NEDO-21944
79NED81
CLASS I
JUNE 1979

MARK I CONTAINMENT PROGRAM QUARTER SCALE PLANT UNIQUE TESTS

TASK NUMBER 5.5.3, SERIES 2

VOLUME 1

1343 002

GENERAL ELECTRIC

NEDO-21944
79NED81
Class I
June 1979

MARK I CONTAINMENT PROGRAM
1/4 SCALE PRESSURE
SUPPRESSION POOL SWELL TEST PROGRAM: PLANT UNIQUE TESTS
TASK NUMBER 5.5.3, SERIES 2

Volume 1, Main Report

This work was performed with the support of Quadrex Corporation, Nuclear Services Division, and Aerotherm Division of Acurex Corporation under contract to General Electric.

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ABSTRACT

This report presents the results of the Plant Unique Tests (Mark I Long Term Program Task 5.5.3-2) that were conducted in the Mark I Quarter Scale Test Facility (QSTF) to obtain subscale two-dimensional net vertical torus forces, vent header impact pressures, and pool surface displacement and velocity transients for seventeen Mark I plants. The data from these tests will be used as input for plant unique pool swell loads for those conditions selected by the utilities as their design basis. Individual plant characteristics were modeled in the QSTF so that pool swell could be evaluated on a plant unique basis. The plants in the order tested were: Hatch 2, Monticello, Pilgrim, Fermi 2, Duane Arnold, Nine Mile Point 1, Brunswick 1 and 2, Cooper Station, Dresden 2 and 3 (applicable to Quad Cities 1 and 2), Browns Ferry 1, 2, and 3, Peach Bottom 2 and 3, Millstone, Oyster Creek 1, Hatch 1, Vermont Yankee, Fitzpatrick, and Hope Creek 1 and 2. Four tests were conducted at planned operating conditions for each plant. In addition, a ΔP sensitivity test (or tests) was conducted for each plant (with the exception of the Brunswick tests, for which only the four load definition tests were run at zero drywell/wetwell ΔP). Scoping pipe deflector tests were conducted for the Monticello plant geometry. A total of 101 tests were conducted from March to October 1978 in the QSTF.

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1.0 INTRODUCTION

1.1 Background

As part of the Mark I Containment Long Term Program (LTP), subscale tests were conducted to provide input for definition of pool swell loads on the Mark I torus and vent system as a result of a postulated Loss-of-Coolant Accident (LOCA). Task 5.5.3 was established as part of the LTP to provide two-dimensional pool swell load definition testing in the Mark I Quarter-Scale Test Facility (QSTF).

Task 5.5.3 load definition testing in the QSTF was divided into two test series:

Series 1, Generic Sensitivity Tests
These tests were designed to provide sufficient data to evaluate specific parameter sensitivities of a generic nature to Mark I pool swell tests (e.g., effect of the location of the vent orifice) and to provide load sensitivities to cover variations in plant operating conditions around the specific plant unique conditions to be tested in the Series 2, Plant Unique Tests. The Generic Sensitivity Tests were performed from February to March 1978 in the QSTF and the test results are reported in Reference 1.

Series 2, Plant Unique Tests
These tests consisted of a sequence of scaled tests for each Mark I plant in which all the hydrodynamic and geometric parameters were modeled for that plant under the operating conditions selected by each plant.

The QSTF program of Plant Unique Tests was designed to model the geometry and appropriate test conditions for an average torus cell of each Mark I plant tested. The plant scale factors were determined by the fixed 93" QSTF torus diameter and each plant's minor torus diameter. All other

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geometric and hydrodynamic parameters were then scaled from actual plant values using the scaling relationship developed for pool swell testing (Reference 2).

This report covers the results of Plant Unique Tests (Task 5.5.3, Series 2), which were performed from March to October 1978 in the QSTF. The work was performed by Nuclear Services Corporation and their subcontractor, the Aerotherm Division of Acurex Corporation. The plants in the order tested were: Hatch 2, Monticello, Pilgrim, Fermi 2, Duane Arnold, Nine Mile Point 1, Brunswick 1 and 2, Cooper Station, Dresden 2 and 3 (applicable to Quad Cities 1 and 2), Browns Ferry 1, 2, and 3, Peach Bottom 2 and 3, Millstone, Oyster Creek 1, Hatch 1, Vermont Yankee, Fitzpatrick, and Hope Creek 1 and 2.* A total of 101 tests were conducted from March to October 1978 in the QSTF.

1.2 Objectives

The objectives of the Plant Unique Tests are to provide subscale plant unique two-dimensional data for net vertical torus forces, vent header impact pressures, and pool surface velocity and displacement transients for all Mark I plants. To satisfy these objectives, the individual plant geometric and hydrodynamic characteristics have been modeled in the QSTF at the operating conditions specified by each utility for these tests. Zero ΔP tests were also conducted to obtain data for zero ΔP evaluations for those plants which plan to operate with a drywell/wetwell ΔP.

The data from these tests will be used as input for plant unique pool swell loads for those conditions selected by the utilities as their design basis.

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* Plant unit numbers are not always called out in the remainder of the report.

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1.3 Report Organization

This report has been organized to provide a concise presentation of test results in a main report together with a comprehensive documentation of test data and supporting analyses in a series of appendices. The main report contains three sections: 1) an introduction, 2) a description of the tests and the test facility, and 3) a set of typical test results which use the data from Monticello tests 1-8 for illustration.

All other test data and analyses are presented in a series of appendices which are described in the following paragraphs:

Appendix A which is a continuation of Section 3 presents the test data for the other sixteen plant configurations tested. The data in Section 3 and Appendix A are not necessarily design basis data. The Task 5.5.3-2 Plant Unique Tests were performed at conditions being evaluated for plant operation. Supplementary tests are being performed for several Mark I Utilities to evaluate alternate conditions including variations in water level, submergence, drywell-wetwell pressure differential and vent header deflector design. After a review of these data, a set of test conditions will be selected for each plant to serve as a design basis for pool swell loads.

Appendix B defines the methodology used for vent header pressure integration. The values used for the six point fits to the impact pressure transducer transients and the resulting pressure integrals are also provided.

Appendix C presents plant unique data comparisons and the results of a linear regression correlation of the plant unique test data.

Appendix D estimates the amount of pool mass that is suspended during the upload.

Appendix E presents a series of still pool swell pictures for each plant configurations.

Appendix F presents the results of a measurement uncertainty analysis.

Appendix G presents the specification for vent system resistance and the methods used to meet the specification.

Appendix H presents the results of evaluations of torus window related download oscillations in the plant unique data and a description of the methods employed to remove these effects for several plants.

2.0 TEST DESCRIPTION

The basic Quarter-Scale Test Facility (QSTF) and hardware modifications required for plant unique testing are described in this section. Test conditions and facility instrumentation are also presented.

2.1 Description of Plant Unique Testing

2.1.1 Hardware

The QSTF shown in Figure 2-1 was built to provide a large subscale facility for two-dimensional Mark I pool swell testing. The facility includes a simulated wetwell (or torus), a drywell, and an air reservoir tank together with supporting structure, flow controls, instrumentation and computer facilities.

The QSTF wetwell is designed to model an average cell of a Mark I torus. An average cell is a right cylindrical section of the torus which contains one pair of downcomers (one downcomer for Duane Arnold) with the width equal to the average torus centerline distance between downcomers. The test facility width is nominally 21.8 inches, but can be varied between 14.67 and 28.55 inches in order to equal the scaled average downcomer spacing for each plant. The torus has an inside diameter of 93 inches (one-fourth of the 31-foot full-scale diameter of the "reference" plant).

Drywell pressurization is modeled by using a large compressed air tank which discharges upon command into a simulated drywell volume (which is volumetrically, but not geometrically, scaled) through double disc valves and a metering orifice. The pressure in the large air reservoir tank changes very little (<5%) during a simulated LOCA transient so that the incoming enthalpy flux is nearly constant.

Transparent end and side ports on the QSTF torus allow visual observation of the phenomena from two directions. High-speed photography is utilized to examine fine details of the one-second event and to measure surface displacements during the pool swell. Transparent downcomers make the vent clearing phenomena visible.

The drywell is structurally isolated from the wetwell by a flexible bellows. The vent header is connected to the drywell through a load cell and is structurally isolated from the wetwell by a roller assembly. The vent header is vertically isolated so that vent header impact forces can be measured separately from the torus forces.

Three struts for stiffening the torus end windows are used in each test configuration to reduce downforce oscillations. Five sets of adjustable length struts are required to cover the full range of facility widths used in the Plant Unique Tests. The strut design is illustrated in Figure 2-2.

A complete description of the reference QSTF is given in Reference 2.

The scaling relationships used as the basis for quarter-scale testing were originated by Dr. F. J. Moody of General Electric and are presented in Reference 2. The results of that development are summarized as:

LENGTH	$\propto$	SCALE FACTOR
TIME	$\propto$	$(\text{SCALE FACTOR})^{1/2}$
VELOCITY	$\propto$	$(\text{SCALE FACTOR})^{1/2}$
PRESSURE	$\propto$	SCALE FACTOR
ENTHALPY FLOW	$\propto$	$(\text{SCALE FACTOR})^{7/2}$
FORCE	$\propto$	$(\text{SCALE FACTOR})^{3}$
IMPULSE	$\propto$	$(\text{SCALE FACTOR})^{7/2}$

Although the QSTF was designed to be a quarter-scale model of a reference plant, sufficient flexibility was provided in the design to model the full range of scaled Mark I plant parameters. The only fixed parameter in the QSTF is the torus diameter (93 inches). For each Mark I plant, the scale factor equals the ratio of 93 inches/full-scale torus minor diameter in inches. All other subscale geometric and hydraulic conditions are derived from the scale factor and full-scale parameters, in accordance with the scaling laws.

Major adjustments to the QSTF which were necessary to match each plant unique configuration included:

a) TORUS WIDTH,
b) VENT SYSTEM CONFIGURATION,
c) DRYWELL VOLUME,
d) VENT SYSTEM RESISTANCE, fL/D,
e) DRYWELL PRESSURIZATION RATE,
f) VENT HEADER DEFLECTOR, and
g) TEST CONDITIONS (including water level, torus pressure and ΔP).

Individual subscale variables were determined as follows:

<u>GEOMETRIC VARIABLES</u>

Subscale Torus Width	= Average Full-Scale Downcomer Spacing x Scale Factor
Subscale Vent Header Dimensions	= Full-Scale Dimensions x Scale Factor
Subscale Drywell and Vent System Volume	= (Full-Scale Volume/Number of Downcomer Pairs) x $(\text{Scale Factor})^3$
Subscale Vent fL/D	= (Temperature-Corrected Full-Scale fL/D)/Scale Factor

HYDRODYNAMIC VARIABLES

Drywell Pressurization Rate	= Full-Scale Value x $(\text{Scale Factor})^{1/2}$
Water Level	= Full-Scale Value x Scale Factor
Torus Pres' --	= Full-Scale Value x Scale Factor

Figure 2-3 presents a sketch of the quarter-scale torus section. The nominal (calculated) torus critical dimensions and volumes along with the permissible tolerance and actual (as-built) values for the Plant Unique Tests are hown in Tables 2-1a, b, and c.

The following paragraphs describe how the QSTF was adjusted to match the calculated subscale plant unique variables.

TORUS WIDTH. The portion of the QSTF which represents an average cell* of a typical torus is shown in Figure 2-1. The torus section is cylindrical with an inside diameter of 93 inches and a minimum width of 14.67 inches. Two circular end plates with plexiglass window inserts are bolted onto the cylinder.

The design permits the addition of spacer rings between the end plates and the torus cylinder as shown in Figure 2-4. By adding pairs of spacers (to ensure symmetry), the width of the torus may be varied over a wide range. In addition to the relatively thick spacers (on the order of 3" to 6" wide), a number of thinner "shims" were manufactured to allow for finer adjustments to the width required for plant unique tests. The individual spacer and shim dimensions are listed below.

Basic Torus Width - 14.67"
Spacer Pair #1 - 6.26" wide**
Spacer Pair #2 - 7.12" wide

*The width of an average cell equals the torus centerline length per pair of downcomers (per downcomer for Duane Arnold).

**Spacers and shims are used in pairs. Width given is for the pair.

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Spacer Pair #3	- 11.30" wide
Spacer Pair #4	- 12.08" wide
Shim Pair #1	- 1.30" wide
Shim Pair #2	- 1.80" wide

These shims and spacers permit variations of the torus width between 14.67 and 28.55 inches. The range of possible torus widths is shown at the bottom of Figure 2-4. The spacer and shim dimensions were selected so that distribution of final torus widths would most accurately match the actual plant unique average cell dimensions. For each plant tested, the torus width was equal to or narrower than the scaled width.

DRYWELL VOLUME. The QSTF drywell is the cylindrical tank located above the torus, as shown in Figure 2-1. The drywell was designed to allow for a variable volume by using a spacer concept similar to that designed for the torus. The design illustrated in Figure 2-5 utilizes two aluminum spacers, a reversible end cap and up to ten internal filler shims. The aluminum spacers increase the baseline drywell volume of 49.83 ft^3 by 16.7 ft^3 and 29.43 ft^3 respectively. Reversal of the drywell end cap reduces the drywell volume by 10 ft^3. The lack of water in the drywell permits the use of a simple shim system. The shims are circular pieces of plywood, each occupying one cubic foot of the drywell. Either of the two aluminum spacers can be used with the reversible end cap to change the drywell volume in large increments. Up to 10 plywood shims can then be bolted to the inside of the drywell end cap to reduce the net volume to the required value.

The distribution of drywell/vent system volume for each of the Plant Unique Tests is shown in Table 2-2.

VENT HEADER DESIGN. Each individual plant's test vent header is geometrically scaled from that plant's full-scale vent header dimensions. Critical dimensions such as vent header outer diameter, downcomer length, overall height and position relative to the torus centerline are matched within specified tolerances. (See Figure 2-6 and Tables 2-1a, b, and c.)

The vent header is stiffened to enhance vent impact force definition. Two bracing struts are welded inside the vent header drum to increase the vertical stiffness of the entire assembly. These struts extend from the bottom of the drum to the top of the drum and are made of 1" O.D. stainless steel tubing with a wall thickness of 3/16". In addition, the rear cover is welded in place. Two accelerometers were installed in the vent header assembly. One was placed in the bottom of the header drum, the other was put on the upper part of the vent header support column. Comparison of these accelerometers permits verification of rigid body response during plant unique tests.

DRYWELL PRESSURIZATION RATE. Drywell pressurization rate adjustment for the Plant Unique Tests is provided by using one of six available drywell flow orifices together with variation in the reservoir tank pressure. Figure 2-7 illustrates the drywell pressurization rates achievable with a combined adjustment of orifice size and tank pressure based on a nominal drywell volume of 53.4 ft^3. The plant unique DBA LOCA pressurization transients were based on computer calculations simulating capped downcomers (constant volume charging of the drywell and vent system). These pressurization transients are then scaled for each plant and form a lower bound for the allowable subscale drywell pressure transient. A tolerance of +10% was specified to provide a target upper bound pressure history. Drywell pressurization rate calibration tests were performed with capped downcomers for each plant to establish the reservoir

pressure and orifice size that would provide a drywell pressure transient that bounded the allowable pressure transient.

VENT SYSTEM fL/D. Plant unique vent flow losses are scaled for each plant to provide an upper bound on the allowable subscale vent system fL/D. In order to more accurately model the distribution of flow loss in an actual Mark I vent system, orifices are installed in two locations (Figure 2-8). One of these flow orifices is placed at the vent pipe entrance, flush with the base of the drywell, and a pair of identical orifices (representing a balanced flow loss) are installed in the downcomer legs. The total vent loss is approximately evenly split between the two locations with a tolerance of ±10%. Appendix G discusses fL/D simulation in more detail.

VENT HEADER DEFLECTOR. Several plants elected to test with vent header deflectors. Figure 2-9 shows the support system selected to allow testing with deflectors of various sizes, shapes, and positions without transmitting deflector loads to the vent header. Deflector loads were not measured in this test series, but they are being measured during supplemental tests. Figure 2-10 shows the sizes, geometries, and positions of deflectors for all plants.

2.1.2 Instrumentation

Test instrumentation for the transient measurements consists of 29 pressure transducers, four accelerometers, one thermocouple, and two load cells. The test instrumentation is divided into a standard instrumentation and data collection group and an analog data collection group. The standard group consists of instrumentation to measure driving conditions and loads exerted on the torus and vent header. The analog group is used to determine the pressure distribution on the vent header shell and provide an independent measure of vent header impact forces. Standard initial condition

measurements (e.g., drywell pressure and temperature, pool water temperature, reservoir pressure and temperature, etc.) are also made.

The instruments included in the standard group are listed in Table 2-3 and their arrangement is shown in Figure 2-11. Transducer ranges, sample rates and low-pass filter settings are also detailed in Table 2-3.

The instruments included in the analog group are listed in Table 2-4 and a typical arrangement on the lower portion of the vent header is shown in Figure 2-12. Specific locations for each plant are shown on Figure 2-13. The pressure transducers that form the analog data group are initially recorded on an analog (FM) tape and later digitized. The pressure transducers have a maximum range of zero to one hundred psia and their signals are unfiltered during data collection.

Transducer locations not used during a test are sealed with plugs which are flush with the vent header external surface. These plugs prevent any water leakage into the vent header or air leakage into the torus during testing.

The QSTF Digital Data Acquisition System (DAS) is designed to sample data and store it on a floppy disc at a maximum rate of 20,000 total measurements per second. Data from floppy disc records are printed and plotted soon after the tests. The data recorded on the FM tape recorder* are played back through the standard Analog to Digital system (used for all normal data recording) and digitized

*The recorder used is a Honeywell 5600c, 14 channel FM tape recorder. The input and output sensitivities are 0-2 volts (peak-to-peak) with a frequency response of 5 kilocycles per channel.

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to give a sample rate of at least 3000 SPS. The additional digitized vent header impact pressure data are added to the appropriate floppy disc for each test. A magnetic tape record of all the digitized data is also created and permanently stored as a backup. A tape copy of the augmented floppy disc is produced. All data records are identified by test ID number, date, and time of the test.

2.2 Test Matrix

The general test program strategy was to modify the QSTF on a plant unique basis and measure the pool swell data for each individual configuration. The modifications to the test facility included the vent header/ downcomer assembly, the test section width, the drywell volume, the drywell pressurization rate and the initial test conditions. These modifications to the test facility were designed to scale the average downcomer cell of each Mark I plant tested. Plant unique testing followed the flow chart shown in Figure 2-14.

The key test parameters which affect the net vertical torus forces, vent header impact forces, and pool surface displacements and velocities are detailed in Tables 2-5a, b, and c. Four "Load Definition" tests were conducted for each plant at maximum submergence and minimum ΔP of the operating range specified by each utility for these tests. These conditions were selected to produce maximum pool swell response. In addition, a "ΔP Sensitivity" test (or tests) was conducted for each plant (with the exception of the Brunswick tests, for which only four load definition tests were run at zero ΔP). A total of 101 tests for 17 Mark I plants were conducted from March to October 1978 in the QSTF (see Test Matrix Tables 2-5a, b, and c).

The wetwell water was conditioned by means of a surfactant so that the surface tension would be no greater than 35 ($\pm$5) dynes/cm (compared to

72 dynes/cm for tap water). This was done to remove surface air bubbles from the windows and shell of the test facility (Reference 3).

High-speed color movies were taken of all tests. For each set of four identical load definition tests, the camera was set up to take movies of the front window for three tests and of the side window for one test.

MARK I BWR CONTAINMENT POOL SWELL

QUARTER-SCALE TEST FACILITY - PERSPECTIVE

FIGURE 2-1

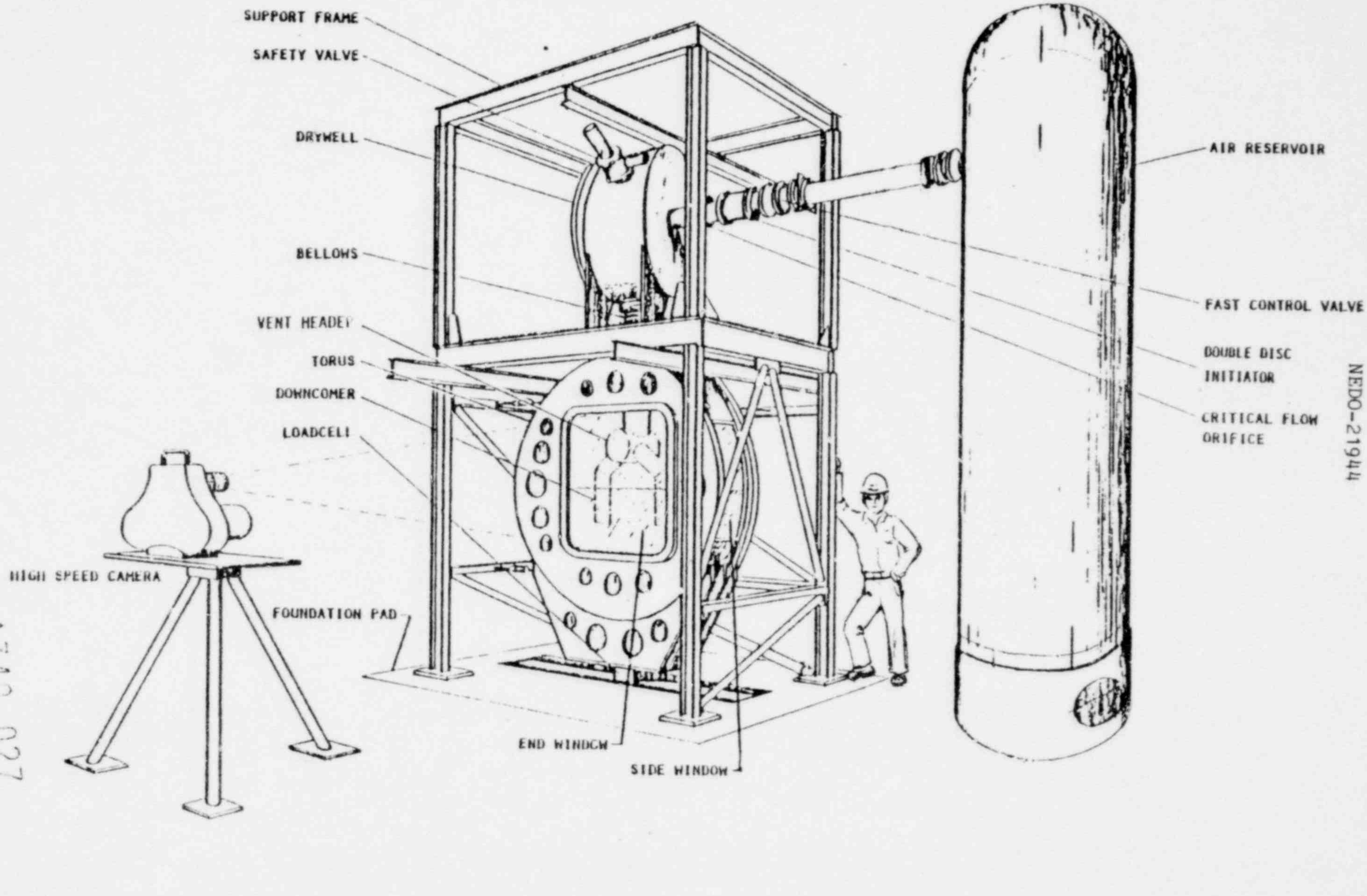

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FIGURE 2-2

TORUS END WINDOW STIFFENERS

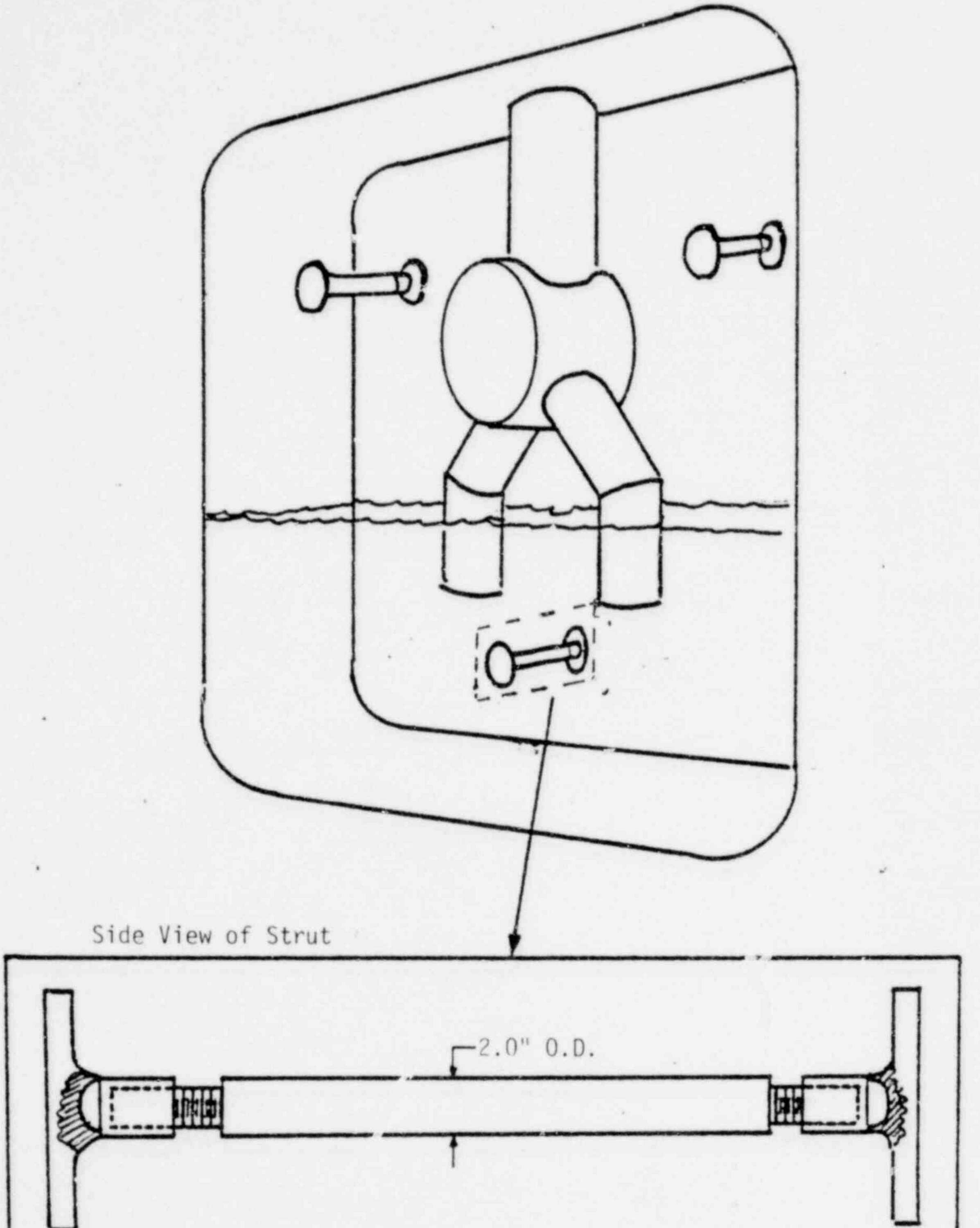

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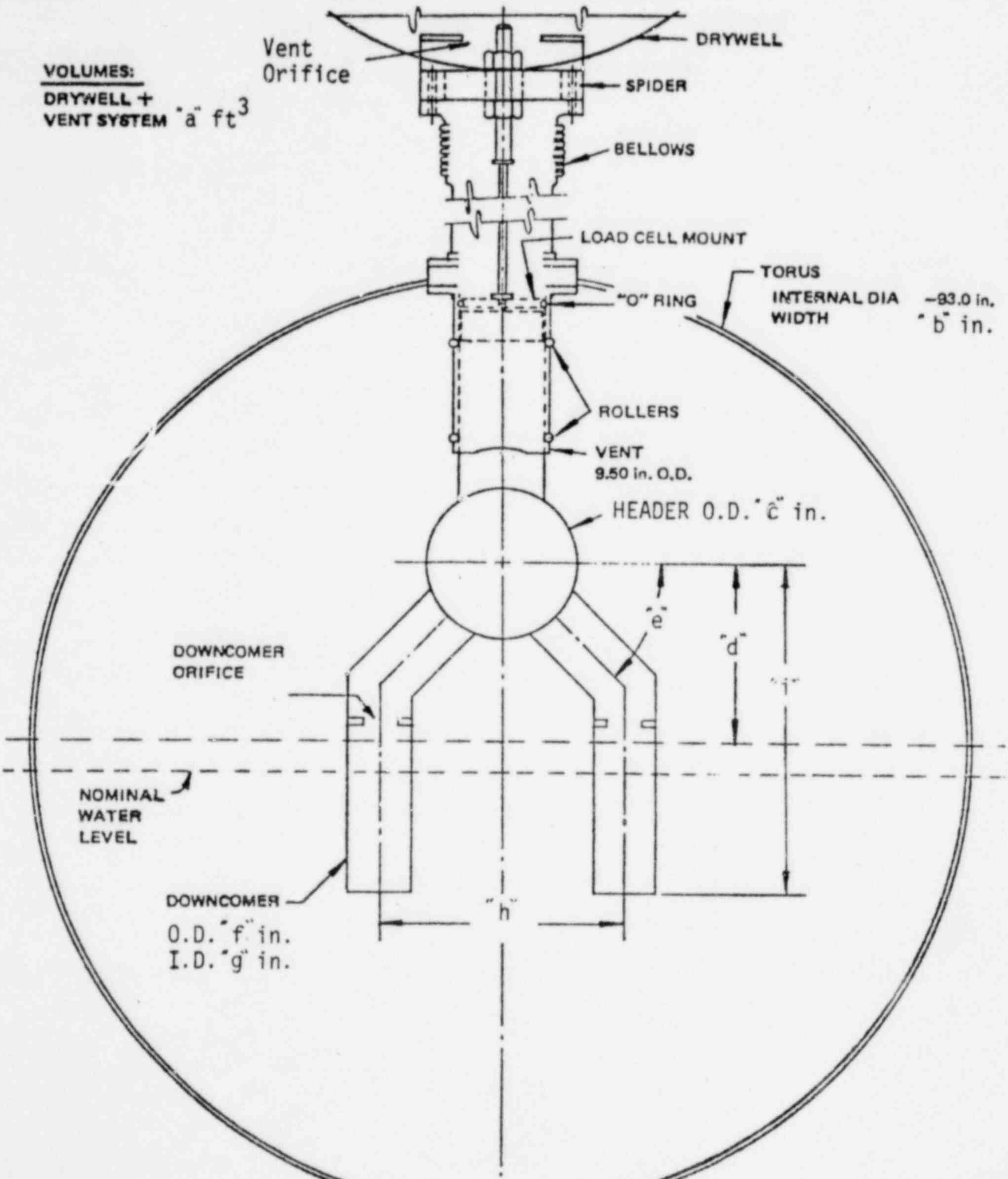
FIGURE 2-3 MARK I QUARTER-SCALE TORUS SECTION



NOTE: See Table 2-1 for torus critical dimensions "a" through "i".

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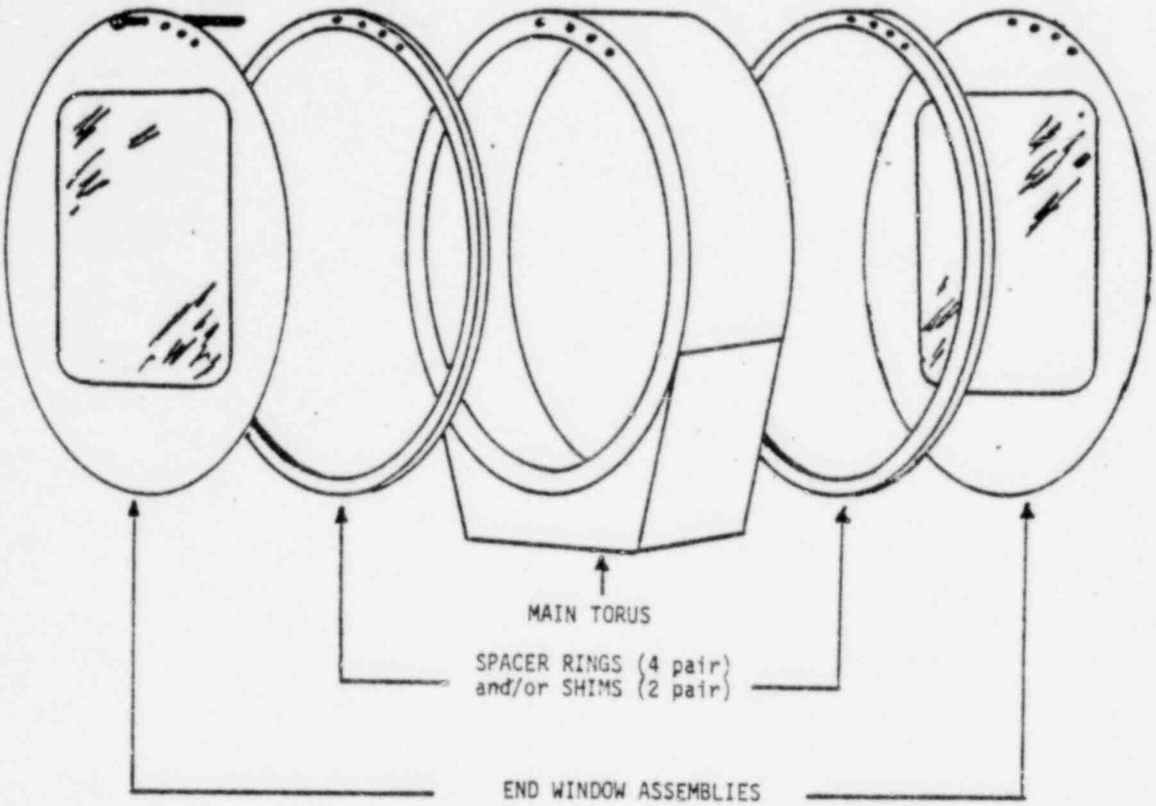
FIGURE 2-4

SPACER CONFIGURATIONS



		Final Width
Basic Torus - No Spacer,	No Shim -	14.67"
	w/Shim #1 -	15.97"
	w/Shim #2 -	16.47"
Basic Torus w/Spacer #1,	No Shim -	20.93"
	w/Shim #1 -	22.23"
	w/Shim #2 -	22.73"
Basic Torus w/Spacer #2,	No Shim -	21.79"
	w/Shim #1 -	23.09"
	w/Shim #2 -	23.59"
Basic Torus w/Spacer #3,	No Shim -	25.97"
	w/Shim #1 -	27.27"
	w/Shim #2 -	27.77"
Basic Torus w/Spacer #4,	No Shim -	26.75"
	w/Shim #1 -	28.05"
	w/Shim #2 -	28.55"

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FIGURE 2-5

DRYWELL CONFIGURATIONS

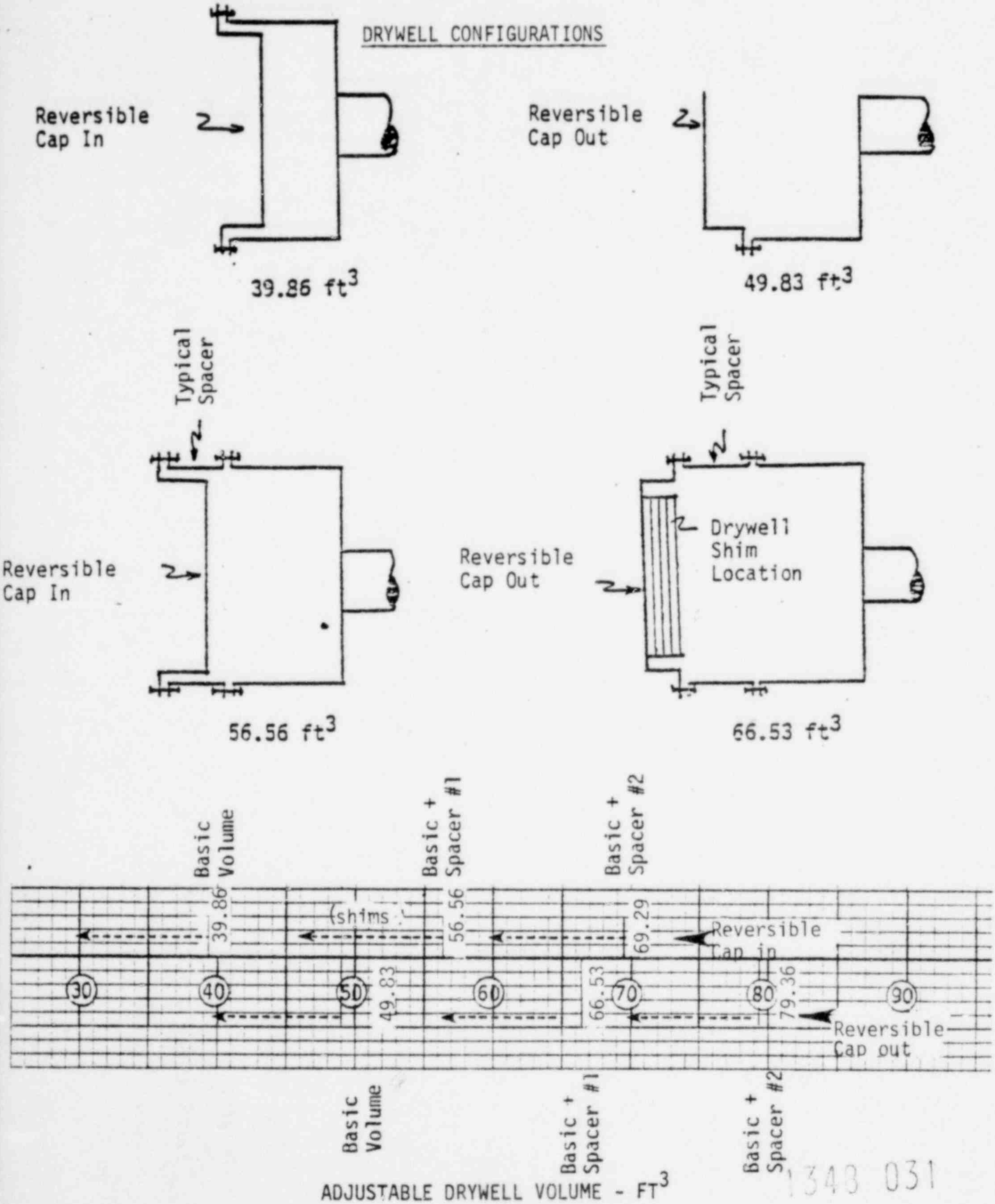

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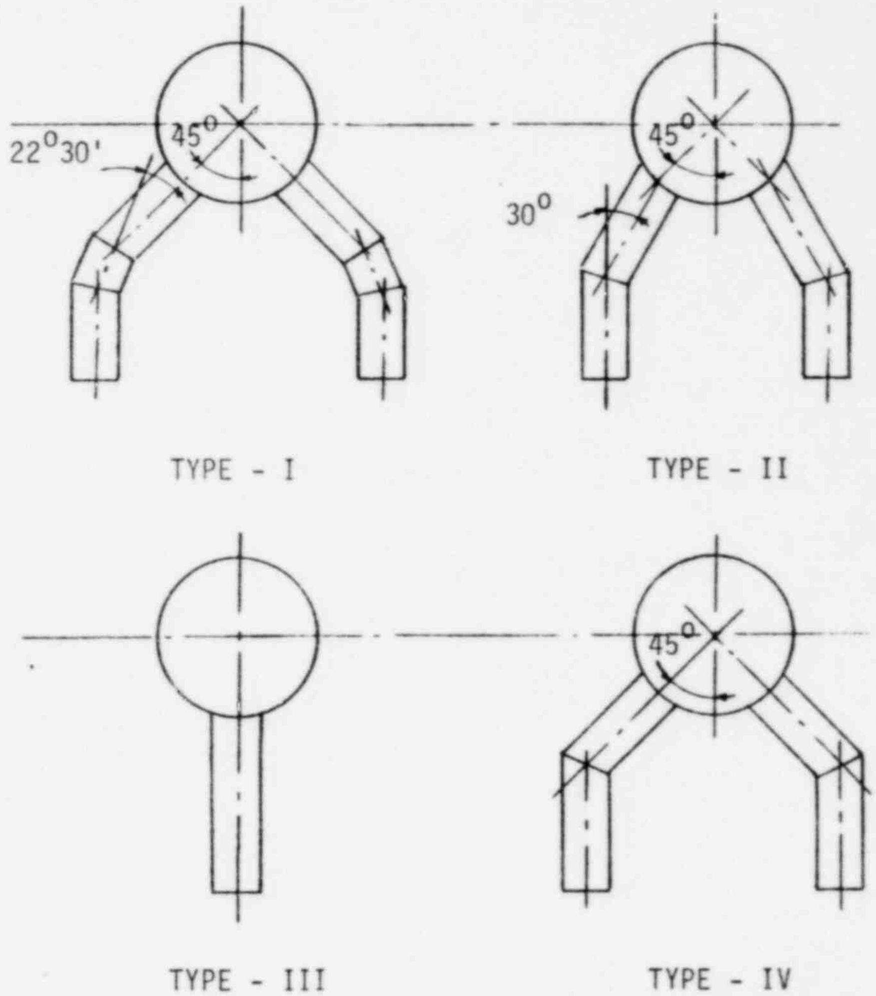
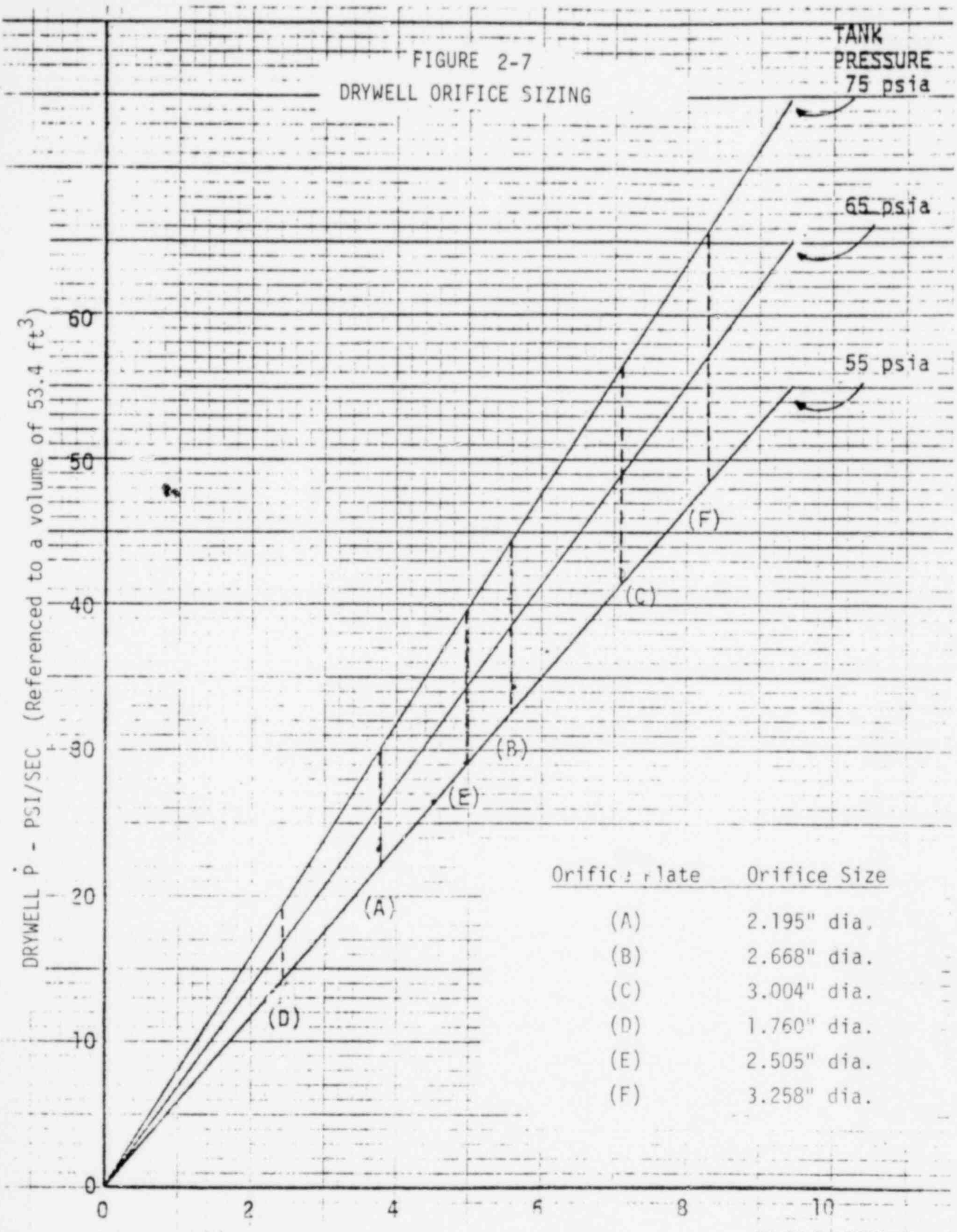
FIGURE 2-6

DOWNCOMER TYPES

Plant	Type	Number of Downcomers
Browns Ferry 1, 2, 3	IV	96
Brunswick 1 & 2	II	96
Cooper Station	II	80
Dresden 2 & 3	II	96
Duane Arnold	III	48
Fermi 2	II	80
Fitzpatrick	II	96
Hatch 1 & 2	II	80
Hope Creek 1 & 2	II	80
Millstone	II	96
Monticello	II	96
Nine Mile Point 1	I	120
Oyster Creek 1	I	120
Peach Bottom 2 & 3	II	96
Pilgrim	II	96
Quad Cities 1 & 2	II	96
Vermont Yankee	II	96





Orifice Plate	Orifice Size
(A)	2.195" dia.
(B)	2.668" dia.
(C)	3.004" dia.
(D)	1.760" dia.
(E)	2.505" dia.
(F)	3.258" dia.

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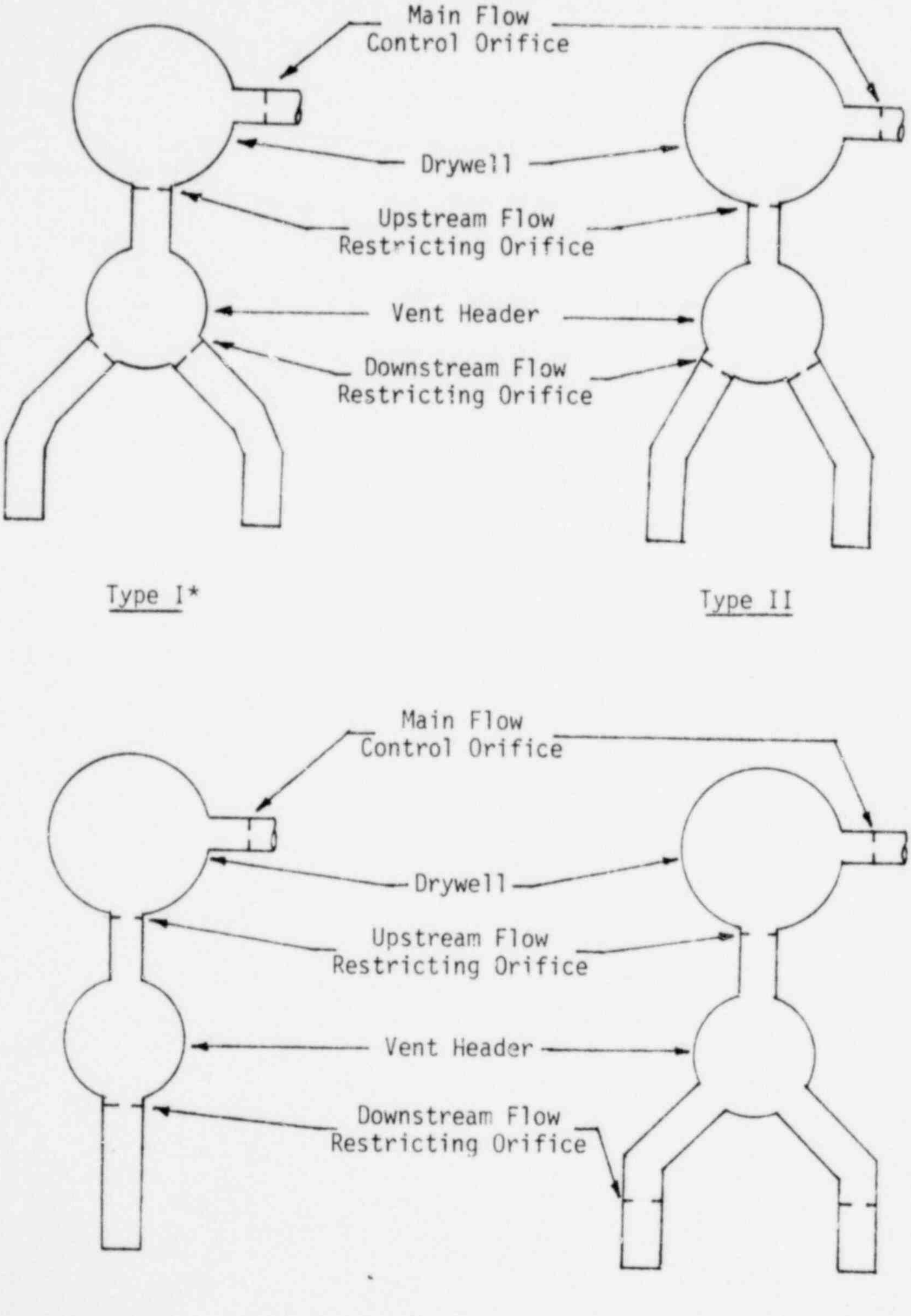
FIGURE 2-8

FACILITY GEOMETRY



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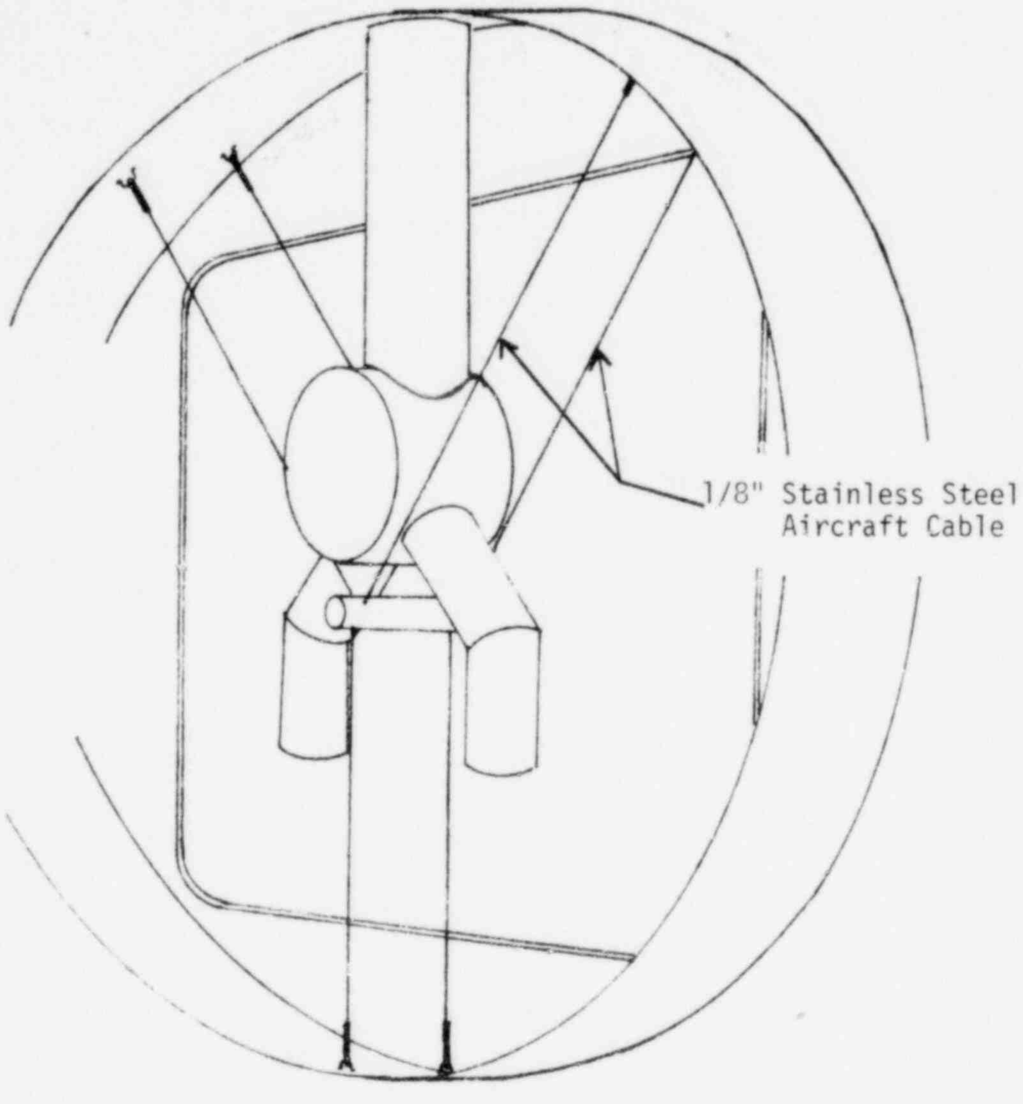
*Types are defined in Figure 2-6.
**Modified reference plant vent header used for Task 5.5.3-1 tests (Reference 2)
Downcomer flow orifices located below downcomer bend

FIGURE 2-9

VENT HEADER DEFLECTOR AND SUPPORT SYSTEM



(Nominal cable locations are shown. Actual equipment is field-fit to avoid struts and other obstructions.)

Deflector Detail

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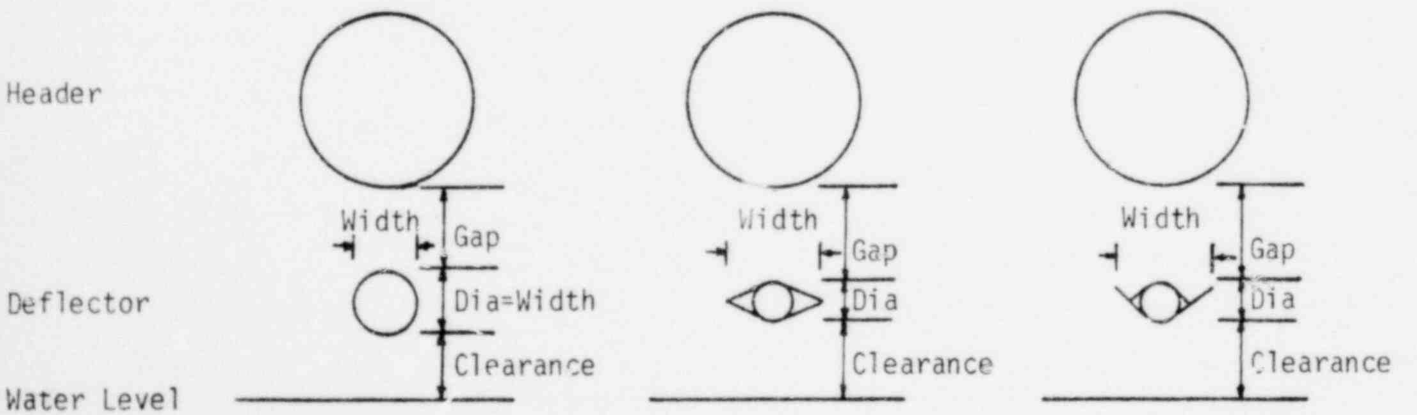
FIGURE 2-10

SUMMARY OF VENT DEFLECTORS TESTED

Plant	Type	Pipe Dia (inches)	Width (inches)	Gap (inches)	Clearance (inches)
Monticello	Pipe with T_s (3)	3.92(14.0)*	8.15(29.08)	6.16(22.0)	-0.62(-2.23)**
	Pipe*** (1)	5.60(20.0)	5.60(20.0)	2.73(9.75)	4.22(15.06)
	Pipe***	3.36(12.0)	3.36(12.0)	2.73(9.75)	6.46(23.06)
Pilgrim	Pipe	4.20(16.0)	4.20(16.0)	2.63(10.01)	3.12(11.89)
Fermi 2	Pipe with T_s	3.24(12.75)	6.566(25.84)	5.18(20.37)	1.94(7.64)
Nine Mile Point	Pipe	4.59(16.0)	4.59(16.0)	2.30(8.0)	1.14(3.96)
Brunswick	Pipe	5.34(20.0)	5.34(20.0)	2.67(10.0)	0.99(3.72)
Dresden	Pipe	5.17(20.0)	5.17(20.0)	2.84(11.0)	3.43(13.27)
Peach Bottom	Pipe with Angles (2)	4.5(18.0)	6.5(26.0)	1.94(7.76)	0.05(0.19)
Millstone	Pipe with Angles	4.2(16.0)	5.2(19.5)	2.63(10.0)	0.58(2.19)
Oyster Creek	Pipe	5.17(20.0)	5.17(20.0)	2.58(10.0)	0.98(3.81)
Hatch 1	Pipe with Angles	4.97(18.0)	7.17(26.0)	6.97(25.25)	0.0(0.0)
Vermont Yankee	Pipe with Angles	4.48(16.0)	7.21(25.75)	7.35(26.25)	1.83(6.53)
Fitzpatrick	Pipe	7.881(30.0)	7.881(30.0)	3.21(12.25)	1.05(4.0)

(1) Pipe (2) Pipe with Angles (3) Pipe with T_s



*Full scale dimension in parentheses.
**Minus sign indicates deflector partially in pool water.
***Generic scoping tests

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FIGURE 2-11
TEST INSTRUMENTATION

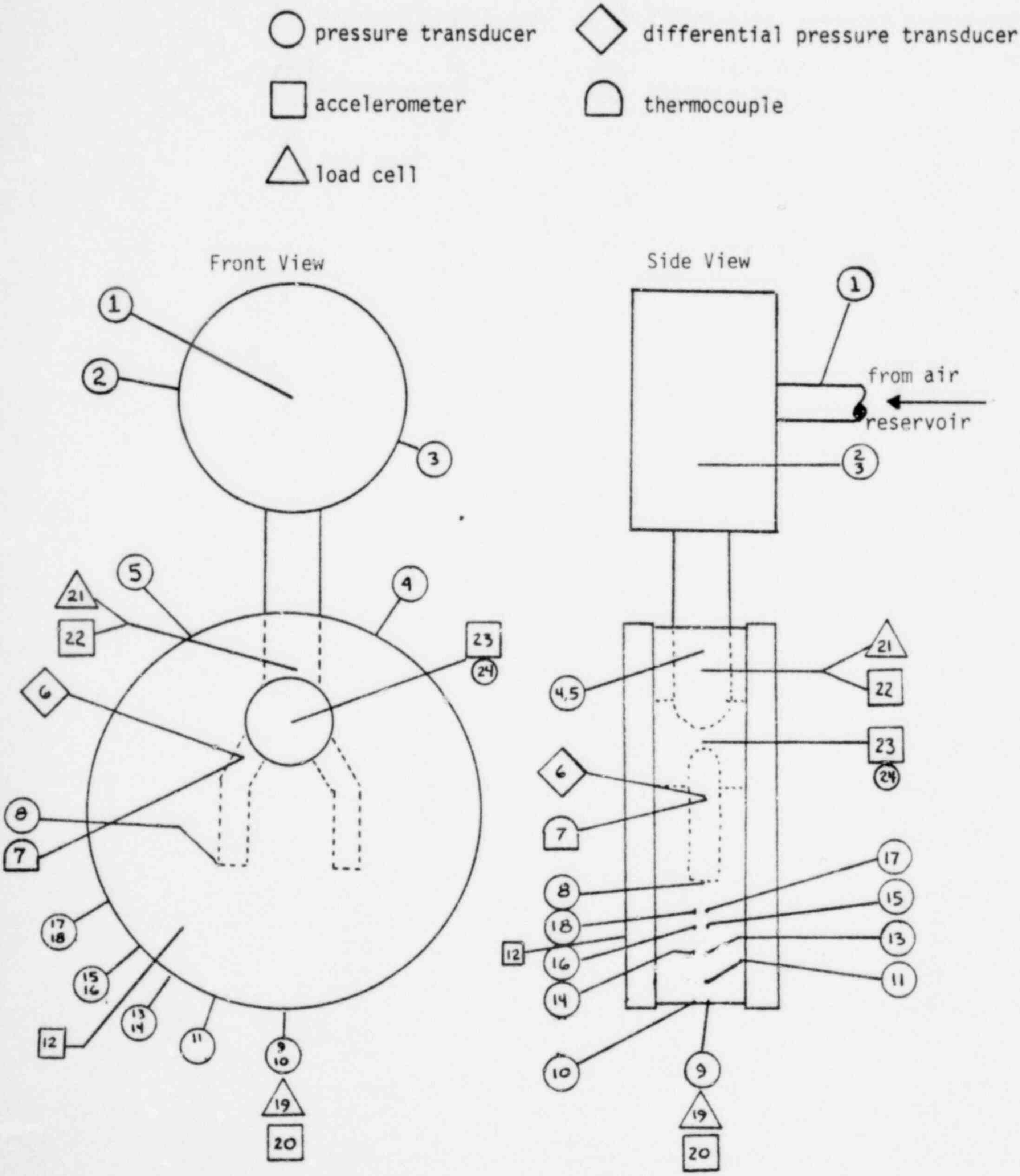

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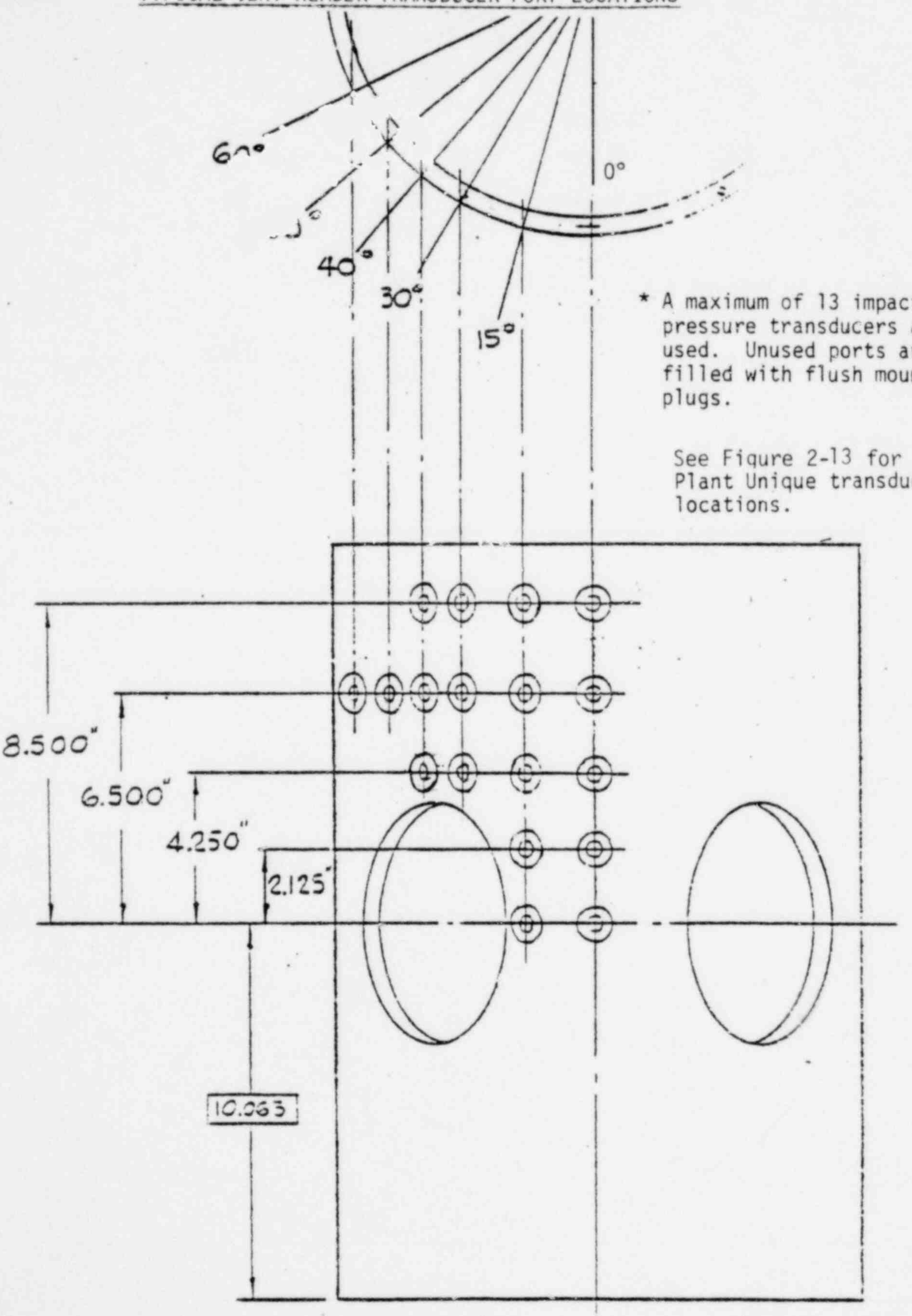
FIGURE 2-12

TYPICAL VENT HEADER TRANSDUCER PORT LOCATIONS*



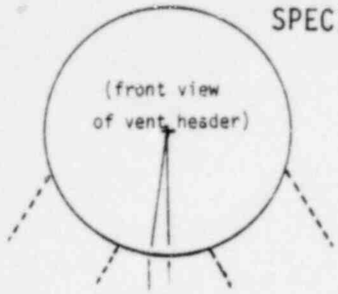
* A maximum of 13 impact pressure transducers are used. Unused ports are filled with flush mounting plugs.

See Figure 2-13 for Plant Unique transducer locations.

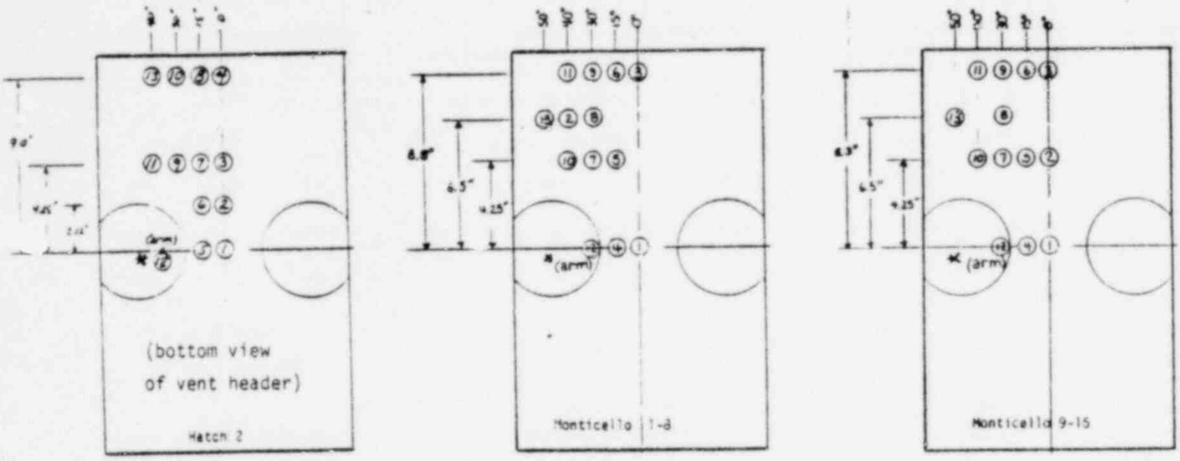
Bottom View of Vent Header

1348 038

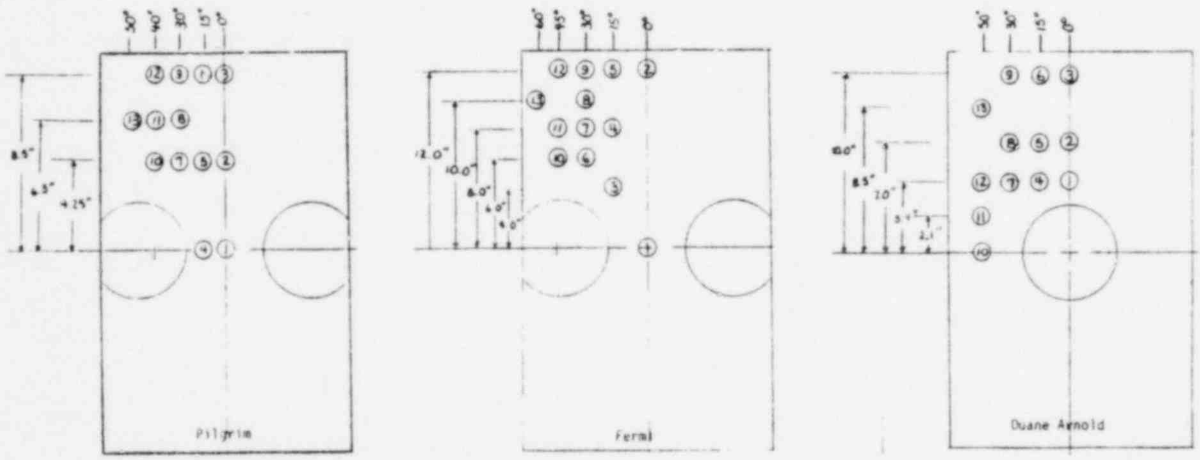
FIGURE 2-13
SPECIFIC LOCATIONS OF VENT HEADER PRESSURE TRANSDUCERS

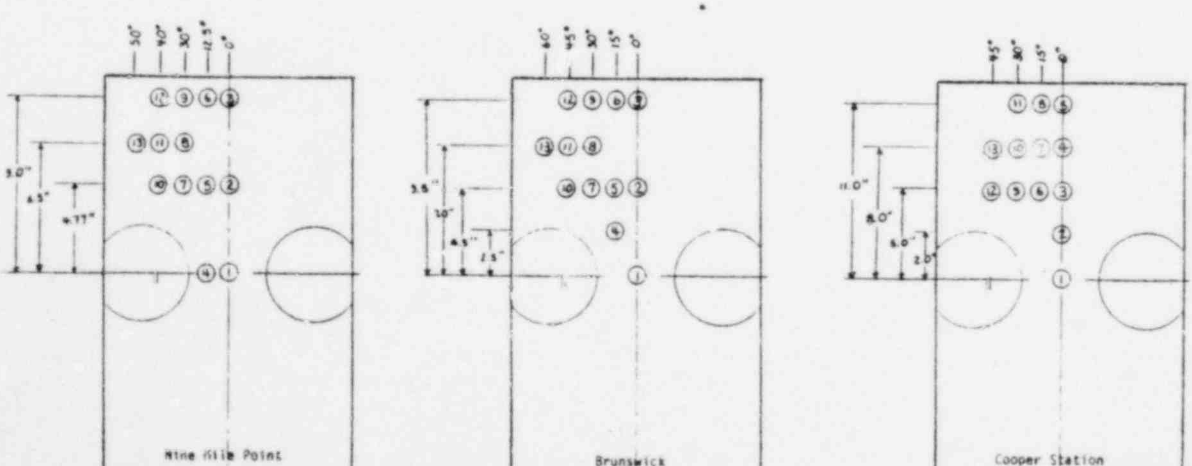


The downcomer legs are eliminated for the sake of clarity in the bottom view of the vent header. They are shown with dashed lines in the front view.



*Transducer 12 was located on the downcomer legs





1348 039

FIGURE 2-13 (cont)

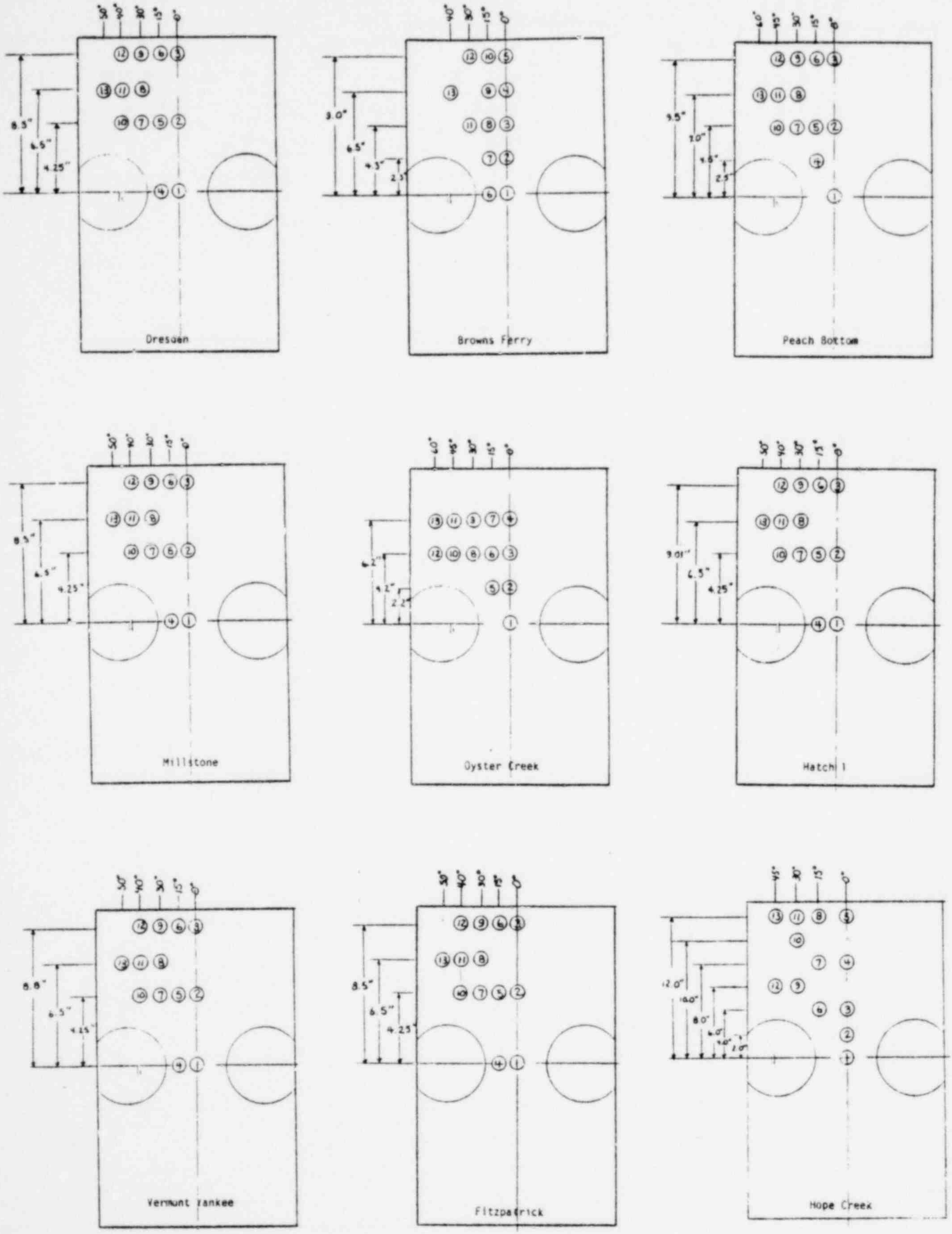


FIGURE 2-14

FLOW CHART FOR PLANT UNIQUE TESTING

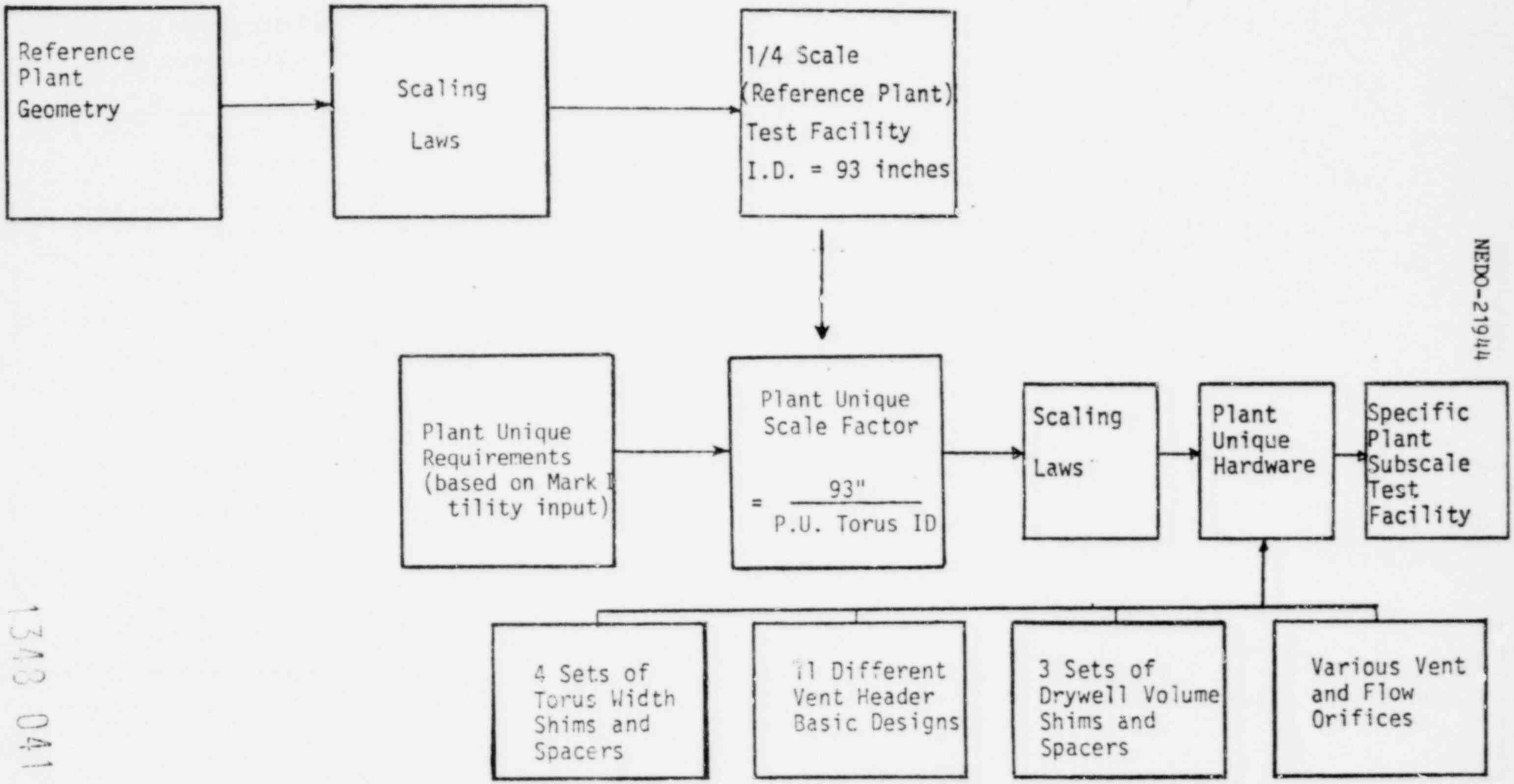


TABLE 2-1a

MARK I QUARTER-SCALE TORUS CRITICAL DIMENSIONS (NOMINAL/ACTUAL)

FOR PLANT UNIQUE TESTS

	Tolerance	Hatch 2	Monticello	Pilgrim	Fermi 2	Duane Arnold
a. Drywell + Vent System Volume, ft^3	$\pm1.0\ ft^3$	76.9/76.95†	61.44/61.82	55.53/54.43*	67.15/67.0	67.68/67.54
b. Torus Width, in.	+0.0, -0.50	28.22/28.05	21.84/21.80	21.32/21.36**	27.30/27.27	23.70/23.59
c. Vent Header O.D., in.	±.01	15.04/15.04	16.108/16.111	15.11/15.11	13.09/13.09	12.83/12.835
d. Header ℄ to Torus ℄, in.	±.01	14.35/14.35	11.765/11.76	12.15/12.15	15.12/15.12	9.96/9.957
e. Downcomer Angle, degrees	±2	30/30	30/30	30/30	30/30	0.0/0°28'
f. Downcomer O.D., in.	+.50, -.05	6.623/6.98	6.723/7.000	6.44/6.50	6.10/6.50	7.25/7.51
g. Downcomer I.D., in.	±.05	6.48[illegible]/6.50	6.581/6.625	6.305/6.25***	5.97/5.97	7.09/7.05
h. Downcomer ℄ to ℄, in.	±.04	26.50/26.46	26.892/26.92	25.22/25.21	24.40/24.42	—
i. Header℄ to Discharge, in.	±.02	33.80/33.80	31.80/31.80	32.64/32.64	27.11/27.11	30.80/30.80
j. Torus Diameter, in.		93.0	93.0	93.0	93.0	93.0
k. Scale Factor		.276	.280	.263	.254	.302

†Nominal/actual

* Tolerance increased to 1.1 $ft.^3$

** Prior to pumpdown (less than 21.32 in. at test inititation)

*** Tolerance changed to +0.0, -.075 in.

TABLE 2-1b

MARK I QUARTER-SCALE TORUS CRITICAL DIMENSIONS (NOMINAL/ACTUAL)

FOR PLANT UNIQUE TESTS

	Tolerance	Nine Mile Point	Brunswick	Cooper Station	Dresden	Browns Ferry	Peach Bottom
a. Drywell + Vent System Volume, ft^3	± 1 ft^3	70.94/70.60 †	63.62/63.48	64.87/65.17	56.83/56.93	51.76/51.4	57.23/57.21
b. Torus Width, in.	+0,-.2	22.43/22.23	23.19/23.09	26.19/25.97	22.40/22.23	22.16/22.23	22.18/22.23
c. Vent Header O.D., in.	± .01	16.68/16.67	14.56/14.57	13.62/13.62	15.10/15.11	14.51/15.00**	14.62/14.58
d. Header ℄ to Torus ℄, in	± .01	8.61/8.61	8.82/8.83	13.87/13.86	18.6/18.6	17.58/17.59	12.00/12.00
e. Downcomer Angle, degrees	±2	45*/45	30/30	30/30	30/30	45/45	30/30
f. Downcomer O.D., in.	-0.0,+0.6	7.068/7.55	6.61/6.95	6.47/6.95	6.33/6.50	6.00/6.00	6.031/6.50
g. Downcomer I.D., in.	-0.0,0.2	6.889/7.05	6.48/6.50	6.334/6.22	6.20/6.25	5.88/5.65	5.906/6.01
h. Downcomer ℄ to ℄, in.	±.04	20.66/20.66	25.66/25.65	25.88/25.89	24.8/25.2	24.00/24.00	24.00/24.00
i. Header ℄ to Discharge, in.	±.02	31.00/31.00	30.20/30.25	32.77/37.77	31.40/31.41	29.61/29.63	27.00/26.98
j. Torus Diameter, in.		93.00	93.00	93.00	93.00	93.00	93.00
k. Scale Factor		0.2870	0.2672	0.2696	0.2583	0.2500	0.2500

†Nominal/actual

*Nine Mile Point has 22.5° intermediate bend.

**Browns Ferry Vent Header O.D. tolerance was increased to .5".

TABLE 2-1c

MARK I QUARTER-SCALE TORUS CRITICAL DIMENSIONS (NOMINAL/ACTUAL)

FOR PLANT UNIQUE TESTS

	Tolerance	Millstone	Oyster Creek	Hatch Unit 1	Vermont Yankee	Fitzpatrick	Hope Creek
a. Drywell + Vent System Volume, ft^3	±1 ft^3	55.49/55.08†	51.72/51.8	75.50/75.55	61.36/66.79††	58.35/57.93	68.19/68.2
b. Torus Width, in.	-0.5, +0.00 in.	21.32/21.32	16.53/16.48	28.22/28.05	21.84/21.8	22.58/22.23	27.2/27.2
c. Vent Header O.D., in.	±0.01 in.**	15.11/15.13	14.34/14.33	15.04/15.034	16.11/16.111	15.11/15.111	13.17/13.074
d. Header ℄ to Torus ℄, in.	±0.01 in.	12.15/12.16	9.30/9.30	14.35/14.345	11.77/11.772	17.34/17.340	15.04/15.04
e. Downcomer Angle, degrees	± 2°	30°/30°	45°*/45°	30°/30°	30°/30°	30°/30°	30°/30°
f. Downcomer O.D., in.	±0.5 in.+	6.43/6.515	6.200/6.515	6.623/7.012	6.723/7.00	6.305/6.50	6.073/6.50
g. Downcomer I.D., in.	±0.5 in.++	6.31/6.275	6.071/5.992	6.485/6.480	6.583/6.625	6.173/6.25	5.883/5.97
h. Downcomer ℄ to ℄, in.	±0.04 in.+++	25.22/25.16	21.70/21.664	26.50/26.442	26.90/26.918	25.22/25.21	24.26/24.416
i. Header ℄ to Discharge, in.	±0.02 in.	25.45/25.45	28.46/28.475	32.70/32.708	36.98/36.7	33.63/33.62	28.05/28.03
j. Torus Diameter, in.		93.0	93.0	93.0	93.0	93.0	93.0
k. Scale Factor		0.2672	0.2583	0.2760	0.2801	0.2627	0.2527

† Nominal/actual

†† See discussion in Section 2.2 for an explanation of this discrepancy

* Oyster Creek has 22.5° intermediate bend, see Figure 2-6.

** Hope Creek has a vent header O.D. tolerance of ± 0.10 in.

\+ Vermont Yankee has a downcomer O.D. tolerance of ± 0.3 in.

++ Vermont Yankee has a downcomer I.D. tolerance of ± 0.1 in.

+++ Hope Creek has a downcomer ℄ to ℄ tolerance of ± 0.10 in.

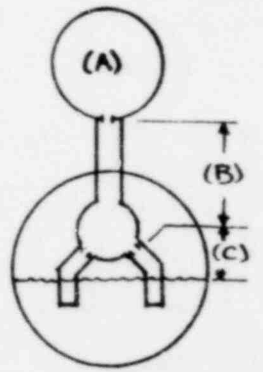
TABLE 2-2

DISTRIBUTION OF DRYWELL/VENT SYSTEM VOLUME

(All measurements in cubic feet)

Plant	Drywell Volume (A)	Volume Between Orifices (B)	Volume, Lower Orifice to Waterline* (C)	Volume, Waterline* to D/C Exit (D)	Volume, Drywell to Waterline (A + B + C)	Utility Specified Volume
Hatch 2	71.4	5.0	.6	.6	77.0	76.9
Monticello	56.6	4.6	.6	.5	61.8	61.4
Pilgrim	49.8	4.0	.6	.5	54.4	55.5
Fermi	62.5	4.0	.5	.3	67.0	67.2
Duane Arnold	63.4	3.9	.2	.3	67.5	67.7
Nine Mile Point	65.4	4.8	.4	.7	70.6	70.9
Brunswick	58.5	4.4	.5	.5	63.4	63.6
Cooper Station	60.5	4.1	.6	.5	65.2	64.9
Dresden	52.6	3.8	.5	.4	56.9	56.8
Browns Ferry	47.8	3.2	.4	.4	51.4	51.8
Peach Bottom	52.6	4.2	.4	.4	57.2	57.2
Millstone	50.6	4.0	.5	.4	55.1	55.4
Oyster Creek	47.8	3.6	.4	.4	51.8	51.7
Hatch 1	70.4	5.1	.6	.5	76.1	75.5
Vermont Yankee	61.5	4.6	.7	.6	66.8	61.4
Fitzpatrick	53.6	3.8	.5	.5	57.9	58.4
Hope Creek	63.5	4.0	.5	.4	68.0	68.2

* At zero ΔP



1343 045

TABLE 2-3

STANDARD GROUP TEST INSTRUMENTATION

Reference Number	Measurement	Transducer Range	Sample Rate (Hz)	Low-Pass Frequency (Hz)	Transducer Manufacturer
1	Drywell Orifice Upstream Pressure	0-100 psia	500	300	Sensometrics
2	Drywell Pressure	0-50 psia	500	300	Sensometrics
3	Drywell Pressure	0-50 psia	500	300	Sensometrics
4.	Torus Air Pressure	0-50 psia	500	300	Sensometrics
5	Torus Air Pressure	0-50 psia	500	300	Sensometrics
6	Downcomer Orifice Differential Pressure	0-10 psia	500	100	Sensotec
7	Downcomer Orifice Upstream Air Temperature	0-500°F	500	100	Aerotherm
8	Downcomer Pressure	0-50 psia	500	300	Sensometrics
9	Torus Water Pressure 180°	0-50 psia	500	300	Sensometrics
10	Torus Water Pressure 180°	0-50 psia	500	300	Sensometrics
11	Torus Water Pressure 195°	0-50 psia	500	300	Sensometrics
12	Window Accelerometer	±10g	500	300	Endevco
13	Torus Water Pressure 210°	0-50 psia	500	300	Sensometrics
14	Torus Water Pressure 210°	0-50 psia	500	300	Sensometrics
15	Torus Water Pressure 225°	0-50 psia	500	300	Sensometrics
16	Torus Water Pressure 225°	0-50 psia	500	300	Sensometrics
17	Torus Water Pressure 240°	0-50 psia	500	300	Sensometrics
18	Torus Water Pressure 240°	0-50 psia	500	300	Sensometrics
19	Torus Load Cell	25,000 lbf	1000	300	Interface
20	Torus Vertical Acceleration	± 1g*	1000	300	Endevco
21	Vent Header Load Cell	10,000 lbf	2500	1000	Interface
22	Vent Header Acceleration	± 10g*	2500	1000	Endevco
23	Vent Header Acceleration	± 10g*	2500	1000	Endevco
24	Vent Pressure	± 10 psia	1500	300	Sensometrics

*Piezo-electric accelerometers, with an adjustable range.

Note: The Sensometrics Transducer is a model SP65A 0-50 psia transducer;
The Sensotec Transducer is model P-30-P, 0-10 psid;
The Interface load cells are models 1221-BO-50K and 1221-BO-10K, and the Endevco Accelerometers are model 7701.

1348 046

TABLE 2-4

ANALOG GROUP TEST INSTRUMENTATION**

Reference Number	Measurement	Transducer Range*
T1	Vent Header Impact Pressure	0-100 psia
T2	Vent Header Impact Pressure	0-100 psia
T3	Vent Header Impact Pressure	0-100 psia
T4	Vent Header Impact Pressure	0-100 psia
T5	Vent Header Impact Pressure	0-100 psia
T6	Vent Header Impact Pressure	0-100 psia
T7	Vent Header Impact Pressure	0-100 psia
T8	Vent Header Impact Pressure	0-100 psia
T9	Vent Header Impact Pressure	0-100 psia
T10	Vent Header Impact Pressure	0-100 psia
T11	Vent Header Impact Pressure	0-100 psia
T12	Vent Header Impact Pressure	0-100 psia
T13	Vent Header Impact Pressure	0-100 psia

Note: All vent header pressure transducers are Bell & Howell Type 512.

* The range shown is the maximum available. 0-25 and 0-50 psia transducers of the same type were also used to improve resolution in locations where smaller impact pressures occurred.

** The analog data is initially recorded on tape and later digitized.

1348 047

TABLE 2-5a
Test Matrix
Task 5.5.3-2 Plant Unique Tests

Site	Test No.	Test Date	Initial Wetwell Pressure (psia)	Drywell/Wetwell ΔP (inches H_2O)	Initial Downcomer Submergence (inches)
Hatch 2	Calibration				
	1	3/31/78	3.92	0	14.35
	2	4/6/78	3.92	0	14.35
	3	4/8/78	3.92	0	14.35
	4	4/8/78	3.92	0	14.35
	5	4/6/78	3.92	14.35	14.35
	6	4/7/78	3.92	14.35	14.35
	7	4/7/78	3.92	14.35	14.35
	8	4/8/78	3.92	14.35	14.35
Monticello	Calibration				
	1	4/25/78	4.09	7.75	14.29
	2	4/26/78	4.09	7.75	14.29
	3	4/26/78	4.09	7.75	14.29
	4	4/26/78	4.09	7.75	14.29
	5	4/27/78	4.09	0	14.02
	6	4/28/78	4.09	0	14.02
	7	4/28/78	4.09	0	14.02
	8	4/28/78	4.09	0	14.02
	9	4/20/78	4.09	0	11.19
	10	4/18/78	4.09	0	11.19
	11	4/20/78	4.09	11.2	11.19
	12	4/20/78	4.09	11.2	11.19
	13	4/21/78	4.09	0	11.19
	14	4/24/78	4.09	0	11.19
	15	4/24/78	4.09	11.2	11.19
	16	4/24/78	4.09	11.2	11.19
Pilgrim	Calibration				
	1	5/5/78	3.86	10.9	15.13
	2	5/6/78	3.86	10.9	15.13
	3	5/6/78	3.86	10.9	15.13
	4	5/6/78	3.86	10.9	15.13
	5	5/6/78	3.86	0	15.13
Fermi	Calibration				
	1	5/17/78	3.61	7.03	10.16
	2	5/18/78	3.61	7.03	10.16
	3	5/18/78	3.61	7.03	10.16
	4	5/18/78	3.61	7.03	10.16
	5	5/19/78	3.61	0	10.16
	6	5/19/78	3.61	0	10.16
	7	5/19/78	3.61	0	10.16
	8	5/19/78	3.61	0	10.16
Duane Arnold	Calibration				
	1	5/31/78	3.83	9.19	12.24
	2	5/31/78	3.83	9.19	12.24
	3	6/1/78	3.83	9.19	12.24
	4	6/1/78	3.83	9.19	12.24
	5	6/1/78	3.83	0	12.08

"T" deflector is a pipe with structural "T"s

1343 048

TABLE 2-5a (cont'd)

Test Matrix

Task 5.5.3-2 Plant Unique Tests

Site	Test No.	Initial Drywell Pressurization Rate (psi/sec) Minimum/Actual	Vent System fL/D Maximum/Actual (Split)*	Pool Water Level (in. below center line)	Remarks
Hatch 2	Calibration	30.5/30.7	17.79/16.4		
	1		(43/57)	5.11	Load Definition Tests, No Deflector
	2			5.11	
	3			5.11	
	4			5.11	
	5			5.11	ΔP Sensitivity Tests, No Deflector
	6			5.11	
	7			5.11	
	8			5.11	
Monticello	Calibration	38.4/40.0	16.04/14.5		
	1		(50/50)	5.75	Load Definition Tests, 8.15-inch "T" Deflector (29" Full Scale) and 6.16" Gap
	2			5.75	
	3			5.75	
	4			5.75	
	5			6.02	8.15-inch "T" Deflector (29" Full Scale) and 6.16" Gap, Zero ΔP
	6			6.02	
	7			6.02	
	8			6.02	
	9			8.84	5.60" Pipe (20" Full Scale) Deflector with 2.73" Gap
	10			8.84	
	11			8.84	
	12			8.84	
	13			8.84	3.36" Pipe (12" Full Scale) Deflector with 2.73" Gap
	14			8.84	
	15			8.84	
	16			8.84	
Pilgrim	Calibration	34.5/37.5	17.68/15.5		
	1		(55/45)	5.36	Load Definition Tests, 4.20" Pipe Deflector with 2.63" Gap
	2			5.36	
	3			5.36	
	4			5.36	
	5			5.36	4.20" Pipe Deflector with 2.63" Gap, Zero ΔP
Fermi	Calibration	27.4/30.0	19.32/17.2		
	1		(50/50)	1.78	Load Definition Tests, 6.566-inch "T" Deflector and 5.17" Gap
	2			1.78	
	3			1.78	
	4			1.78	
	5			1.78	6.566-inch "T" Deflector and 5.17" Gap, Zero ΔP
	6			1.78	
	7			1.78	
	8			1.78	
Duane Arnold	Calibration	25.4/27.8	13.38/12.6		
	1		(51/49)	8.59	Load Definition Tests, No Deflector
	2			8.59	
	3			8.59	
	4			8.59	
				8.76	ΔP Sensitivity Tests

*fl/D split= percent of actual fl/D in vent orifice and downcomer orifices respectively (vent/downcomer)

"T" deflector is a pipe with structural "T"s

1348 049

TABLE 2-5b

Test Matrix

Task 5.5.3-2 Plant Unique Tests

Site	Test* No.	Test Date	Initial Wetwell Pressure (psia)	Drywell/Wetwell ΔP (inches H_2O)	Initial Downcomer Submergence (inches)
Nine Mile Point	Calibration				
	1	6/9/78	4.22	7.94	14.64
	2	6/15/78	4.22	7.94	14.64
	3	6/19/78	4.22	7.94	14.64
		6/19/78	4.22	7.94	14.64
	5	6/15/78	4.22	0	14.64
Brunswick	Calibration				
	1	6/30/78	3.97	0	13.89
	2	6/30/78	3.97	0	13.89
	3	7/5/78	3.97	0	13.89
	4	7/5/78	3/97	0	13.89
Cooper Station	Calibration				
	1	7/13/78	3.96	7.46	14.15
	2	7/13/78	3.96	7.46	14.15
	3	7/13/78	3.96	7.46	14.15
	4	7/13/78	3.96	7.46	14.15
	5	7/13/78	3.96	0	14.15
Dresden	Calibration				
	1	7/19/78	3.75	7.15	12.4
	2	7/20/78	3.75	7.15	12.4
	3	7/20/78	3.75	7.15	12.4
	4	7/20/78	3.75	7.15	12.4
	5	7/20/78	3.75	0	12.4
Browns Ferry	Calibration				
	1	7/27/78	3.55	7.61	10.5
	2	7/27/78	3.55	7.61	10.5
	3	7/27/78	3.55	7.61	10.5
	4	7/28/78	3.55	7.61	10.5
	5	7/28/78	3.55	0	10.5
Peach Bottom	Calibration				
	1	8/4/78	3.63	7.61	13.2
	2	8/4/78	3.63	7.61	13.2
	3	8/4/78	3.63	7.61	13.2
	4	8/4/78	3.63	7.61	13.2
	5	8/4/78	3.63	0	13.2

* A "winged" deflector is a standard pipe with structural angles

1348 050

TABLE 2-5b (cont.)

Test Matrix

Task 5.5.3-2 Plant Unique Tests

Site	Test No.	Initial Drywell Pressurization Rate (psi/sec) Minimum/Actual	Vent System fL/D Maximum/Actual (Split)**	Pool Water Level (in. below center line)	Remarks
Nine Mile Point	Calibration	31.4/31.7	16.85/15.2		
	1		(53/47)	7.75	Load Definition tests, 4.59"
	2			7.75	Pipe Deflector (16.0" Full
	3			7.75	Scale) and 2.30" Gap
	4			7.75	(8.0" Full Scale)
				7.75	4.59" Deflector, ΔP Sensitivity Test
Brunswick	Calibration	29.31/29.7	16.81/16.3		
	1		(46/54)	7.47	Load Definition Tests, 5.34"
	2			7.47	Pipe Deflector (20.0 Full Scale)
	3			7.47	
	4			7.47	
Cooper Station	Calibration	38.4/40.0	17.76/17.4		
	1		(43/57)	4.72	Load Definitions Tests,
	2			4.72	No Deflector
	3			4.72	
	4			4.72	
	5			4.72	ΔP Sensitivity Test
Dresden	Calibration	31.1/32.0	17.45/16.3		
	1		(49/51)	0.39	Load Definition Tests, 5.17"
	2			0.39	Pipe Deflector (20.0" Full
	3			0.39	Scale) and 2.84" Gap (11.0"
	4			0.39	Full Scale)
	5			0.39	5.17" Deflector, ΔP Sensitivity Test
Browns Ferry	Calibration	31.2/31.3	18.49/18.3		
	1		(43/57)	1.5	Load Definition Tests,
	2			1.5	No Deflector
	3			1.5	
	4			1.5	
	5			1.5	ΔP Sensitivity Test
Peach Bottom	Calibration	27.8/29.3	18.42/17.5		
	1		(49/51)	1.8	Load Definition Tests,
	2			1.8	6.5" Winged Deflector
	3			1.8	(25" Full Scale)*
	4			1.8	
	5			1.8	6.5" Winged Deflector, ΔP Sensitivity Test

* A "winged" deflector is a standard pipe with structural angles

** fl/D split= percent of actual fl/D in the vent orifice and downcomer orifices respectively (vent/downcomer)

TABLE 2-5C TEST MATRIX

Task 5.5.3-2 Plant Unique Tests

Site	Test Number	Initial Drywell Pressurization Rate (psi/sec) Minimum/Actual	Vent System fL/D Maximum/Actual (Split)*	Pool Water Level (Inches Below Center Line)	Remarks
Millstone	Calibration	34.3/37.6	16.05/14.6		
	1		(59/41)	2.81	Load Definition Tests 5.20" Winged Deflector (19.5" Full Scale; 16" Pipe Diameter) with 2.63" Gap (10" Full Scale)
	2			2.81	
	3			2.81	
	4			2.81	
	5			2.81	ΔP Sensitivity Test (Same Deflector)
Oyster Creek	Calibration	27.7/29.6	19.88/18.8		
	1		(54/46)	6.60	Load Definition Tests 5.17" Deflector (20" Full Scale) with 2.58" Gap (10" Full Scale)
	2			6.60	
	3			6.60	
	4			6.60	
	5			6.60	ΔP Sensitivity Test (Same Deflector)
Hatch 1	Calibration	34.5/34.7	17.64/16.3		
	1		(42/58)	5.11	Load Definition Tests 7.17" Winged Deflector (26" Full Scale) with 6.97" Gap (25.25" Full Scale)
	2			5.11	
	3			5.11	
	4			5.11	
	5			5.11	ΔP Sensitivity Test (Same Deflector)
Vermont Yankee	Calibration	39.54/41.3	16.04/14.5		
	1		(51/49)	9.95	Load Definition Tests 7.21" Winged Deflector (25.5" Full Scale; 16" Pipe Diameter) with 7.35" Gap (26.25" Full Scale)
	2			9.95	
	3			9.95	
	4			9.95	
	5			9.95	ΔP Sensitivity Test (Same Deflector)
Fitzpatrick	Calibration	30.6/31.0	17.1/15.7		
	1		(48/52)	2.36	Load Definition Tests 7.88 Deflector (30" Full Scale) With 3.21" Gap (1'-[illegible] Full Scale)
	2			2.36	
	3			2.36	
	4			2.36	
	5			2.36	ΔP Sensitivity Test (Same Deflector)
Hope Creek	Calibration	26.5/27.2	18.94/17.2		
	1		(55/45)	2.91	Load Definition Tests (Zero ΔP) No Deflector
	2			2.91	
	3			2.91	
	4			2.91	
	5			2.91	ΔP Sensitivity Test (No Deflector)

*fL/D split = percent of actual fL/D in the vent orifice and downcomer orifices respectively (vent/downcomer)

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TABLE 2-5C TEST MATRIX

Task 5.5.3-2 Plant Unique Tests

Site	Test Number	Initial Wetwell Pressure (psia)	Drywell/Wetwell ΔP (Inches of Water)	Initial Downcomer Submergence (Inches)
Millstone	Calibration			
	1	3.78	8.73	10.50
	2	3.78	8.73	10.50
	3	3.78	8.73	10.50
	4	3.78	8.73	10.50
	5	3.78	8.73	10.50
Oyster Creek	Calibration			
	1	3.80	7.15	12.59
	2	3.80	7.15	12.59
	3	3.80	7.15	12.59
	4	3.80	7.15	12.59
	5	3.80	0	12.59
Hatch 1	Calibration			
	1	3.99	11.46	13.25
	2	3.99	11.46	13.25
	3	3.99	11.46	13.25
	4	3.99	11.46	13.25
	5	3.99	0	13.25
Vermont Yankee	Calibration			
	1	4.12	13.2	15.26
	2	4.12	13.2	15.26
	3	4.12	13.2	15.26
	4	4.12	13.2	15.26
	5	4.12	0	15.26
Fitzpatrick	Calibration			
	1	3.73	12.36	13.92
	2	3.73	12.36	13.92
	3	3.73	12.36	13.92
	4	3.73	12.36	13.92
	5	3.73	0	13.92
Hope Creek	Calibration			
	1	3.59	0	10.1
	2	3.59	0	10.1
	3	3.59	0	10.1
	4	3.59	0	10.1
	5	3.59	7.0	10.1

*fL/D split = percent of actual fL/D in the vent orifice and downcomer orifices respectively (vent/downcomer)

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3.0 TYPICAL PLANT TEST RESULTS (MONTICELLO TESTS)

The purpose of this section is to present the subscale data that were obtained from a typical test and to demonstrate the methods used to reduce data for obtaining subscale forces. Since data acquisition and reduction is essentially the same for all the plants, only data from the Monticello tests were chosen for inclusion in the body of the report. Data for other plants are included in Appendix A.

The typical data presented in this section for the Monticello Tests and the data presented in Appendix A for the other sixteen plant configurations are not necessarily design basis data. The Task 5.5.3-2 Plant Unique Tests were performed at conditions being evaluated for plant operations. Supplementary tests are being performed for several Mark I Utilities to evaluate alternate conditions including variations in water level, submergence, drywell-wetwell pressure differential and vent header deflector design. After a review of these data, a set of test conditions will be selected for each plant to serve as a design basis for pool swell loads.

3.1 Typical Data

Time-history plots of the driving conditions and pool response are presented in this section for Monticello Tests 2 and 8. Test 2 was a load definition test which was conducted at a partial drywell/wetwell differential pressure of 7.75" H_2O*. Test 8 was a ΔP sensitivity test which was conducted without an initial drywell/wetwell differential pressure (0" H_2O ΔP)*. The Monticello tests (1-8) were conducted with a "T" deflector**.

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*ΔP values given in inches of water

**Pipe with a structural "T" welded on each side (see Figure 2-10)

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3.1.1 Driving Conditions

Driving conditions for Monticello Test 2 are presented in Figures 3-1 through 3-5. Similar plots for Monticello Test 8 are shown in Figures 3-6 through 3-10.

The oscillatory nature of the drywell orifice upstream pressure (Figures 3-1 and 3-6) illustrates the early presence of acoustic waves in the piping between the pressure supply tank and drywell. These drywell supply line acoustic waves are created in the QSTF by the rapid test initiation using burst disks. They are a feature of the test facility and are not prototypical of Mark I plants. The very smooth graph of the actual drywell pressure (Figures 3-2 and 3-7) shows that the acoustic waves do not propagate through the choked drywell flow orifice into the drywell.

The initial slope of the drywell pressure graph is a result of the compression of the relatively constant drywell and vent volumes prior to vent clearing. As the vents clear and bubble growth begins, the effective vent system volume increases and the rate of pressurization decreases dramatically. Peak downforce occurs shortly after the time of vent clearing (see Appendix E for photographs of this series of events).

For the zero ΔP test, the time at which drywell pressurization rate changes is shifted due to the additional time required to clear the water from the downcomer legs (Figure 3-7). Since the drywell is being pressurized during this delay, the driving pressure is higher at the time of vent clearing than for the 7.75" H_2O ΔP run. This higher pressure results in higher system flow rates, pressure differentials, and measured pool pressures (see Figures 3-3, 3-8, 3-12, and 3-14).

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Figures 3-3 and 3-8 show the pressure differential across (hence, flow through) the downcomer orifice. The change in drywell pressurization rate occurs just as flow through the downcomers is beginning (compare Figures 3-2 and 3-7 with Figures 3-3 and 3-8, respectively). The plateau and subsequent decrease in the differential pressure illustrates first, the inability of the vent system flow to sustain the initial pressure in the bubble and, later, the gradual equalization of system pressures.

A thermocouple is installed by the downcomer orifice, along with the differential pressure gauge. Figures 3-4 and 3-9 show the temperature rise which is attributable to work done in compressing the drywell air.

Figures 3-5 and 3-10 combine the mass flow rate (from Figures 3-3 and 3-8) with the temperature (Figures 3-4 and 3-9) to obtain enthalpy flow into the pool. Comparison of the driving conditions indicates that enthalpy flow into the pool starts at an earlier time and peaks at a slightly lower value in Test 2 with 7.75" ΔP (Figure 3-5 versus 3-10) but that the equilibrium enthalpy flows are about the same. This comparison indicates that ΔP affects the initial enthalpy flow rate, but that overall vent resistance, drywell pressurization and other parameters control the equilibrium enthalpy flow rate.

3.1.2 Pool Response

Downcomer internal pressure and wetwell pressures are presented in Figures 3-11 and 3-12 for Monticello Test 2 and in Figures 3-13 and 3-14 for Monticello Test 8. The downcomer internal pressure is measured at the exit of the left downcomer. The pool pressures are recorded at the bottom of the torus and the freespace pressures at the top of the torus (see Figure 2-11). The difference in initial pool pressure readings is a function of the different water head at each location. An oscillation can be observed in the downcomer

internal pressure of Figure 3-13. This oscillation is characteristic of 0" H_2O ΔP runs and is also evident in Figure 3-14. A smaller oscillation of the downcomer internal pressure is seen in the load definition test, which was conducted at a partial ΔP (Figure 3-11).

For the load definition tests, net torus force from spatial integration of the measured wetwell pressure (Figure 3-15) indicates some downforce oscillations which dampen out rapidly after the first oscillation. Small residual oscillations in the downforce caused by end window vibrations were observed in load definition tests of some plants. A detailed discussion of this phenomenon is presented in Appendix H. For the zero ΔP test, the torus pressure integral also shows a downforce oscillation (Figure 3-16). The one cycle oscillation, which appeared in some of the plant tests, is thought to be at least partially caused by bubble pressure variations during vent clearing.

Net torus force is also determined from the torus load cell (Figures 3-17 and 3-19) by applying inertial correction with the torus accelerometer (Figures 3-18 and 3-20) and subtracting the initial weight of the torus. The corrected load cell is a secondary (and redundant) method of measuring the net torus force, while the pressure integral is the primary measure. Figures 3-21 and 3-22 show good agreement between the net torus force based on the torus pressure integral and the corrected load cell during Monticello Tests 2 and 8.

Figures 3-23 and 3-24 present the net torus force based on the spatial integration of the measured wetwell pressure (torus pressure integral) with a correction for the vertical acceleration of the torus (correction for water inertia). These figures represent the same force data as Figures 3-15 and 3-16, except for inclusion of the inertial correction. This correction adjusts the integrated

pressure (force on an accelerating boundary) by the mass of water times the torus acceleration to define the pressure force on a non-accelerating boundary. The downforce oscillation from the pressure integral (Figure 3-16) is reduced when the pressure integral is corrected for water inertia (Figure 3-24).

Another method of comparing the relative pool forces for Monticello Tests 2 and 8 is illustrated in Figures 3-25 through 3-28. Figures 3-25 and 3-27 show what an "average" pool pressure transducer would register (simulated by dividing the integrated water pressures over the lower half of the torus corrected for initial hydrostatic head by the total torus projected area). Figures 3-26 and 3-28 are the same as Figures 3-23 and 3-24 with force replaced by average pressure (force/torus projected area).

The vent header impact pressures for Monticello Test 2 are presented in Figures 3-29 through 3-31. Vent header impact pressures for Monticello Test 8 are presented in Figures 3-32 through 3-34. Locations of the pressure transducers in the quadrant are identified by alphanumeric characters. The "T" deflector was effective in mitigating the vent header impact during the Monticello Tests 2 and 8. Time-history plots of the vent header impact pressures illustrate the lag that occurs in vent header impact times, between the bottom center and the outer locations (see Figures A-29 through A-31 for Hatch 2 Test 2 in Appendix A). The impact pressure is highest at the point of first impact. When deflectors are used, this impact location is moved upward and outward by about 30 degrees and the impact force is substantially reduced in magnitude (see Figures A-519 through A-523 for Millstone Test 3 in Appendix A). Impact pressures under 0" ΔP conditions increased relative to partial ΔP conditions.

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Vent header impact force can be determined by: (1) integrating the vent pressures over appropriate areas and (2) correcting the vent header load cell for inertia (mass x acceleration). A comparison of the vent header force from the corrected load cell with the pressure integral is shown in (Figure 3-35). Both the pressure integral and corrected load cell show negligible vent header impact force. A detailed discussion of vent header pressure integration is presented in Appendix B.

Two accelerometers were installed in the vent header assembly. One was placed in the bottom of the header drum, the other was put on the upper part of the vent header support column. In Figures 3-36 and 3-37, the accelerometers show little activities because of the negligible vent header impact, but in general the measurements from these two accelerometers are in good agreement (see Figure A-37 for Hatch 2 Test 6 in Appendix A). This agreement confirms that the vent header acts as a rigid body.

3.2 Pool Dynamics

High-speed color movies taken during the tests were viewed frame-by-frame to obtain the data given in this section. The pool contours at various times of pool swell are shown in Figures 3-38 through 3-41 for Monticello Tests 1, 2, 3, and 5. Tests 1, 2, and 3 were performed at a drywell/wetwell differential pressure of 7.75" H_2O, while Test 5 was performed at 0" ΔP. A "T" deflector was used in these tests.

Pool surface displacement curves for Tests 1, 2, and 3, shown on Figure 3-42, were obtained by re-drawing data points from Figures 3-38 through 3-40 on a displacement/time axis. An "average" curve was then drawn for each offset position. Pool surface velocities were calculated by graphical differentiation of the displacement curves (Figure 3-43). For Tests 1, 2, and 3, the pool surface velocity at six inches from the pool centerline reached a maximum value at about 0.200 second. The pool surface displacement graph and pool surface velocity profiles for Test 5

are shown in Figures 3-44 and 3-45, respectively. The Test 4 pool surface displacement graph and velocity profile (as viewed from the side window) is shown in Figure 3-46. The pool displacements and velocities are accurate within approximately ±10 percent of the value given.

The downcomer water slug displacement, velocity, and acceleration plots for Tests 2 and 7* are presented in Figures 3-47 and 3-48, respectively. The time at which displacement is zero implies vent clearing. It can be observed that both velocity and acceleration approach their maximum values at or near the vent clearing during Tests 2 and 7*. (Vent clearing occurs over a time interval. The first movie frame to show an air/water interface outside the downcomers was used in this report to define the "clearing time" which preceded total clearing of water from the downcomer by about 6 milliseconds.)

3.3 Data Summaries

Tables 3-1 through 3-4 present the Monticello test data for wetwell vertical forces. For each test condition, values for the four tests are tabulated along with the mean and standard deviation. In Tables 3-3 and 3-4, 5.60 and 3.36 inch deflector data are tabulated together under 0" ΔP and 11.2" ΔP, because the size of the deflectors should not affect downforce and does not seem to affect upforce. Conditions such as first and second downforce peaks, first and second upforce peaks, upforce and downforce valleys, Δt downforce, and zero force are illustrated on Figure 3-49.

Reference time T_o is obtained by using a linear regression fit of the first portion of the drywell pressure plot, in order to extrapolate back to the effective start of testing. This reference time allows test events for all runs to be compared on a common time basis.

---

*Test 7 was a front view movie test and is used in this section for typical pool profile data.

Tables 3-5 and 3-6 present the Monticello test data for vent header impact loads. The 8.12 inch "T" deflector was effective in preventing the vent header impact during Tests 1 through 4 with 7.75" ΔP and Tests 5 through 8 with 0" ΔP.

3.4 Discussion and Analysis

Figure 3-50 presents the effect of drywell/wetwell ΔP on enthalpy flow into the bubbles. The enthalpy flow starts at an earlier time (vents clear at an earlier time) and reaches slightly lower peak value in the 7.75" ΔP run. Later in time the enthalpy flow for both conditions is about the same.

Effect of drywell/wetwell ΔP on downcomer internal pressure is shown in Figure 3-51. It can be inferred from the downcomer internal pressure that the bubble pressure reaches a higher peak under 0" ΔP conditions than at the 7.75" ΔP condition. This higher bubble pressure results in a greater peak downforce for 0" ΔP.

Figure 3-52 presents the effect of drywell/wetwell ΔP on pool and free-space (air space) pressures. The downforce is greater for 0" ΔP, as can be inferred from a higher peak pool pressure. The upforce is also greater for tests with 0" ΔP. At peak upforce, the air space pressure exceeds the pool pressure to a greater extent in the 0" ΔP run. After peak upforce, the air space and pool pressures oscillate at almost 180 degrees out of phase for about one cycle. This means break through has not occurred until well after peak upforce. The measured upforce oscillation was more noticeable in the 0" ΔP run.

The Monticello load definition tests were conducted at 7.75" H_2O ΔP and with a "T" deflector installed below the vent header. ΔP sensitivity tests at 0" ΔP were also conducted. In addition, scoping pipe deflector tests were conducted. Both the downforce and upforce showed some oscillations. The "T" deflector (29" full scale) effectively prevented vent header impact. The 5.60 inch pipe deflector (20 inch full scale) was

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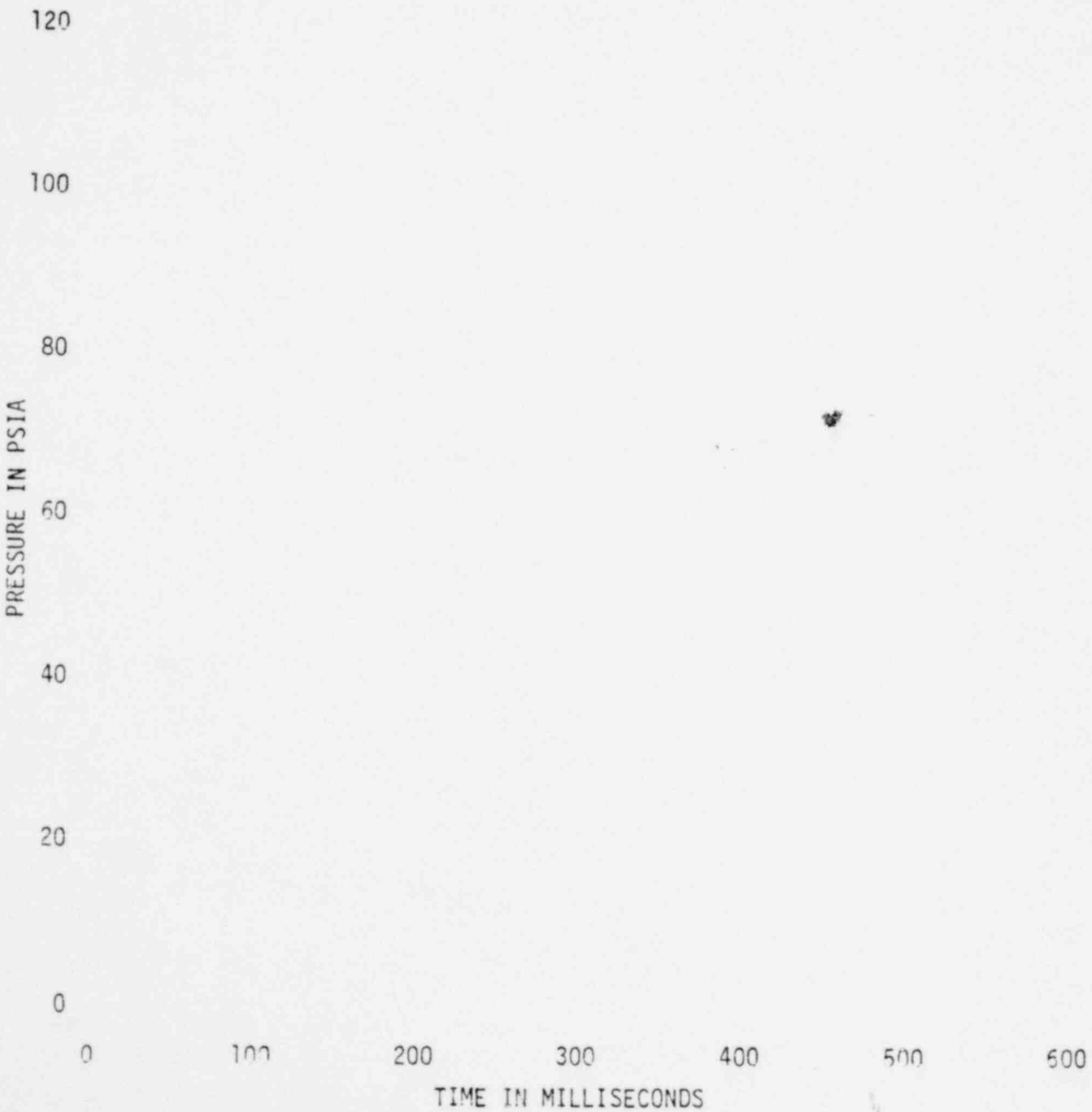
much more effective in reducing vent header impact force than the 3.36 inch pipe deflector (12 inch full scale). The four load definition tests show excellent reproducibility and consistency. A comparison of load cell data and pressure integral data for both the torus and vent header shows that these redundant measurements are in good agreement.

FIGURE 3-1

DRYWELL ORIFICE UPSTREAM PRESSURE

Task 5.5.3-2 Monticello Test 2



*

*Proprietary information deleted.

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FIGURE 3-2

DRYWELL PRESSURE*

Task 5.5.3-2 Monticello Test 2

*

PRESSURE IN PSIA

20

16

12

8

4

0

0 100 200 300 400 500 600

TIME IN MILLISECONDS

*The given drywell pressurization rate is a function of the changing vent volume (as the water slug is ejected from the downcomer). The actual pressurization rate in Table 2-5 is based on a separate calibration test.

*Proprietary information deleted.

FIGURE 3-3

DOWNCOMER ORIFICE DIFFERENTIAL PRESSURE

Task 5.5.3-2 Monticello Test 2

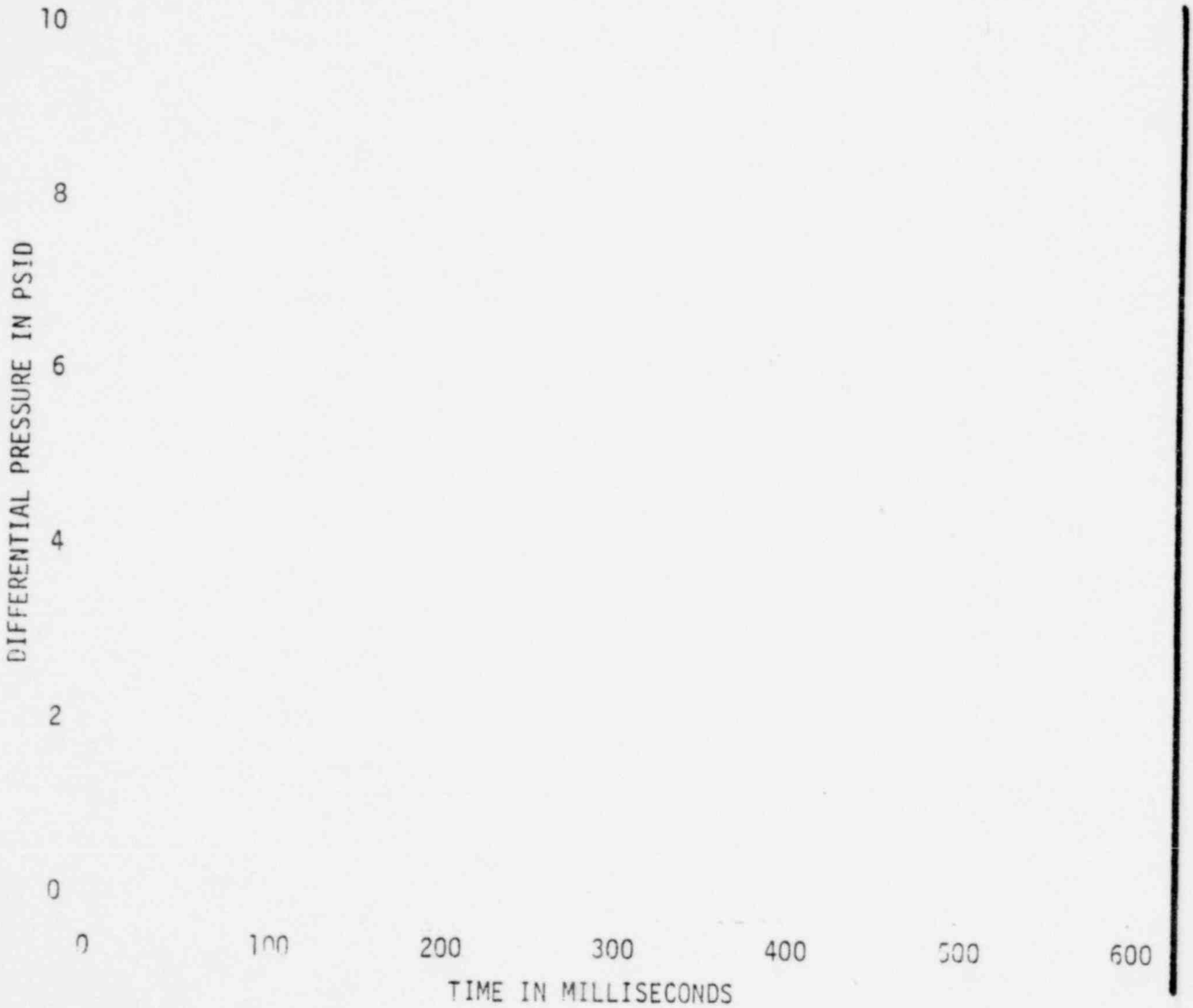

FIGURE 3-4

DOWNCOMER ORIFICE UPSTREAM TEMPERATURE

Task 5.5.3-2 Monticello Test 2

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FIGURE 3-5

ENTHALPY FLOW INTO POOL

Task 5.5.3-2 Monticello Test 2

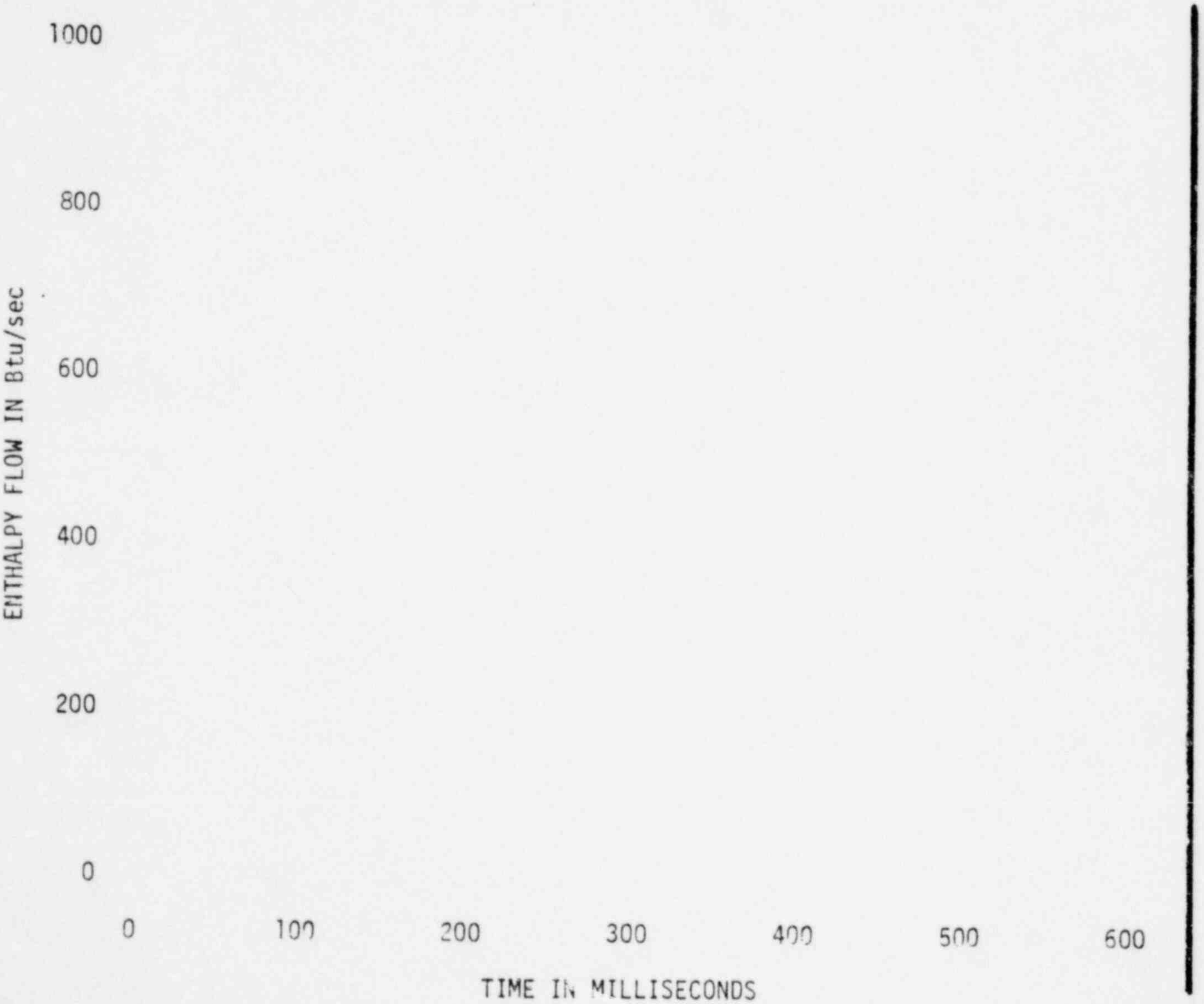

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FIGURE 3-6

DRYWELL ORIFICE UPSTREAM PRESSURE

Task 5.5.3-2 Monticello Test 8

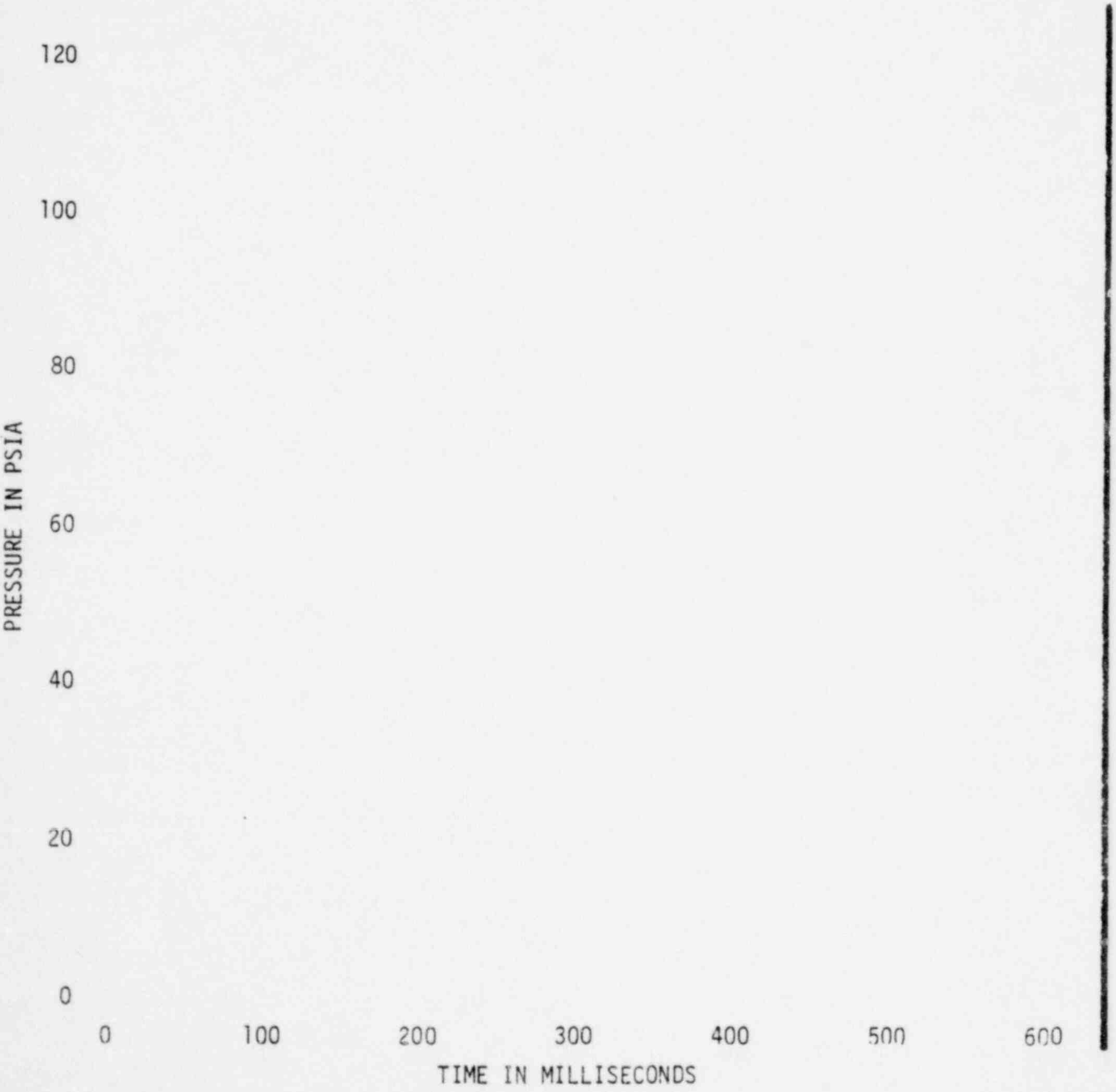

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FIGURE 3-7

DRYWELL PRESSURE

Task 5.5.3-2 Monticello Test 8

FIGURE 3-8

DOWNCOMER ORIFICE DIFFERENTIAL PRESSURE

Task 5.5.3-2 Monticello Test 8

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FIGURE 3-9

DOWNCOMER ORIFICE UPSTREAM TEMPERATURE

Task 5.5.3-2 Monticello Test 8

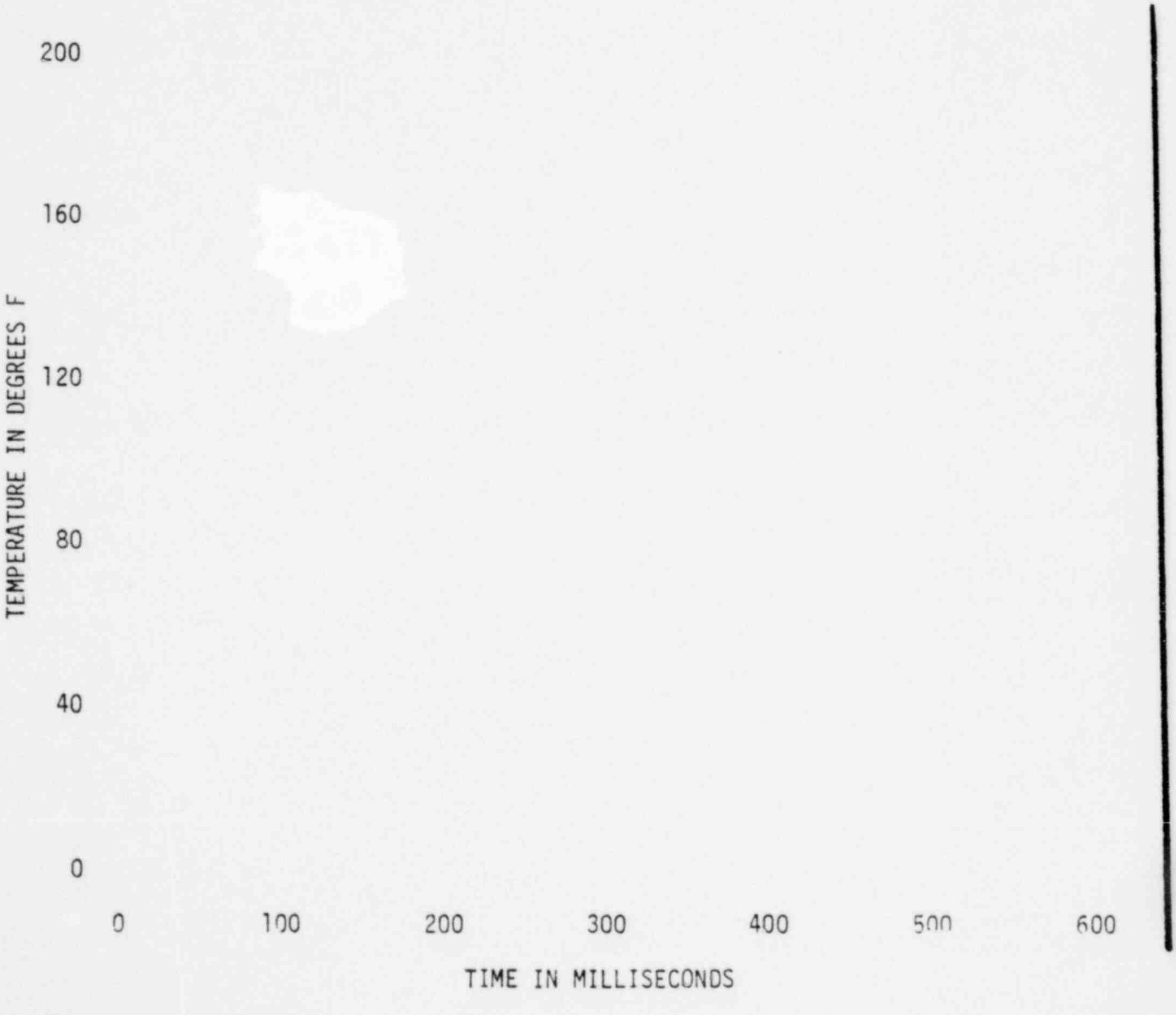

FIGURE 3-10

ENTHALPY FLOW INTO POOL

Task 5.5.3-2 Monticello Test 8

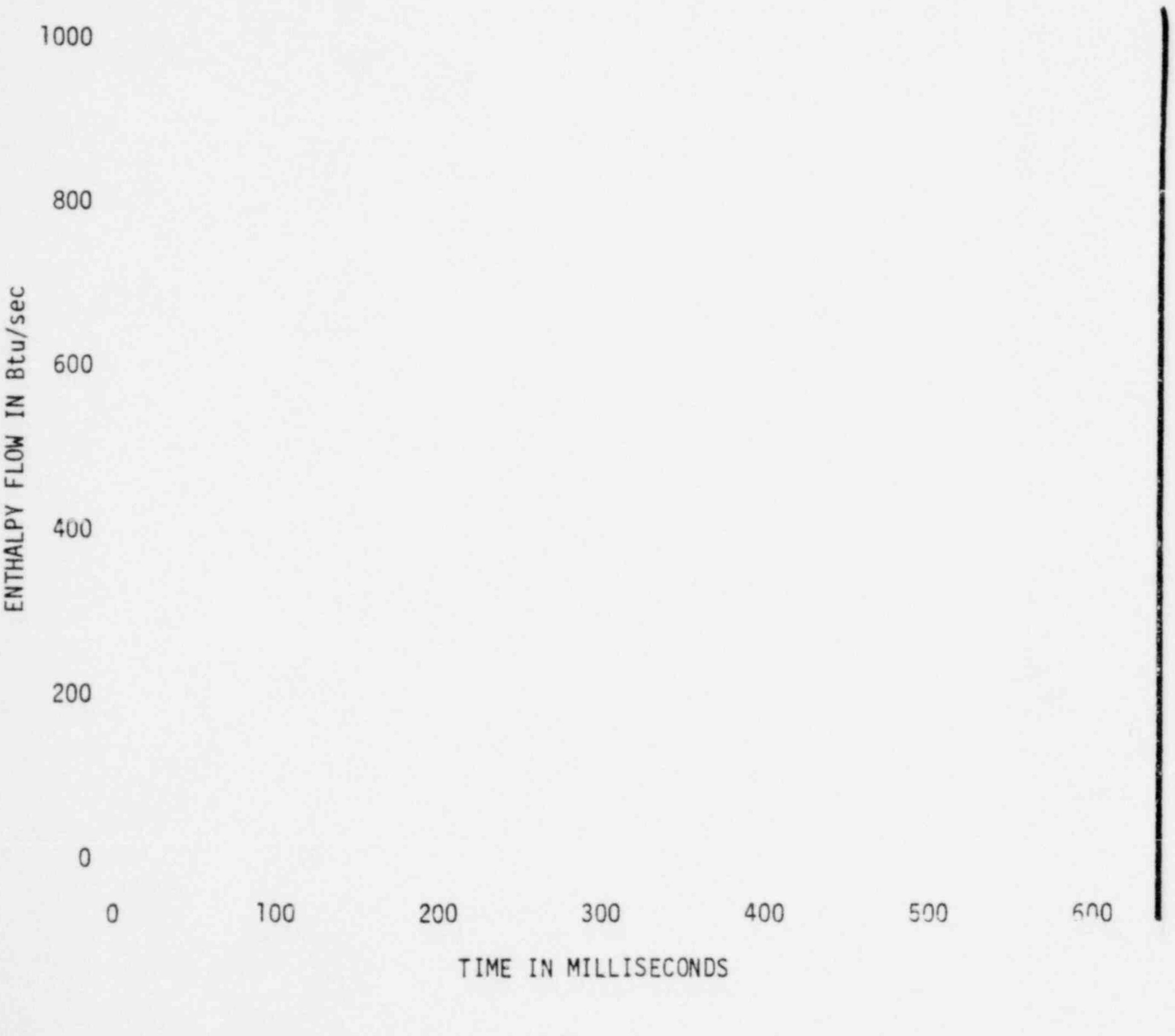

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FIGURE 3-11

DOWNCOMER INTERNAL PRESSURE

Task 5.5.3-2 Monticello Test 2

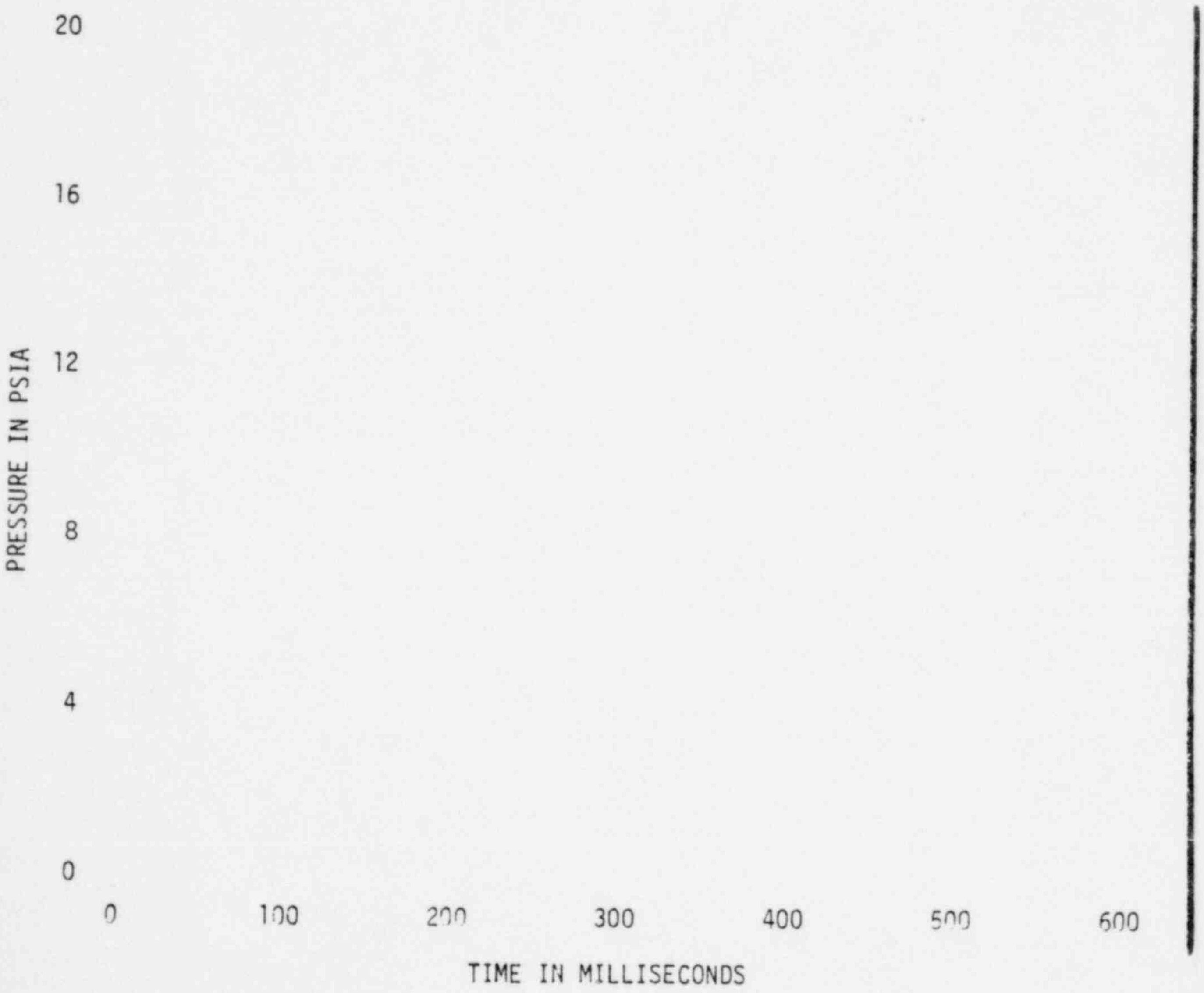

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FIGURE 3-12

WETWELL PRESSURES

Task 5.5.3-2 Monticello Test 2

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FIGURE 3-13

DOWNCOMER INTERNAL PRESSURE

Task 5.5.3-2 Monticello Test 8

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FIGURE 3-14

WETWELL PRESSURES

Task 5.5.3-2 Monticello Test 8

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FIGURE 3-15

NET TORUS FORCE FROM PRESSURE INTEGRAL

Task 5.5.3-2 Monticello Test 2

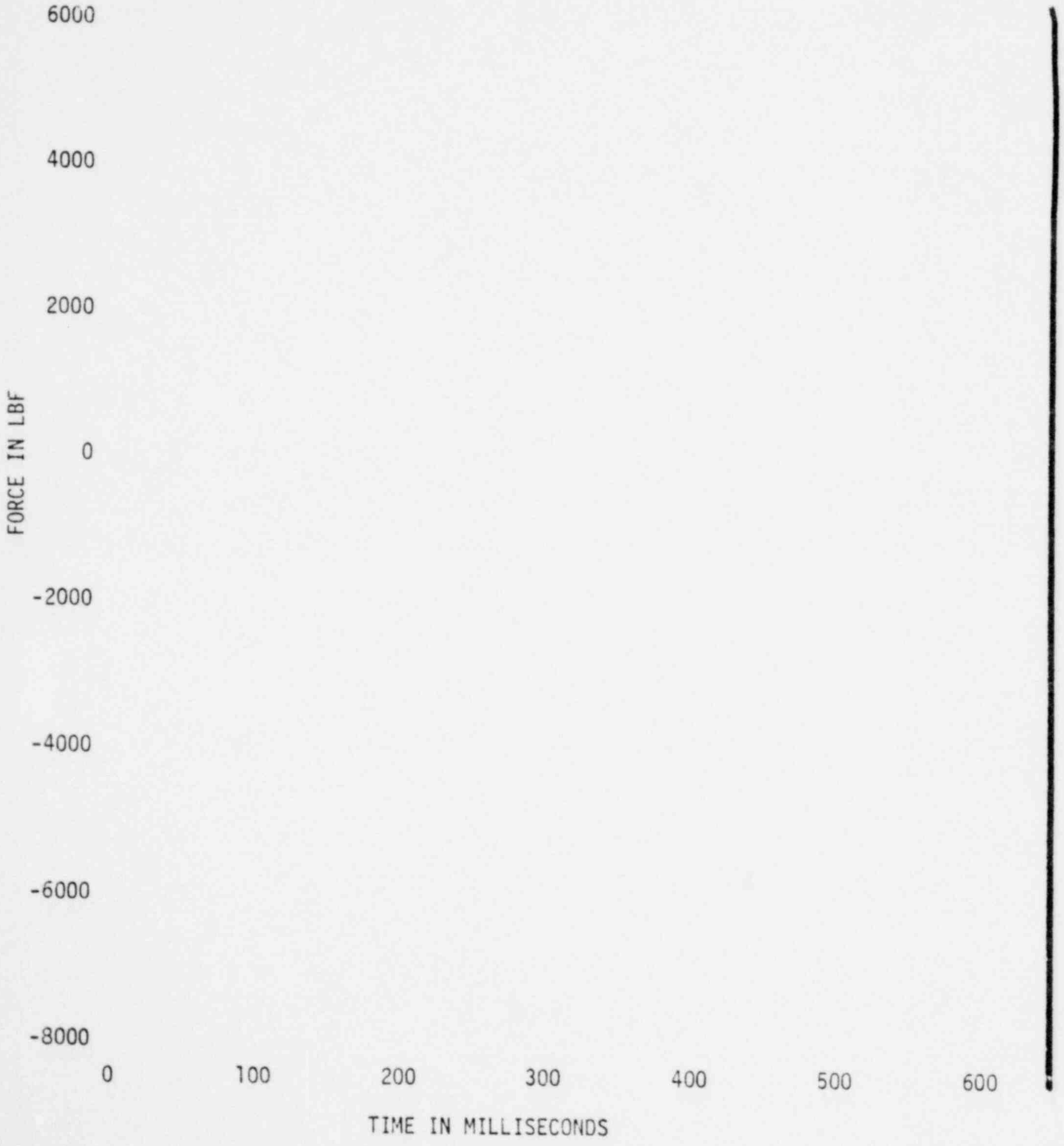

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FIGURE 3-16

NET TORUS FORCE FROM PRESSURE INTEGRAL

Task 5.5.3-2 Monticello Test 8

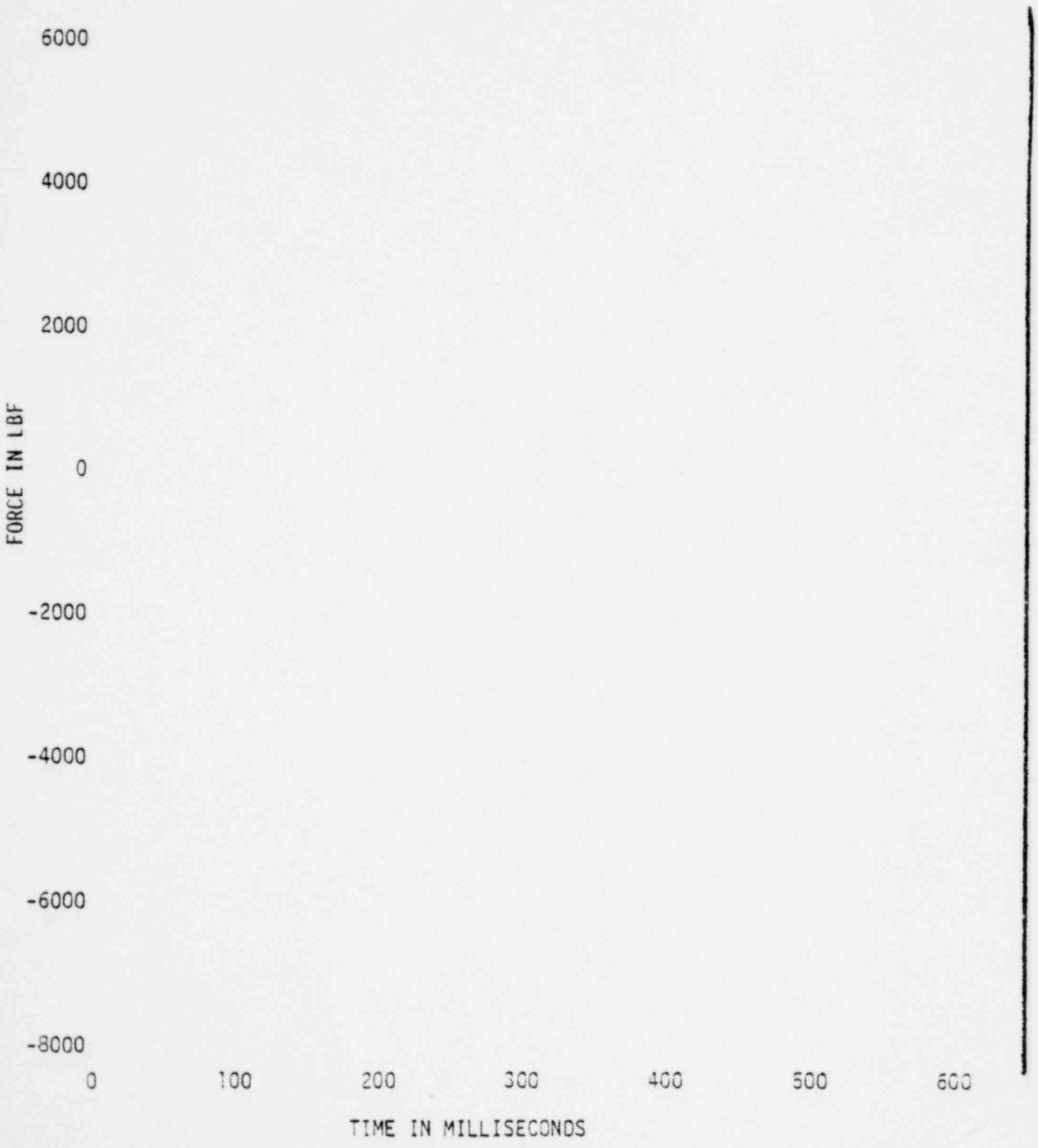

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FIGURE 3-17

TORUS LOAD CELL

Task 5.5.3-2 Monticello Test 2

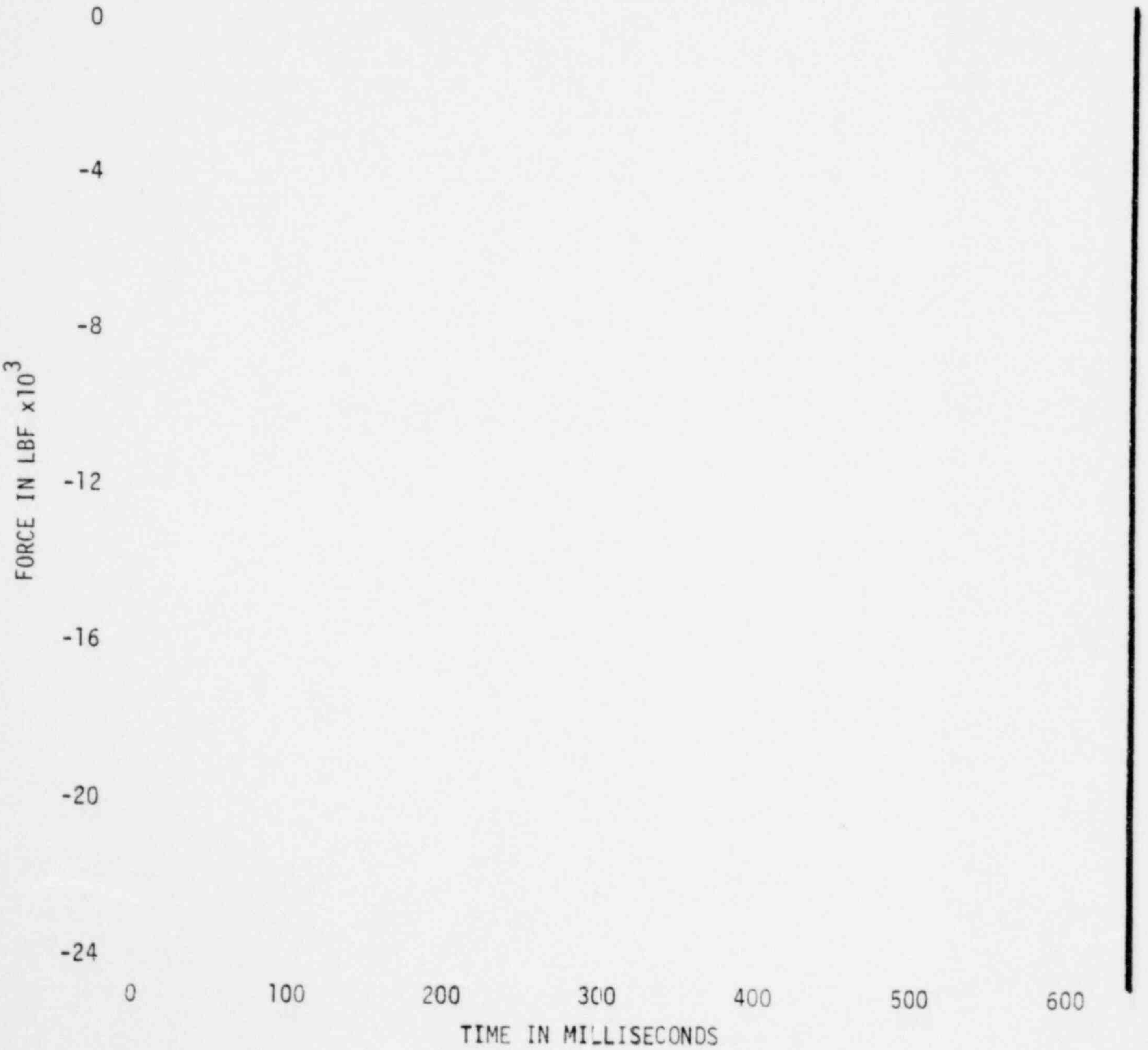

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FIGURE 3-18

TORUS VERTICAL ACCELERATION

Task 5.5.3-2 Monticello Test 2

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FIGURE 3-19

TORUS LOAD CELL

Task 5.5.3-2 Monticello Test 8

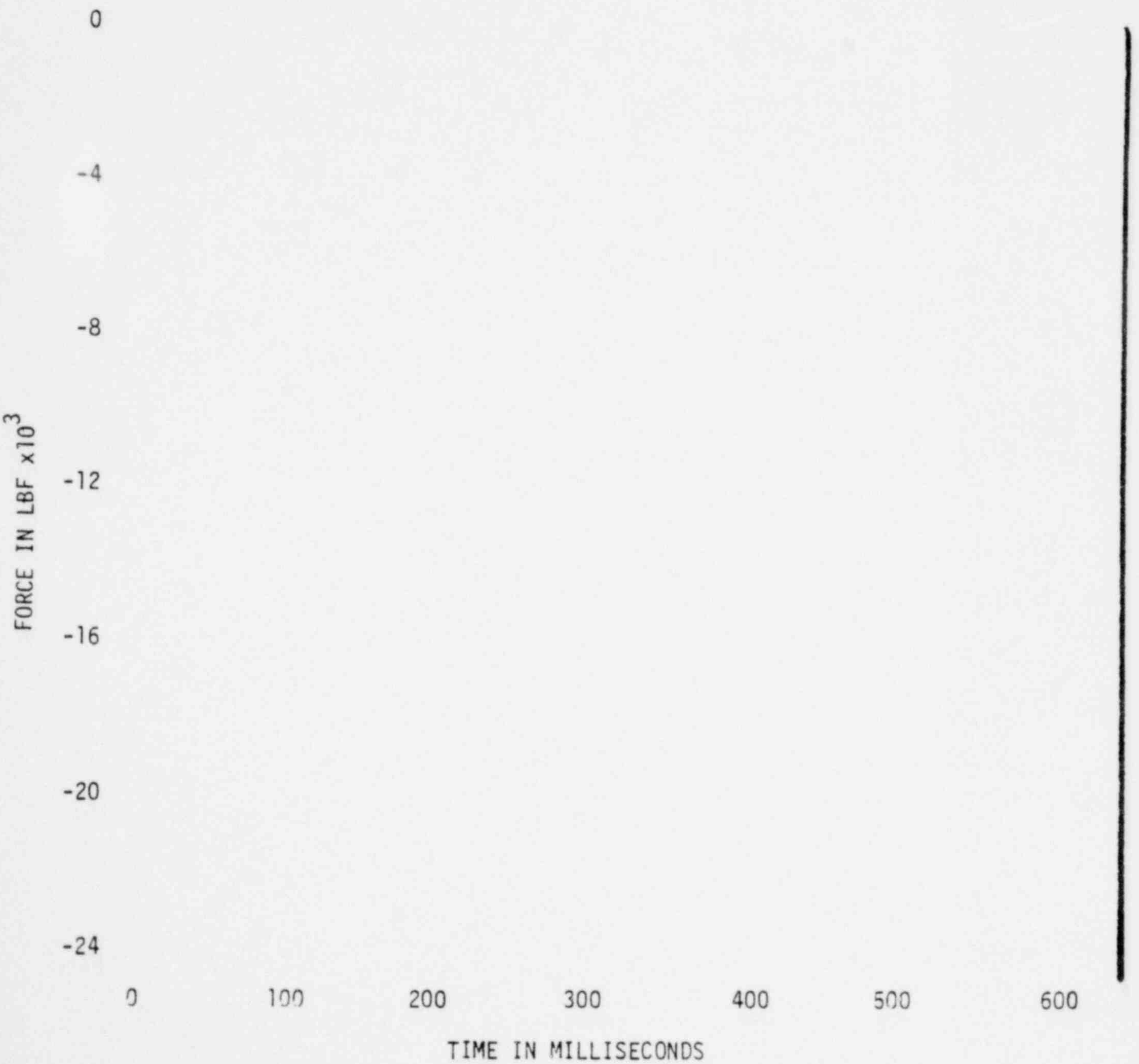

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FIGURE 3-20

TORUS VERTICAL ACCELERATION

Task 5.5.3-2 Monticello Test 8

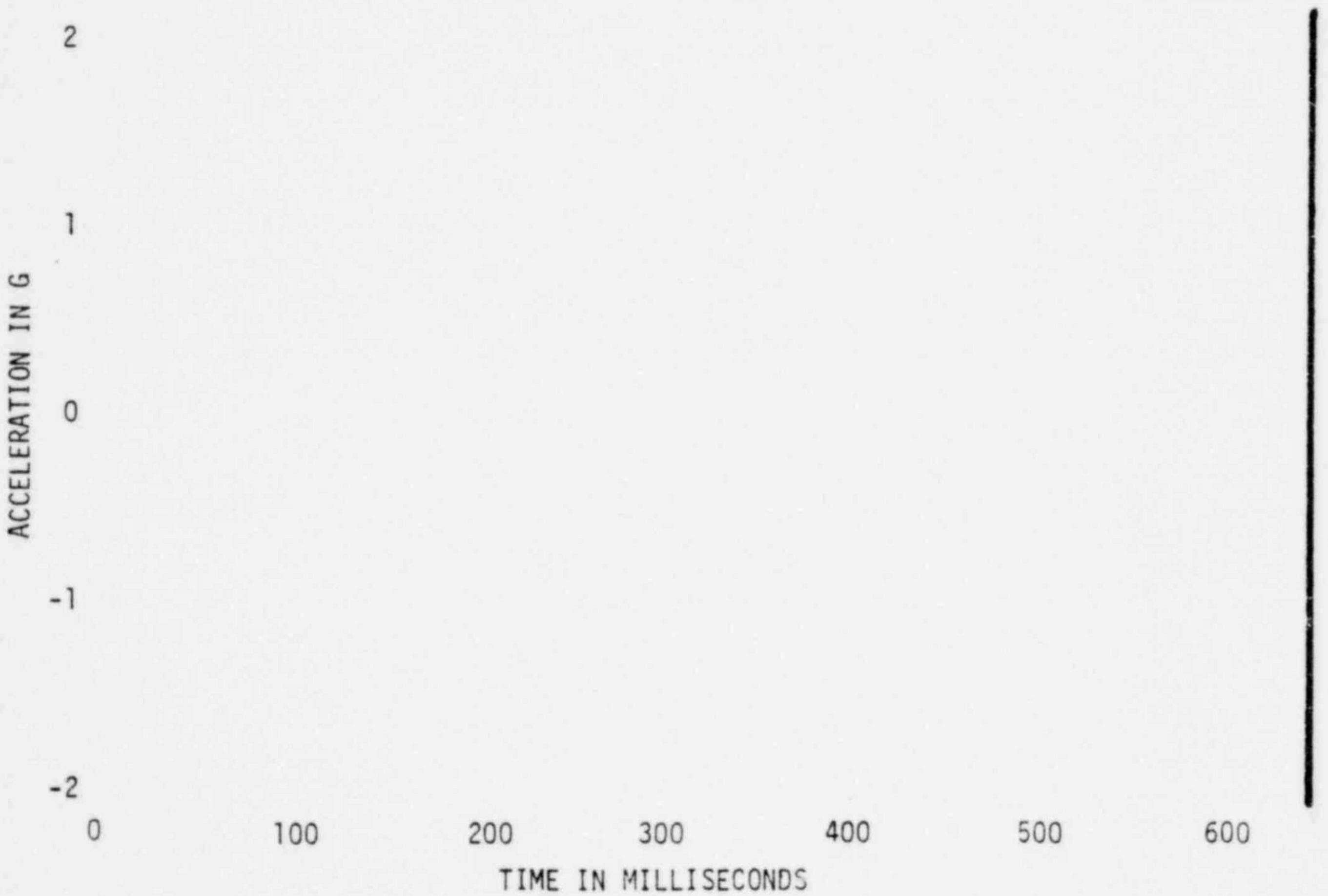

FIGURE 3-21

COMPARISON OF NET TORUS FORCE FROM PRESSURE INTEGRAL
WITH NET TORUS FORCE FROM LOAD CELL CORRECTED FOR TORUS INERTIA

Task 5.5.3-2 Monticello Test 2

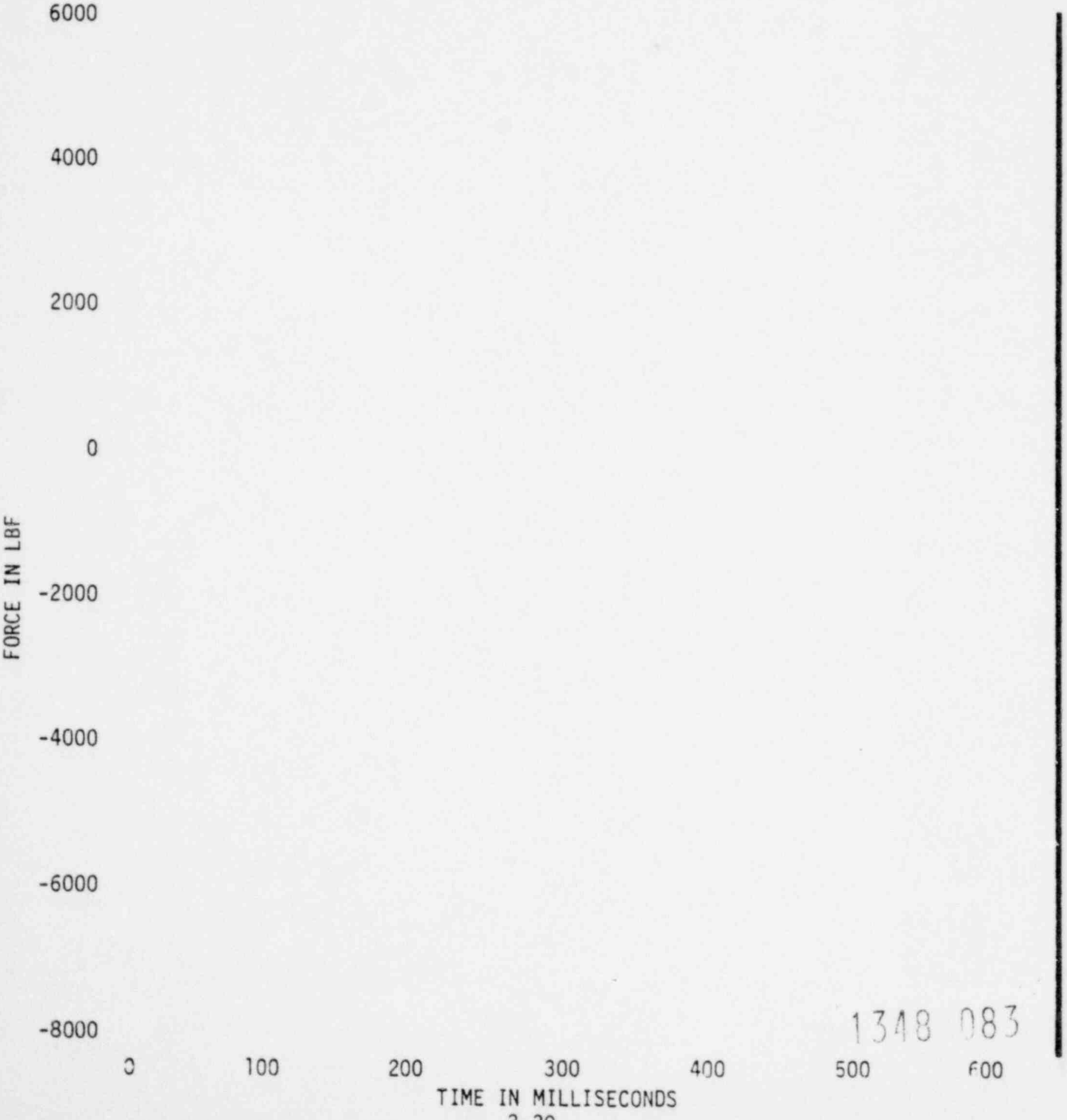

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FIGURE 3-22 COMPARISON OF NET TORUS FORCE FROM PRESSURE INTEGRAL WITH NET TORUS FORCE FROM LOAD CELL CORRECTED FOR TORUS INERTIA

Task 5.5.3-2 Monticello Test 8

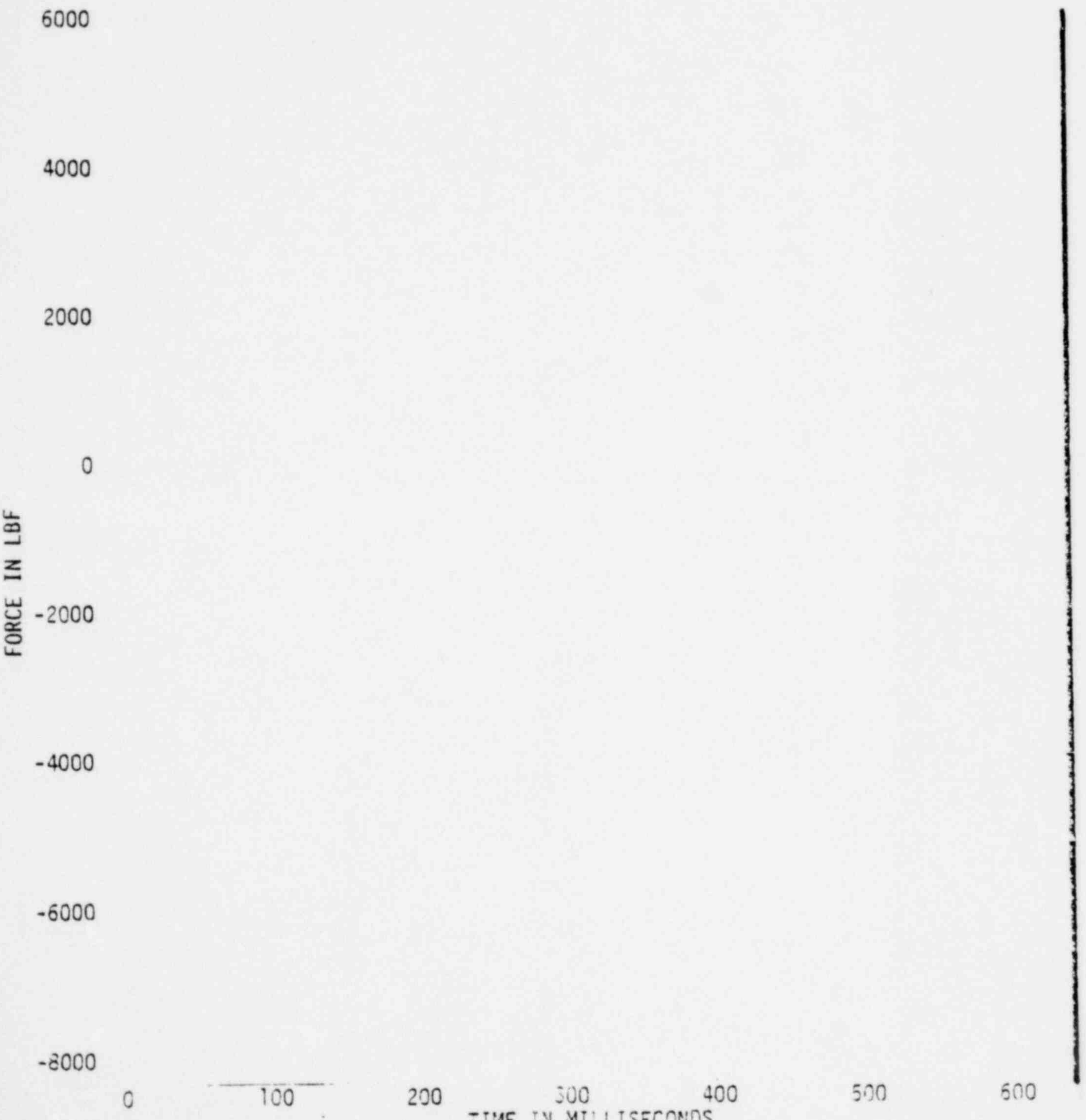

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FIGURE 3-23

NET TORUS FORCE FROM PRESSURE INTEGRAL, CORRECTED FOR WATER INERTIA

Task 5.5.3-2 Monticello Test 2

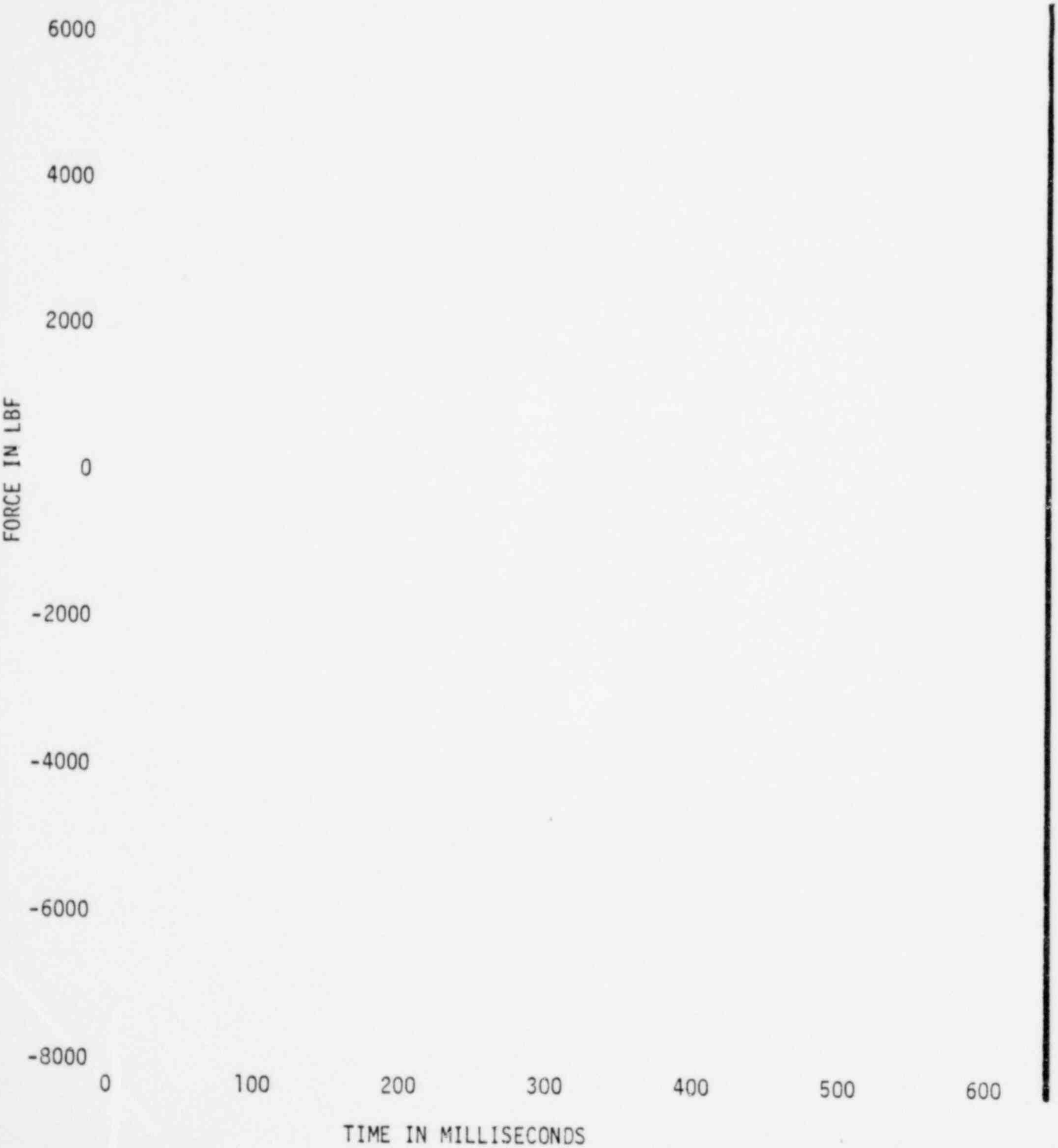

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FIGURE 3-24

NET TORUS FORCE FROM PRESSURE INTEGRAL, CORRECTED FOR WATER INERTIA

Task 5.5.3-2 Monticello Test 8

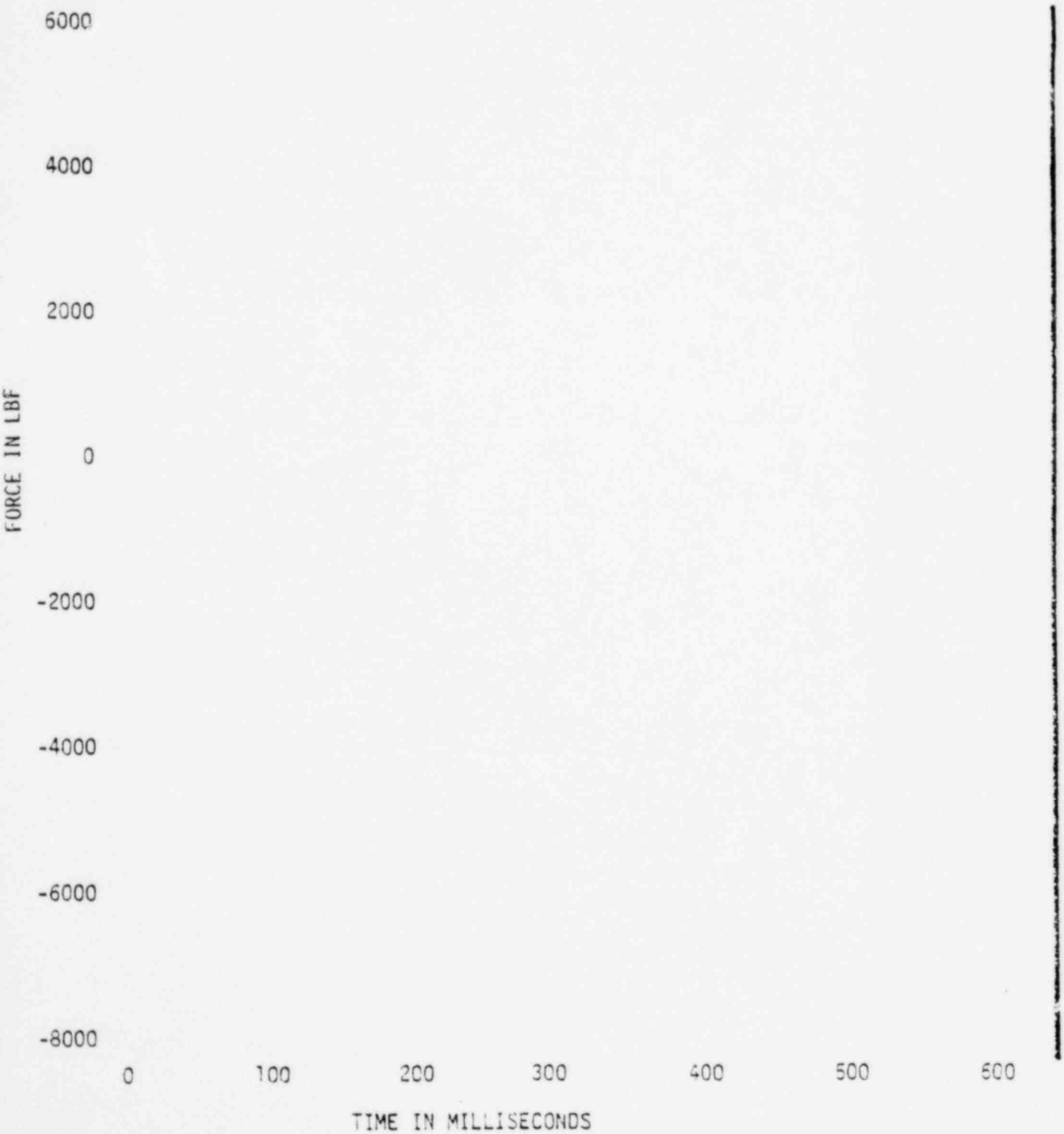

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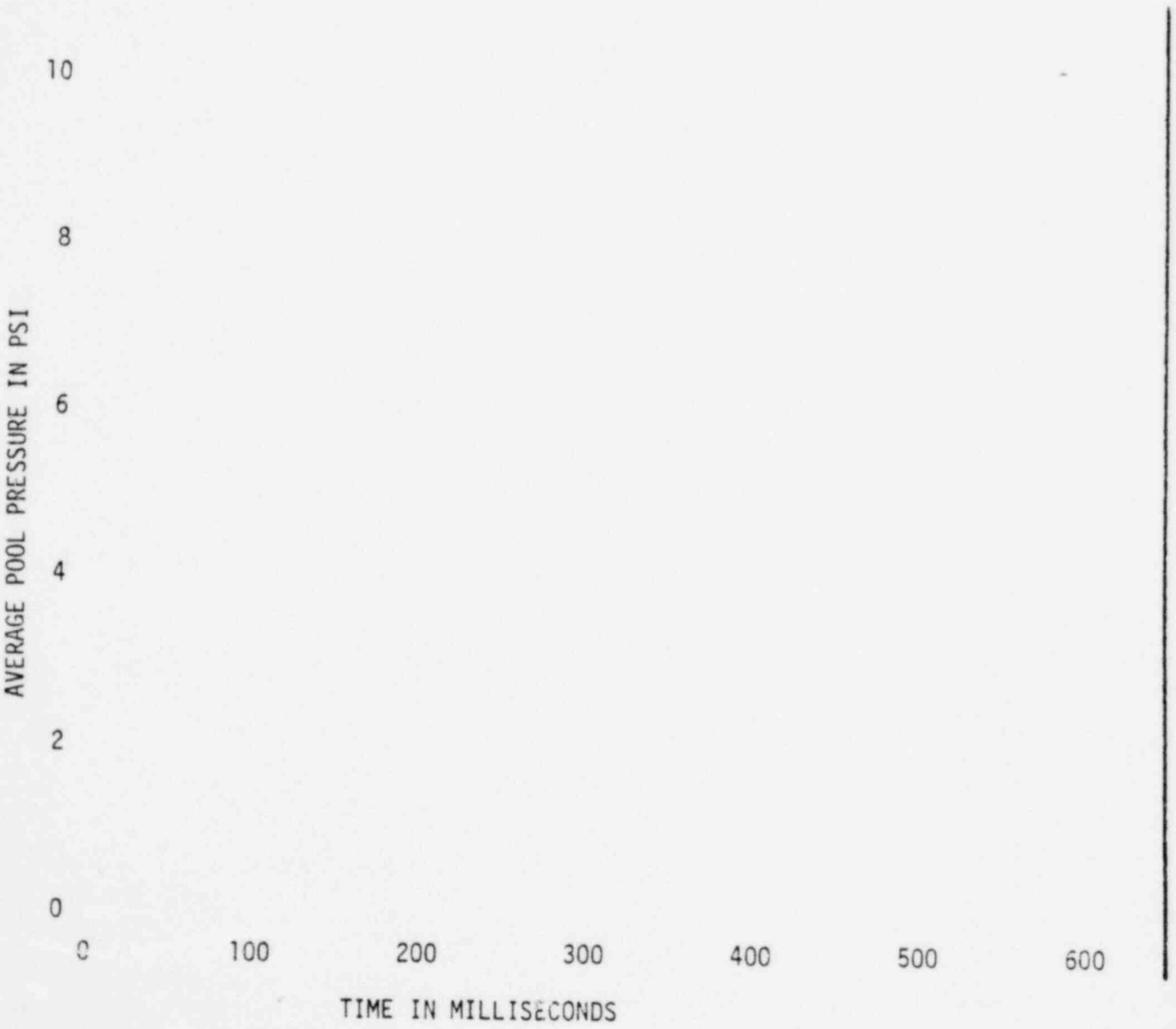
FIGURE 3-25

AVERAGE POOL PRESSURE, CORRECTED FOR WATER INERTIA

Task 5.5.3-2 Monticello Test 2

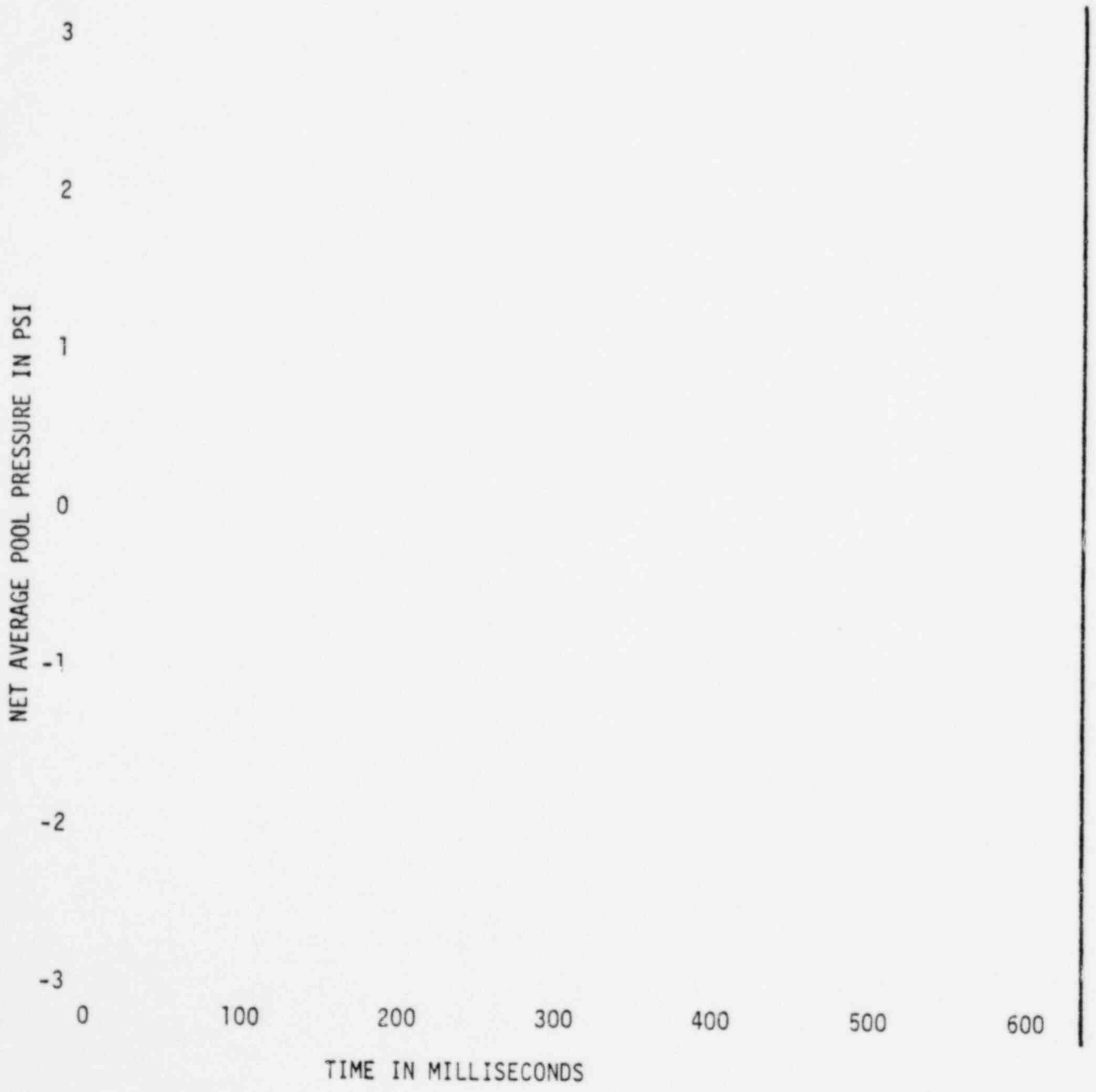


1348 087

FIGURE 3-26

NET AVERAGE POOL PRESSURE, CORRECTED FOR WATER INERTIA

Task 5.5.3-2 Monticello Test 2



1348 088

FIGURE 3-27

AVERAGE POOL PRESSURE, CORRECTED FOR WATER INERTIA

Task 5.5.3-2 Monticello Test 8

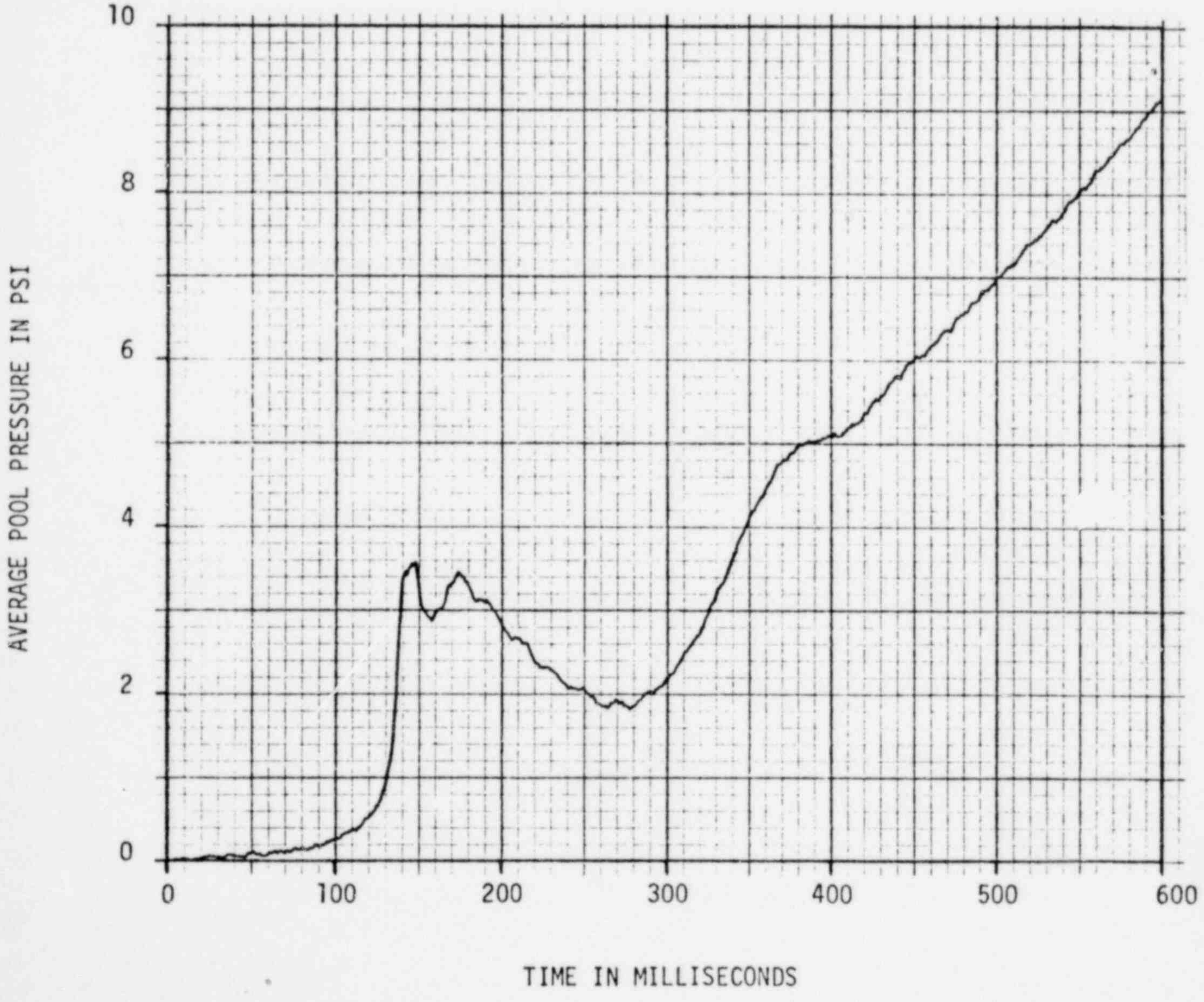
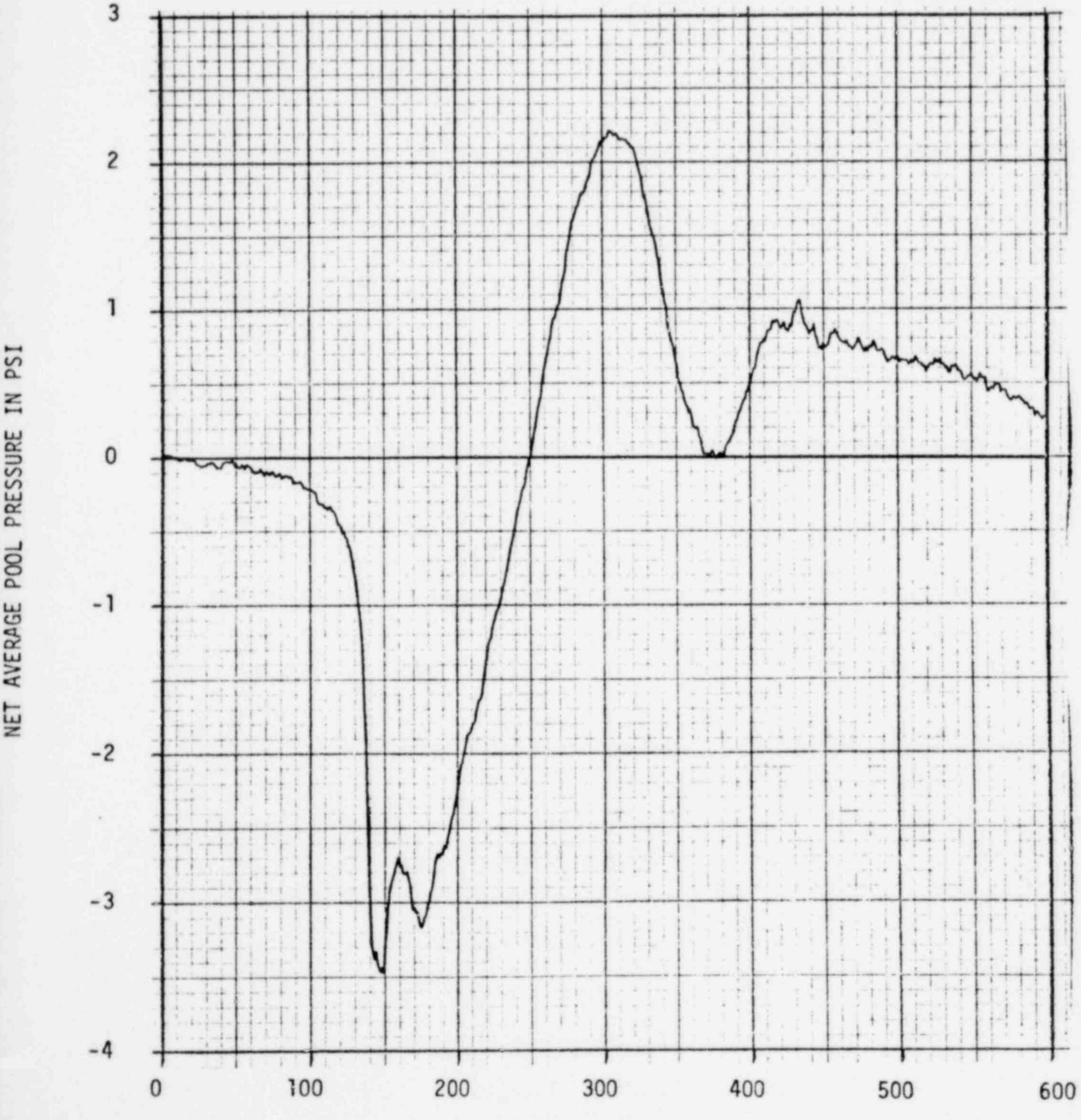


FIGURE 3-28

NET AVERAGE POOL PRESSURE, CORRECTED FOR WATER INERTIA

Task 5.5.3-2 Monticello Test 8

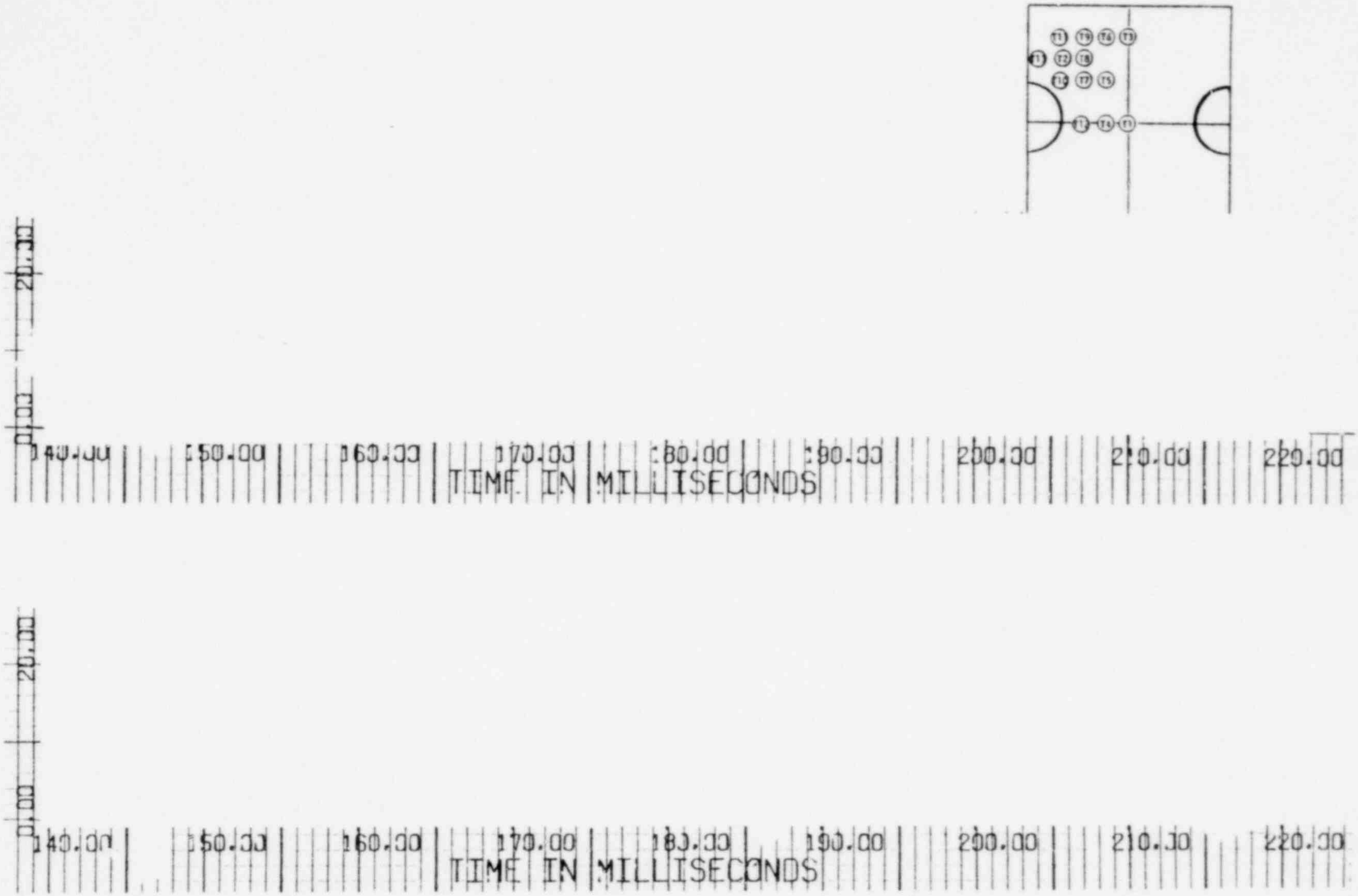


1348 090

FIGURE 3- 29

VENT HEADER IMPACT PRESSURES

Task 5.5.3-2 Monticello Test 2

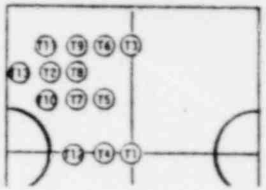


1348 091

FIGURE 3-30

VENT HEADER IMPACT PRESSURES

Task 5.5.3-2 Monticello Test 2



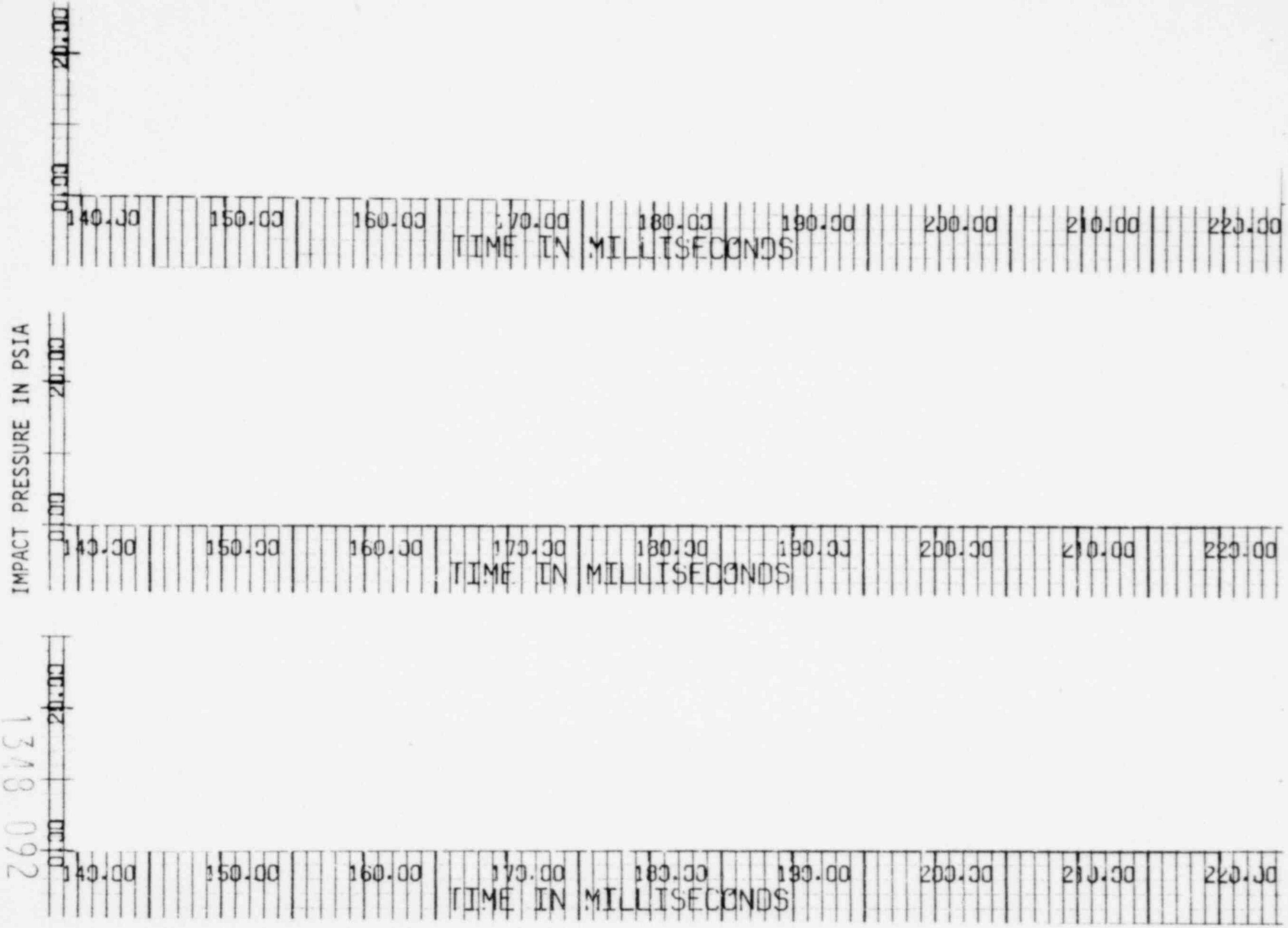
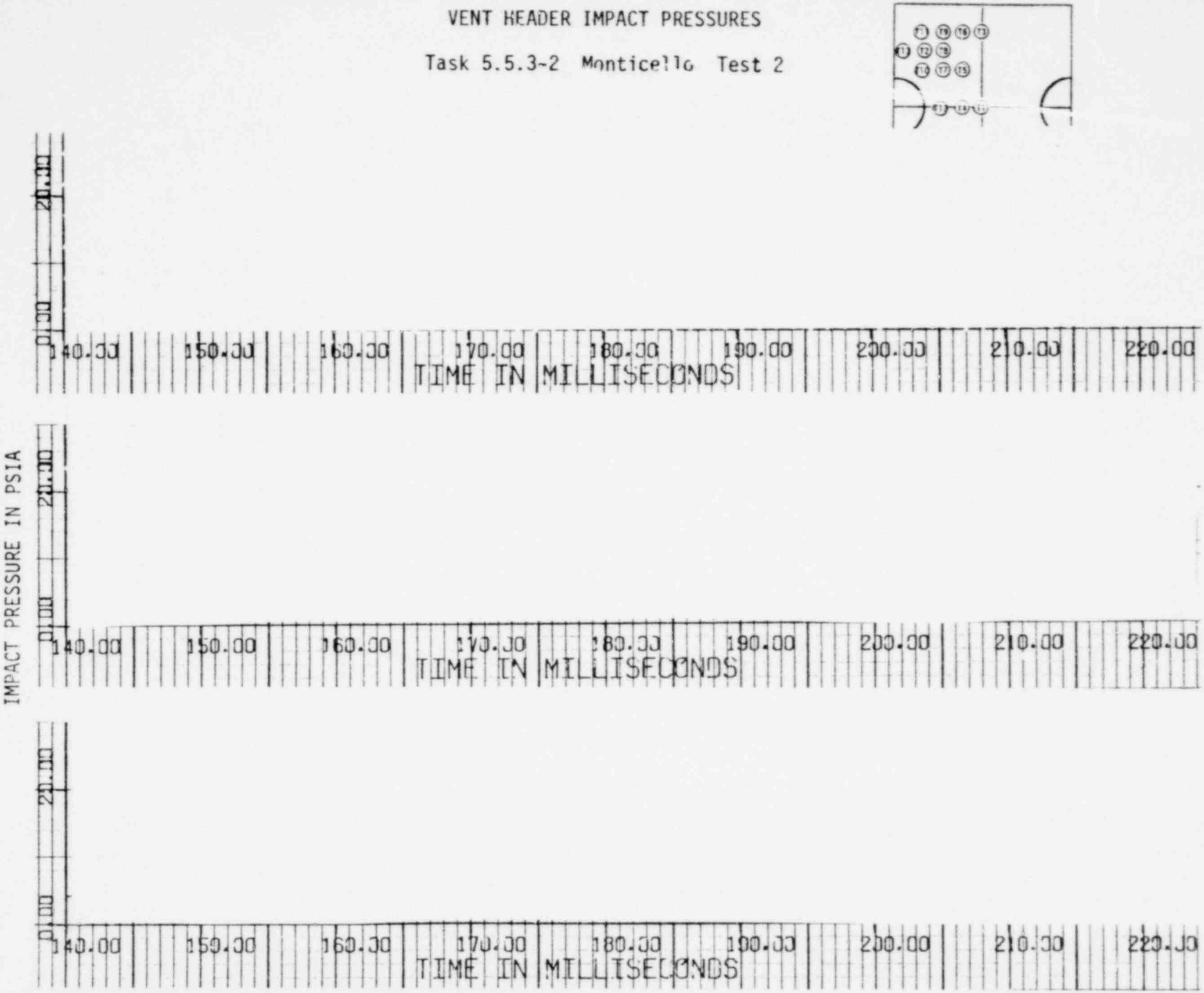


FIGURE 3-31

VENT HEADER IMPACT PRESSURES

Task 5.5.3-2 Monticello Test 2

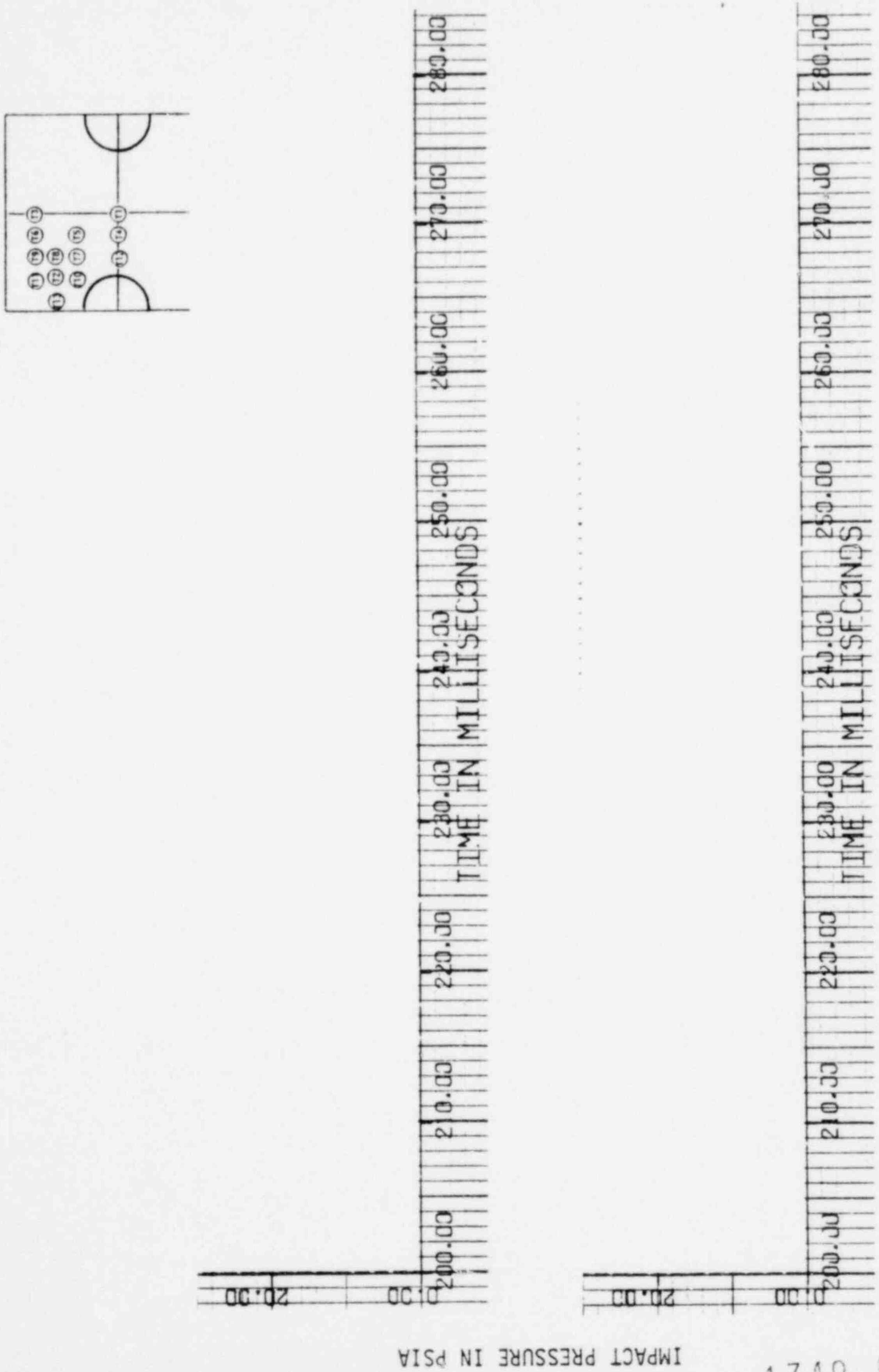


1348 093

FIGURE 3-32

VENT HEADER IMPACT PRESSURES

Task 5.5.3-2 Monticello Test 8

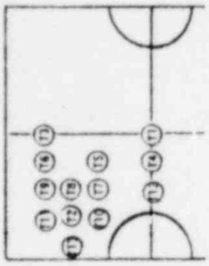


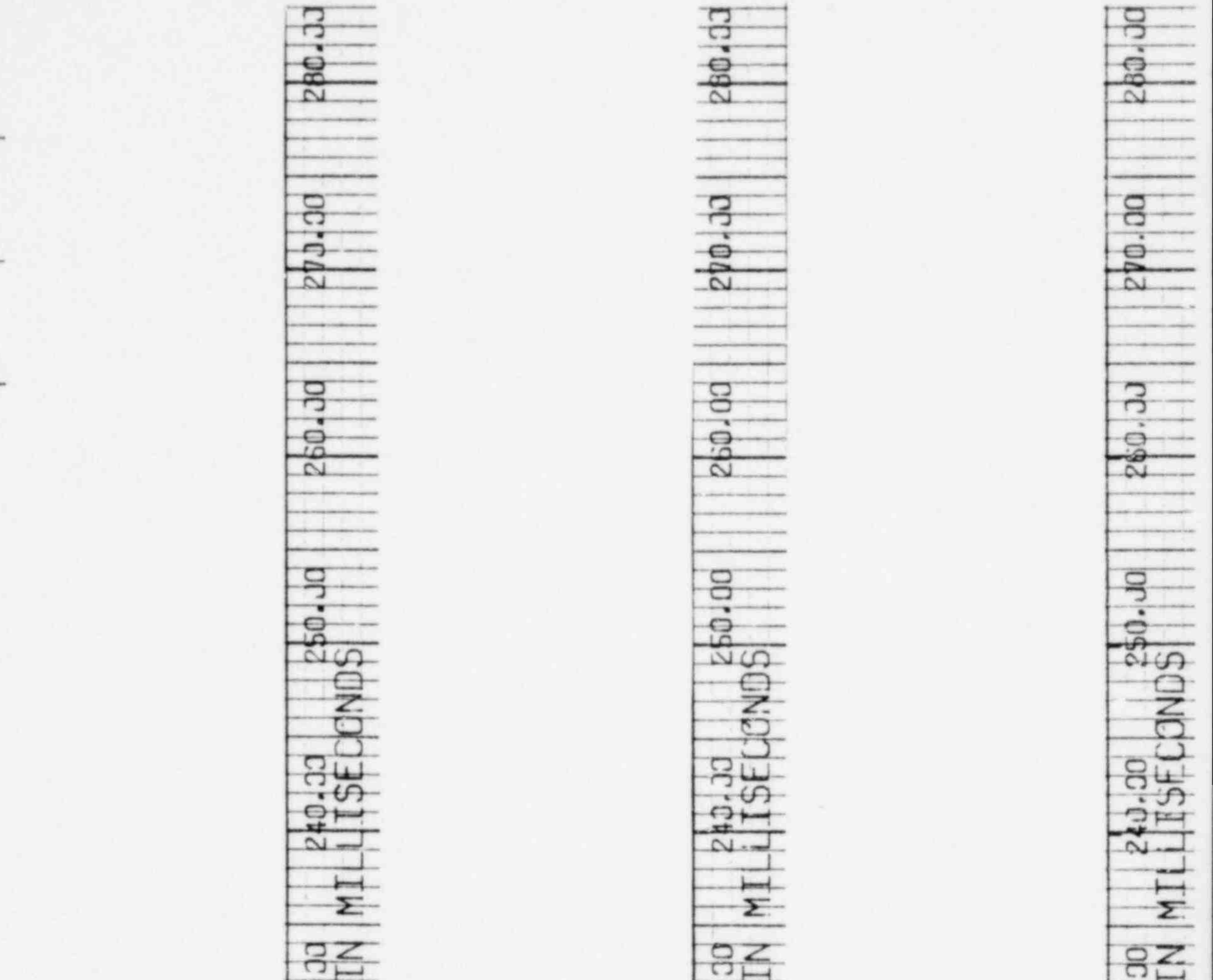
1348 094

FIGURE 3-33

VENT HEADER IMPACT PRESSURES

Task 5.5.3-2 Monticello Test 8



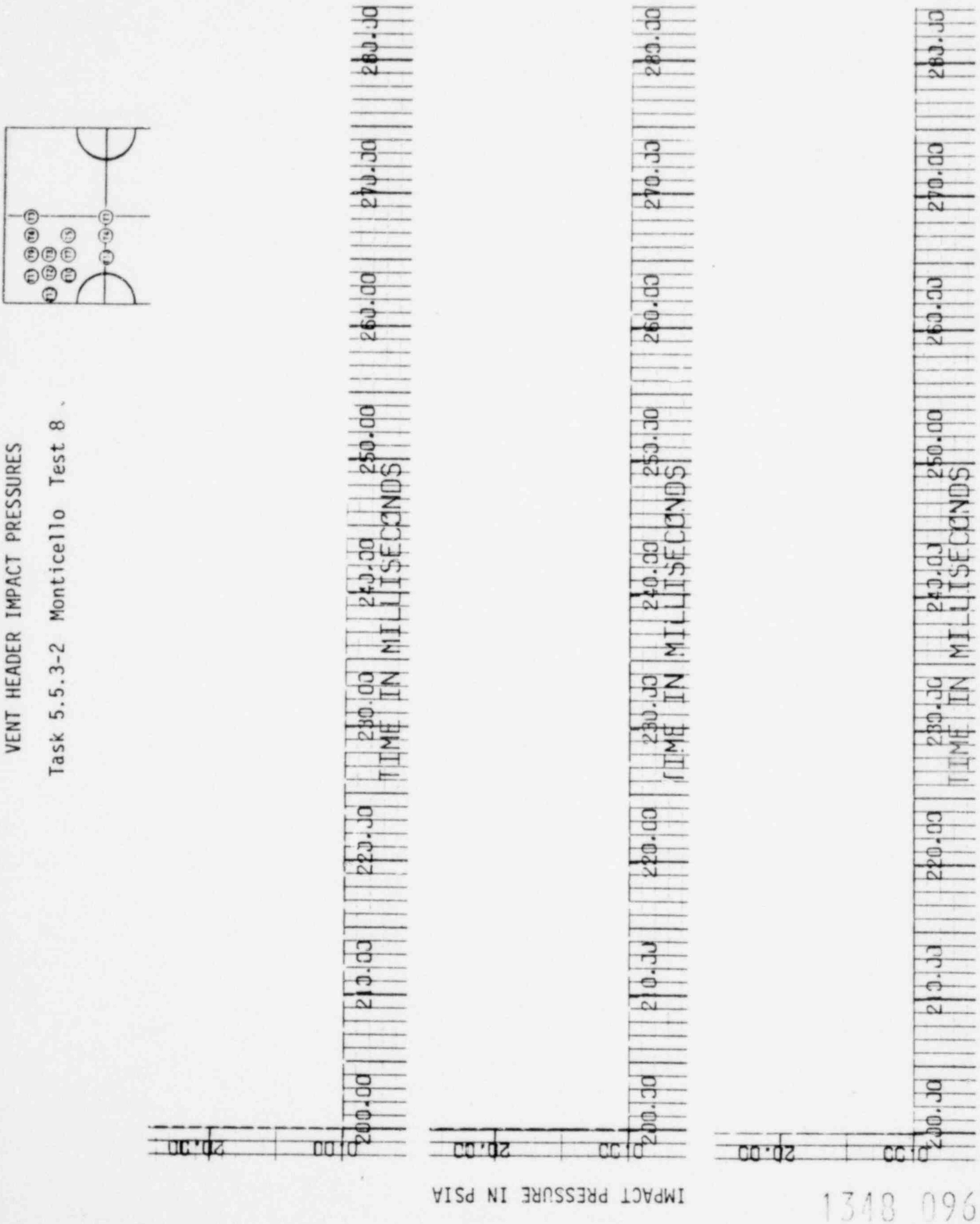


1348 095

FIGURE 3-34

VENT HEADER IMPACT PRESSURES

Task 5.5.3-2 Monticello Test 8



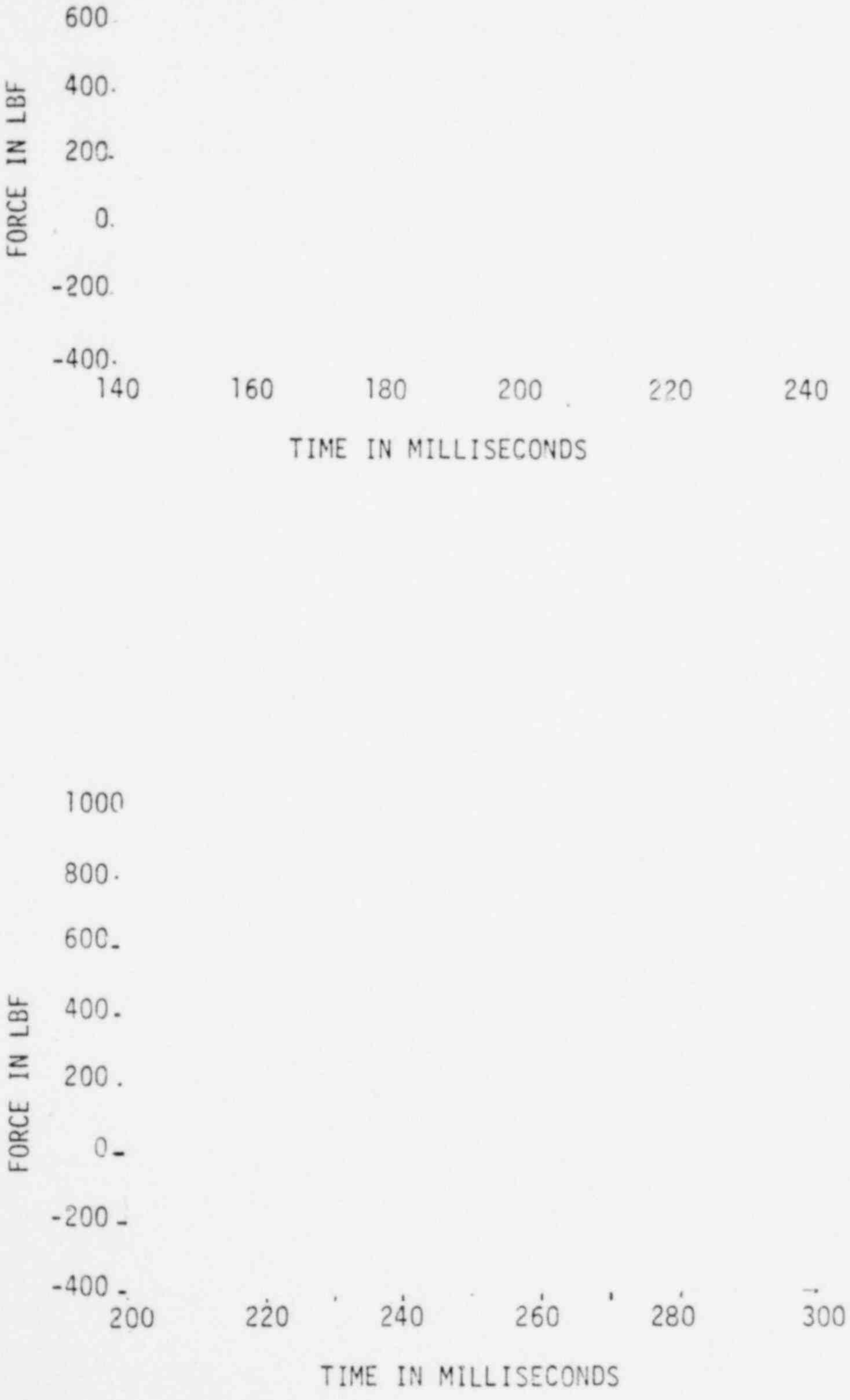
1348 096

FIGURE 3-35

COMPARISON OF VENT HEADER IMPACT RESULTS

(Corrected Load Cell and Pressure Integration)

Task 5.5.3 Monticello Tests 2, 8



1348 097

TABLE 2-5b (cont.)

Test Matrix

Task 5.5.3-2 Plant Unique Tests

Site	Test No.	Initial Drywell Pressurization Rate (psi/sec) Minimum/Actual	Vent System fL/D Maximum/Actual (Split)**	Pool Water Level (in. below center line)	Remarks
Nine Mile Point	Calibration	31.4/31.7	16.85/15.2		
	1		(53/47)	7.75	Load Definition tests, 4.59"
	2			7.75	Pipe Deflector (16.0" Full
	3			7.75	Scale) and 2.30" Gap
	4			7.75	(8.0" Full Scale)
				7.75	4.59" Deflector, ΔP Sensitivity Test
Brunswick	Calibration	29.31/29.7	16.81/16.3		
	1		(46/54)	7.47	Load Definition Tests, 5.34"
	2			7.47	Pipe Deflector (20.0" Full Scale)
	3			7.47	
	4			7.47	
Cooper Station	Calibration	38.4/40.0	17.76/17.4		
	1		(43/57)	4.72	Load Definitions Tests,
	2			4.72	No Deflector
	3			4.72	
	4			4.72	
	5			4.72	ΔP Sensitivity Test
Dresden	Calibration	31.1/32.0	17.45/16.3		
	1		(49/51)	0.39	Load Definition Tests, 5.17"
	2			0.39	Pipe Deflector (20.0" Full
	3			0.39	Scale) and 2.84" Gap (11.0"
	4			0.39	Full Scale)
	5			0.39	5.17" Deflector, ΔP Sensitivity Test
Browns Ferry	Calibration	31.2/31.3	18.49/18.3		
	1		(43/57)	1.5	Load Definition Tests,
	2			1.5	No Deflector
	3			1.5	
	4			1.5	
	5			1.5	ΔP Sensitivity Test
Peach Bottom	Calibration	27.8/29.3	18.42/17.5		
	1		(49/51)	1.8	Load Definition Tests,
	2			1.8	6.5" Winged Deflector
	3			1.8	(25" Full Scale)*
	4			1.8	
	5			1.8	6.5" Winged Deflector, ΔP Sensitivity Test

* A "winged" deflector is a standard pipe with structural angles

** fl/D split= percent of actual fl/D in the vent orifice and downcomer orifices respectively (vent/downcomer)

1348 098

TABLE 2-5C TEST MATRIX

Task 5.5.3-2 Plant Unique Tests

Site	Test Number	Initial Drywell Pressurization Rate (psi/sec) Minimum/Actual	Vent System fL/D Maximum/Actual (Split)*	Pool Water Level (Inches Below Center Line)	Remarks
Millstone	Calibration	34.3/37.6	16.05/14.6		
	1		(59/41)	2.81	Load Definition Tests
	2			2.81	5.20" Winged Deflector
	3			2.81	(19.5" Full Scale; 16"
	4			2.81	Pipe Diameter) with 2.63" Gap (10" Full Scale)
	5			2.81	ΔP Sensitivity Test (Same Deflector)
Oyster Creek	Calibration	27.7/29.6	19.88/18.8		
	1		(54/46)	6.60	Load Definition Tests
	2			6.60	5.17" Deflector (20" Full
	3			6.60	Scale) with 2.58" Gap (10"
	4			6.60	Full Scale)
	5			6.60	ΔP Sensitivity Test (Same Deflector)
Hatch 1	Calibration	34.5/34.7	17.64/16.3		
	1		(42/58)	5.11	Load Definition Tests
	2			5.11	7.17" Winged Deflector
	3			5.11	(26" Full Scale) with 6.97"
	4			5.11	Gap (25.25" Full Scale)
	5			5.11	ΔP Sensitivity Test (Same Deflector)
Vermont Yankee	Calibration	39.54/41.3	16.04/14.5		
	1		(51/49)	9.95	Load Definition Tests
	2			9.95	7.21" Winged Deflector
	3			9.95	(25.5" Full Scale; 16"
	4			9.95	Pipe Diameter) with 7.35" Gap (26.25" Full Scale)
	5			9.95	ΔP Sensitivity Test (Same Deflector)
Fitzpatrick	Calibration	30.6/31.0	17.1/15.7		
	1		(48/52)	2.36	Load Definition Tests
	2			2.36	7.88 Deflector (30" Full
	3			2.36	Scale) With 3.21" Gap (1'-
	4			2.36	Full Scale)
	5			2.36	ΔP Sensitivity Test (Same Deflector)
Hope Creek	Calibration	26.5/27.2	18.94/17.2		
	1		(55/45)	2.91	Load Definition Tests
	2			2.91	(Zero ΔP)
	3			2.91	No Deflector
	4			2.91	
	5			2.91	ΔP Sensitivity Test (No Deflector)

*fL/D split = percent of actual fL/D in the vent orifice and downcomer orifices respectively (vent/downcomer)

1348 099

FIGURE 3-36

VENT HEADER VERTICAL ACCELERATION

Task 5.5.3-2 Monticello Test 2

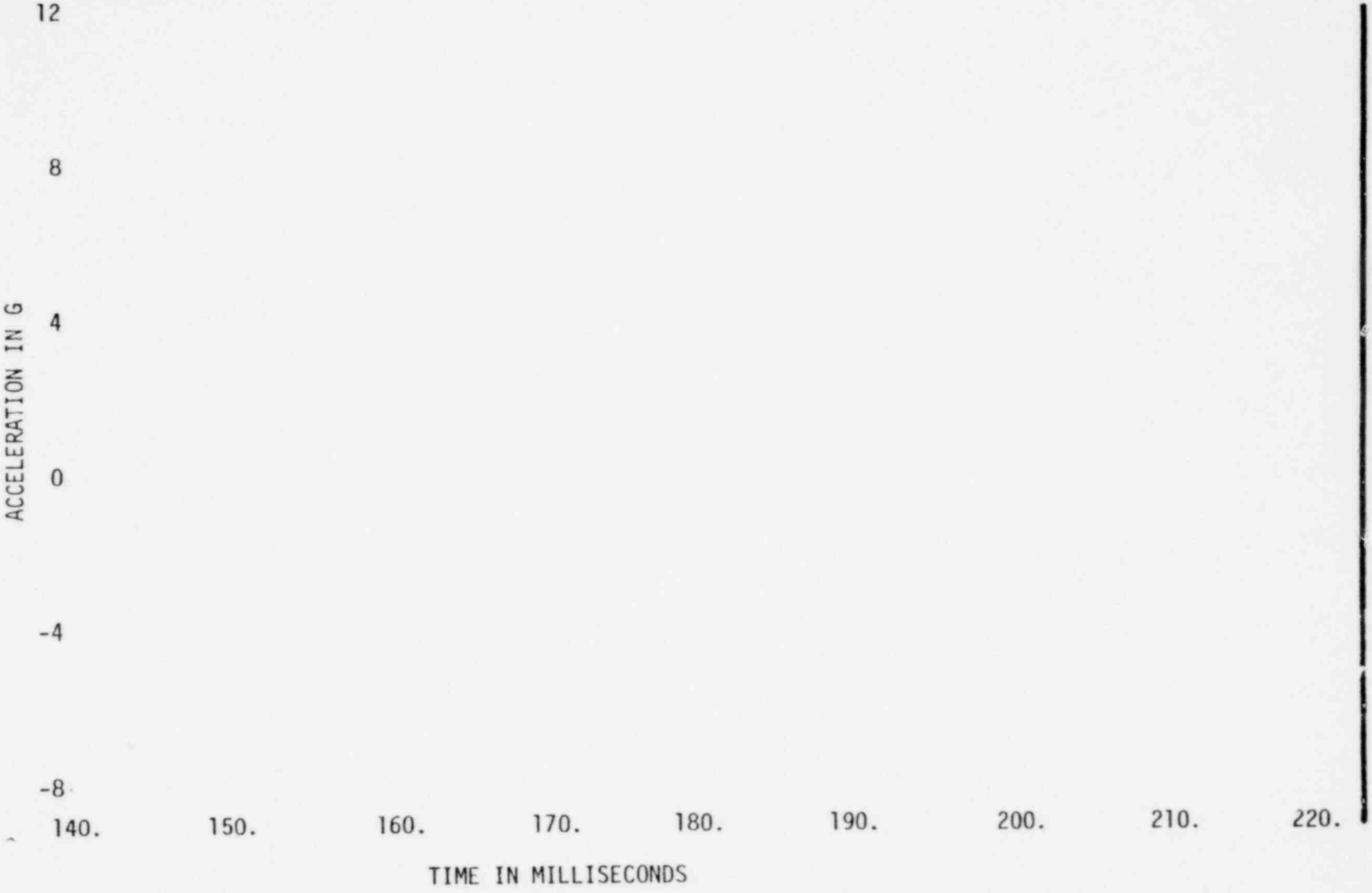


FIGURE 3-37

VENT HEADER VERTICAL ACCELERATION

Task 5.5.3-2 Monticello Test 8

ACCELERATION IN G

12

8

4

0

-4

-8

200. 210. 220. 230. 240. 250. 260. 270. 280.

TIME IN MILLISECONDS

FIGURE 3-38

TIME HISTORY OF

POOL DISPLACEMENT

MONTICELLO, TEST 1

Vertical Distance from Original Pool Water Level - inches

30

25

20

15

10

5

0

0 5 10 15 20 25 30

Horizontal Distance from Pool Centerline - inches

Time (from T_0) - seconds

1348 102

FIGURE 3-39

TIME HISTORY OF

POOL DISPLACEMENT

MONTICELLO, TEST 2

Vertical Distance from Original Pool Water Level - inches

30

25

20

15

10

5

0

Time (from T_o) - seconds

0 5 10 15 20 25 30

Horizontal Distance from Pool Centerline - inches

1348 103

FIGURE 3-40

TIME HISTORY OF

POOL DISPLACEMENT

MONTICELLO, TEST 3

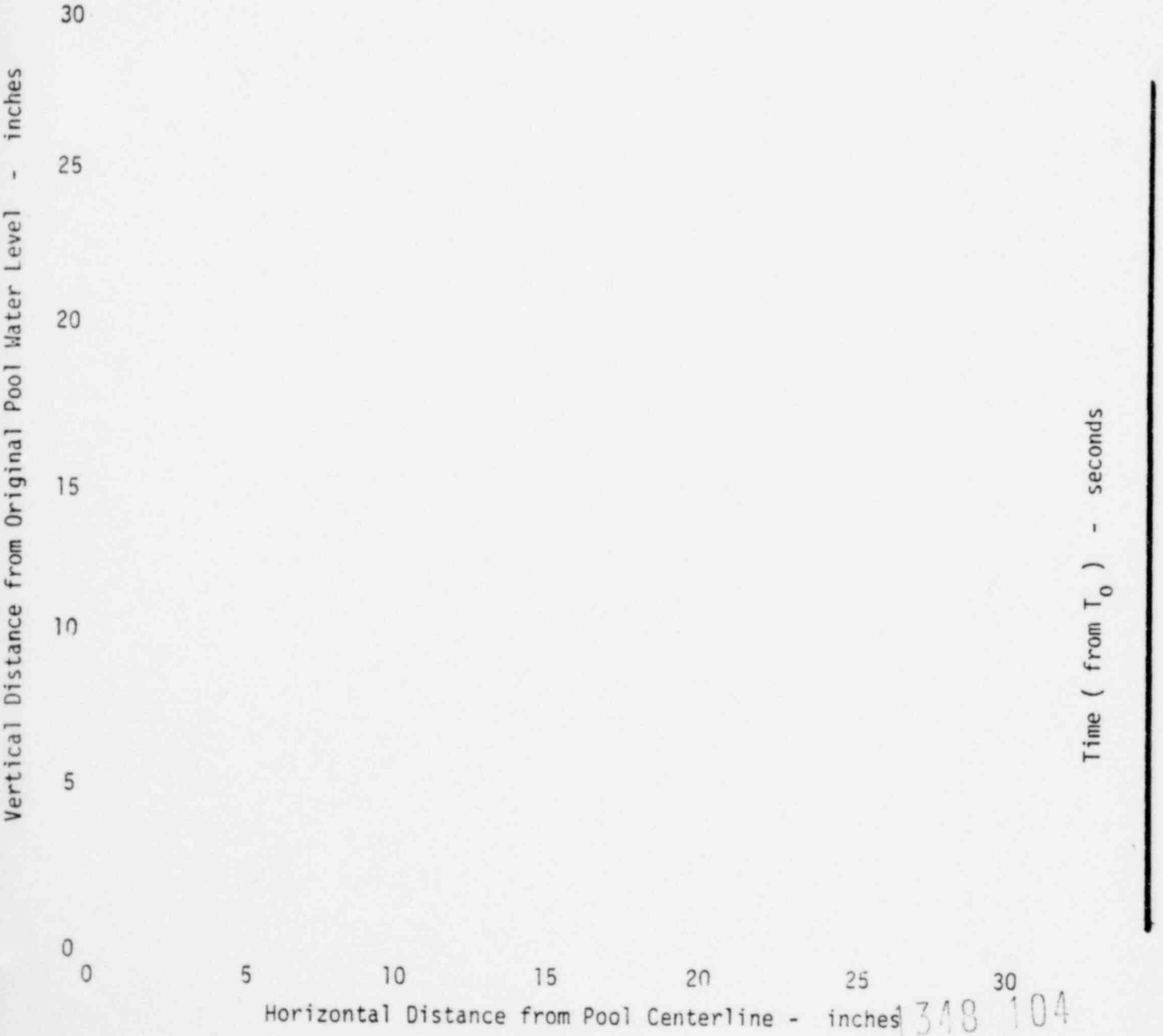


FIGURE 3-41

TIME HISTORY OF

POOL DISPLACEMENT

MONTICELLO, TEST 5

1348 105

FIGURE 3-42

POOL SURFACE DISPLACEMENT

MONTICELLO TESTS 1,2,3

(Combined Data)

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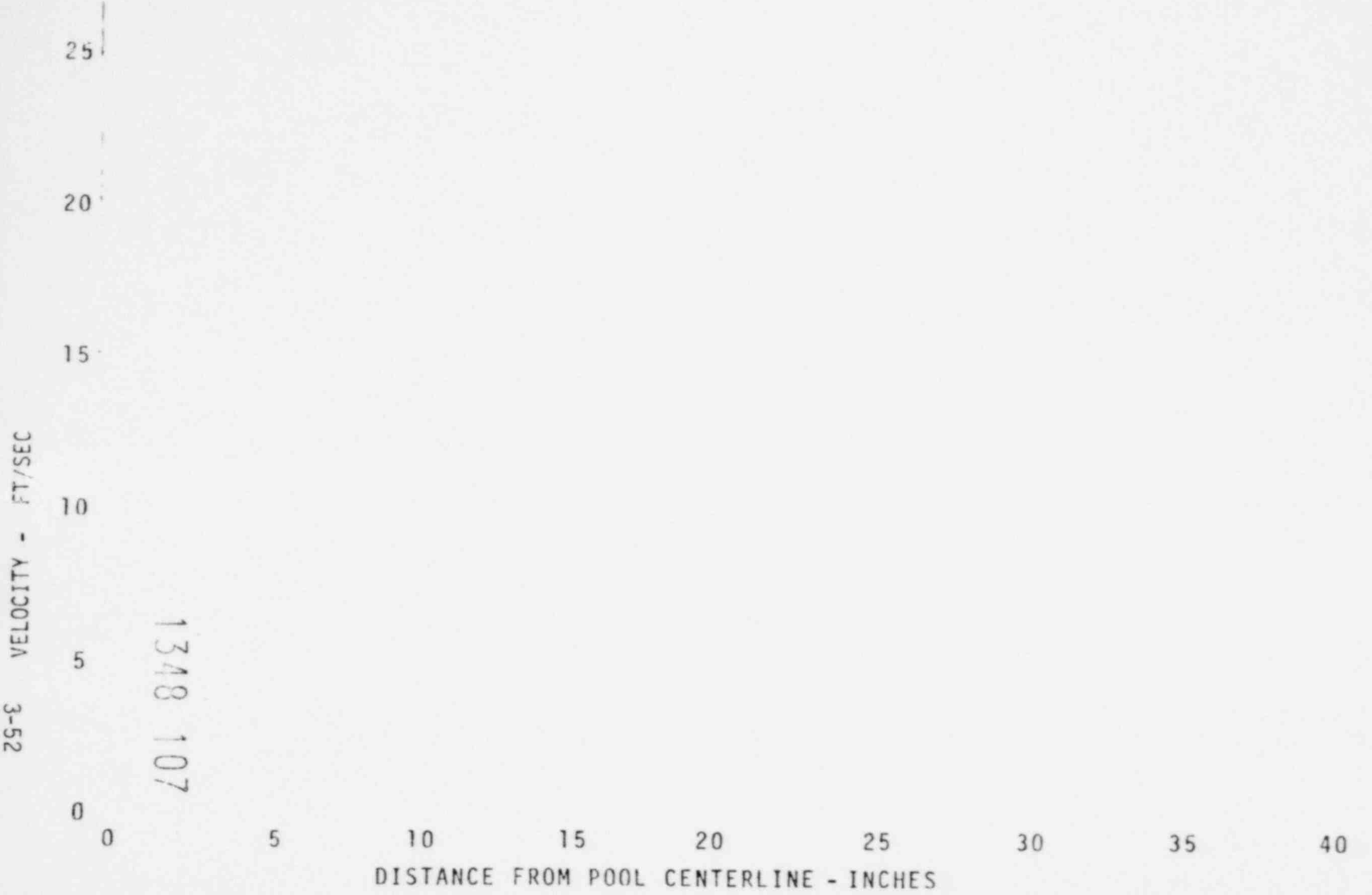
1340 106

POOL SURFACE VELOCITY PROFILES

FIGURE 3-43

MONTICELLO TESTS 1, 2, 3

(Combined Data)



1348 107

NUCLEAR SERVICES CORPORATION

NUCLEAR SERVICES CORPORATION

FIGURE 3-44

POOL SURFACE DISPLACEMENT

MONTICELLO TEST 5

Height above original pool surface - inches

25
20
15
10
5
0

0
100
200
300
400

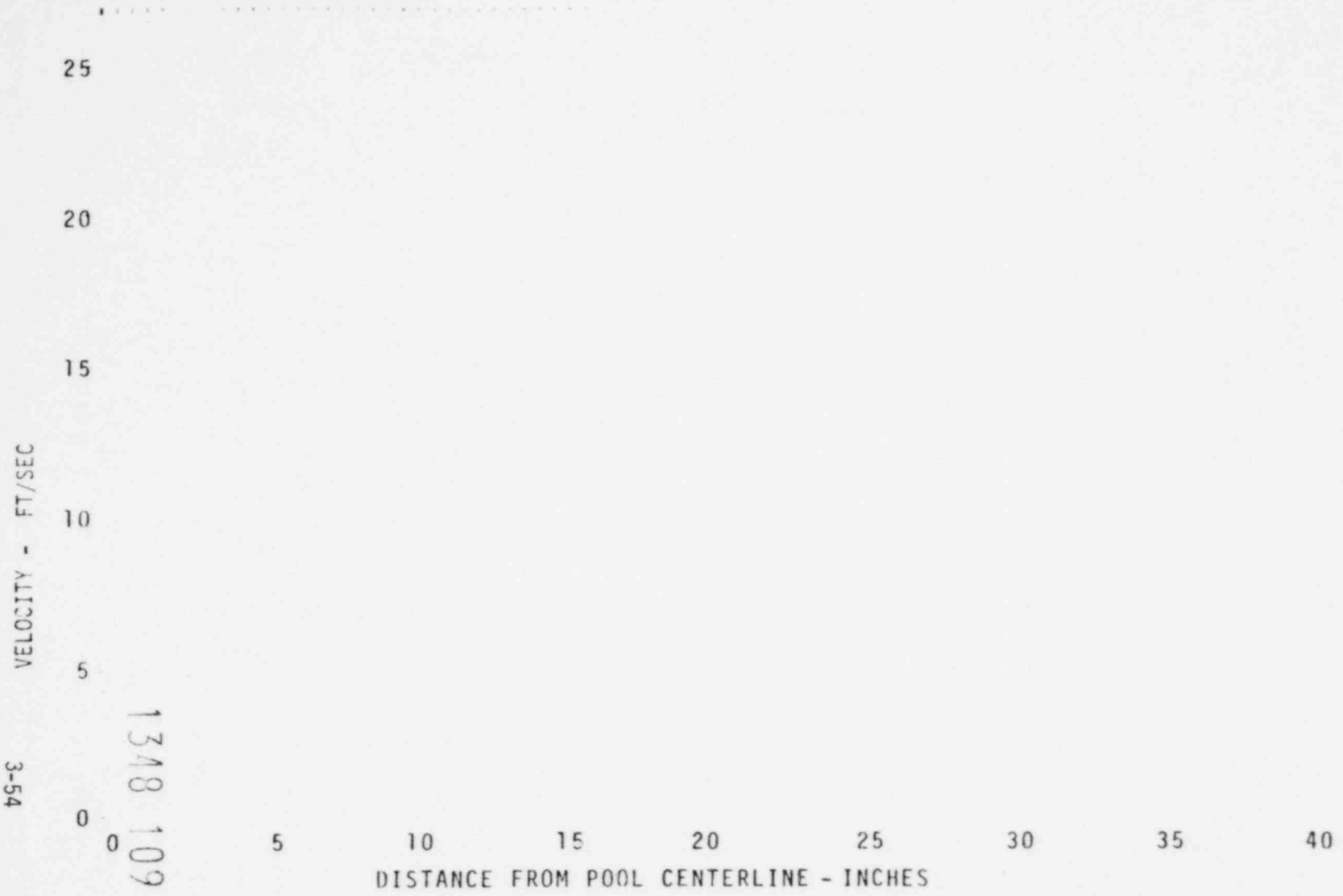
Time- milliseconds

1348 108

FIGURE 3-45

POOL SURFACE VELOCITY PROFILES

MONTICELLO TEST 5

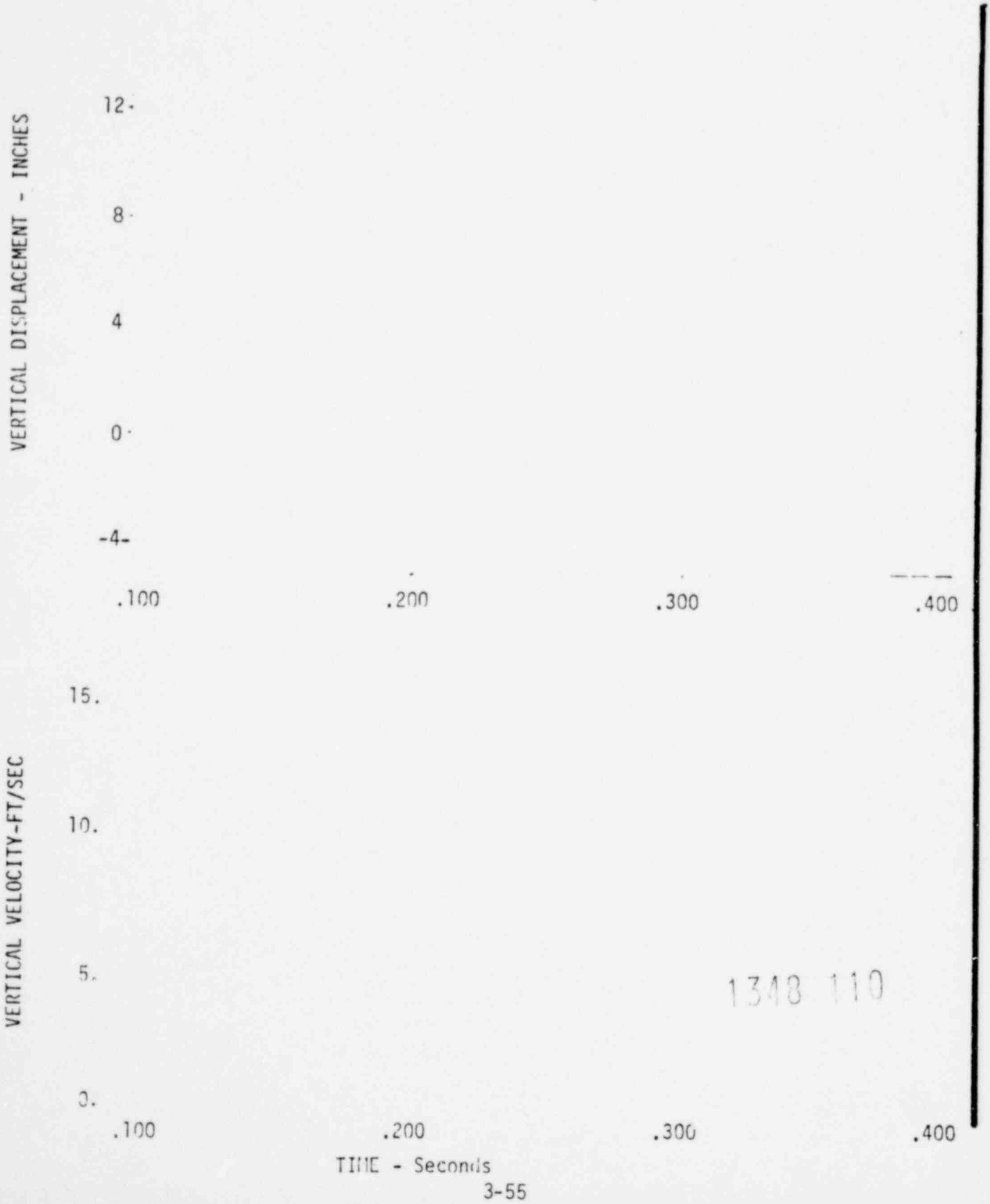


1348 109

NUCLEAR SERVICES CORPORATION

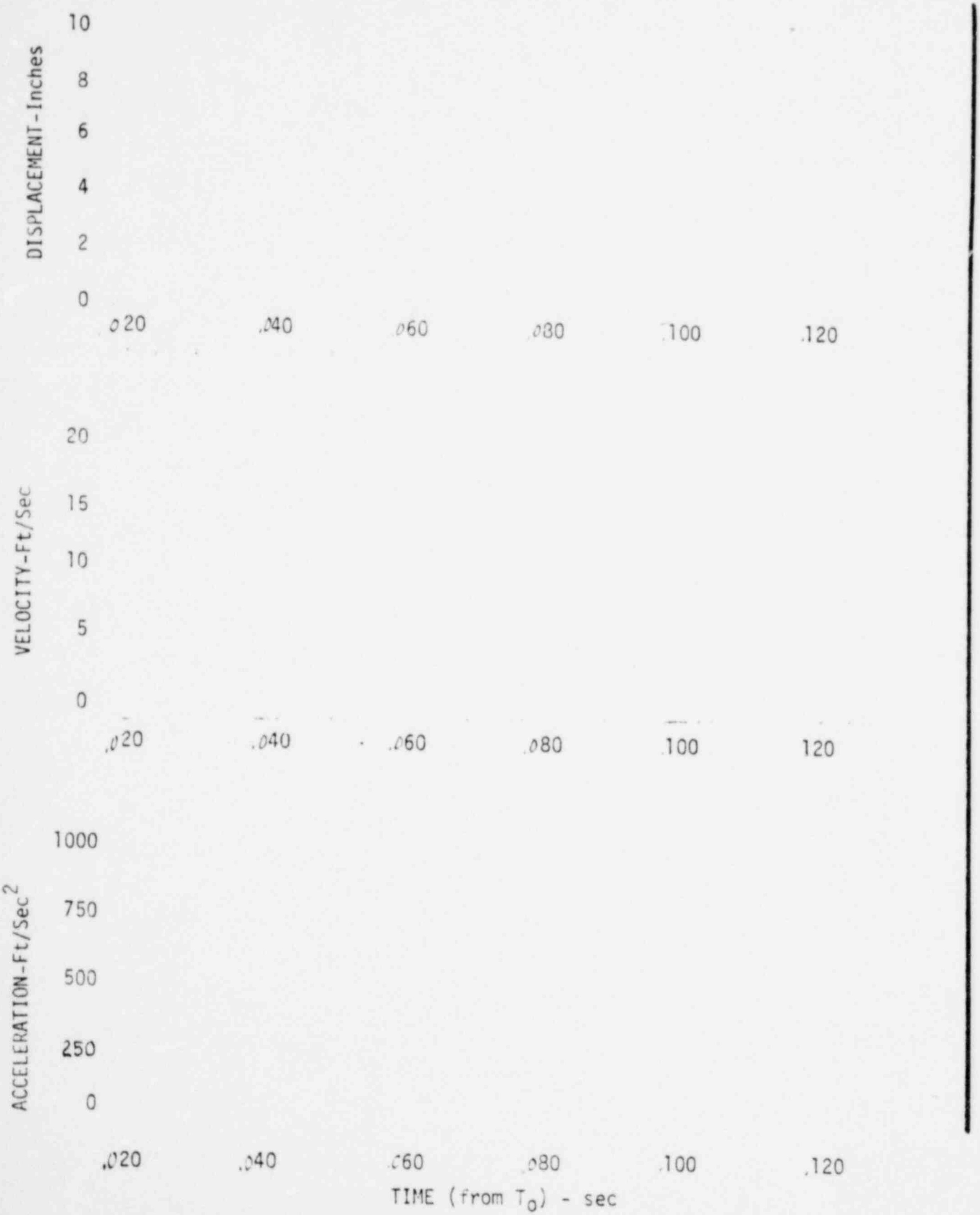
FIGURE 3-46 SIDE WINDOW DISPLACEMENT AND VELOCITY PROFILES

MONTICELLO TEST 4



NUCLEAR SERVICES CORPORATION

FIGURE 3- 47 DOWNCOMER WATER SLUG EJECTION
MONTICELLO TEST 2

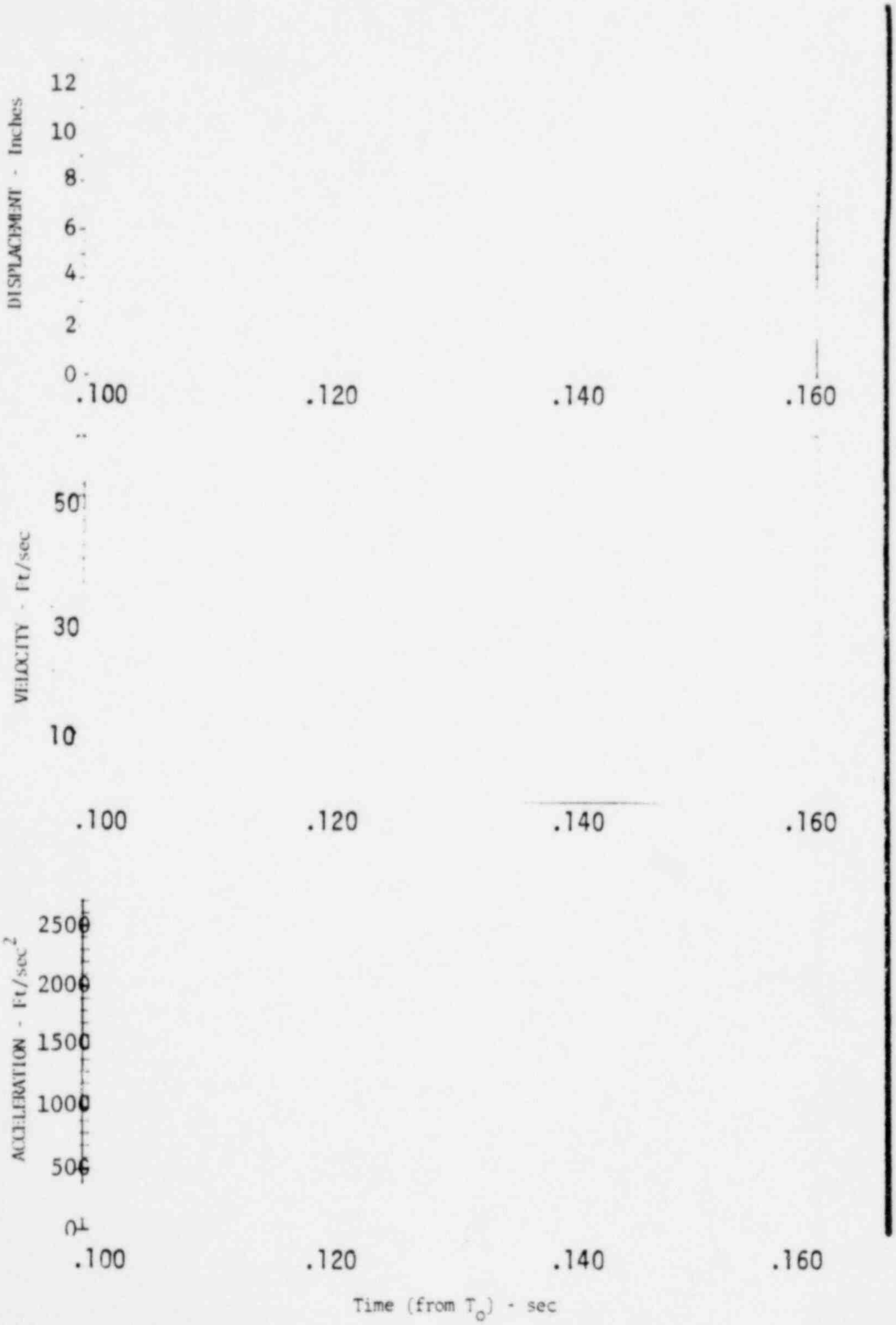


1348 111

Figure 3-48

DOWNCOMER WATER SLUG EJECTION

Monticello Test 7



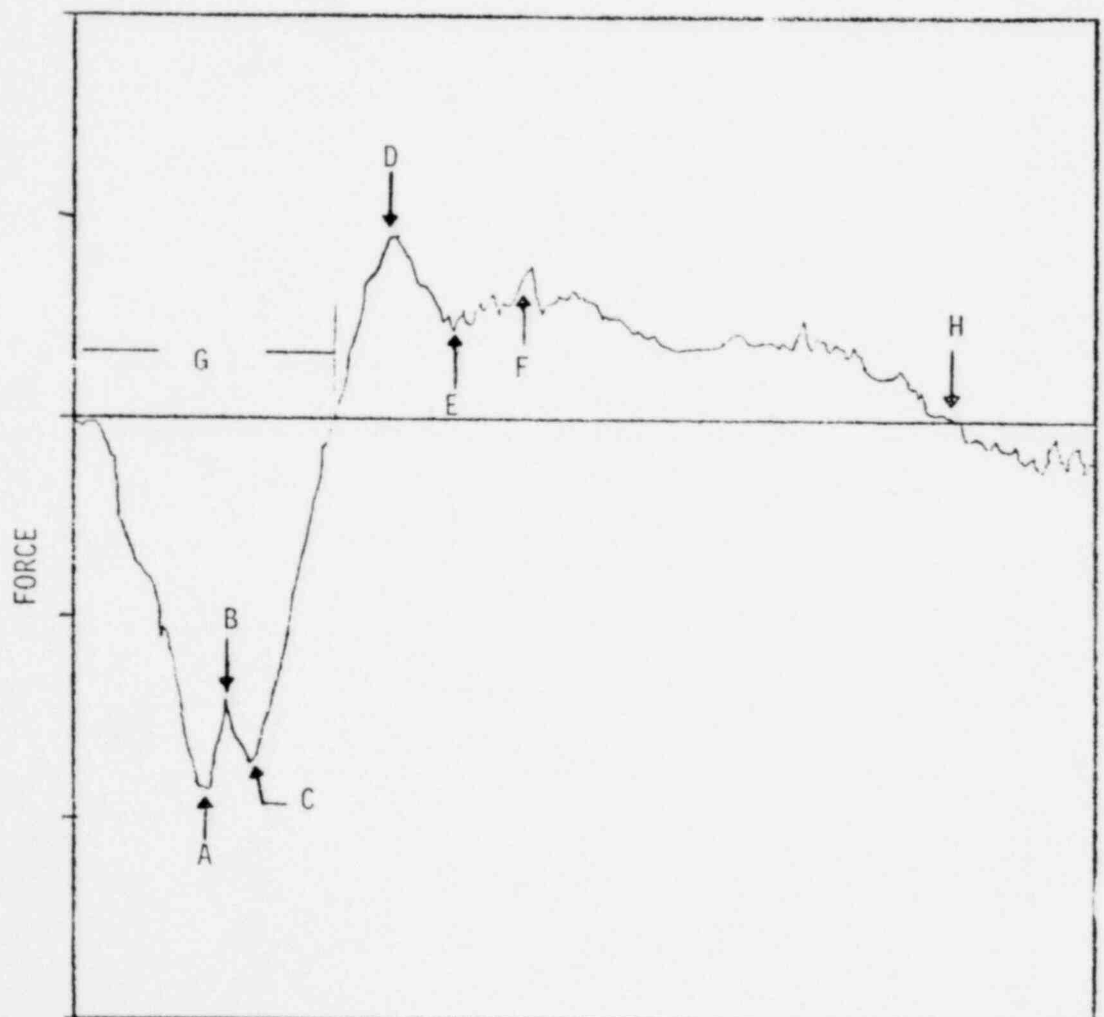
1348 112

FIGURE 3-49

ILLUSTRATION OF NET TORUS FORCE

AND ZERO FORCE CONDITIONS

A 1st Downforce Peak
B Downforce Valley
C 2nd Downforce Peak
D 1st Upforce Peak
E Upforce Valley
F 2nd Upforce Peak
G [Δt] Downforce
H Zero Force



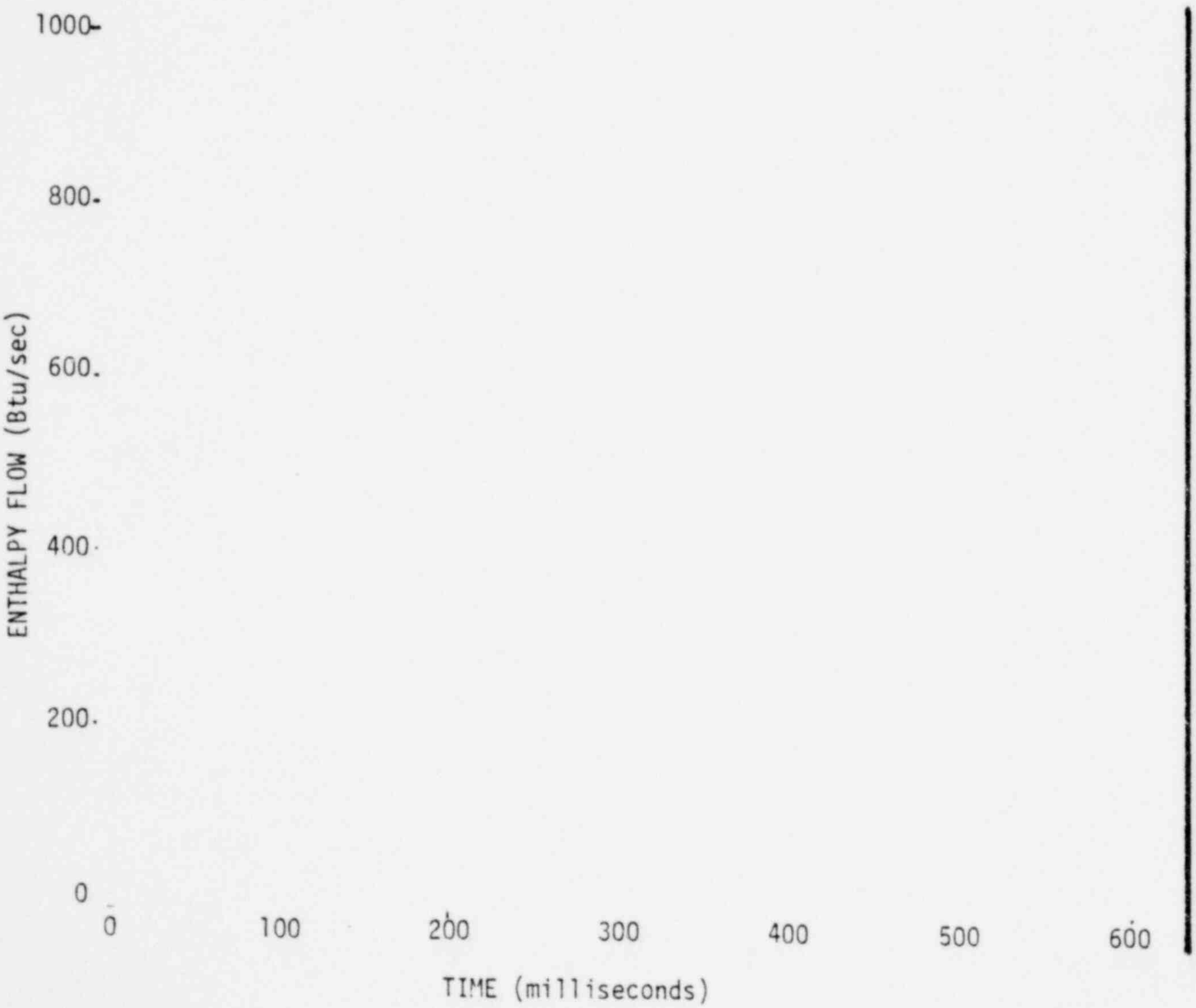
1348 113

FIGURE 3-50

EFFECT OF DRYWELL/WETWELL ΔP ON

ENTHALPY FLOW INTO POOL

Monticello Tests



1348 114

FIGURE 3-51

EFFECT OF DRYWELL/WETWELL ΔP ON

DOWNCOMER INTERNAL PRESSURE

Monticello Tests

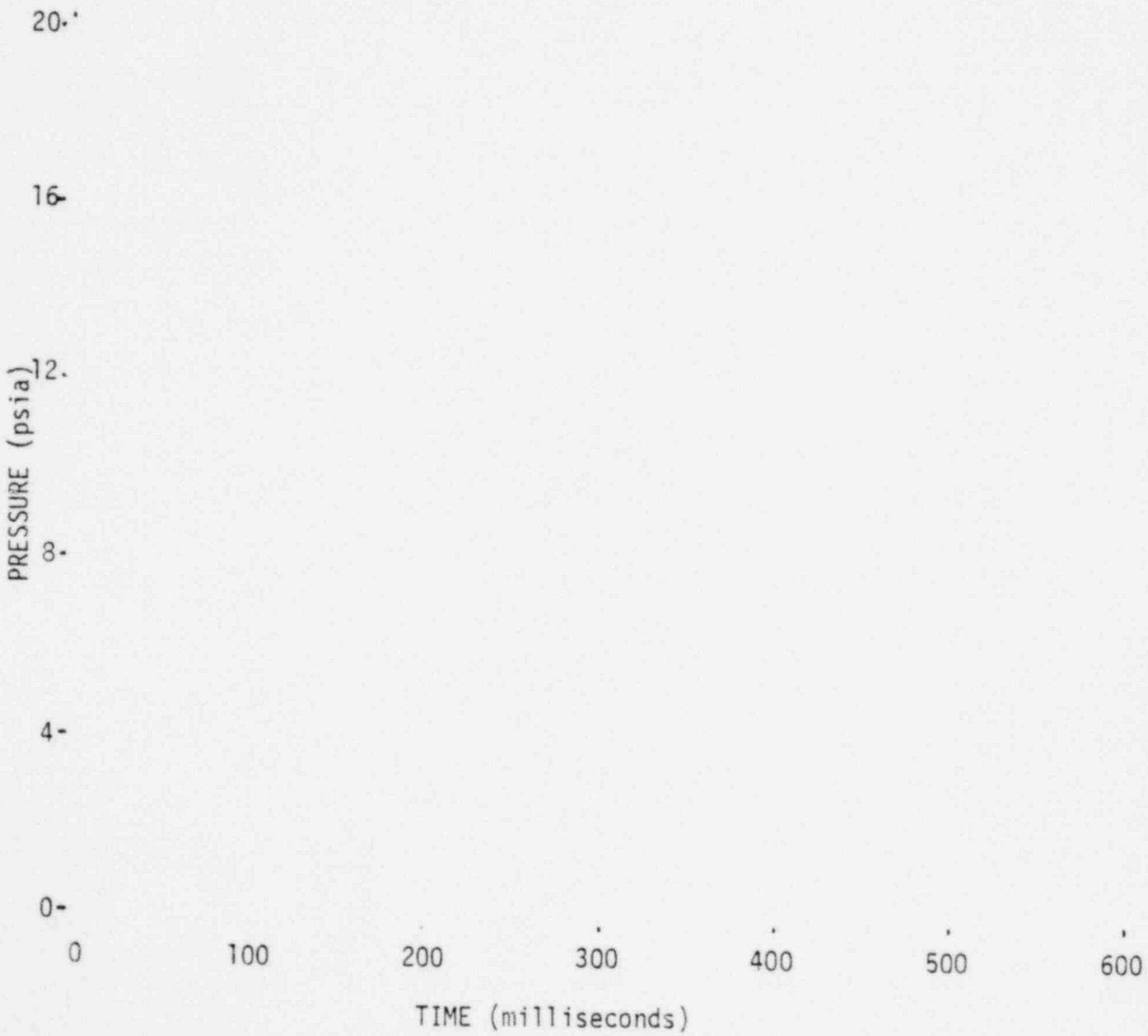
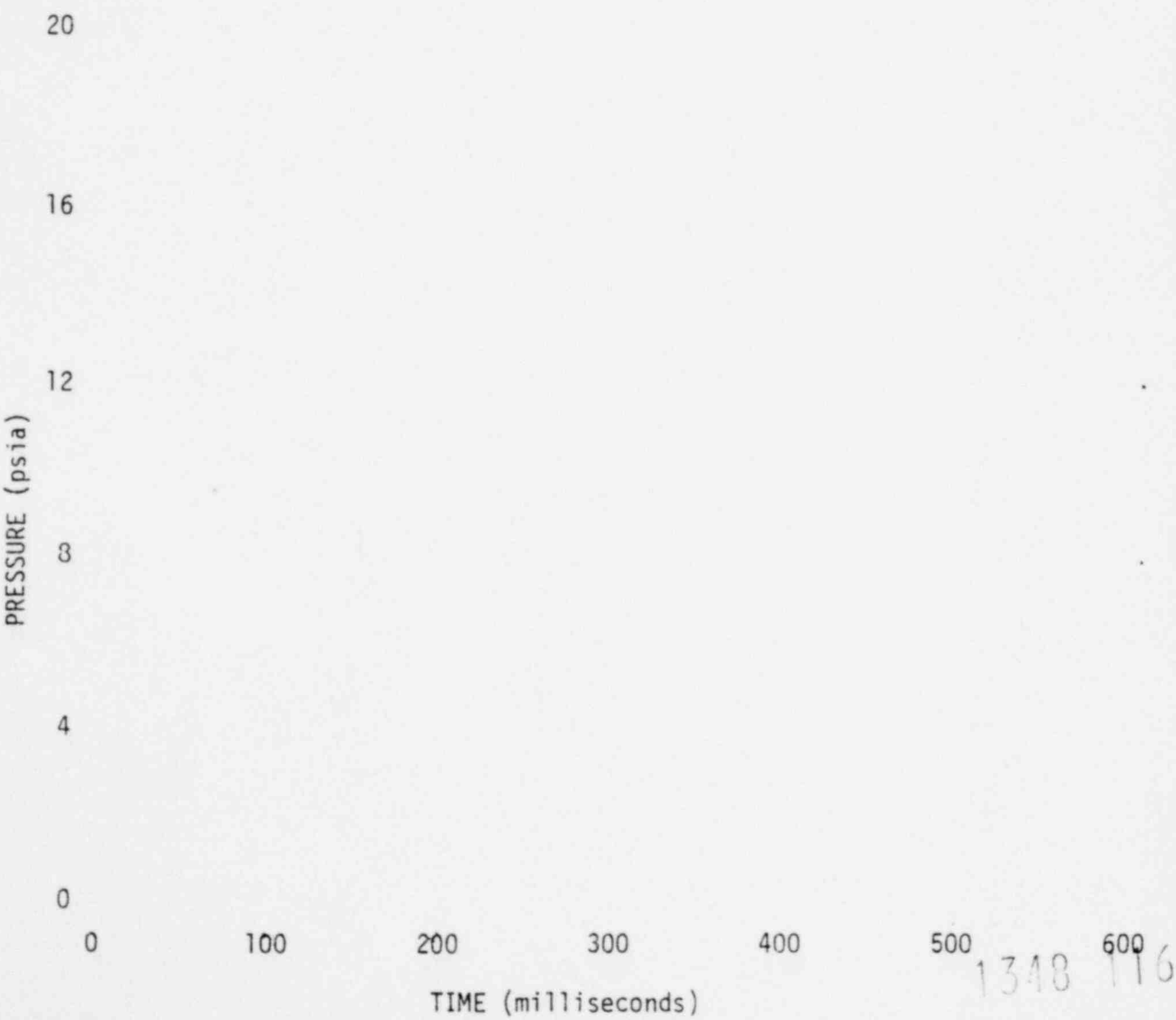


FIGURE 3-52

EFFECT OF DRYWELL/WETWELL ΔP ON POOL PRESSURE

AT 180 DEGREE AND FREESPACE PRESSURE

Monticello Tests



1348 116

TABLE 3-1
DATA FOR WETWELL VERTICAL LOADS
Task 5.5.3-2 Monticello Tests

Parameter \ Test No.		7.75" ΔP, 8.12-inch "T" Deflector (1)	(2)	(3)	(4)	Mean	Std. Dev.
T_o *(1)	(sec)						
Vent Clearing Time*	(sec)						
Peak Downforce							
Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Load Cell:							
Force	(lb)						
Time (from T_o)	(sec)						
Downforce Valley							
Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Load Cell:							
Force	(lb)						
Time (from T_o)	(sec)						
2nd Peak Downforce							
Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Load Cell:							
Force	(lb)						
Time (from T_o)	(sec)						
[Δt] Downforce Time**							
Pressure Integral	(sec)						
Corrected Pressure Integral	(sec)						
Corrected Load Cell	(sec)						
Downforce Impulse							
Pressure Integral:							
Impulse	(lb-sec)						

*Vent clearing time (from T_o) determined from the movie films.
**Time difference from T_o to time of zero downforce.
*(1) Start-of-test reference time defined as the intercept of a linear fit to the drywell pressure history with the initial drywell pressure.

1348 117

*Time at force is zero (from T_0)

TABLE 3-1 (Continued)
DATA FOR WETWELL VERTICAL LOADS (continued)

Task 5.5.3-2 Monticello Tests

Parameter \ Test No.	7.75" ΔP, 8.12-inch "T" Deflector (1)	(2)	(3)	(4)	Mean	Std. Dev.
Peak Upforce						
Pressure Integral:						
Force (lb)						
Time (from T_0) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_0) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_0) (sec)						
Upforce Valley						
Pressure Integral:						
Force (lb)						
Time (from T_0) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_0) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_0) (sec)						
2nd Peak Upforce						
Pressure Integral:						
Force (lb)						
Time (from T_0) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_0) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_0) (sec)						
Zero Force Time*						
Pressure Integral (sec)						
Corrected Pressure Integral (sec)						
Corrected Load Cell (sec)						

1348 118

TABLE 3-2

DATA FOR WETWELL VERTICAL LOADS

Task 5.5.3-2 Monticello Tests

Parameter \ Test No.	0" ΔP, 8.15-inch "T" Deflector (5)	(6)	(7)	(8)	Mean	Std. Dev.
T_o *(2) (sec)						
Vent Clearing Time* (sec)						
Peak Downforce						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
Downforce Valley						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
2nd Peak Downforce						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
[Δt] Downforce Time**						
Pressure Integral (sec)						
Corrected Pressure Integral (sec)						
Corrected Load Cell (sec)						
Downforce Impulse						
Pressure Integral:						
Impulse (lb-sec)						

*Vent clearing time (from T_o) determined from the movie films.
**Time difference from T_o to time of zero downforce.

*(2) Start-of-test reference time defined as the intercept of a linear fit to the drywell pressure history with the initial drywell pressure.

1348 119

*Time at force is zero (from T_o)
*(1) No accelerometer data for correction

TABLE 3-2 (Continued)

DATA FOR WETWELL VERTICAL LOADS (continued)

Task 5.5.3.-2 Monticello Tests

Parameter \ Test No.	0" ΔP, 8.15-inch "T" Deflector (5)	(6)	(7)	(8)	Mean	Std. Dev.
Peak Upforce						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
Upforce Valley						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
2nd Peak Upforce						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
Zero Force Time*						
Pressure Integral (sec)						
Corrected Pressure Integral (sec)						
Corrected Load Cell (sec)						

1348 120

TABLE 3-3

DATA FOR WETWELL VERTICAL LOADS

Task 5.5.3-2 Monticello Tests

Parameter \ Test No.	0" ΔP 5.60" Deflector (9)	 (10)	 3.36" Deflector (13)	 (14)	Mean	Std. Dev.
T_o *(1) (sec)						
Vent Clearing Time* (sec)						
Peak Downforce						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
Downforce Valley						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
2nd Peak Downforce						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
[Δt] Downforce Time**						
Pressure Integral (sec)						
Corrected Pressure Integral (sec)						
Corrected Load Cell (sec)						
Downforce Impulse						
Pressure Integral:						
Impulse (lb-sec)						

*Vent clearing time (from T_o) determined from the movie films.

**Time difference from T_o to time of zero downforce.

—No significant downforce valley or 2nd peak downforce.

*(1) Start-of-test reference time defined as the intercept of a linear fit to the drywell pressure history with the initial drywell pressure.

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*Time at force is zero (from T_o)

TABLE 3-3 (Continued)

DATA FOR WETWELL VERTICAL LOADS (continued)

Task 5.5.3-2 Monticello Tests

Test No. / Parameter	0" ΔP 5.60" Deflector (9)	0" ΔP 5.60" Deflector (10)	0" ΔP 3.36" Deflector (13)	0" ΔP 3.36" Deflector (14)	Mean	Std. Dev.
Peak Upforce						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
Upforce Valley						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
2nd Peak Upforce						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
Zero Force Time*						
Pressure Integral (sec)						
Corrected Pressure Integral (sec)						
Corrected Load Cell (sec)						

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TABLE 3-4

DATA FOR WETWELL VERTICAL LOADS

Task 5.5.3-2 Monticello Tests

Parameter / Test No.		11.2" ΔP 5.60" Deflector (11)	11.2" ΔP 5.60" Deflector (12)	11.2" ΔP 3.36" Deflector (15)	11.2" ΔP 3.36" Deflector (16)	Mean	Std. Dev.
T_o *(1)	(sec)						
Vent Clearing Time*	(sec)						
Peak Downforce							
Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Load Cell:							
Force	(lb)						
Time (from T_o)	(sec)						
Downforce Valley							
Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Load Cell:							
Force	(lb)						
Time (from T_o)	(sec)						
2nd Peak Downforce							
Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Pressure Integral:							
Force	(lb)						
Time (from T_o)	(sec)						
Corrected Load Cell:							
Force	(lb)						
Time (from T_o)	(sec)						
[Δt] Downforce Time**							
Pressure Integral	(sec)						
Corrected Pressure Integral	(sec)						
Corrected Load Cell	(sec)						
Downforce Impulse							
Pressure Integral:							
Impulse	(lb-sec)						

*Vent clearing time (from T_o) determined from the movie films.
**Time difference from T_o to time of zero downforce.
— No significant downforce valley or 2nd peak downforce.
*(1) Start-of-test reference time defined as the intercept of a linear fit to the drywell pressure history with the initial drywell pressure

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*Time at force is zero (from T_o)

TABLE 3-4 (Continued)
DATA FOR WETWELL VERTICAL LOADS (continued)

Task 5.5.3-2 Monticello Tests

Parameter \ Test No.	11.2" ΔP 5.60" Deflector (11)	(12)	3.36" Deflector (15)	(16)	Mean	Std. Dev.
Peak Upforce						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
Upforce Valley						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
2nd Peak Upforce						
Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Pressure Integral:						
Force (lb)						
Time (from T_o) (sec)						
Corrected Load Cell:						
Force (lb)						
Time (from T_o) (sec)						
Zero Force Time*						
Pressure Integral (sec)						
Corrected Pressure Integral (sec)						
Corrected Load Cell (sec)						

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TABLE 3-5

DATA FOR VENT HEADER IMPACT LOADS

Task 5.5.3-2 Monticello Tests

*(2) Offset 6" from pool centerline
*(3) Start-of-test reference time
* Based on impact pressure measurements
** At start of the first impact pressure recorded
*** Pipe with structural "T"s

Parameter \ Test No.	7.75" ΔP, 8.15 inch "T" Deflector *** (1)	(2)	(3)	(4)	Mean	Std. Dev.	0" ΔP, 8.15 inch "T" Deflector *** (5)	(6)	(7)	(8)	Mean	Std. Dev.
T_o *(3) (sec)												
Vent Header Impact Pressure Integral:												
Maximum Force (lb)		--Negligible vent header impact--						--Negligible vent header impact--				
Impulse (lb-sec)												
Duration* (sec)												
Load Cell Corrected:												
Maximum Force (lb)												
Impulse (lb-sec)												
Duration (sec)												
Pool Surface Velocity*(2) (ft/sec)												
Time (from T_o)** (sec)												

*Based on impact pressure measurements

**At start of the first impact pressure recorded.

†Start of Reference time

TABLE 3-6

DATA FOR VENT HEADER IMPACT LOADS

Task 5.5.3-2 Monticello Tests

Test No. / Parameter	0" ΔP						11.2" ΔP					
	5.60" Deflector		3.36" Deflector		Mean Values		5.60" Deflector		3.36" Deflector		Mean Values	
	(9)	(10)	(13)	(14)	9 10	13 & 14	(11)	(12)	(15)	(16)	11 & 12	15 & 16
T_0 † (sec)												
Vent Header Impact												
Pressure Integral:												
Maximum Force (lb)												
Impulse (lb-sec)												
Duration* (sec)												
Load Cell Corrected:												
Maximum Force*** (lb)												
Impulse (lb-sec)												
Duration (sec)												
Pool Surface Velocity (ft/sec)												
Time (from T_0)** (sec)												

*** Represents the peak value of noisy data, mean value would be significantly lower.

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4.0 CONCLUSIONS

The following conclusions and observations are made from analysis of test results:

- The QSTF has successfully modeled the scaled average cell geometric and hydrodynamic conditions for the seventeen Mark I plant configurations tested*. The facility and instrumentation achieved the primary objective of the test program to provide two-dimensional subscale pool swell data for input to the Mark I Load Definition Report.

- Deflectors provide significant mitigation of vent header impact. Small deflectors significantly reduce peak vent header impact pressures and deflectors with side extensions (structural angles or "T"s) whose total width is roughly half the width of the vent header virtually eliminate vent header impact.

- Peak torus downforce and upforce decrease as the initial drywell/wetwell ΔP is increased. Peak vent header impact force slightly decreases as the ΔP is increased, but a deflector is more effective in mitigating the vent header impact. Reduced submergence is also effective in mitigating the pool swell loads.

- The decision to perform plant unique tests was justified. Although good repeatability has been observed for sequential tests of individual plants, the wide variations in hydrodynamic parameters among the plants tested have led to a considerable spread in the total program data. A limited data correlation was performed and successfully demonstrated overall consistency of the Plant Unique Tests.

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*Supplementary tests are being performed for several Mark I Utilities to evaluate additional hydrodynamic conditions.

5.0 REFERENCES

1. "Mark I Containment Program 1/4-Scale Pressure Suppression Pool Swell Test Program: LDR Load Tests - Generic Sensitivity, Task Number 5.5.3, Series 1," General Electric Company, NEDO-23545, June 1979.

2. "Mark I Containment Program 1/4-Scale Pressure Suppression Pool Swell Test Program: Scaling Evaluation," by D. L. Galyardt, C. G. Hayes, and S. L. Kushman, General Electric Company, NEDO-21627, March 1978.

3. "Mark I Containment Program 1/4-Scale Pressure Suppression Pool Swell Test Program: Download Oscillation Evaluation, Task Number 5.5.2," General Electric Company, NEDO-21943, June 1979.

4. "Loads and Their Application for Torus Support System Evaluation," General Electric Company, NEDC-20989, June 1976.

5. "Final Air Test Results for the 1/5-Scale Mark I Boiling Water Reactor Pressure Suppression Experiment," Lawrence Livermore Laboratory, Report No. UCRL-52371, October 31, 1977.