ft.) long with an inside diameter of 0.073 m (2.88 in.). The pipe was filled with water and brought to initial conditions ranging from 3.55 MPa (500 psig) and 514.8°K (467°F) to 17.34 MPa (2500 psig) and 616.5°K (650°F). Standard Problem 1 was performed at nominal initial conditions of 7.00 MPa (1000 psig) and 513.7°K (465°F).

A glass disk at one end of the pipe was designed to rupture with a single shot from a pellet gun to initiate the depressurization phase of the transient. The time for the disk to fully open was estimated to be 1.0 ms. Following the experiment, a small amount of glass was observed around the circumference of the opening. Based on this, Standard Problem 1 stipulates that the break flow area be reduced by 13% from the pipe cross sectional area.

Fast response temperature and pressure measuring instruments were located along the length of the pipe. The instrument locations (gauge stations) were identified as GS-1 through GS-7 and were positioned as shown in Figure 1.

Data reported from the experiment included time dependent pressures at each of the gauge stations and temperature and void fraction information at GS-5. These parameters were measured for 600 ms. after the initiation of the depressurization.

Description of the Model

The calculational model used in this analysis was based on the *edhtrk.i* standard installation problem for RELAP5-3D. [2] The nodalization used in the installation problem consists of 20 volumes of equal length. The initial conditions are isothermal at 502.2°K (444.3°F) and 7.00 MPa (1000 psig). The flow area in the installation problem was approximately 6.7% less than the experimental value.

For this analysis, the nodalization was modified to model more accurately the geometry of the test, paying particular attention to the location of the installed instrumentation. The isothermal initial conditions were modified to reflect the actual enthalpy at the gauge stations as given by Hendrie. [3] The initial conditions for volumes between gauge stations were determined by linearly interpolating between the measured data. The modified nodalization and initial conditions used in this analysis are presented in Table 1 and shown graphically in Figure 2. The pipe flow area was increased to model faithfully the experiment.

The flow area at the rupture disk was taken to be 87% of the pipe flow area. The abrupt area change option was used to model the non-recoverable losses at the break. The break opening time was assumed to be 1.0 ms. The heat structures modeled in the installation problem were removed as they were judged to have an insignificant effect on the results owing to the extremely short duration of the transient.

The semi-implicit time integration scheme was used for all cases in this analysis. RELAP5-3D with no developmental (Card 1) options was used in this analysis. The Ransom-Trapp critical flow model with the default discharge coefficients was used instead of the Henry-Fauske model. [4]

Results

The RELAP5-3D calculations were performed using the semi-implicit time integration scheme with a maximum time step of 0.1 ms. The calculated pressures at each gauge station using both the modified nodalization and the installation problem nodalization are presented in Figures 3 through 9 and compared with data. The volume containing the gauge station (but not necessarily at the volume center) was used in the installation problem analysis. The calculated void fraction data at each gauge station for each nodalization are presented in Figures 10 through 16. A comparison of the calculated void fraction and measured data at GS-5 is presented in Figure 14.

The modelling changes that had the greatest effect on the results were modifying the nodalization to model more accurately the location of the installed instrumentation and modifying the initial conditions to reflect the initial temperature variation within the pipe. The calculated pressure was least affected by these changes. The void fraction was markedly changed at some locations, particularly near the break, Figures 10 through 12.

Another factor affecting the void fractions history near the break was the break flow. The predicted break flow was shown to be very sensitive to these changes, Figure 17. An additional calculation was performed to determine whether the re-nodalization or the modified initial conditions led to the erratic break flow behavior. An isothermal case using the modified nodalization was run and the results are presented in Figure 17. These results clearly indicate that the erratic behavior was due entirely to the modified initial conditions. However, it should be noted that the erratic behavior in the break flow did not result in erratic behavior in either the predicted pressure or void fraction at the gauge station locations.

A third variation of the modified model was evaluated using the Henry-Fauske critical flow model. The break flow in this calculation showed much less sensitivity to the initial temperature distribution in the test section, Figure 17. The Henry-Fauske model also predicted a higher break flow during the initial phase of the blowdown. The effect of the higher break flow on the predicted void fraction at GS-5 is presented in Figure 14. No significant improvement was seen in the void fraction prediction.

The effect of changing the flow area, critical flow model and pipe roughness had only minor effects on the results.

Conclusions

A model of the Edwards-O'Brien Blowdown Test has been developed and used in the assessment of the RELAP5-3D computer code. Unlike previous models used in the assessment, this model faithfully represents the locations of the installed instrumentation and the actual initial conditions present in the test. The results of this analysis indicate relatively good agreement with the experimental data.

The Edwards-O'Brien test was designed specifically to assess the critical flow models used in computer programs. This analysis indicated that the predicted break flow was very sensitive to the initial temperature distribution and, to a lesser extent, the nodalization used in the model. Therefore, particular attention must be paid to modelling the location of instruments in experiments and to the determination of the correct initial conditions to be used in the evaluation of transient test data if an accurate assessment of the calculational model is to be obtained.

Since break flow was not measured directly in the experiment and the prediction of the measured parameters was shown to be relatively insensitive to the break flow behavior, it is difficult to determine which of the break flow models yield the correct prediction of the break flow. However, the results of the various analyses show that an inadequate representation of the experiment could lead to incorrect conclusions regarding the adequacy of the model being assessed.

References

[1] Edwards, A. R., and T. P. O'Brien, "Studies of Phenomena Connected with the Depressurization of Water Reactors," Journal of the British Nuclear Energy Society, pp. 125-135, April 1970.

[2] Johnsen, G. W., C. B. Davis, W. L. Weaver, and K. E. Carlson, "Benchmarking the RELAP5-3D Computer Code," Proceedings of the 6th International Conference on Nuclear Engineering, ICONE-6 San Diego, CA, May 10-15, 1998.

[3] Letter, J. M. Hendrie to J. H. MacMillan, AEC DIRECTION and Guidance Letter on Comparative Analyses of Standard Problems, USAEC, January 31, 1973.

[4] Henry, R. E., and H. K. Fauske, "The Two-Phase Critical Flow of One-Component Mixtures in Nozzles, Orifices, and Short Tubes," Journal of Heat Transfer, pp. 179-187, May 1971.

Table 1: Modified Nodalization for the Edwards-O'Brien Blowdown Problem (Standard Problem 1)

Volume Number	Volume Length (ft.)	Length Overall (ft. from end)	Center (ft. from end)	Temperature (°F)	Notes
1	0.52	0.52	0.26	447.5	GS-7
2	0.52	1.04	0.78	448.4	
3	0.52	1.56	1.30	449.4	
4	0.52	2.08	1.82	450.3	
5	0.61	2.69	2.385	451.4	
6	0.62	3.31	3.00	452.5	GS-6
7	0.61	3.92	3.615	451.7	
8	0.59	4.51	4.215	450.8	
9	0.62	5.13	4.82	450.0	GS-5
10	0.59	5.72	5.425	449.2	
11	0.61	6.33	6.025	448.3	
12	0.62	6.95	6.64	447.5	GS-4
13	0.61	7.56	7.255	448.0	
14	0.52	8.08	7.82	448.5	
15	0.52	8.60	8.34	448.9	
16	0.68	9.28	8.94	449.4	
17	0.70	9.98	9.63	450.0	GS-3
18	0.68	10.66	10.32	446.5	
19	0.52	11.18	10.92	443.4	
20	0.52	11.70	11.44	440.8	
21	0.41	12.11	11.905	438.4	
22	0.52	12.63	12.37	436.0	GS-2
23	0.52	13.15	12.89	437.0	GS-1
24	0.29	13.44	13.295	437.8	
BREAK LOCATION					

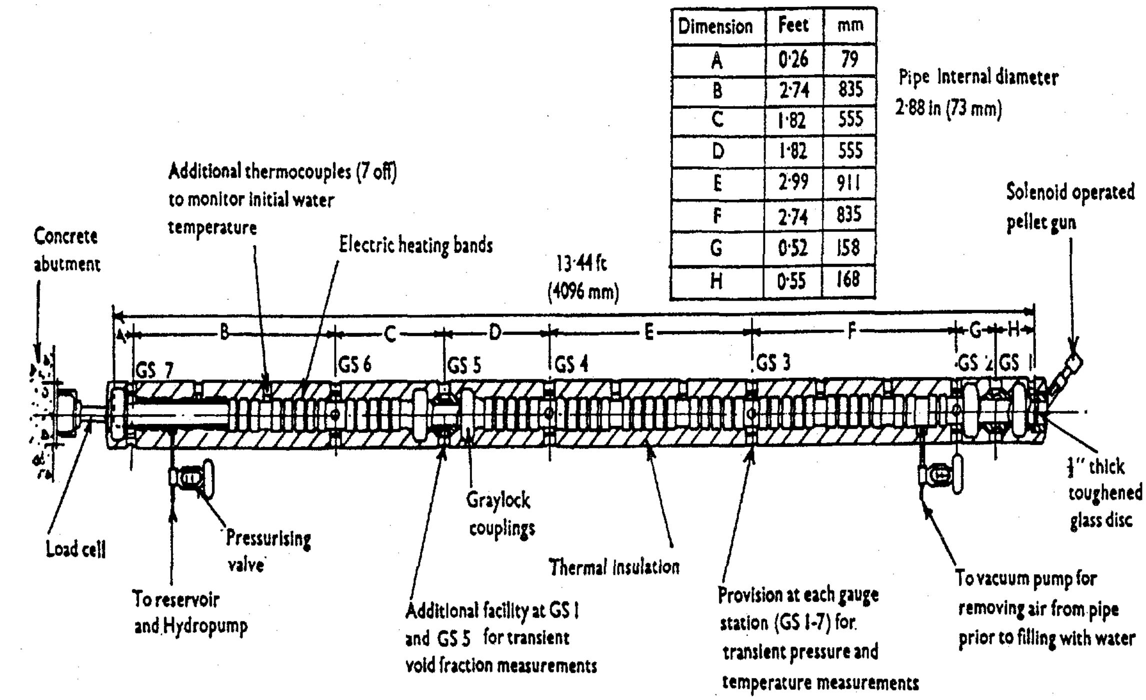

Figure 1: Edwards-O'Brien Blowdown Test (taken from [1])

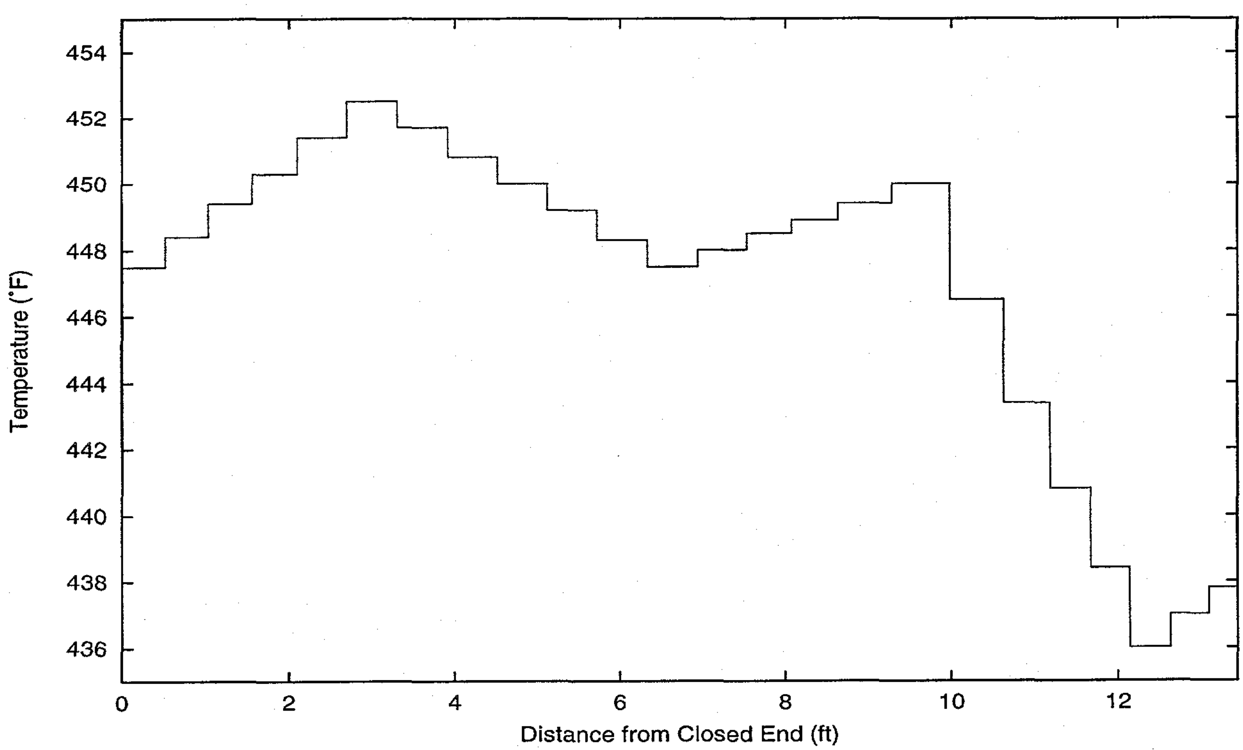

Figure 2: Modified Initial Temperature Profile

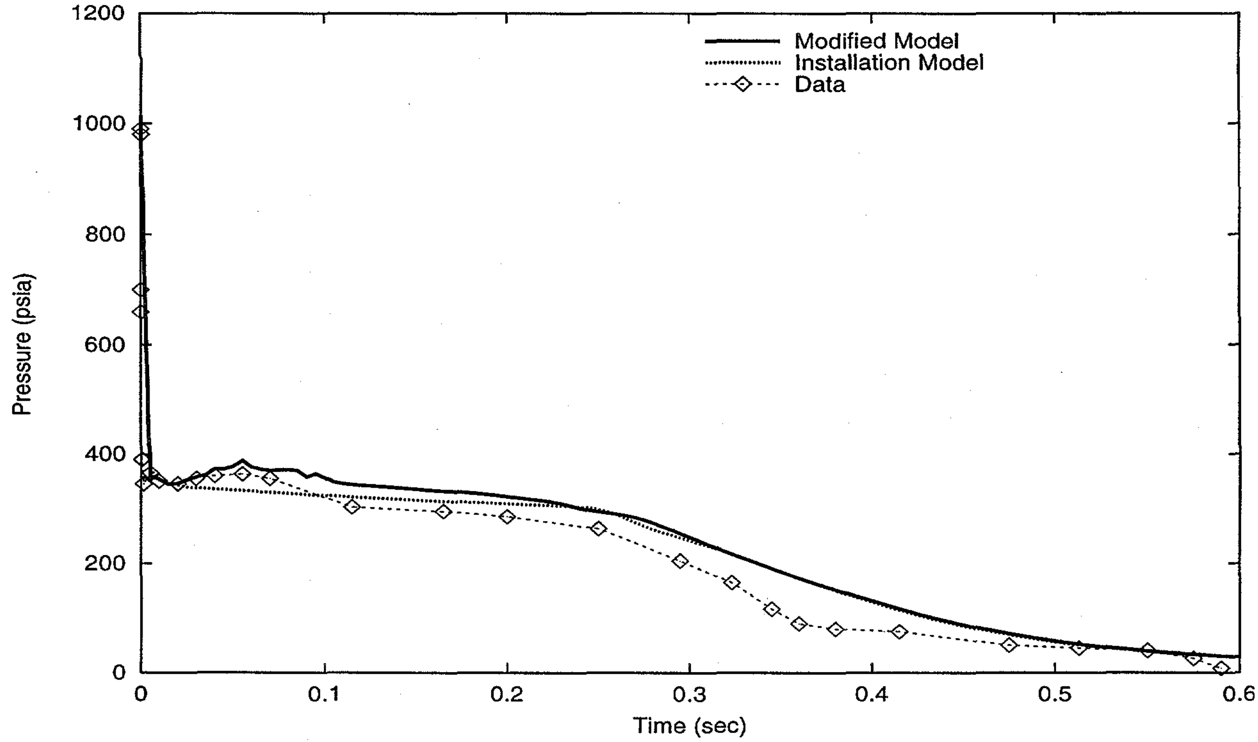

Figure 3: Pressure as a Function of Time at GS-1

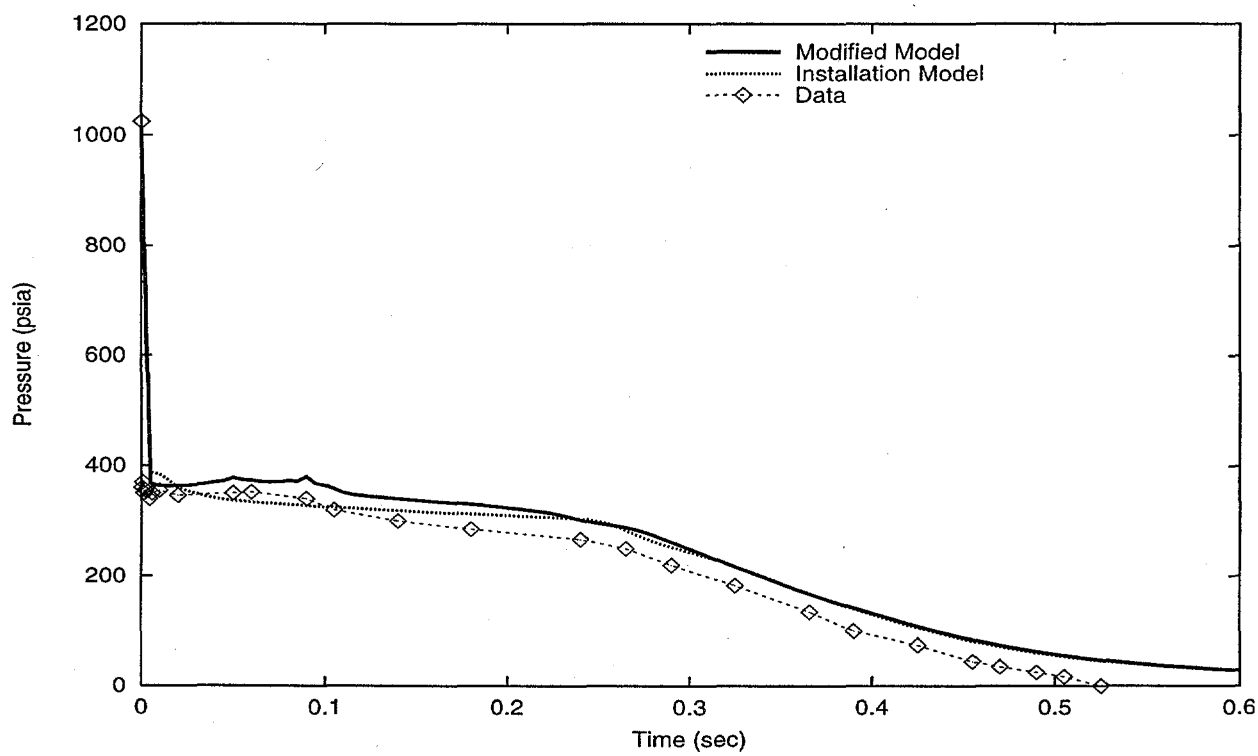

Figure 4: Pressure as a Function of Time at GS-2

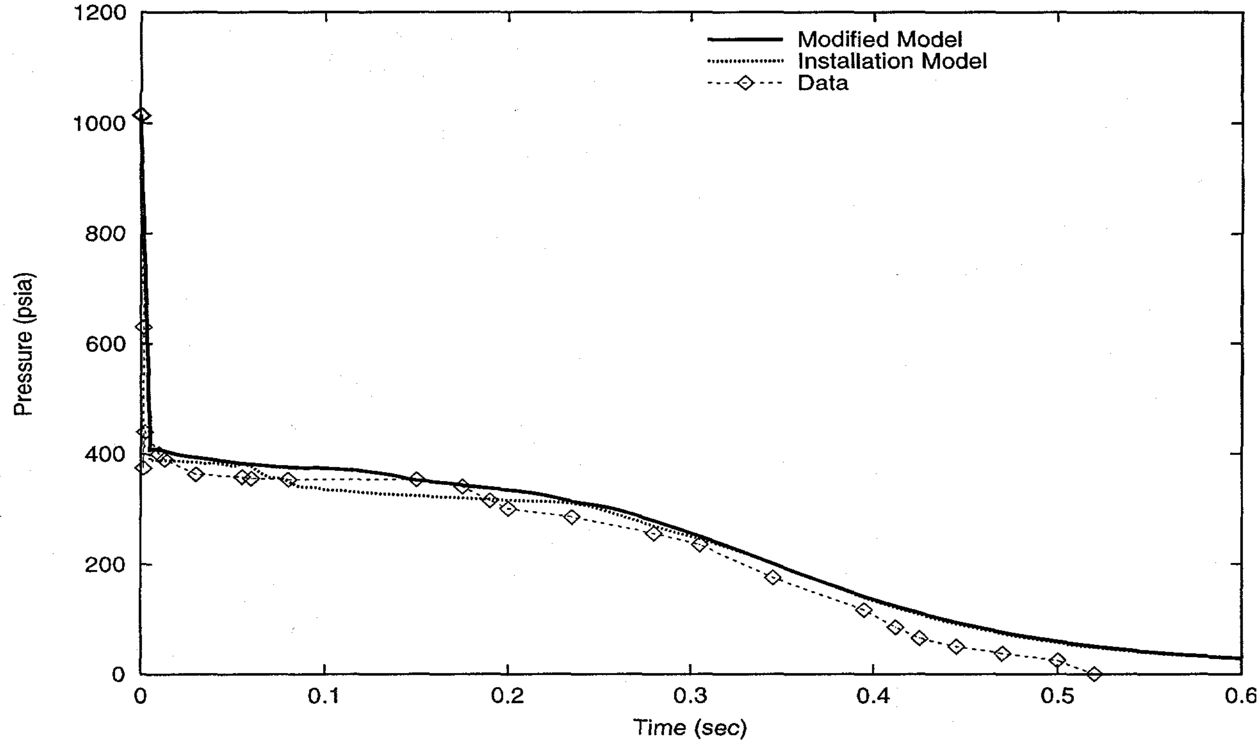

Figure 5: Pressure as a Function of Time at GS-3

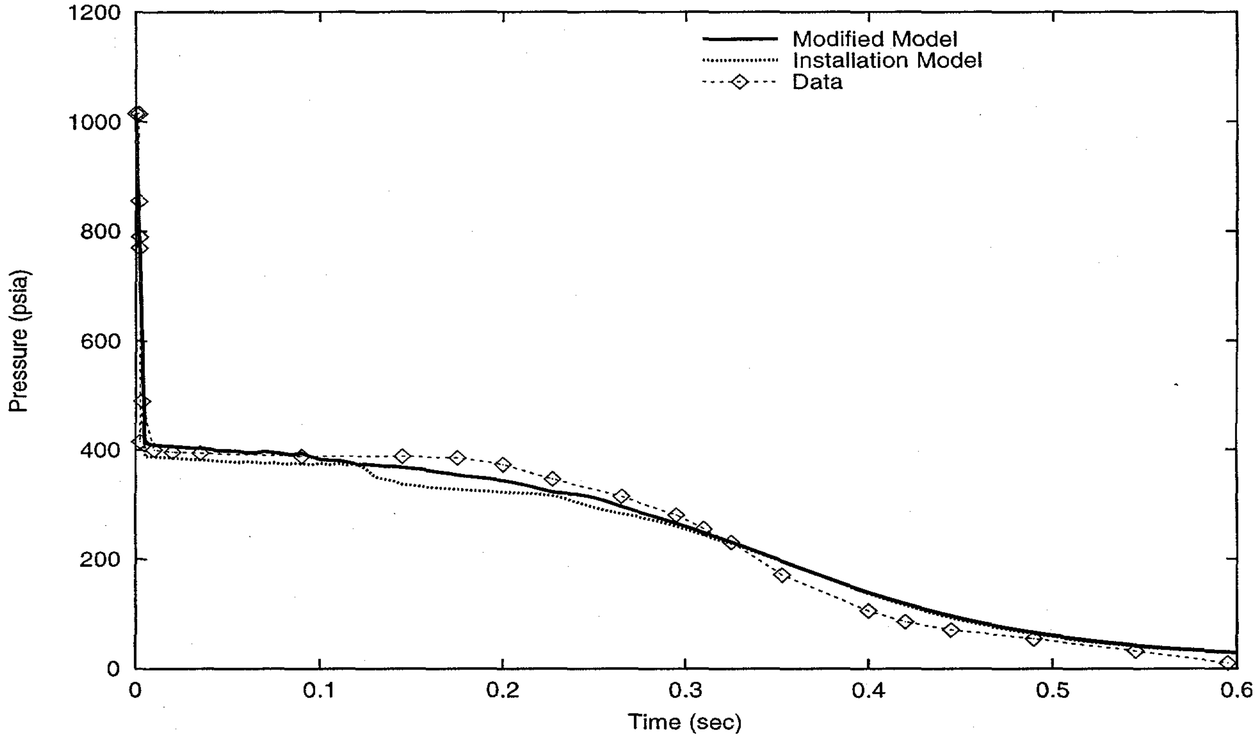

Figure 6: Pressure as a Function of Time at GS-4

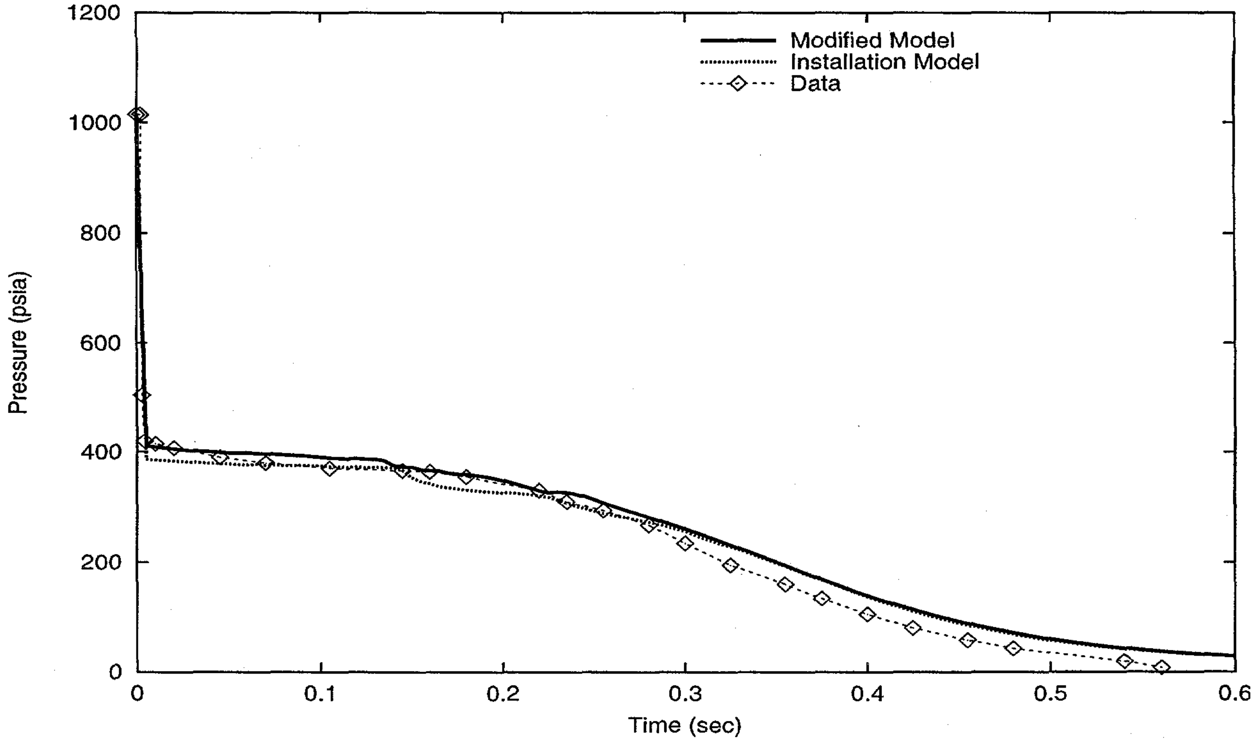

Figure 7: Pressure as a Function of Time at GS-5

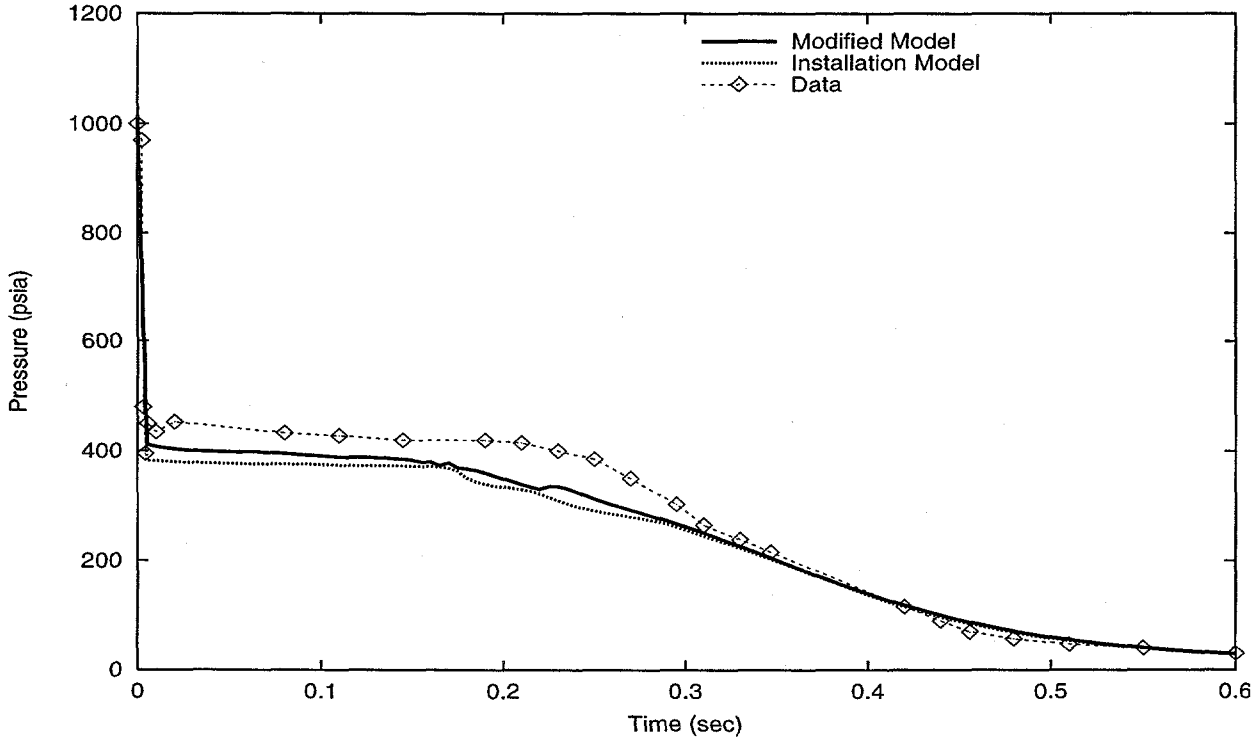

Figure 8: Pressure as a Function of Time at GS-6

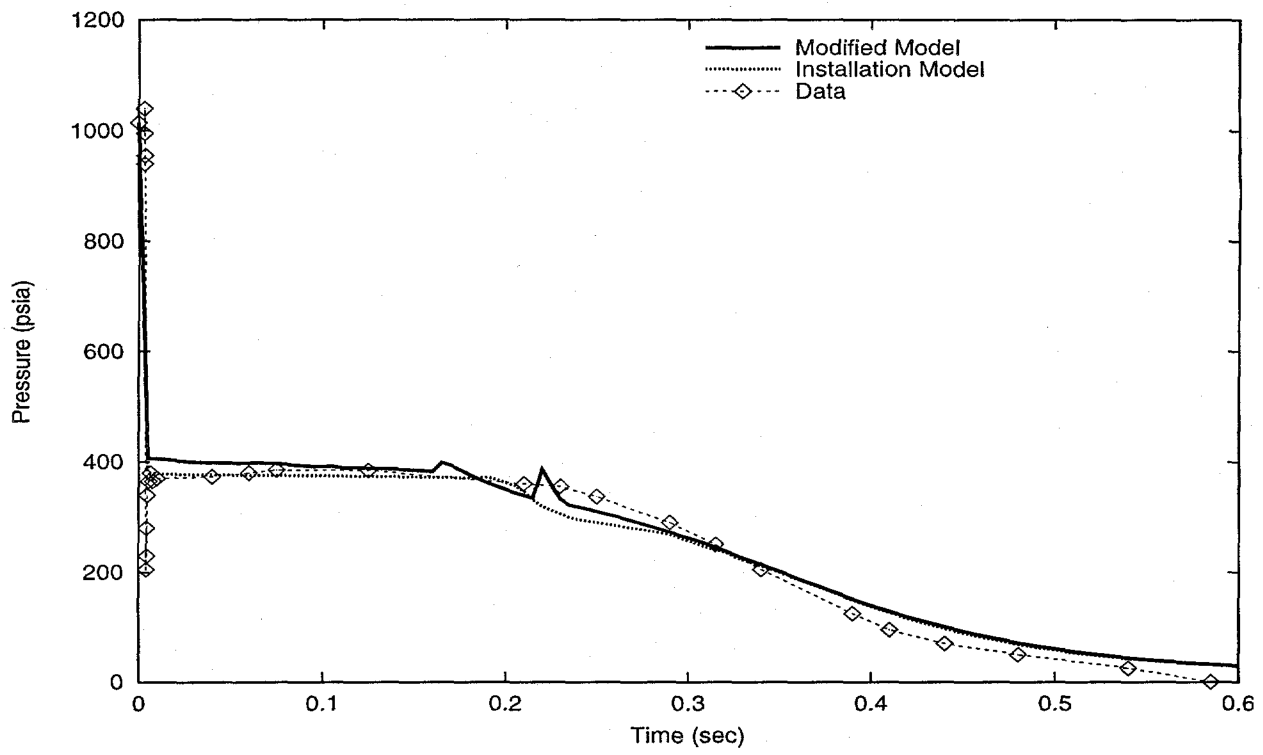

Figure 9: Pressure as a Function of Time at GS-7

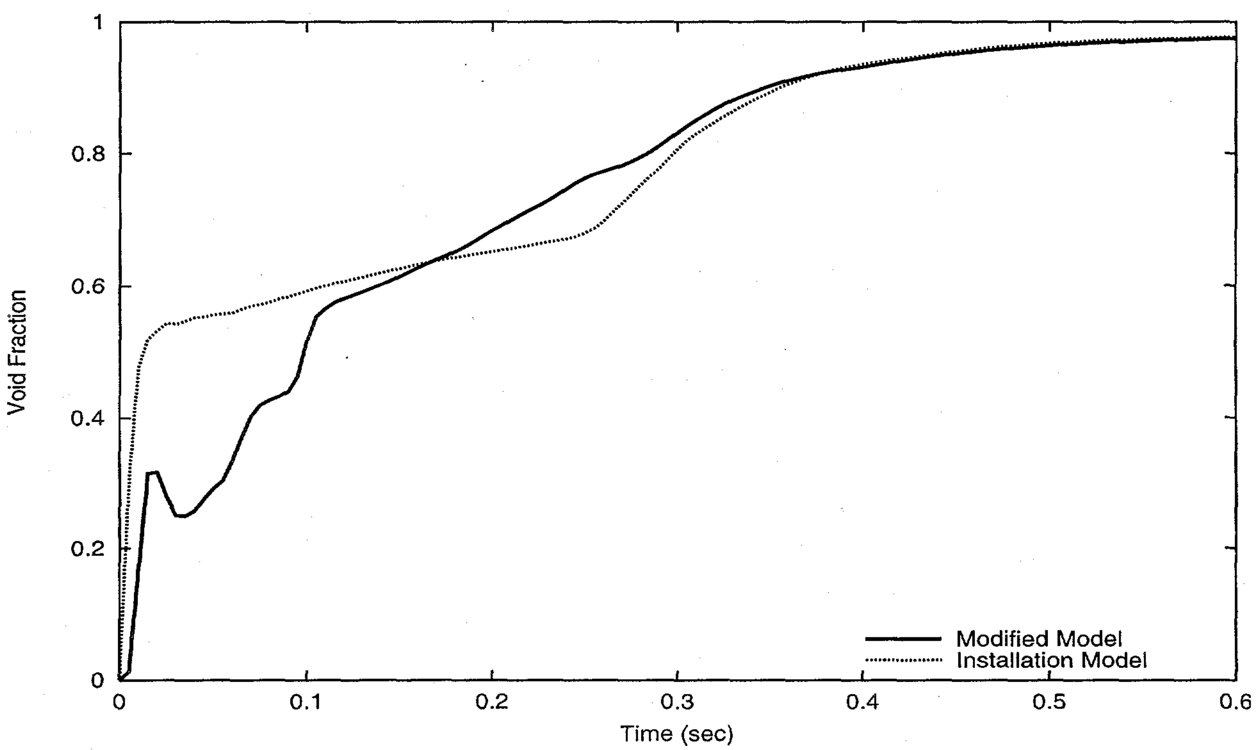

Figure 10: Void Fraction as a Function of Time at GS-1

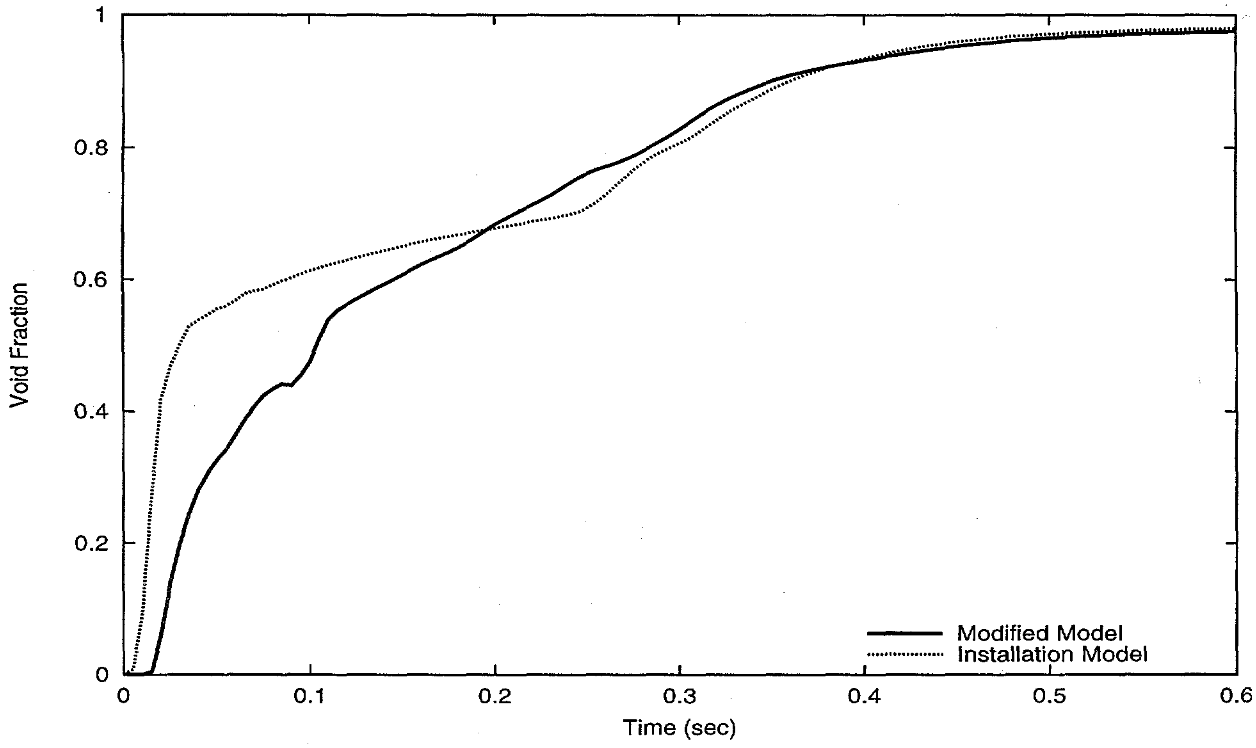

Figure 11: Void Fraction as a Function of Time at GS-2

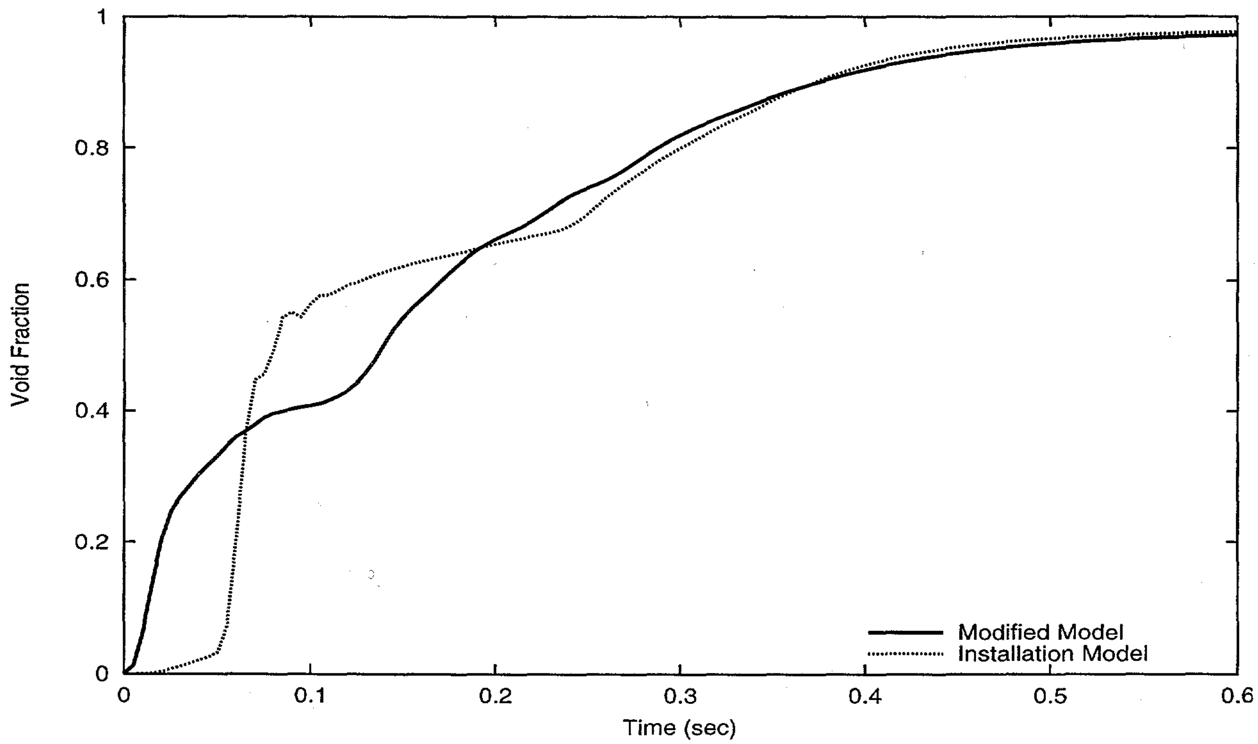

Figure 12: Void Fraction as a Function of Time at GS-3

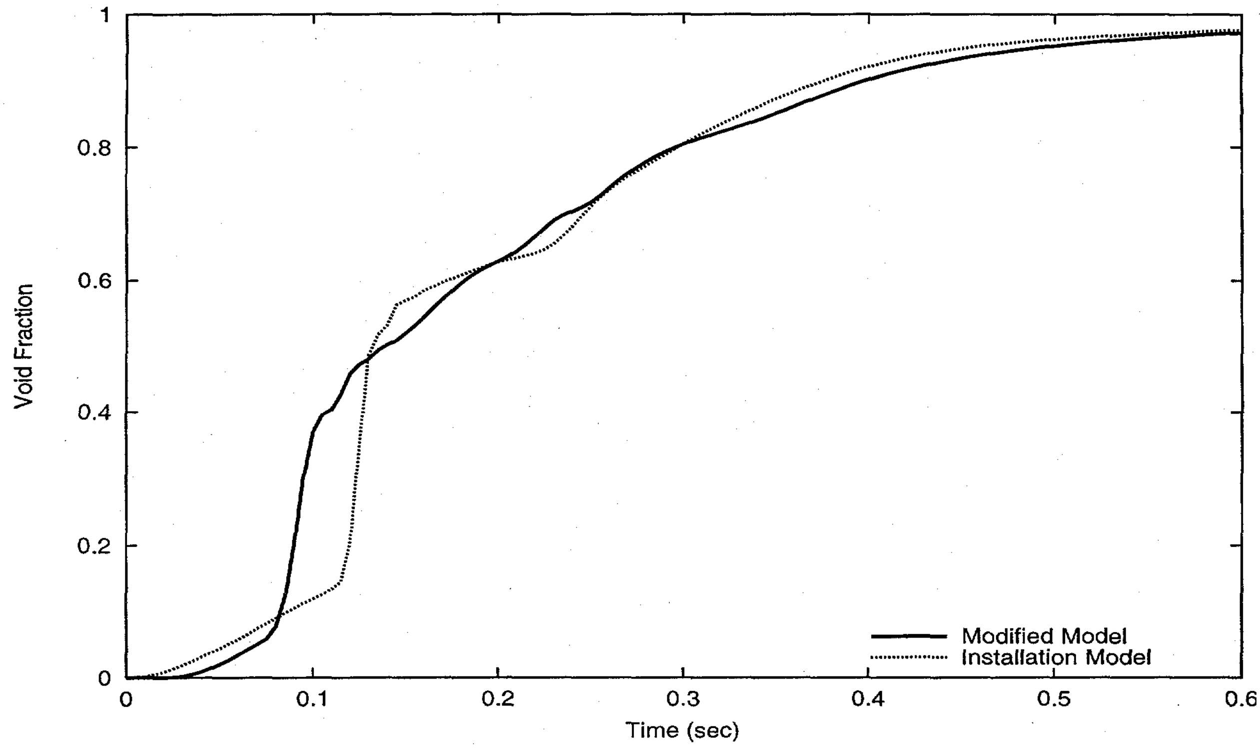

Figure 13: Void Fraction as a Function of Time at GS-4

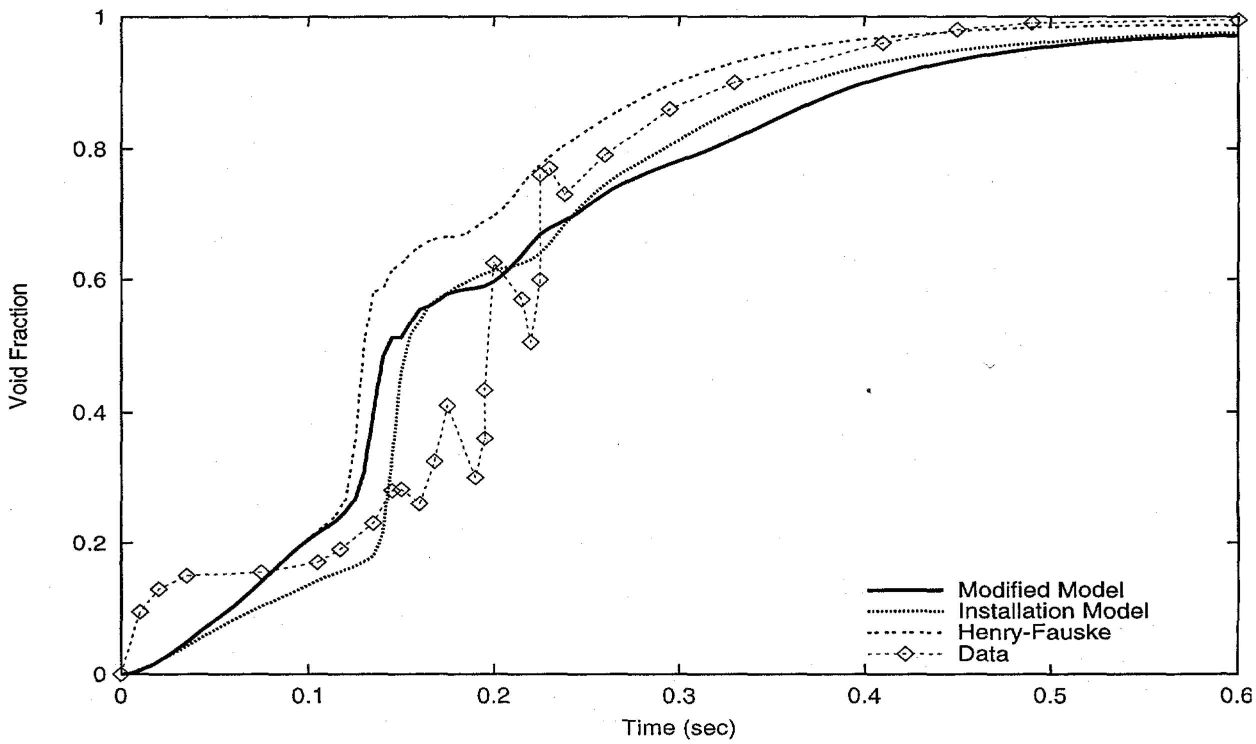

Figure 14: Void Fraction as a Function of Time at GS-5

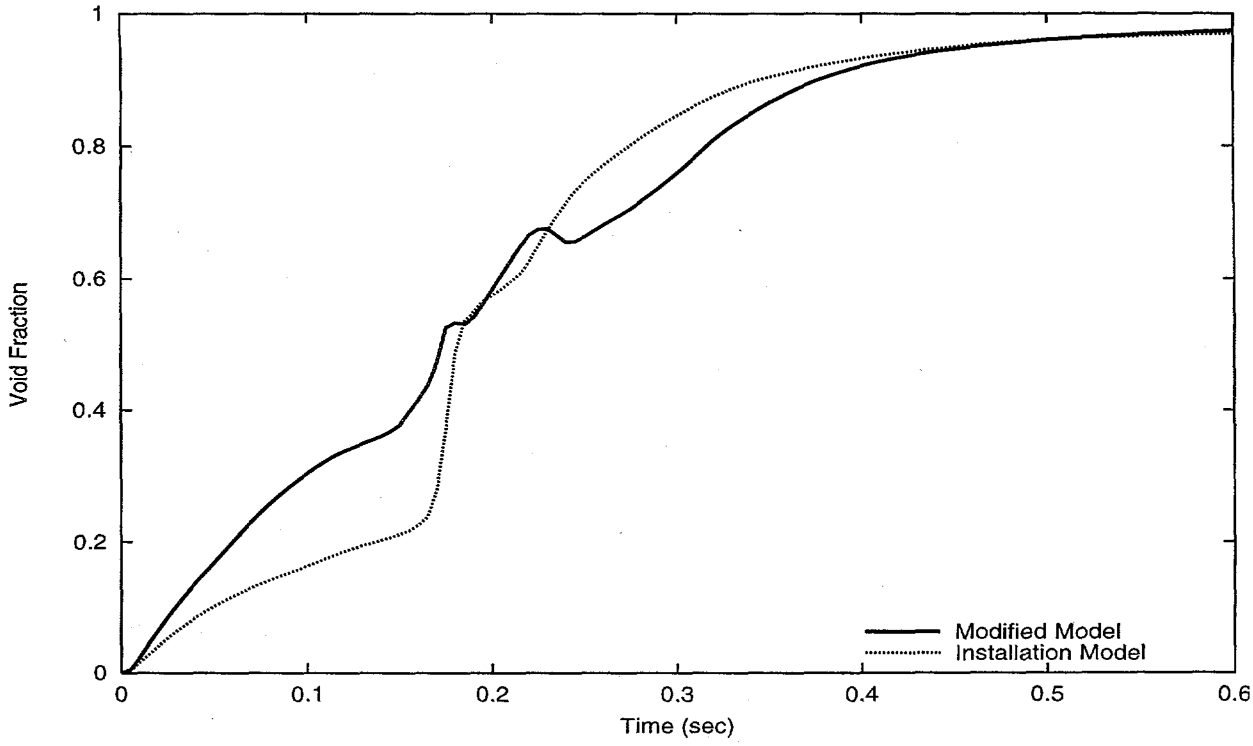

Figure 15: Void Fraction as a Function of Time at GS-6

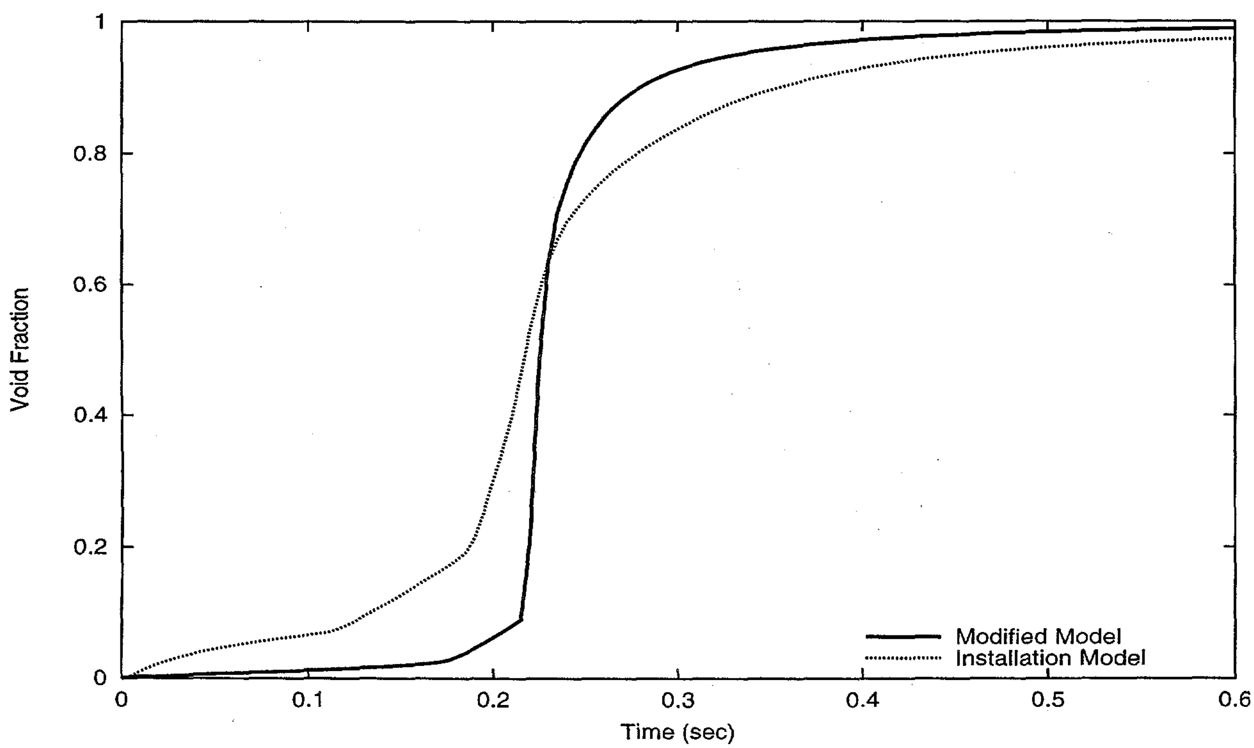

Figure 16: Void Fraction as a Function of Time at GS-7

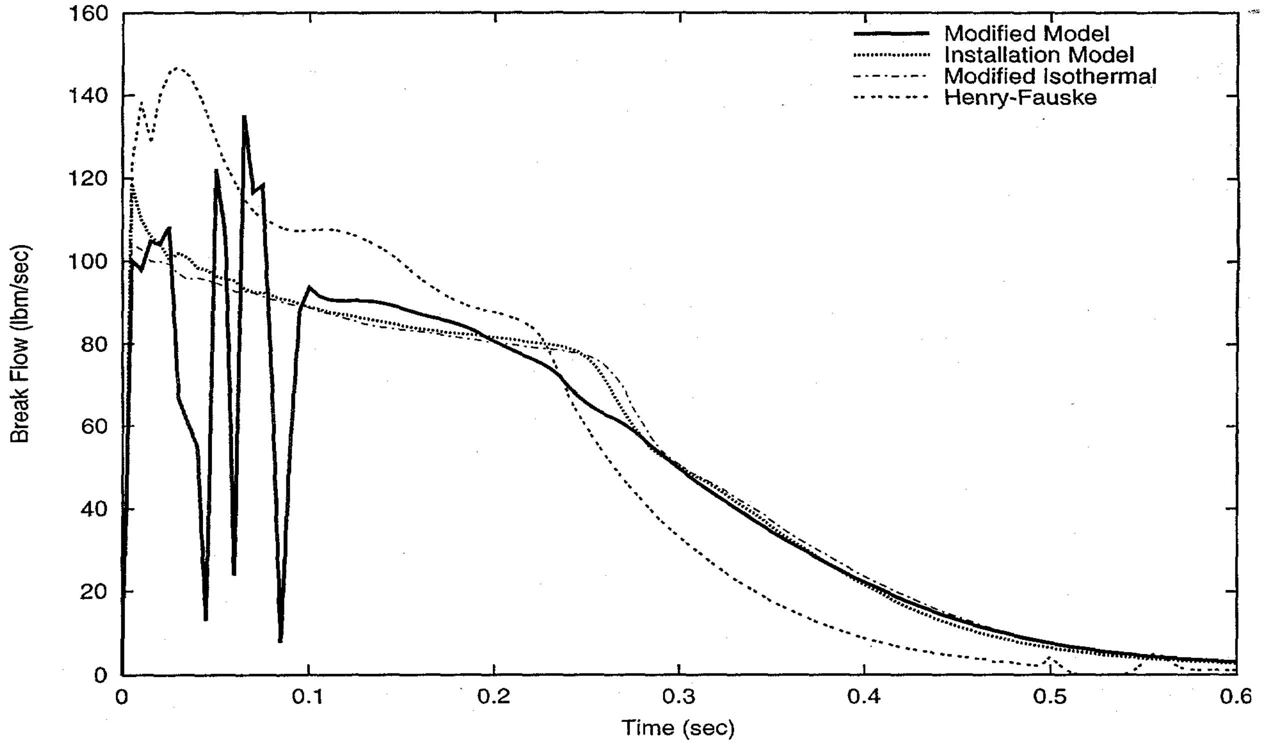

Figure 17: Break Flow as a Function of Time