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DRYWELL PRESSURIZATION TEST FOR THE NRC 1/5 SCALE PRESSURE SUPPRESSION EXPERIMENT

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FEBRUARY 21, 1977

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Prepared for U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

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DRYWELL PRESSURIZATION TEST FOR THE NRC 1/5 SCALE
PRESSURE SUPPRESSION EXPERIMENT

by

T. J. Altenbach & J. H. Pitts

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SUMMARY

A drywell pressurization test was conducted at LLL on February 1, 1977, as part of the NRC 1/5 scale pressure suppression experiment. A series of four test runs were completed with predicted initial drywell pressurization rates of 14.0, 18.6, 23.0, and 26.0 psi/sec (96.5, 128, 159, and 179 KPa/sec). Each test run consisted of charging various combinations of bottles with nitrogen under high pressure, evacuating the drywell to 1/5 atmosphere, and opening a valve between the two to allow quick pressurization of the drywell. The pressure-time signatures of all four test runs were in excellent agreement with predicted results made through 1) a computer model developed at LLL and 2) the CONTEMPT-LT computer code which was run by E.G.&G. at the I.M.E.L. Based on the results of the test, only very minor adjustments will be made for the upcoming nitrogen tests with the drywell and toroidal wetwell system linked together.

INTRODUCTION

One series of tests for the NRC 1/5 scale pressure suppression experiment to be conducted at LLL consists of the injection of pressurized nitrogen into the evacuated drywell and toroidal wetwell. The nitrogen supply exists in tanks at high pressure and flow is induced after the failure of a rupture disk in a line connecting the nitrogen storage bottles to the drywell. The drywell is quickly pressurized and the flow continues through vent pipes and downcomers into the toroidal wetwell. The toroidal wetwell is approximately half-filled with water.

As a prelude to this experiment, a similar test of drywell pressurization was conducted at LLL on February 1, 1977. A schematic of the test apparatus is shown in Figure 1. The setup consisted of a commercially available high pressure nitrogen supply which was used to charge from one to a maximum of six

*This work was performed under the auspices of the U.S. Energy Research and Development Administration under Contract No. W-7405-Eng. 48.

SCHEMATIC OF DRYWELL PRESSURIZATION TEST APPARATUS

FIGURE 1

bottles at a desired pressure. The nitrogen storage bottles vary in volume as shown in Table 1.

The nitrogen bottles were isolated from the drywell by means of a manually operated valve. The drywell and the gas line downstream from the manually operated valve were then pumped down to a pressure of about 1/5 atmosphere. The gas line consisted of 3.826" (9.72 cm) I.D. line and contained a flow nozzle with a throat diameter of 1.913 (4.86 cm). The drywell exit flanges leading to the torus were capped off. The toroidal wetwell was not involved in these tests. The instrumentation for the test consisted of three pressure transducers connected to associated electronics providing a continuous digital readout and a high speed chart recording of the pressure histories. The transducers were located in the high pressure gas line, and at the top and bottom of the drywell.

Four drywell pressurization tests were then conducted. Each consisted of charging a combination of bottles to a desired pressure which was determined by calculations to be described subsequently. With the valve closed the drywell was evacuated. Then the valve was rapidly opened and the resulting drywell pressurization observed and recorded.

PREDICTED RESULTS

The initial gas bottle pressure and volume combinations for each test were chosen on the basis of a computer code model of the system developed by J. K. Meier at LLL. Meier's report¹ describes the model, and an addendum to the report treats the details of the pressure and volume selections. A brief summary of the model follows.

Meier's code considers the test apparatus to consist of three volumes and two connecting lines. The volumes represent the gas storage bottles, the drywell, and the toroidal wetwell. Each volume is considered to contain gas at a constant temperature and pressure. The walls of each volume are approximated as being adiabatic. Only the volumes for the nitrogen storage bottles and the drywell are considered active when predicting runs for the drywell pressurization tests.

¹ Meier, J. K., "Preliminary Thermodynamic Analysis of the 1/5 Scale P.S.E. Air-Water Test Apparatus", LLL Internal Report ENN 76-112 of December 1976.

TABLE 1

NITROGEN STORAGE BOTTLE VOLUMES

<u>BOTTLE NUMBER</u>	<u>VOLUMES</u>
1	not used
2	15.4 ft ³ (.436m ³)
3	3.0 (.0850)
4	6.0 (.170)
5	6.0 (.170)
6	6.0 (.170)
7	9.0 (.255)

The connecting lines are considered to have resistance to flow but no volume. The resistance to flow² was determined using choked flow characteristics in the appropriate portions of the connecting lines and Fanno line (constant area adiabatic flow) in the constant area portions. The volumes associated with the connecting line were added as appropriate to the nitrogen storage bottles or the drywell.

Also used as input to the tests and as a verification of Meier's code were computer runs made by E.G. & G. at the INEL in Idaho Falls. There the CONTEMPT-LT computer code³ was used to model the pressure suppression experiment nitrogen tests. The CONTEMPT-LT computer code has the advantage of allowing heat transfer to the walls of the volumes, but is limited to two volumes with a single connecting line.

Results of both Meier's code and CONTEMPT-LT were used to obtain the most accurate predictions possible. Meier's code was used to specify inlet flow conditions to the drywell. CONTEMPT-LT was used to obtain predictions that included heat transfer. Then Meier's code was used to adjust the CONTEMPT-LT predictions to match the drywell pressurization test conditions.

Table 2 lists the predicted results of the four runs comprising the drywell pressurization test. The run numbers correspond to those of the test matrix for air tests. These runs encompass all planned initial rise rates. The dual columns for initial bottle pressure and and rise rate are given to illustrate the agreement between the two computer codes. The initial pressures chosen for the test were those listed in the CONTEMPT column of the table. However, the actual test pressures used were somewhat higher. The predicted pressure histories for the gas bottles and drywell were obtained by using Meier's code with the initial pressures listed in the LLL column. Figures 2 through 9 plot the predicted pressure histories of the gas bottles and the drywell.

EXPERIMENTAL RESULTS

A summary of the initial conditions and results appears in Table 3. The experimentally determined pressure histories are also plotted in Figures 2

2 Hall, Newman A. "Thermodynamics of Fluid Flow", Prentice Hall, 1951.

3 Wheat, L. L., et al "CONTEMPT-LT - A Computer Program for Predicting Containment Pressure-Temperature Response to a Loss-of-Coolant Accident". ANCR-1219. INEL, June 1975

TABLE 2

DATA FOR DRYWELL PRESSURIZATION TEST AND NITROGEN RUNS

RUN	INITIAL BOTTLE PRESSURE		INITIAL RISE RATE - PSE		EXPECTED DRYWELL TEST RISE RATE	NITROGEN STORAGE BOTTLES		FINAL DRYWELL PRESSURE
	LLL	CONTEMPT-LT	LLL	CONTEMPT-LT		VOLUME	NUMBERS USED	
1.1	4.55.5 Psia (3140 KPa)	474.3 (3270)	18.6 psi/sec (128 KPa/sec)	18.66 (129)	20.8 psi/sec (143 KPa/sec)	15.0 ft ³ (.425m ³)	3,4,5	23.7 psia (163 KPa)
1.4	316.0 (2179)	323.7 (2232)	14.0 (96.5)	13.95 (96.2)	15.6 (108)	24.0 (.680)	3,4,5,7	24.4 (168)
1.5	685.0 (4722)	718.8 (4955)	23.0 (159)	21.44 (148)	25.6 (176)	9.0 (.25)	3,4	23.1 (159)
1.6	774.5 (5339)	811.5 (5595)	26.0 (179)	26.01 (179)	28.9 (199)	9.0 (.25)	3,4	25.6 (176)

through 9 along with the predicted results. The peak pressure rise rates in the drywell as measured on the chart recording were all slightly lower than the predictions. The reason for this is due to the differences in initial flow as the valve is manually opened as compared to the computer model's rupture disk with instantaneous flow.

The final drywell pressures are all slightly above the predicted final pressures. This is explained because the initial pressures used in the experiment were higher than those used in the calculation. Also possible is that the volume of the nitrogen bottles and exit headers above the valve was slightly larger than thought previously. The final pressure in the drywell and storage bottles should be identical. The more accurate reading is that of the final drywell pressure, because the instrumentation in the drywell covered a much smaller range of pressures than the storage bottle instrumentation.

Another difference appears in Figures 6 and 8. The slopes of the nitrogen supply pressure history curves differ for about the first 1/2 second of the runs. This effect is thought to be due to the differences between ideal flow and the flow from only two bottles of different volumes (3 and 6 ft³). In runs 1.1 and 1.4, more gas bottles were used and the initial flow rates were more accurately predicted by the computer models.

CONCLUSIONS

Several conclusions can be drawn from the drywell pressurization test. There was very close agreement between the predicted and experimental results on each run. Therefore, the drywell, nitrogen supply, and instrumentation were all operating as expected. The test also provided an excellent check on the two computer models used. Based on the results of the test, only very minor adjustments will be made for the upcoming nitrogen tests with the drywell and toroidal wetwells connected together.

TABLE 3

DRYWELL PRESSURIZATION TEST
INITIAL CONDITIONS AND RESULTS

INITIAL PRESSURE*

RLN	STORAGE BOTTLES	DRYWELL	PEAK RISE RATE ⁺	FINAL DRYWELL PRESSURE ⁺	FINAL STORAGE BOTTLE PRESSURE*
1.1	489.5 psia (3374 KPa)	3.75 psia (25.8 KPa)	18 psi/sec (124 KPa/sec)	28.3 psia (195 KPa)	27.5 psia (189 KPa)
1.4	338.5 (2332)	3.75 (25.8)	13 (90)	27.5 (189)	39.5 (272)
1.5	733.5 (5054)	3.78 (26.0)	22 (152)	24.8 (171)	39.5 (272)
1.6	827.5 (5701)	3.80 (26.2)	22 (152)	30.8 (212)	40.5 (279)

* Measured via electronic digital readout

⁺ Measured via chart recorder

FIGURE 2
DRYWELL PRESSURIZATION TEST
AIR SUPPLY PRESSURE HISTORY
TEST 1.1

FIGURE 3
DRYWELL PRESSURIZATION TEST
AIR SUPPLY PRESSURE HISTORY
TEST 1.1

FIGURE 4
DRYWELL PRESSURIZATION TEST
AIR SUPPLY PRESSURE HISTORY
TEST 1.4

FIGURE 5
DRYWELL PRESSURIZATION TEST
DRYWELL PRESSURE HISTORY
TEST 1.4

FIGURE 6
DRYWELL PRESSURIZATION TEST
AIR SUPPLY PRESSURE HISTORY
TEST 1.5

FIGURE 7
DRYWELL PRESSURIZATION TEST
DRYWELL PRESSURE HISTORY
TEST 1.5

FIGURE 8
DRYWELL PRESSURIZATION TEST
AIR SUPPLY PRESSURE HISTORY
TEST 1.6

FIGURE 9
DRYWELL PRESSURIZATION TEST
DRYWELL PRESSURE HISTORY
TEST 1.6

ACKNOWLEDGEMENTS

We appreciate the help of J. K. Meier at LLL and R. Wells, J. Mills, and W. Minks at INEL for the predictions of the results. W. Shay and others in the LLL Materials Engineering Division set-up the instrumentation.

J. O'Connor and other technicians completed assembly of the test apparatus.

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