ENCLOSURE 3

April 21/22, 1980

R. Palaniswamy

DOWNCOMER LOADS DURING CONDENSATION OSCILLATION

OVERALL PLAN

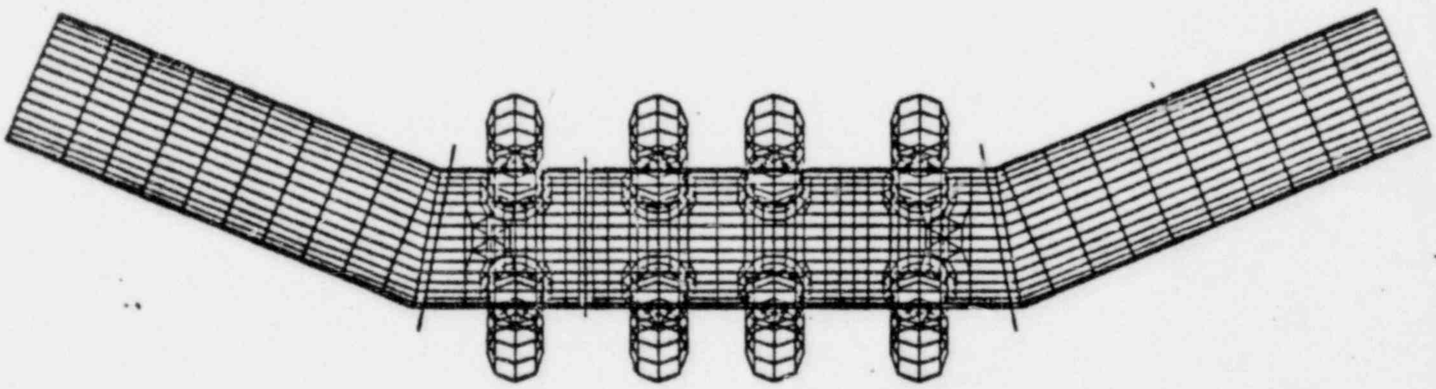
- Finite Element Model of FSTF Header/Downcomers
- Verification Based On Downcomer Jacking Tests and Snap Tests
- Postulation of Load Definition (Based on Pressure Data Measured In Test M-8)
- Dynamic Analysis For Postulated Loading
- Correlation of Dynamic Analysis and Test Data
- Load Definition

BECHTEL

COMPUTER MODEL

- NASTAN Computer Program
- Full Model of Header (End of Bellows to End of Bellows)
- Shell Elements (Quad 4 & Tria 3)
- Vacuum Breaker Flanges and Stiffening Ring Included
- Diameter of Vent Is 58" Compared to Actual of 57"
- Configurations
  - Untied Downcomers for Jacking Test
  - Tied Downcomers (Compression & Tension) for 'SNAP' Test
  - Test M8 Configuration for CO Test Correlation
    - . Downcomers 1 & 2 and 3 & 4 With Compression-Tension Ties
    - . Downcomers 5 & 6 Untied
    - . Downcomers 7 & 8 With "Tension Only" Tie
  - Effective Mass of Water Simulating Condition During CO
  - Damping From 'SNAP' Test

DOWNCOMER LOADS
DURING CONDENSATION OSCILLATION

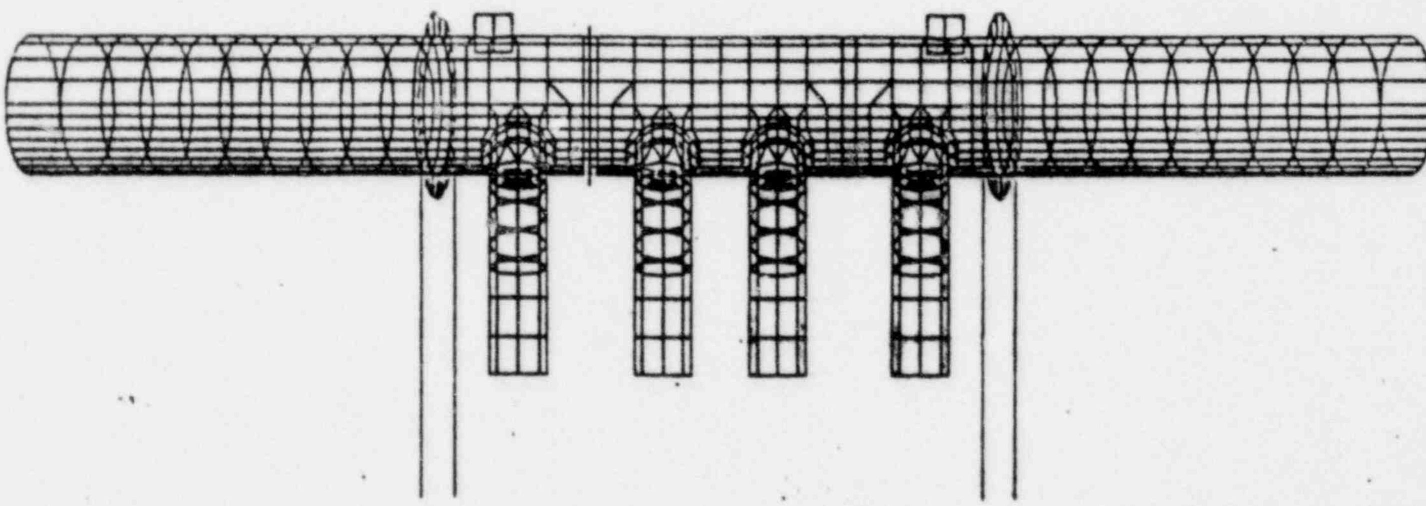


COMPUTER PLOT OF
FSTF VENT SYSTEM

PLAN

FULL SCALE TEST FACILITY WITH EIGHT DOWNCOMERS - REV 3
UNDEFORMED VIEW
UNDEFORMED SHAPE

DOWNCOMER LOADS
DURING CONDENSATION OSCILLATION



COMPUTER PLOT OF
FSTF VENT SYSTEM

<u>ELEVATION</u>

[illegible] FACILITY WITH EIGHT DOWNCOMERS - REV 3
UNDEFORMED SHAPE

TESTS ON THE FSTF DOWNCOMERS

- Static
  - Push Adjacent Downcomers Apart Or Pull Them Together. Measure Deflection.
  - Downcomers Untied
- Snap Test
  - Pull A Downcomer Or Downcomer Pair To One Side And Release
  - Measure Transient Response
  - Determine Frequencies
  - Determine Damping
  - Downcomers Tied And Untied
  - 3 Cases: Dry, Water Outside Downcomers Only, Water Both Inside And Outside Downcomers

FSTF SNAP TEST

"QUICK-LOOK" RESULTS

NATURAL FREQUENCIES AND DAMPING

TEST NO.	TEST CONDITION*	D/C NO.	AVERAGE ω_D (Hz)	DAMPING RATIO ξ (%)
SD1	UDD	6	8.0	2
SD2	UDD	8	10.2	2
1	UDF	6	5.6	10
2	UDF	8	7.1	6
3	TDF	6	3.4	7
4	TDF	8	5.8	5
5	TFF	6	3.0	7
6	TFF	8	5.0	6
7	TDD	6	5.0	2
8	TDD	8	7.6	2

* U = UNTIED T = TIED

D = DRY F = FLOODED

E.G. UDD = UNTIED, DRY DOWNCOMER, DRY WETWELL

MODEL VERIFICATION

- Static Verification Runs
  - Jacking Between Downcomers 5 & 6 (Test #7)
  - Jacking Between Downcomers 6 & 8 (Test #6)
  - Jacking Between Downcomers 7 & 8 (Test #8)
  - Correlate On Deflection

- Dynamic Verification Runs
  - 'SNAP' Test With Water

DOWNCOMER LOADS DURING

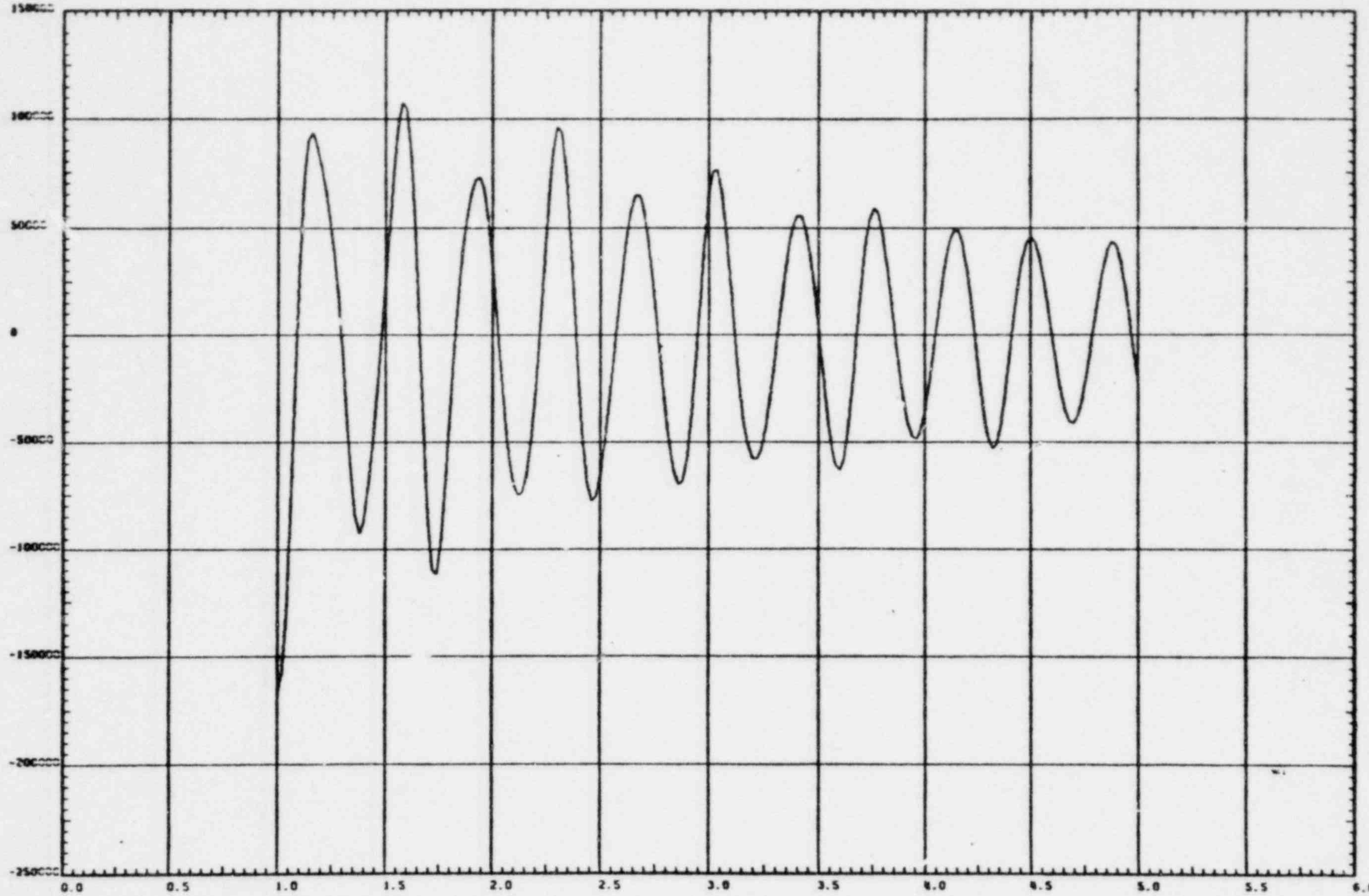
CONDENSATION OSCILLATION

MODEL VERIFICATION

	DESCRIPTION	COMPARISON OF RESULTS		REMARKS
		TEST	ANALYSIS	
				CALIBRATION TESTS
STATIC ANALYSIS	PUSH 5 & 6	0.55 inch	0.65 inch	TEST NO. 7
	PUSH 6 & 8	0.09 inch	0.11 inch	TEST NO. 6
	PUSH 7 & 8	0.45 inch	0.51 inch	TEST NO. 8

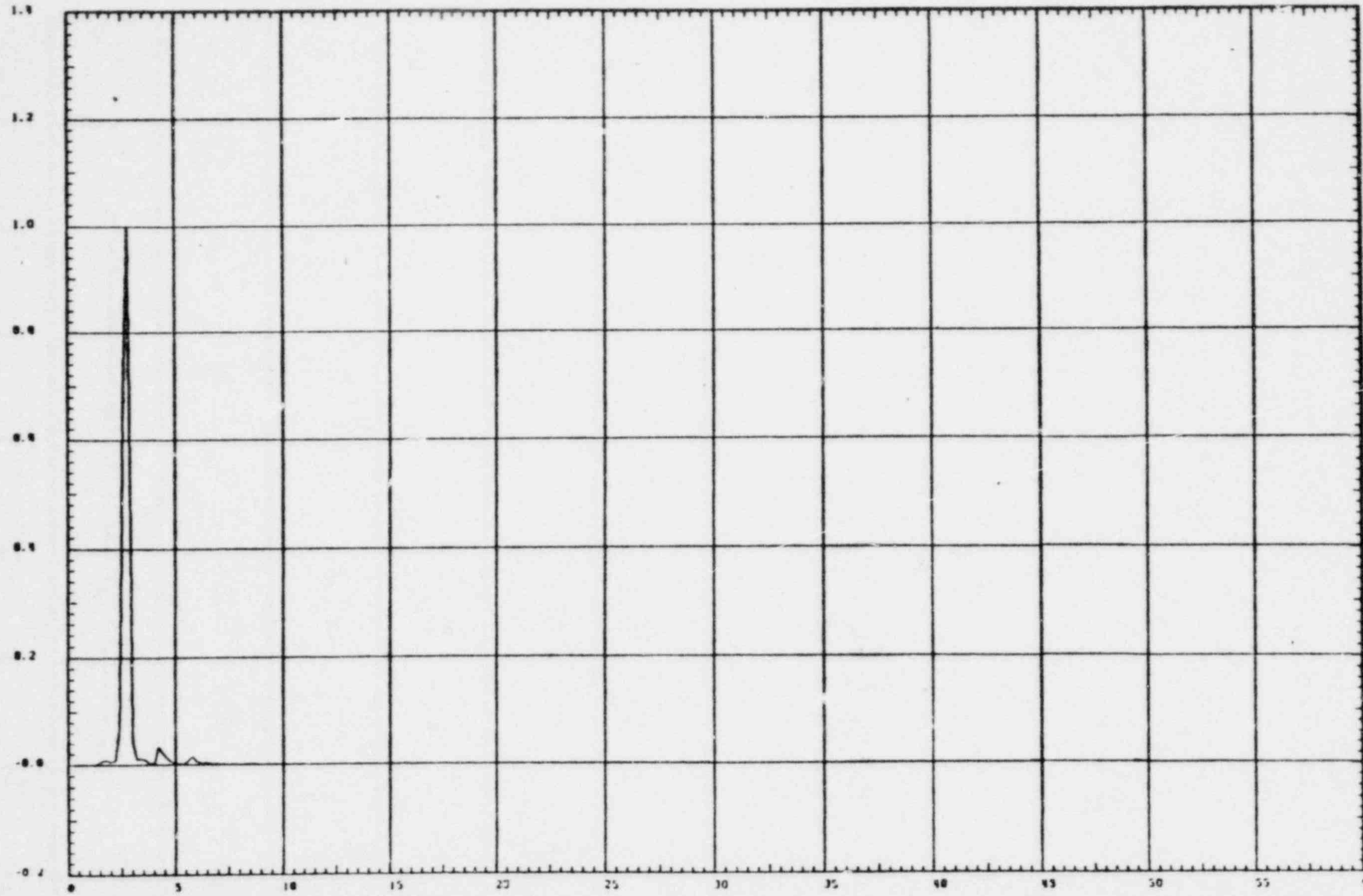
FSTF SNAP TEST SIMULATION

CALCULATED HOOP STRAN TIME-HISTORY AT D/C 6



FSTF SNAP TEST SIMULATION

PSD FOR CALCULATED HOOP STRAN TIME-HISTORY AT D/C 6 (S5911)



DYNAMIC TEST CORRELATION RUNS

- Postulated Load Definition (Test M-8 From 25-30 Seconds)

  1.5 psi Static Differential Pressure

  ± 2.5 psi @5.5 Hz In Header

  ± 5 psi @5.5 Hz In Downcomer

- Dynamic Analysis

  - Harmonic Analysis (5.5 Hz Loading)

  - "Two To One" Pressure In Downcomers and Header

  - Correlation With M-8 Test Data (Strains On The Header At The Intersection)

DOWNCOMER LOADS DURING

CONDENSATION OSCILLATION

SUMMARY OF RESULTS

GAUGE LOCATION	LOAD	EXTREME FIBER HOOP STRAIN		REMARKS
		TEST	MASS OF EXTERNAL DISPLACED WATER = D/C sub ANALYSIS	
S-5911 (UNTIED D/C) AT THE VENTHEADER NEAR D/C 6	2.5 PSI IN HEADER 5.0 PSI IN DOWNCOMER FREQUENCY = 5.5 Hz	1.70×10^{-3}	5.40×10^{-3}	2% Damping
			3.29×10^{-3}	6% Damping
S-5921 (TIED D/C) AT THE VENT NEAR D/C 8		4.00×10^{-4}	9.54×10^{-4}	2% Damping
			5.45×10^{-4}	6% Damping

CONCLUSIONS

- Static Jacking Test Verification Runs Compare Well With Test Data

- Modal Analysis Predicts The Measured Frequencies Well

- Postulated Load Definition With 6% Damping Overpredict

  - Tied Downcomer Strains By 35%

  - Untied Downcomer Strains By 95%

INTENDED LOAD SPECIFICATION

(IN LIEU OF LDR SECTIONS 4.4.3 AND 4.4.4)

- LOAD DEFINITION
  - 1.5 PSI STATIC DIFFERENTIAL PRESSURE
  - ± 2.5 PSI @ 5.5 HZ IN HEADER
  - ± 5.0 PSI @ 5.5 HZ IN DOWNCOMERS
  - ALL PRESSURES IN PHASE
- NO OUT OF PHASE PRESSURE OR LATERAL LOAD
- MASS OF EXTERNAL DISPLACED WATER
- 6% DAMPING

MARK I POOL SWELL LOADS

QUARTER SCALE TESTS 1978-79

NRC REVIEW

COMPRESSIBILITY STUDY 1979

NRC REVIEW

REPORT NEDE-24778-P 1/80

NRC REVIEW/QUESTIONS 4/80

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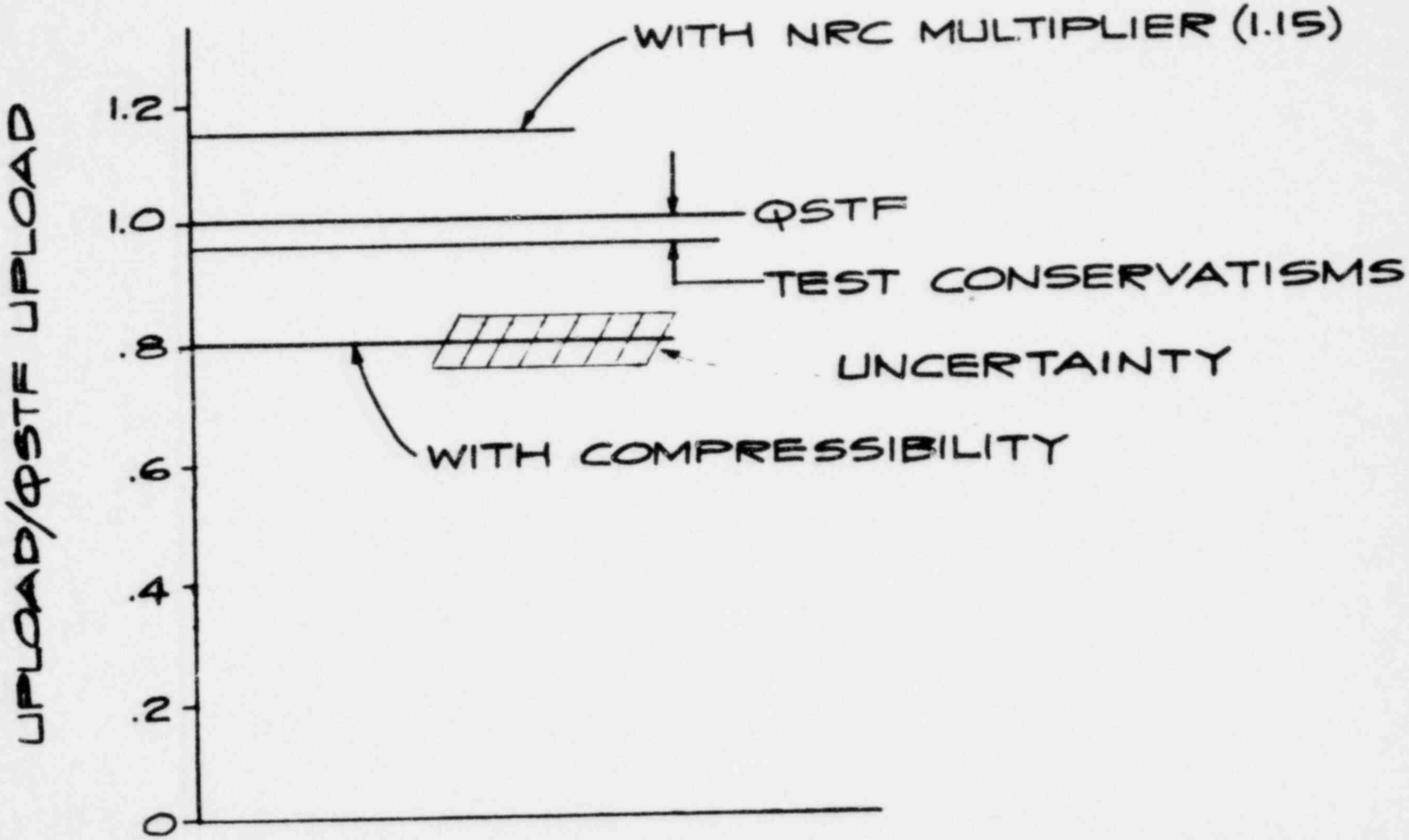
NRC/BROOKHAVEN CONCERNS

- $\Delta t / \Delta x$ EXCESSIVE
- LINEAR PROPERTY VARIATION
- FS Δt NON-CONSERVATIVE
- NODALIZATION INFO

ACUREX Corporation

UPLOAD PERSPECTIVE



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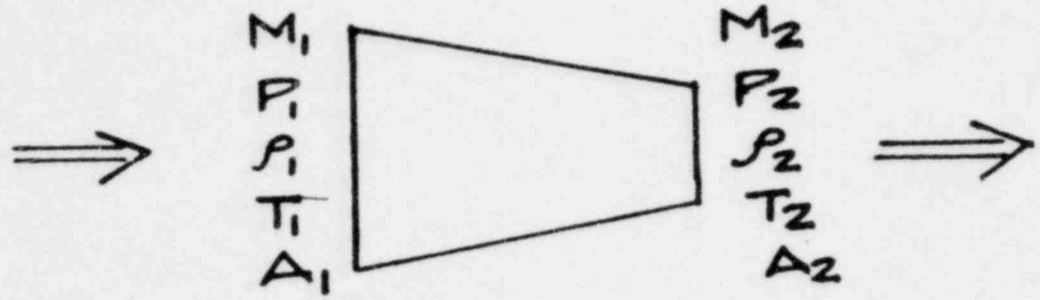
ISENTROPIC NOZZLE

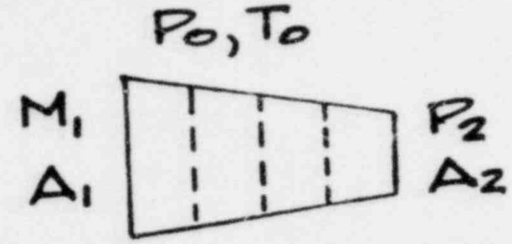


$$u_i^2 - u_{i-1}^2 \stackrel{?}{=} -\left(\frac{1}{\rho_i} + \frac{1}{\rho_{i-1}}\right)\left(P_i - P_{i-1}\right)$$

- $M_1 = .05$, $M_2 = .6$
  $\Rightarrow$ .6% DISCREPANCY

- $M_1 = .06$, $M_2 = 1.0$
  $\Rightarrow$ 4.2% DISCREPANCY

ISENTROPIC NOZZLE



FULL SCALE DOWNCOMER ENTRANCE

$M_1 = .2 \quad M_2 = .4 \quad P_2 = 27.6 \quad T_0 = 700$

	2 NODES	3 NODES	5 NODES	TABLE
M_1	.1998	.1998	.1998	.20
M_2	.3995	.3995	.3995	.40
P_1	29.9887	29.9898	29.9902	30.00
$\frac{P_1 - P_{1\,TABLE}}{P_{1\,TABLE} - P_2}$	-.0048	-.0043	-.0041	0.

ISENTROPIC NOZZLE

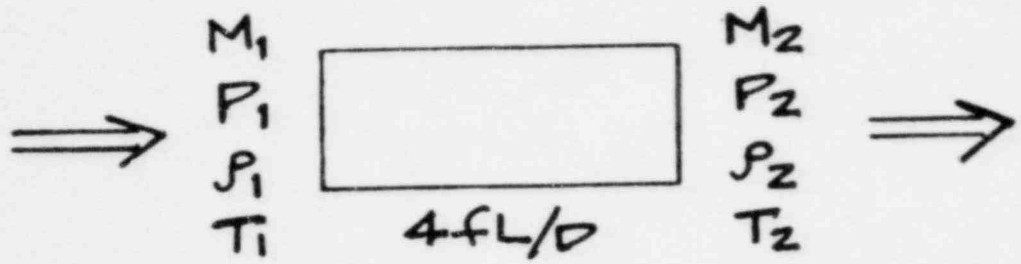
FULL SCALE VENT ENTRANCE

$M_1 = 0.$ $M_2 = .2$ $P_2 = 30.$ $T_0 = 706.$

	2 NODES	3 NODES	5 NODES	TABLE
M_1	~ 0	~ 0	~ 0	0.
M_2	.2001	.2001	.2001	.20
P_1	30.8483	30.8483	30.8483	30.8483
$\frac{P_1 - P_{1\,TABLE}}{P_{1\,TABLE} - P_2}$	<.0001	<.0001	<.0001	0.

ACUREX Corporation

FANNO FLOW

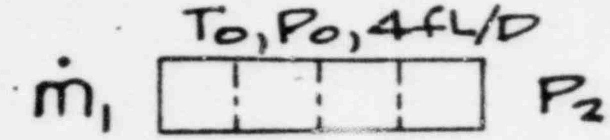


$$\left(U_i^2-U_{i-1}^2\right)+\frac{1}{2}\left(U_i^2+U_{i-1}^2\right)\left(\frac{4fL}{D}\right) \stackrel{?}{=} -\left(\frac{1}{\rho_i}+\frac{1}{\rho_{i-1}}\right)\left(P_i-P_{i-1}\right)$$

M_1	M_2	4fL/D	DISCREPANCY
.2	.25	6.05	2.3%
.25	.60	8.0	25%

ACUREX Corporation

FANNO FLOW



QSTF DOWNCOMER ORIFICE

$M_1 = .2$ $M_2 = .3$ $4fL/D = 9.2$ $T_o = 645$ $P_2 = 5.3$

	2 NODES	3 NODES	5 NODES	TABLE
M_1	.1946	.1989	.1998	.20
M_2	.3030	.3003	.2997	.30
P_1	8.2455	8.0390	7.994	8.0
$\frac{P_1 - P_{1\,TABLE}}{P_{1\,TABLE} - P_2}$	+.0912	+.0145	−.0022	0.

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FANNO FLOW

QSTF VENT ORIFICE

$M_1 = .2 \quad M_2 = .25 \quad 4fL/D = 6.05 \quad T_0 = 530. \quad P_2 = 11.97$

	2 NODES	3 NODES	5 NODES	TABLE
M_1	.1989	.1996	.1998	.2
M_2	.2500	.2497	.2496	.25
P_1	15.0662	15.0057	14.9913	15.00
$\frac{P_1 - P_{1\,TABLE}}{P_{1\,TABLE} - P_2}$	+.0219	+.0019	−.0029	0.

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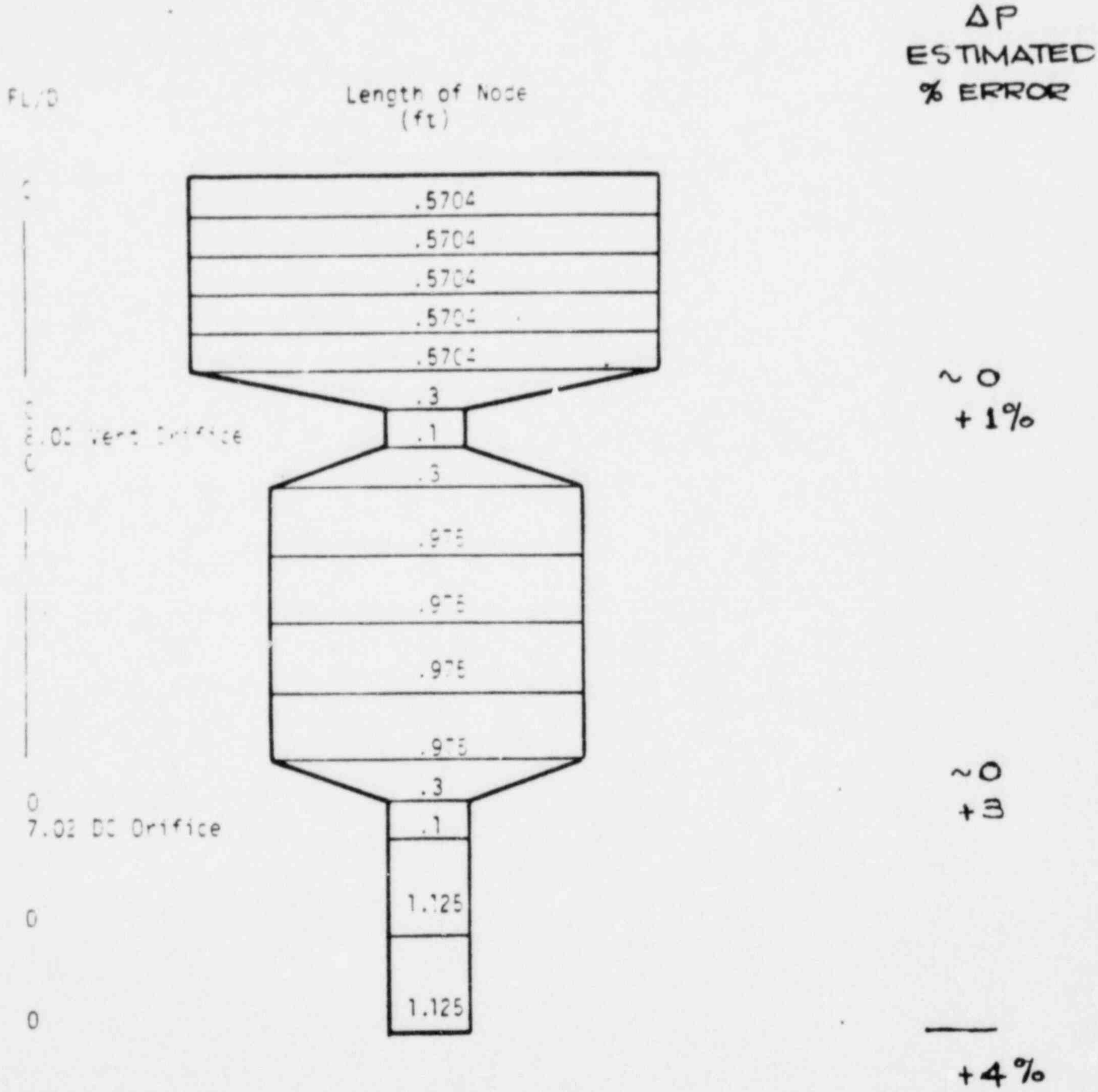


Figure 7-1. Nodal system -- QSTF "Perfect".

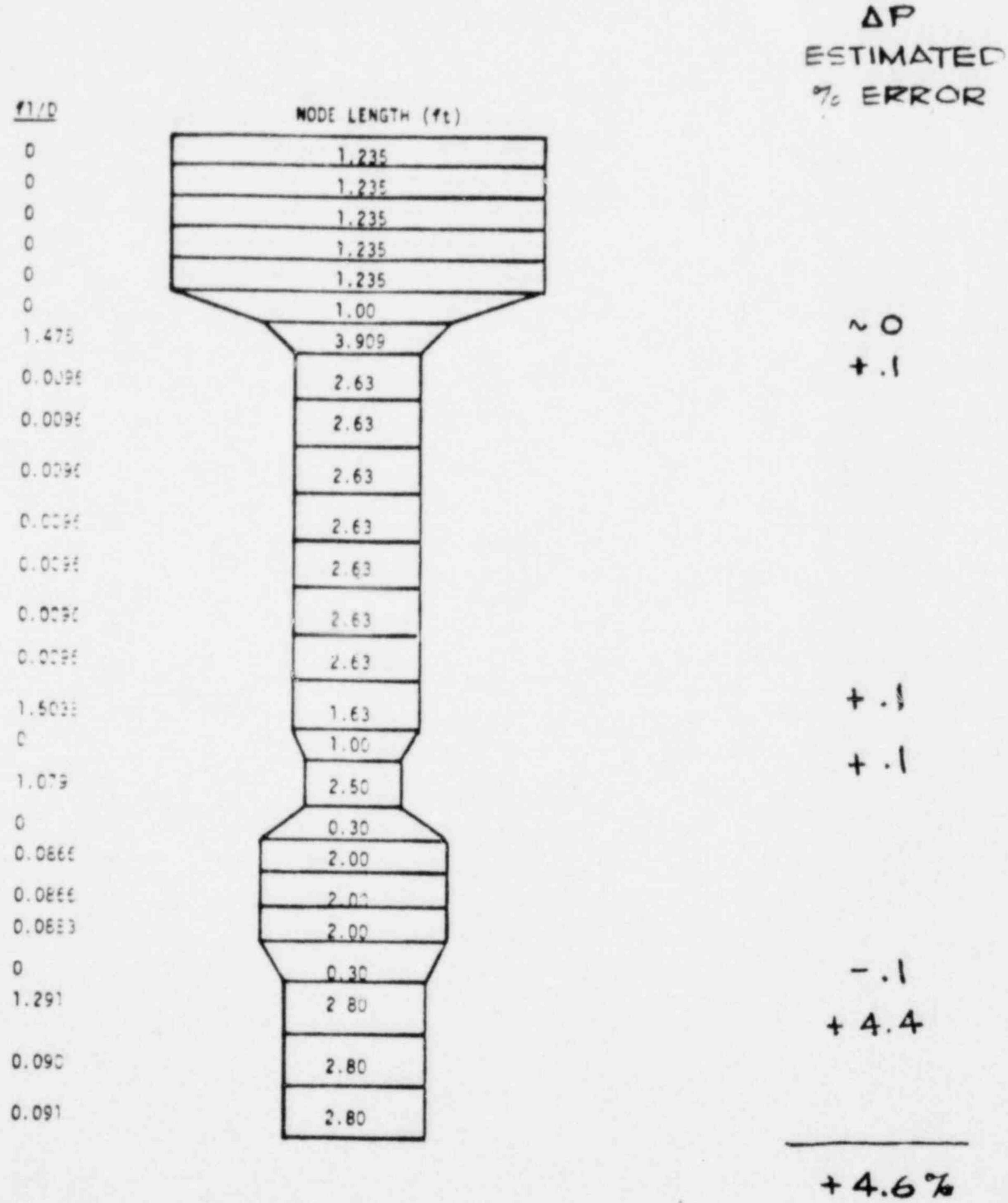


Figure 7-2. Nodal system -- full scale.

11

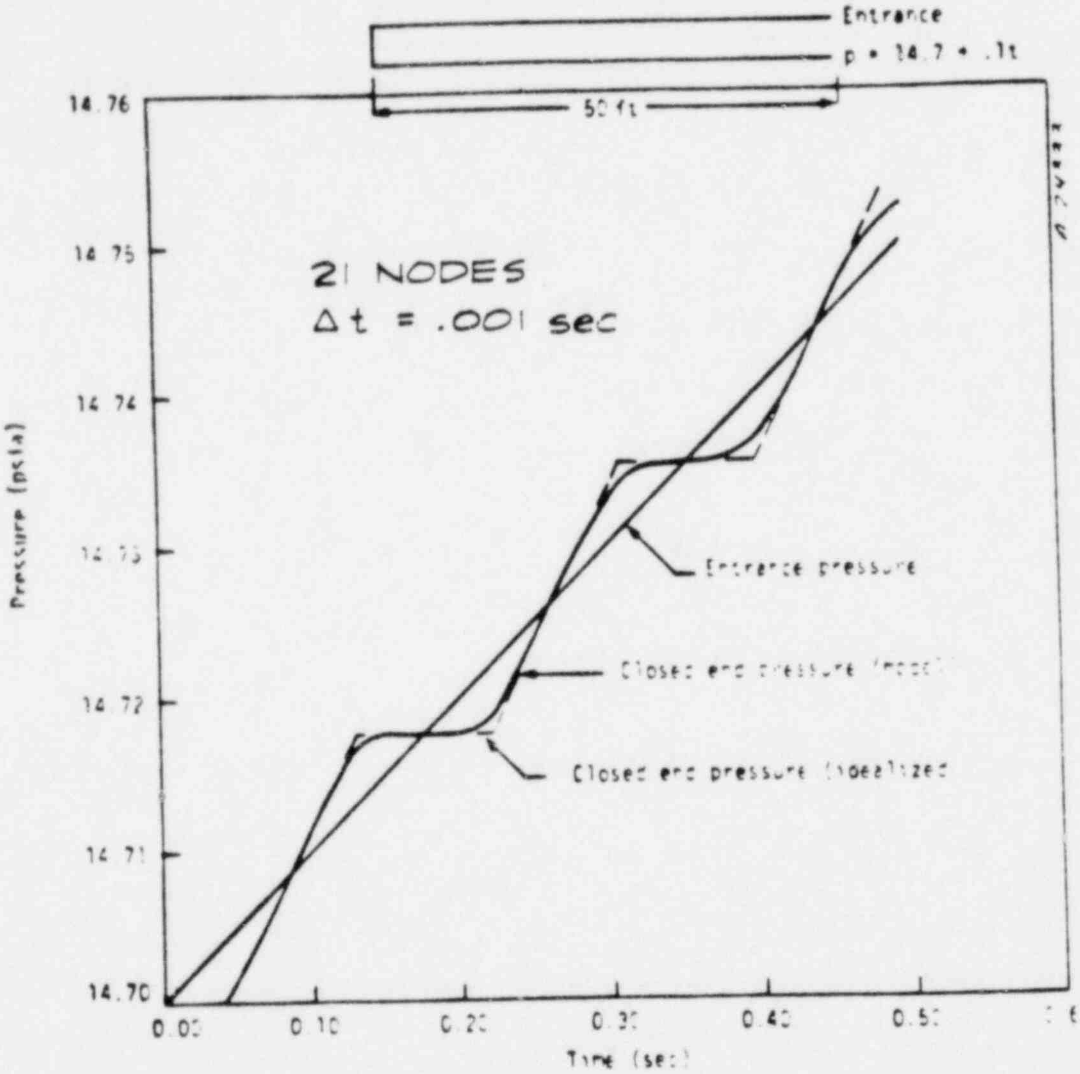


Figure 4-2. Test Case 3 -- transient ramp pressure at entrance to dead-end pipe.

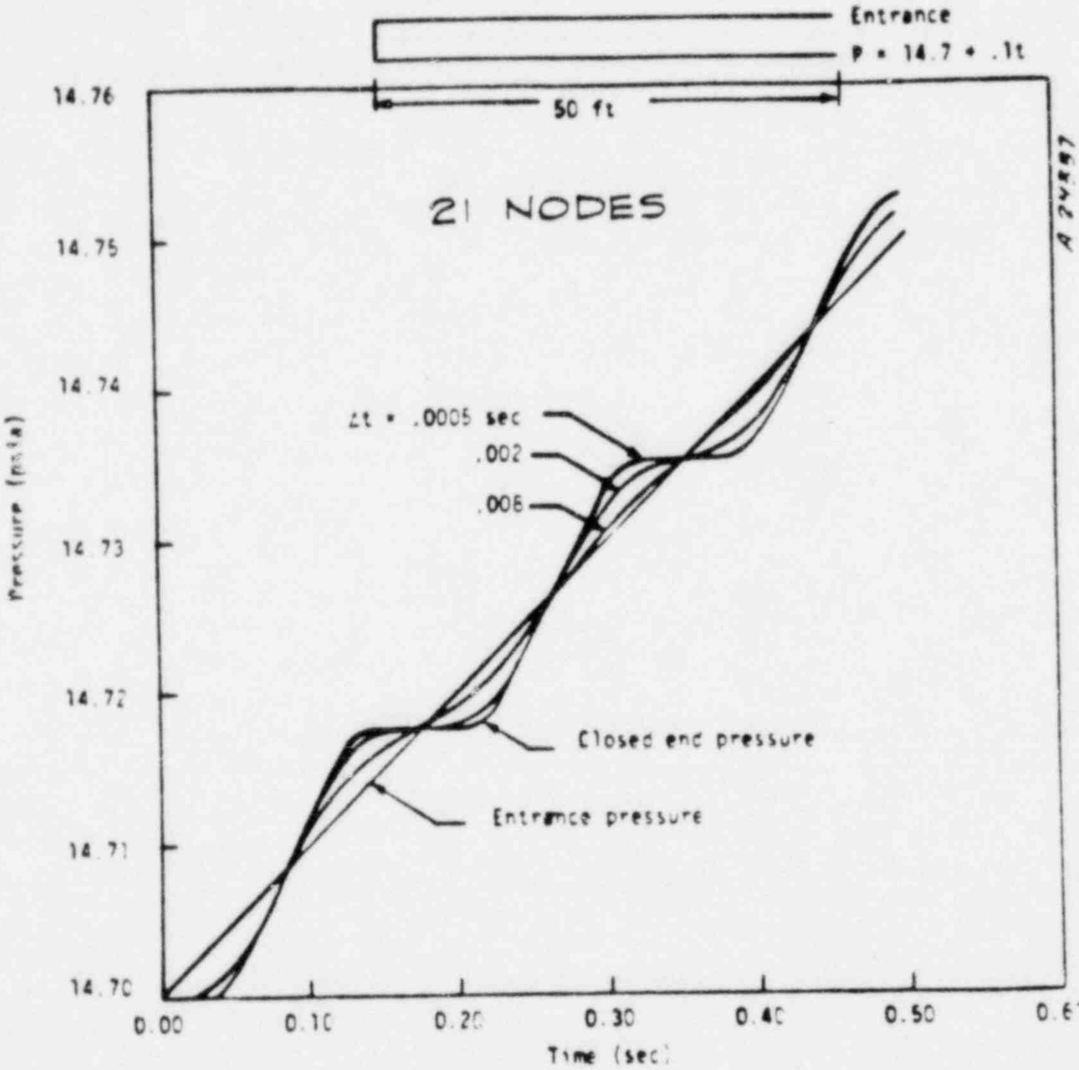
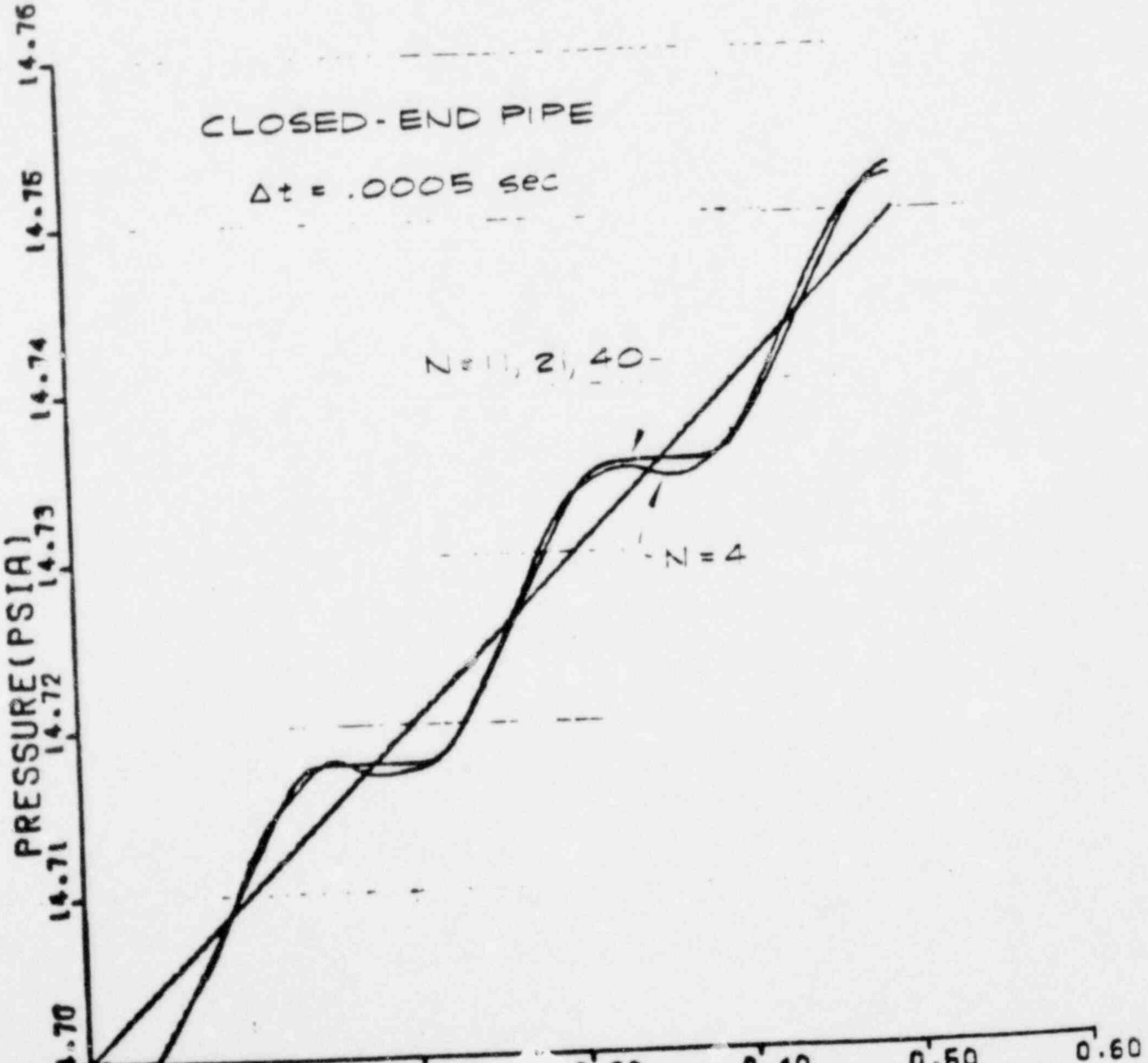
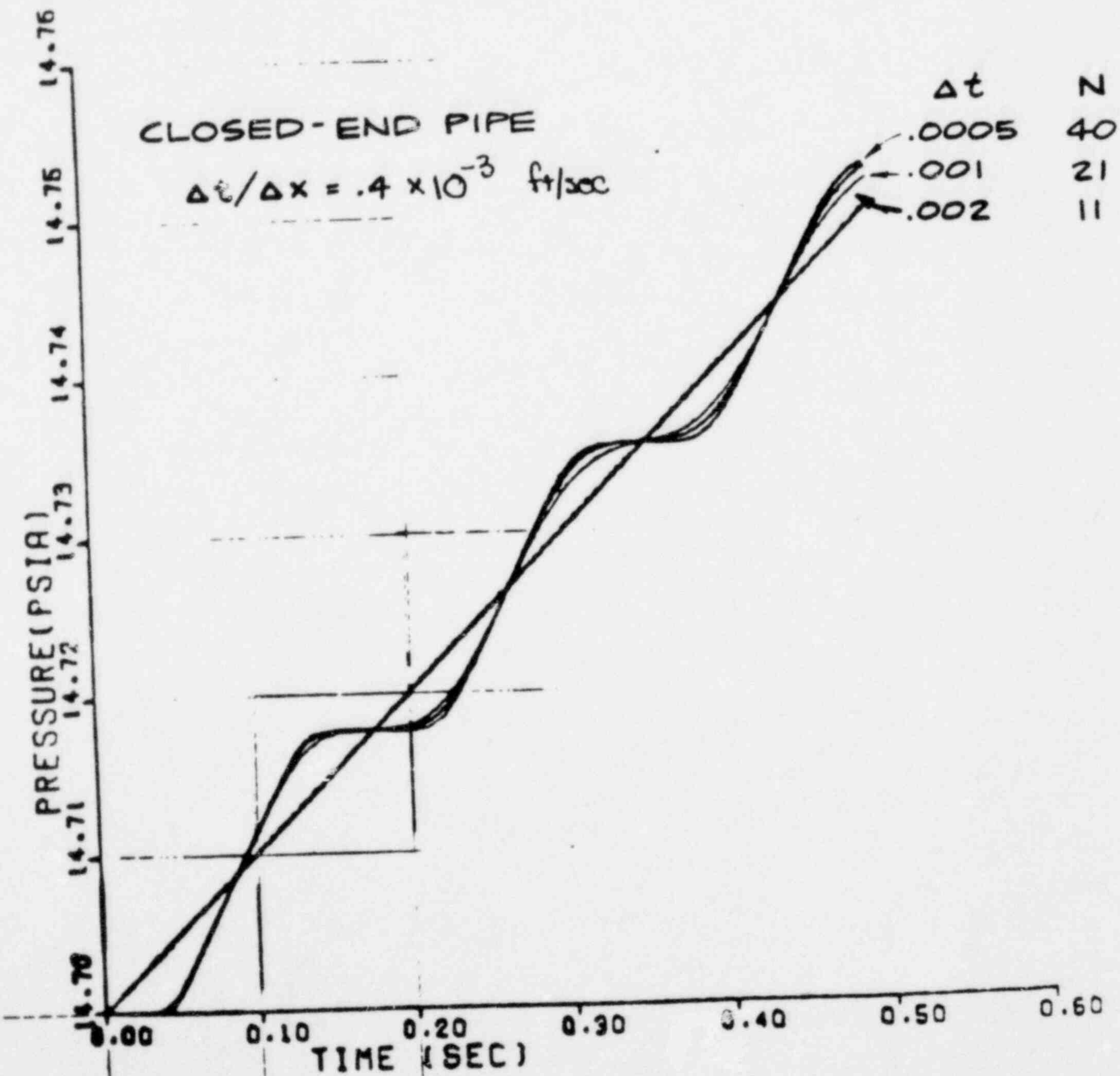


Figure 4-3. Test Case 4 -- timestep sensitivity.



CLOSED-END PIPE
Δt = .0005 sec
N = 1, 2, 40
N = 4
PRESSURE (PSIA)
14.70
14.71
14.72
14.73
14.74
14.75
14.76
0.00
0.10
0.20
0.30
0.40
0.50
0.60
TIME (SEC)



CLOSED-END PIPE
Δt/Δx = .4 × 10^-3 ft/sec
Δt N
.0005 40
.001 21
.002 11
PRESSURE (PSIA)
14.70
14.71
14.72
14.73
14.74
14.75
14.76
0.00
0.10
0.20
0.30
0.40
0.50
0.60
TIME (SEC)

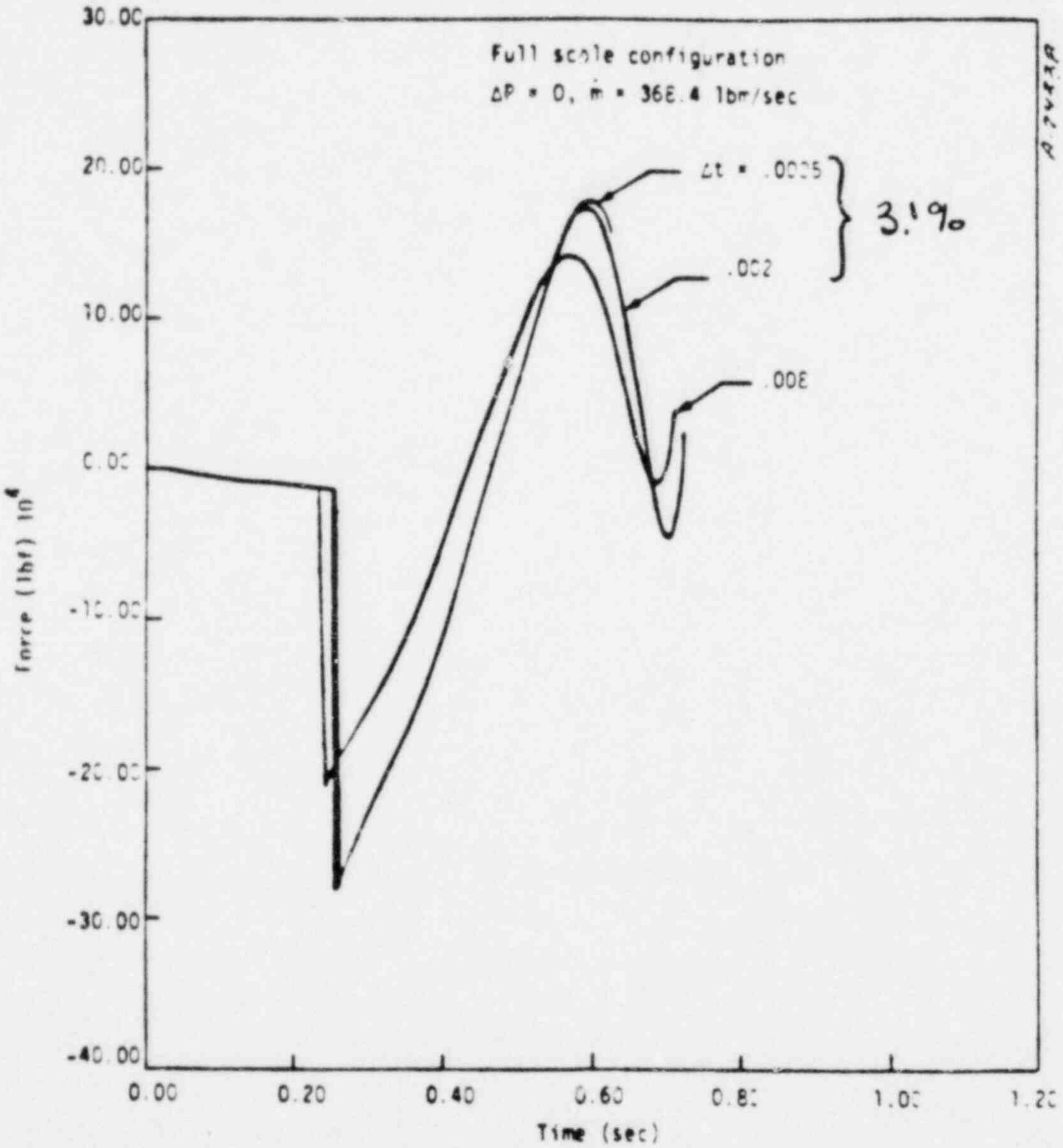
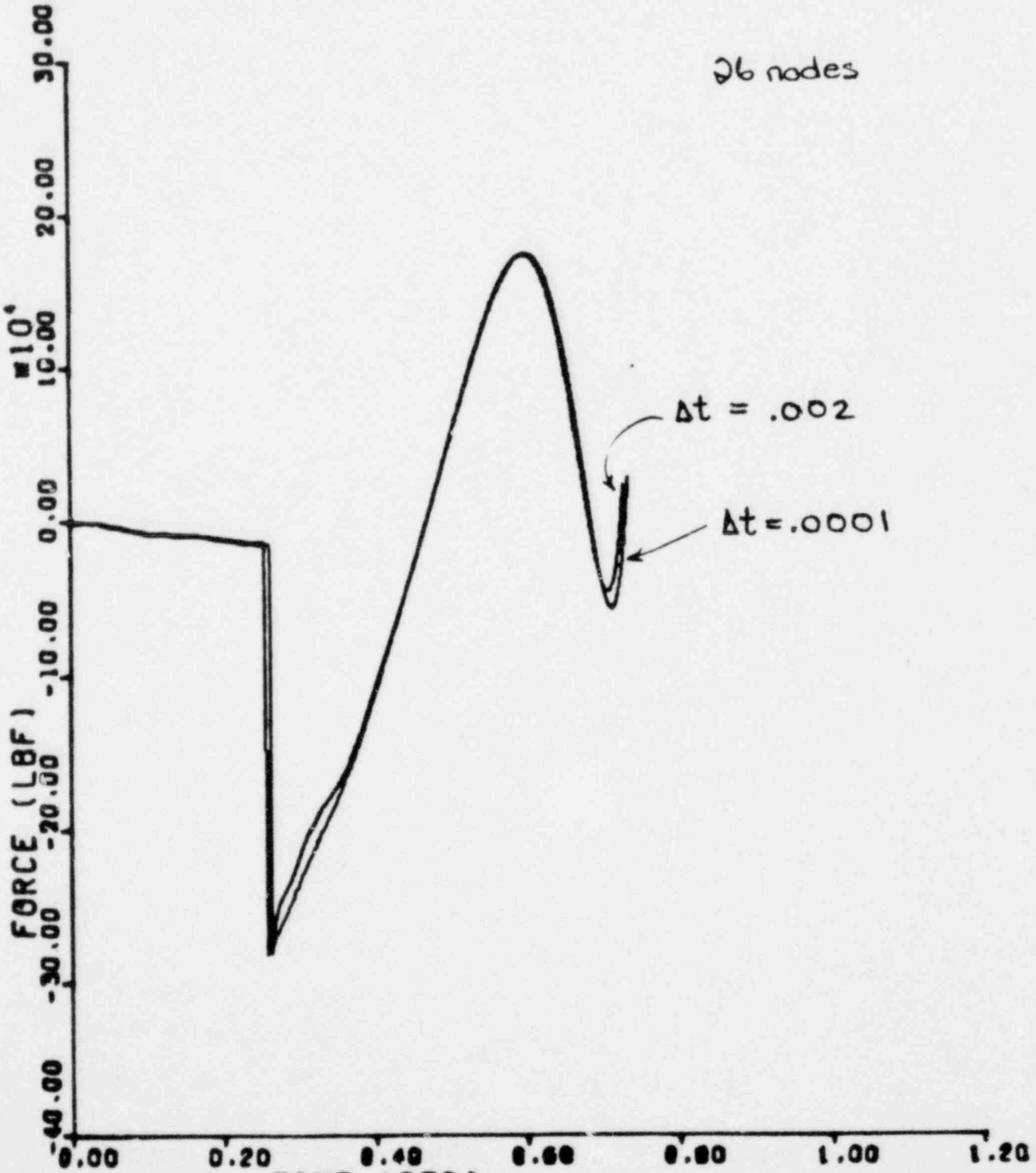


Figure 4-7. Timestep sensitivity -- force.

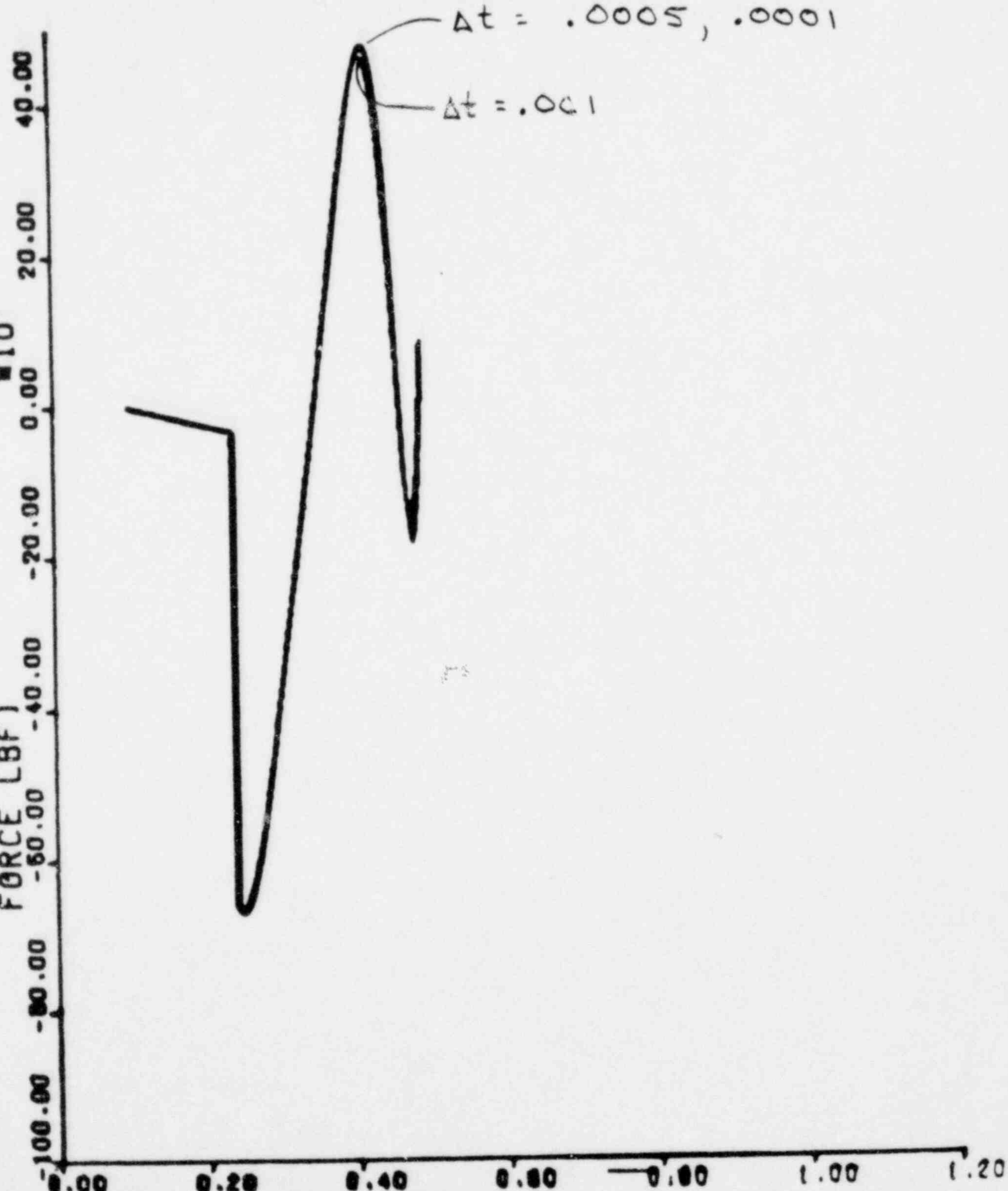
5

FULL SCALE

TIMESTEP SENSITIVITY



QUARTER SCALE
TIMESTEP SENSITIVITY



ANALYSIS UNCERTAINTY

	QSTF	FS	NET
NODALIZATION ERROR (ΔP)	+4%	+4.6%	-.6%
Δt UNCERTAINTY	3.7%	3.1%	
TOTAL UNCERTAINTY	< 5%		

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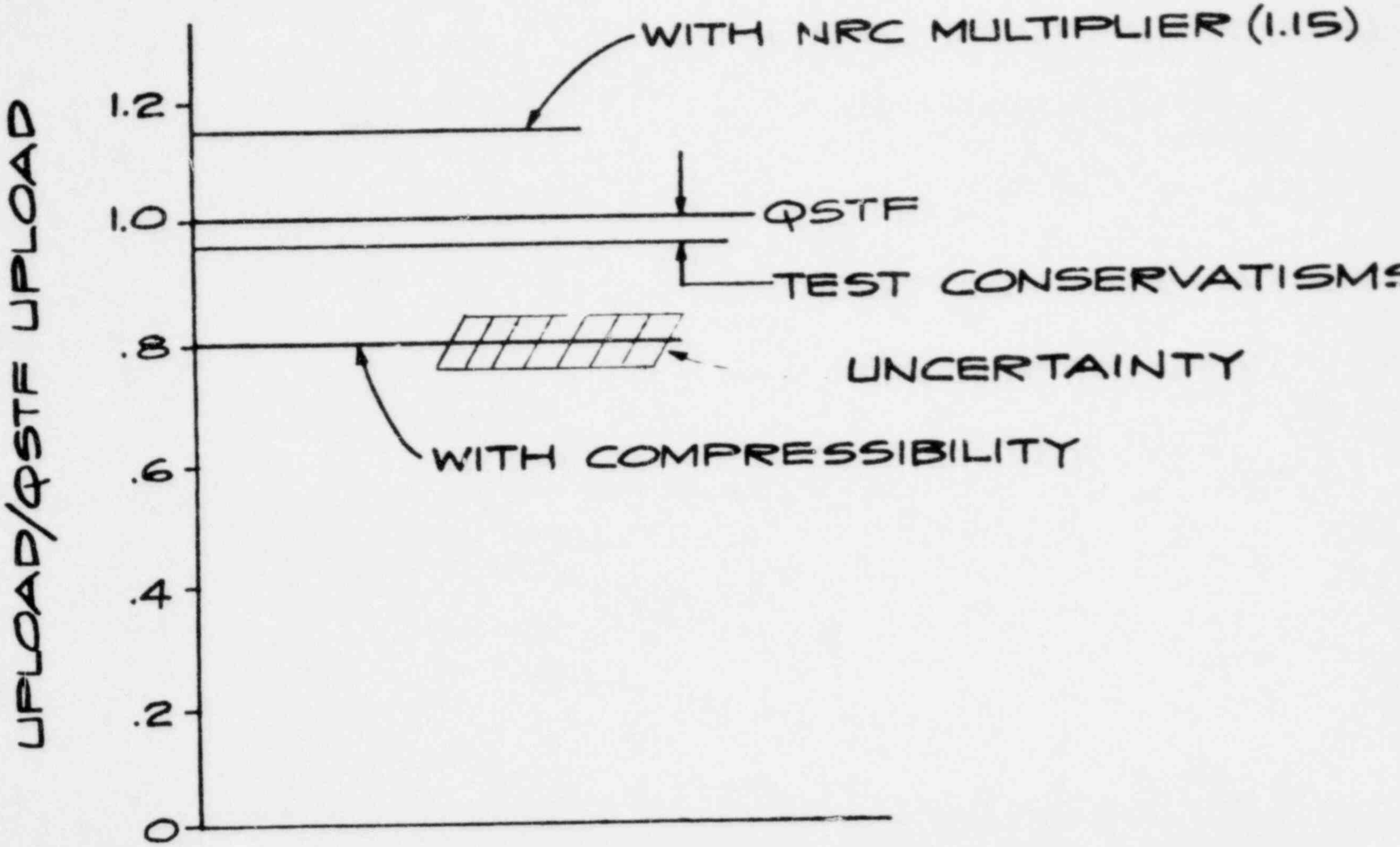
UPLOAD PERSPECTIVE



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MARK I FULL SCALE TEST FACILITY

FSTF SUPPLEMENTAL TESTS

NRC MEETING 4/23/80

FSTF SUPPLEMENTAL TESTS

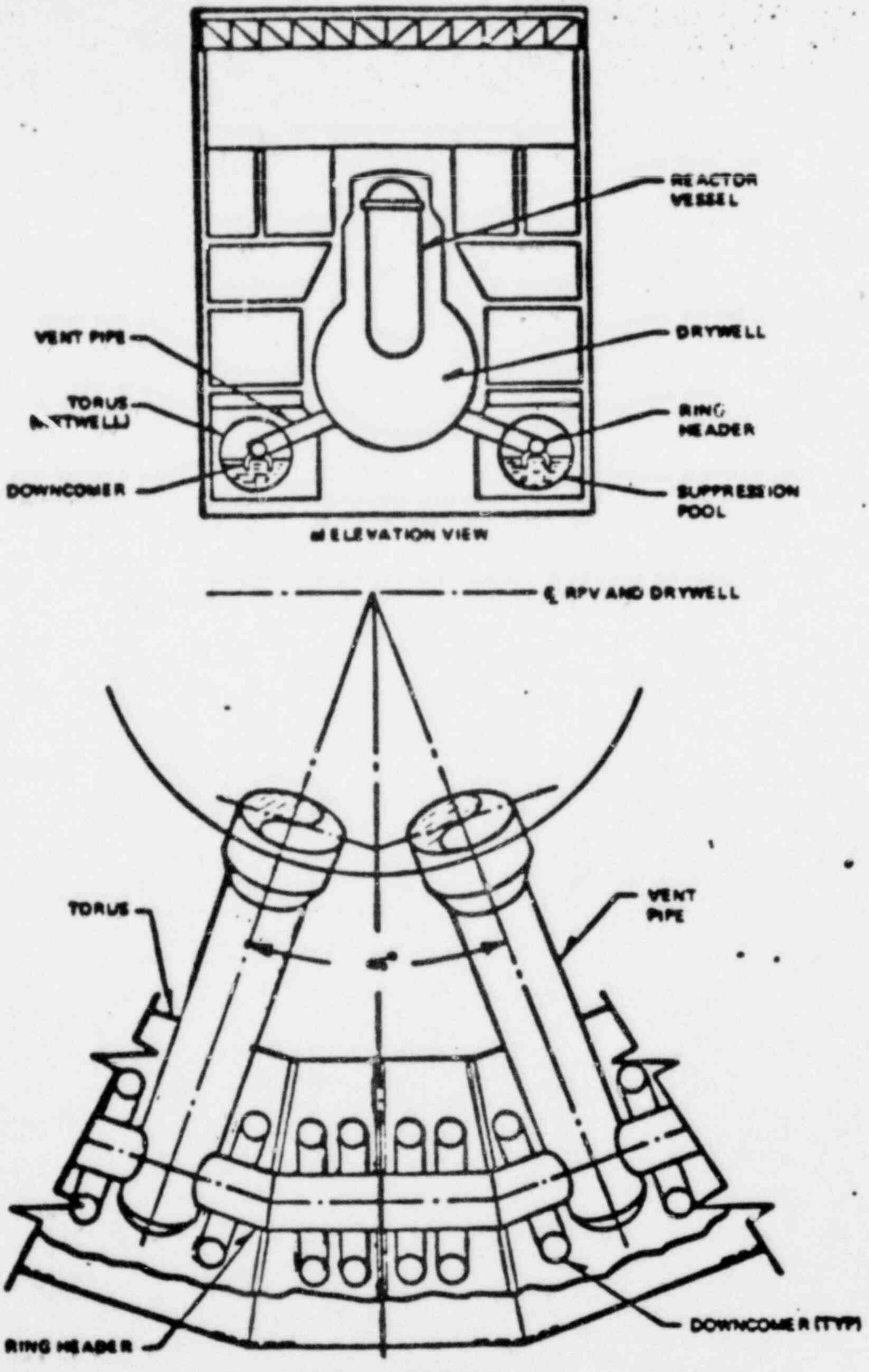
- o TEST OBJECTIVE
- o FSTF FACILITY
- o TEST MATRIX
- o TEST PLAN
- o TEST INSTRUMENTATION
- o DATA REDUCTION AND ANALYSES
- o DATA REPORTING
- o SUMMARY

MARK I

FSTF SUPPLEMENTAL TESTS

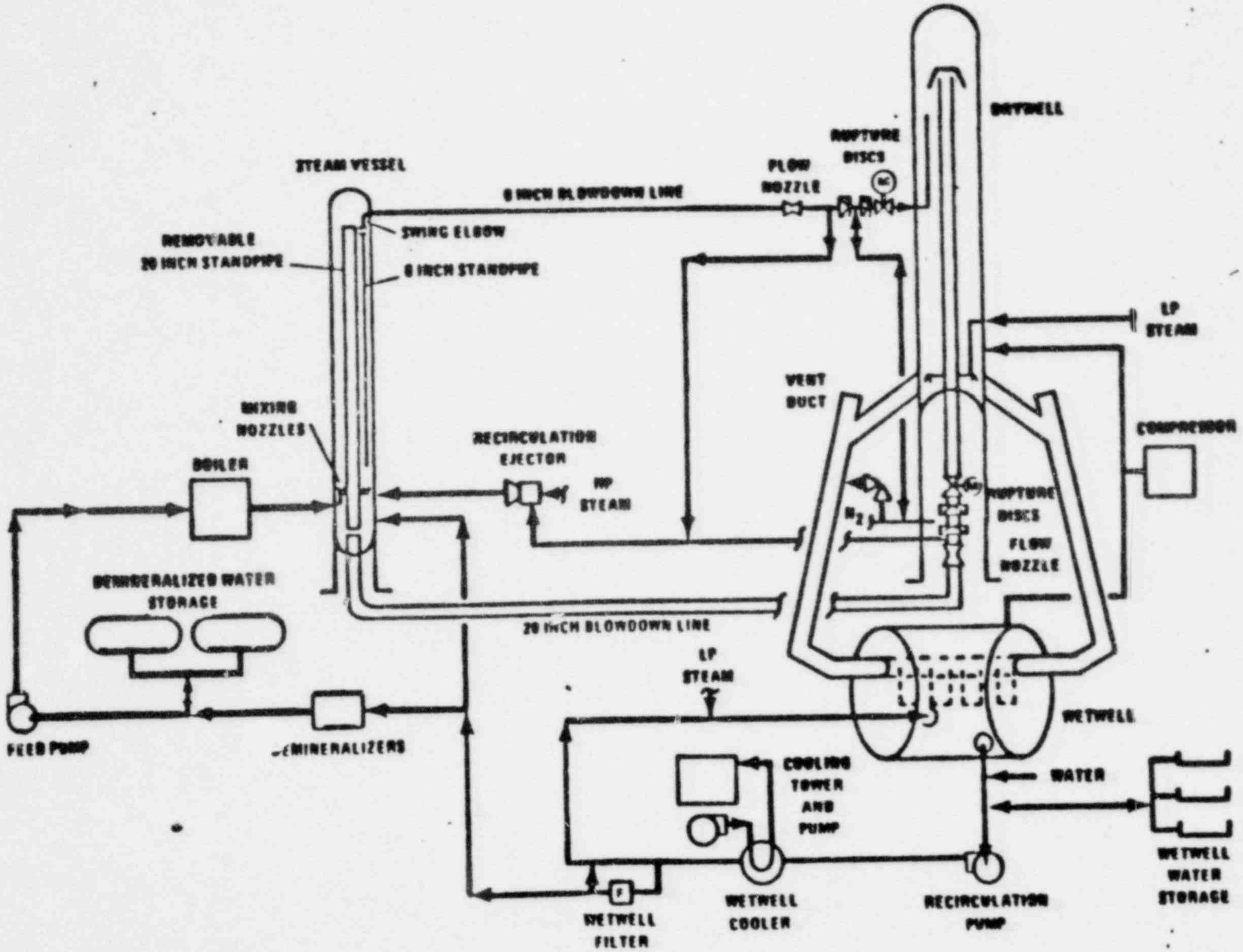
TEST OBJECTIVE:

CONFIRM THAT THE VARIATION IN EXPERIMENTAL DATA IS LESS THAN THE INHERENT CONSERVATISM IN LDR APPLICATION OF THE CO LOAD.



Mark 1 Containment Schematic

SIMPLIFIED FLOW DIAGRAM



PG 5

1978 FSTF TESTS

		BREAK		WETWELL NOMINAL INITIAL CONDITIONS		
TEST* NUMBER	DATE PERFORMED	SIZE	TYPE	SUBMERGENCE	TEMPERATURE	PRESSURE
M1	5/5/78	Small	Steam	3 ft 4 in	70°F	0 psig
M2	5/12/78	Medium				
M3	5/25/78	Small	Liquid			
M4	6/17/78		Steam			5 psig
M5	6/26/78				120°F	0 psig
M6	7/6/78			1 ft 6 in		
M9	7/11/78			4 ft 6 in	70°F	
M10**	7/27/78			3 ft 4 in		
M7	8/10/78	Large				
M8	8/22/78		Liquid			

*Shown in order of performance

**Air sensitivity test performed with vacuum breaker replaced with rupture discs

MARK I TASK 8.4

FSTF SUPPLEMENTAL TESTS

TEST MATRIX

	DATE	BREAK TYPE	BREAK SIZE	SUBMERGENCE	POOL TEMPERATURE
M-11	MAY	LIQUID	LARGE	3'4"	70°F
M-12	JUNE	LIQUID	LARGE	3'4"	95°F

- M-11 DUPLICATES 1978 CO TEST (M-8) AT FSTF
- M-12 DUPLICATES M-8 WITH EXCEPTION OF INITIAL POOL TEMPERATURE

MARK I FSTF SUPPLEMENTAL TESTING

TEST PLAN

- o DUPLICATE INITIAL CONDITIONS OF M-8
- o RECORD SAME INSTRUMENTATION AS M-8
  - o 256 CHANNELS OF DATA
- o COMPARE FOR REPEATABILITY
  - o INITIAL CONDITIONS
  - o GROSS SYSTEM PARAMETERS
  - o MAGNITUDE AND FREQUENCY OF CO LOAD
- o DOWNCOMER CO LOAD DATA
  - o ALL D/C PAIRS TENSION COMPRESSION TIED
  - o STRAIN GAGE ROSETTES AT INTERSECTION VENT HEADER AND DOWNCOMERS

MARK I FSTF SUPPLEMENTARY TEST INSTRUMENTATION

LOCATION	INSTRUMENT TYPE	MEASUREMENT
WETWELL & SUPPRESSION POOL	PRESSURE XDCR	POOL BOUNDARY PRESSURE
	PRESSURE XDCR	WETWELL AIRSPACE PRESSURE
	ACCELEROMETERS	FACILITY RESPONSE
	STRAIN GAGES	FACILITY RESPONSE
	THERMOCOUPLE	POOL TEMPERATURE
		AIRSPACE TEMPERATURE
	LVDT'S	FACILITY RESPONSE
DOWNCOMER & VENT HEADER	PRESSURE XDCR	PRESSURE IN VENT HEADER
	LEVEL PROBE	WATER LEVEL IN DOWNCOMER/ VENT HEADER
	ACCELEROMETERS	DOWNCOMER RESPONSE
	STRAIN GAGES	DOWNCOMER/VENT HEADER RESPONSE
DRYWELL & BLOWDOWN LINE	PRESSURE XDCR	DRYWELL PRESSURE
	THERMOCOUPLE	DRYWELL/VENT ARM TEMPERATURE
	ΔP PRESSURE XDCR	BLOWDOWN FLOW
	GRAB SAMPLERS	AIR CONTENT
STEAM VESSEL	ΔP PRESSURE XDCR	BLOWDOWN FLOW
	PRESSURE XDCR	VESSEL PRESSURE
	THERMOCOUPLES	VESSEL TEMPERATURE

MARK I FSTF SUPPLEMENTAL TESTS

DATA REPORTING

OBJECTIVE: COMPARISON OF M-11 & M-12 WITH M-8 TO CONFIRM REPEATABILITY.

QUICK LOOK DATA - PROVIDED TO ALLOW RAPID ASSESSMENT OF FACILITY TEST RESULTS. INCLUDES:

- o TEST INITIAL CONDITIONS
- o STRUCTURAL EVALUATION
- o SYSTEM PERFORMANCE EVALUATION
- o WETWELL WALL PRESSURE MEASUREMENTS

NRC REQUESTS

- o TEST INITIAL CONDITIONS
- o BOTTOM DEAD CENTER WALL PRESSURE MEASUREMENTS
- o PRESSURE TIME HISTORIES FROM TWO "DISTANT" DOWNCOMERS.

o PLAN TO MEET WITH NRC IN A TIMELY MANNER AFTER COMPLETION OF M-12.

MARK I FSTF SUPPLEMENTAL TEST

DATA REDUCTION & ANALYSES

- o REAL TIME DATA - TIME HISTORIES OF ALL DATA FOR ANY INTERVAL
  - \- USED FOR EVALUATING
    - o SYSTEM PARAMETERS
    - o BLOWDOWN FLOWS
- o HYDRODYNAMIC ANALYSIS
  - o MAXIMUM POSITIVE & MAXIMUM NEGATIVE WETWELL WALL PRESSURES
  - o FREQUENCY OF PRESSURE LOADING
- o SPECTRAL ANALYSIS
  - o SELECTED PSD's AT 1 SECOND INTERVALS DURING CONDENSATION OSCILLATION
  - o CPSD's AT TIME BLOCKS OF INTEREST
- o EVALUATE STRAIN/ACCELEROMETER DATA FOR MAJOR STRUCTURAL COMPONENTS - WETWELL SHELL, SUPPORT COLUMNS, VENT HEADER & DOWNCOMERS
- o NET VERTICAL PRESSURE TIME HISTORY ON WETWELL SHELL
- o POOL TEMPERATURE HISTORY

MARK I FSTF SUPPLEMENTAL TESTS

SUPPLEMENTARY TEST REPORT

- o INCLUDES PREVIOUSLY DISCUSSED ANALYSES PLUS ADDITIONAL NRC REQUESTS:
  - CROSS CORRELATION OF DOWNCOMER PRESSURES TO RESOLVE QUESTIONS OF ASYMMETRIC LOADING
  - AMPLITUDE & FREQUENCY OF DOWNCOMER CO LOADS ON A TIED DOWNCOMER PAIR
  - TORUS WALL PRESSURES WITH FSI REMOVED

MARK I FSTF SUPPLEMENTAL TESTS

SUMMARY

- o PROGRAM OBJECTIVE : CONFIRM THE LDR CO LOAD DEFINITION BY TWO TESTS AT FSTF
- o TWO ADDITIONAL LARGE LIQUID BREAK TESTS WILL BE RUN
- o DATA INSTRUMENTATION SIMILAR TO CO TEST OF 1978
- o DOCUMENTATION OF COMPARISONS OF M-11, M-12 & M-8 WITH LDR LOAD DEFINITION

EVALUATION OF HARMONIC PHASING FOR MARK I TORUS SHELL CONDENSATION OSCILLATION LOADS

April 23, 1980

STRUCTURAL MECHANICS ASSOCIATES
A Calif. Corp.

4740 Von Karman, Newport Beach, Calif. 92660 (714)833-7552

EVALUATION OF MK I CO RESPONSE

PURPOSE OF WORK

- EVALUATE SOURCES OF CONSERVATISM
  - LDR LOAD AMPLITUDE
  - RELATIVE PHASING OF HARMONICS
  - STRUCTURAL RESPONSE METHODS
- DEVELOP RATIONAL DESIGN APPROACH WHICH LEADS TO CO RESPONSE AT 50 PERCENT NON-EXCEEDANCE PROBABILITY (NEP) ASSOCIATED WITH RANDOMNESS OF PHASING. BASED ON THE CONSERVATIVE LOAD DEFINITION, THE ACTUAL NEP WILL BE MUCH HIGHER.

PROCEDURE

- DETERMINE FLEXIBLE WALL FOURIER AMPLITUDE AND FOURIER PHASE SPECTRA FOR INTEGRATED VERTICAL FORCE FROM THE FSTF TEST DATA (M8, 24 TO 28 SECONDS)

- CORRECT THE FLEXIBLE WALL DATA FOR FLUID-STRUCTURE INTERACTION TO OBTAIN RIGID WALL NET VERTICAL FORCE FOURIER AMPLITUDE AND PHASE SPECTRA

- USE LDR SPATIAL DISTRIBUTION TO OBTAIN BDC RIGID WALL PRESSURE FOURIER AMPLITUDES

- COMPARE RIGID WALL FOURIER AMPLITUDES WITH LDR CASE 2 AMPLITUDES

- INVESTIGATE RELATIVE PHASING OF HARMONICS

- COMPUTE STRUCTURAL RESPONSE USING FSTF RIGID WALL FOURIER AMPLITUDE AND PHASE SPECTRA

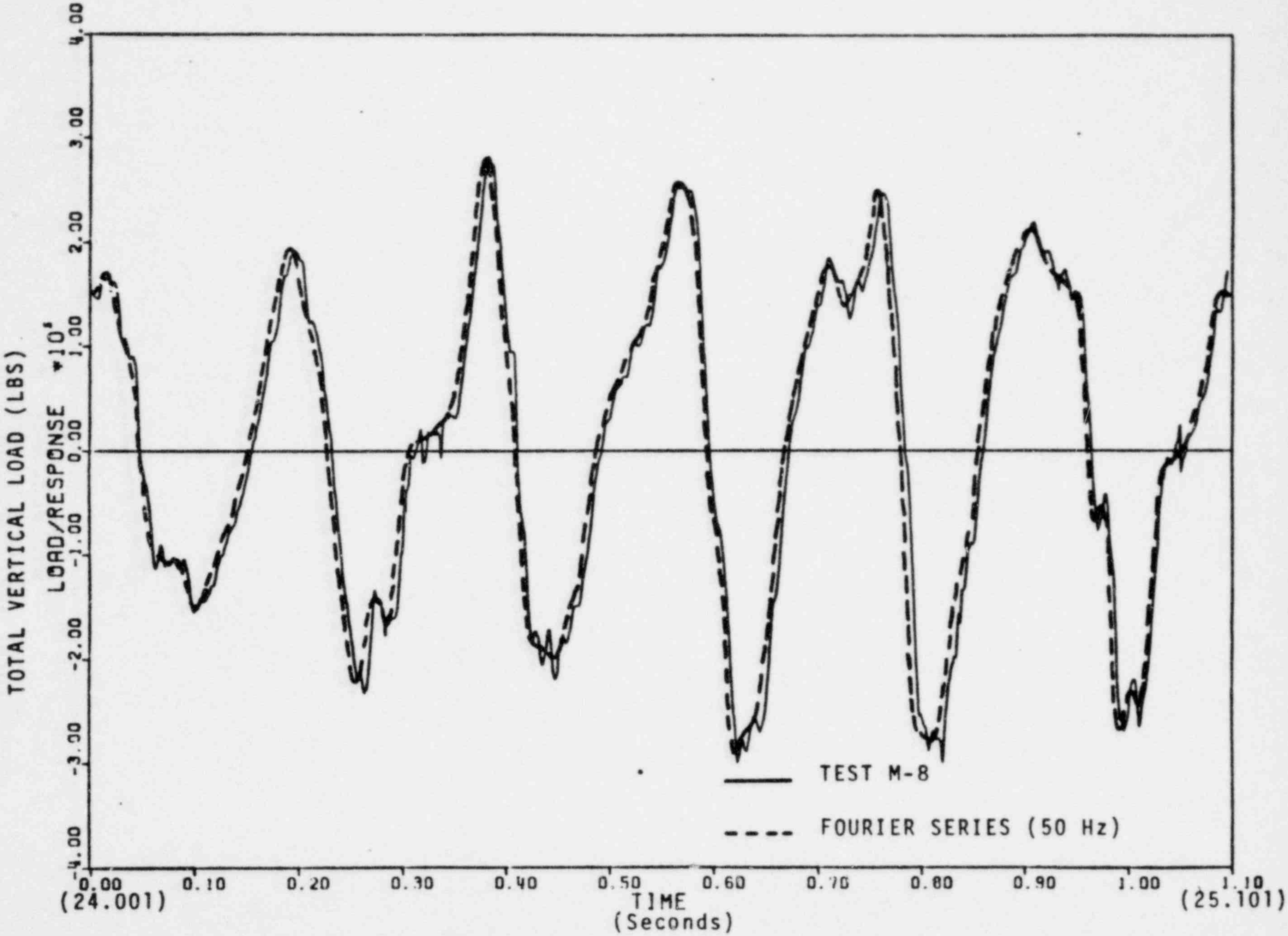
- COMPARE CALCULATED RESPONSE WITH FSTF TEST DATA

- CONSTRUCT CDF CURVES CONSIDERING RANDOMNESS OF HARMONICS FOR BOTH THE FSTF AND THE OYSTER CREEK PLANT

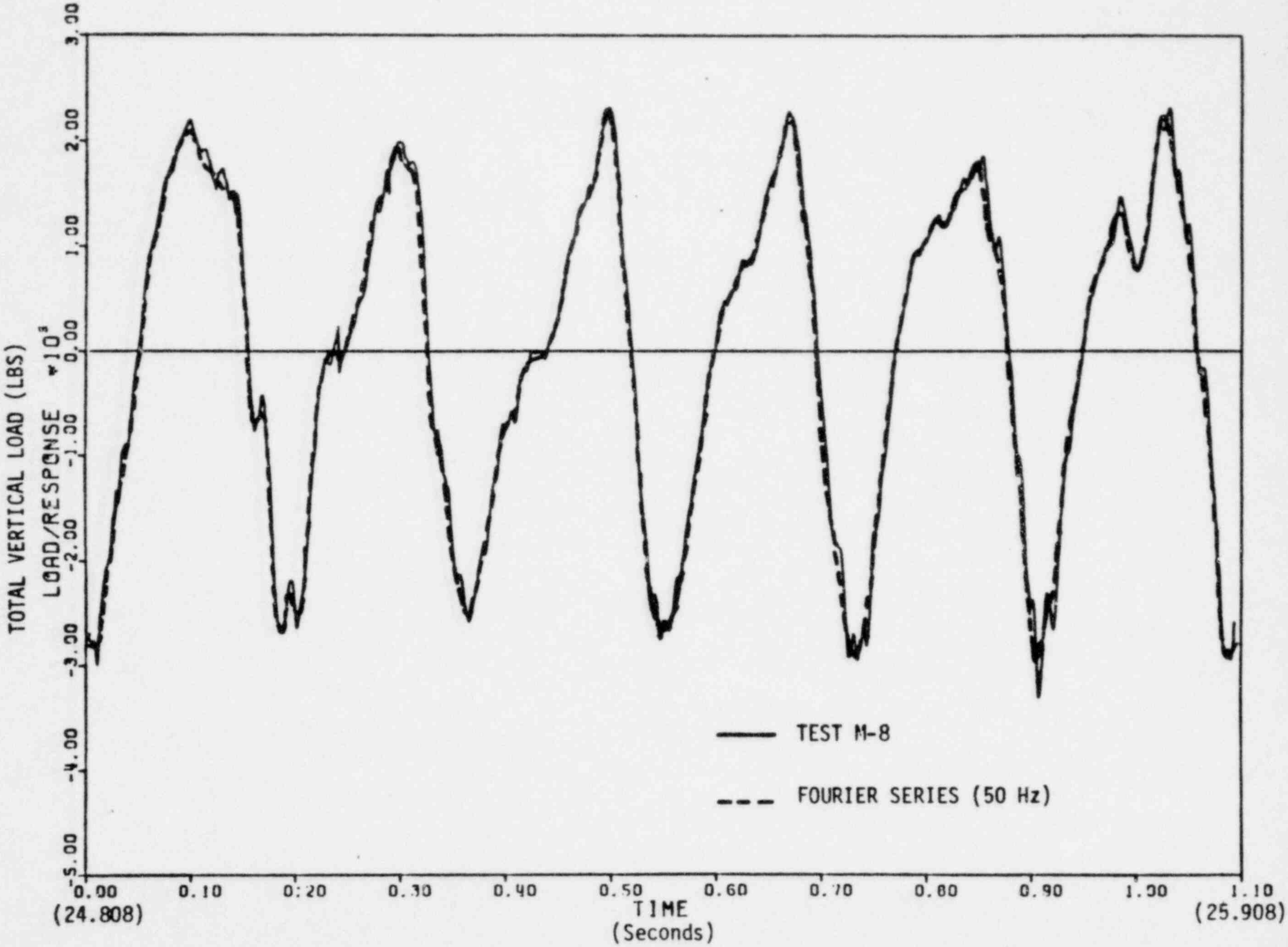
- DEVELOP HARMONIC COMBINATION RULES FOR DESIGN

ASSUMPTIONS

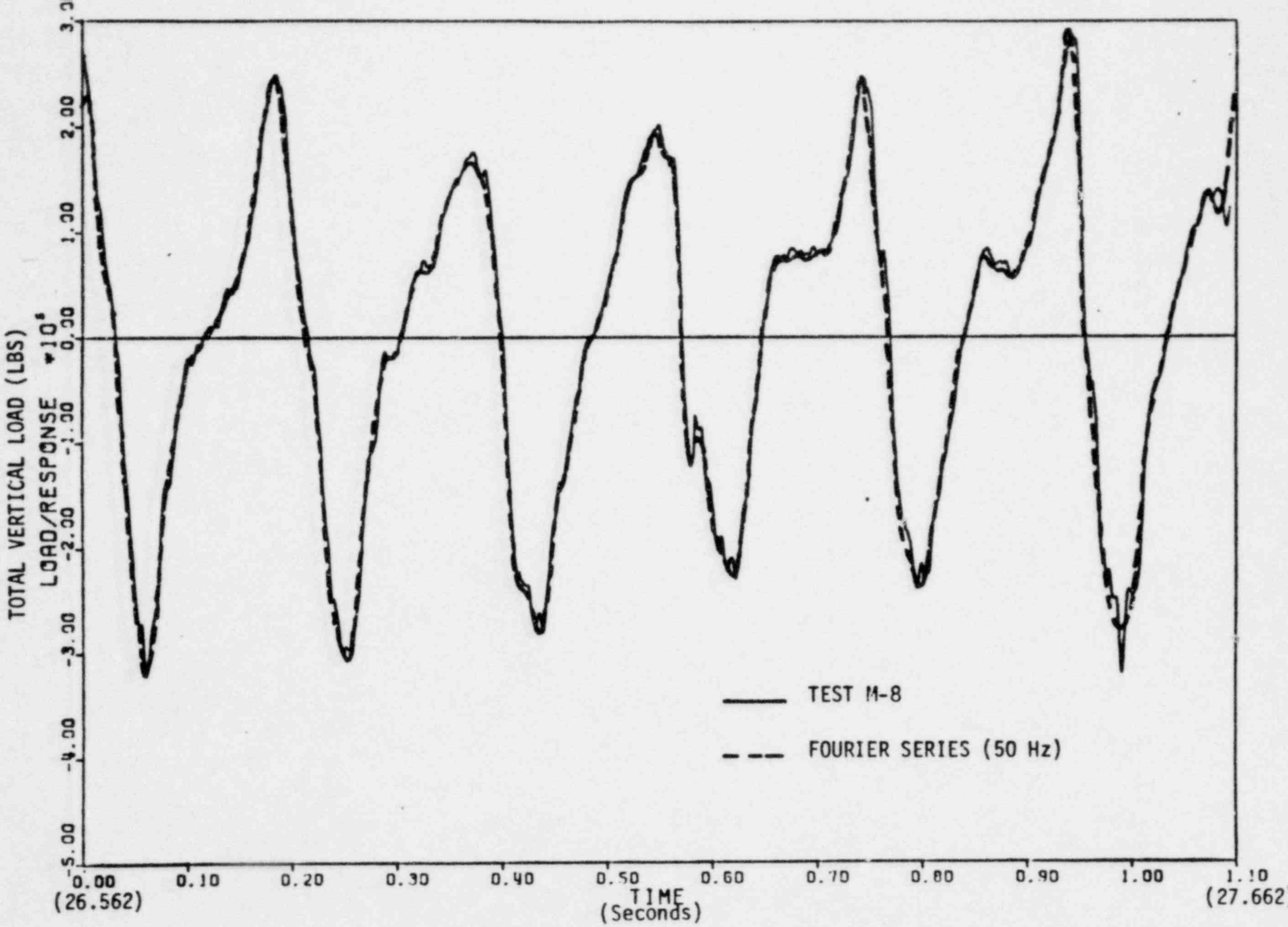
- FSTF MEASURED VERTICAL LOAD IS REPRESENTED BY A FOURIER SERIES
- FLUID-STRUCTURE INTERACTION AFFECTS TORUS SHELL PRESSURES
- 2 PERCENT STRUCTURAL DAMPING
- STEADY STATE HARMONIC RESPONSE



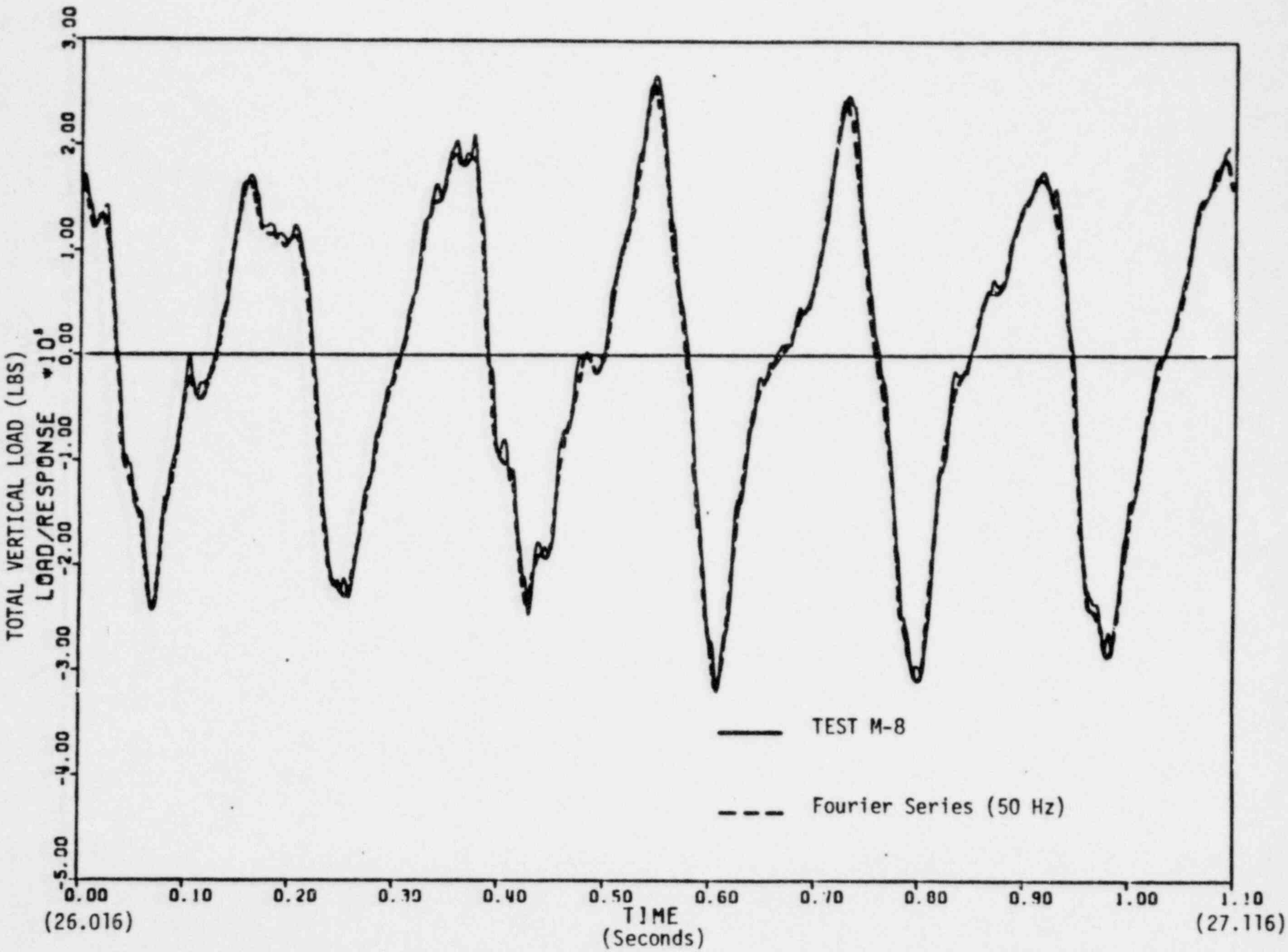
COMPARISON OF MEASURED AND FOURIER SERIES REPRESENTATION OF TOTAL INTEGRATED VERTICAL LOAD (24.001 through 25.095 SEC)



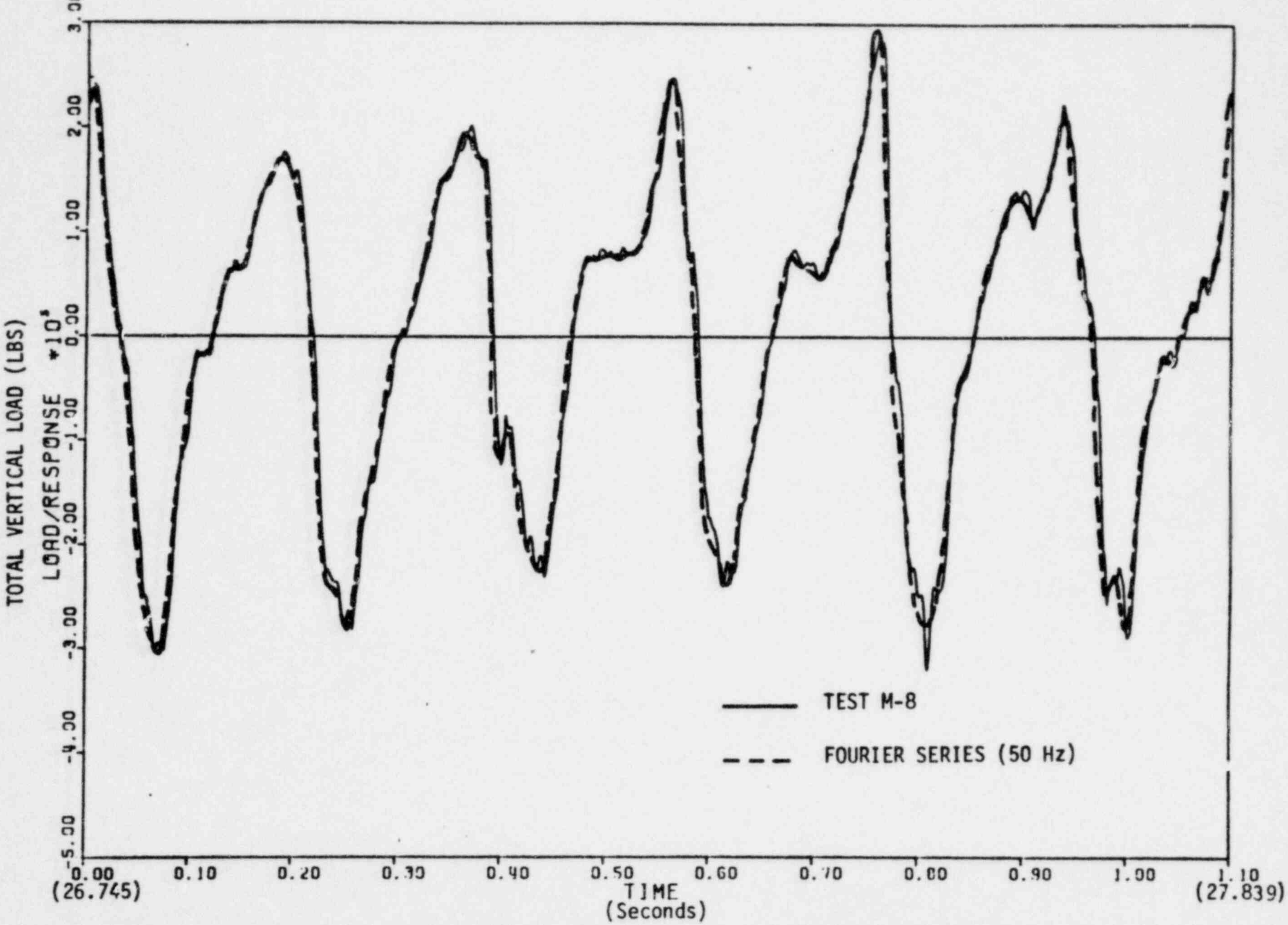
COMPARISON OF MEASURED AND FOURIER SERIES REPRESENTATION OF TOTAL INTEGRATED VERTICAL LOAD
(24.808 THROUGH 25.902 SEC)



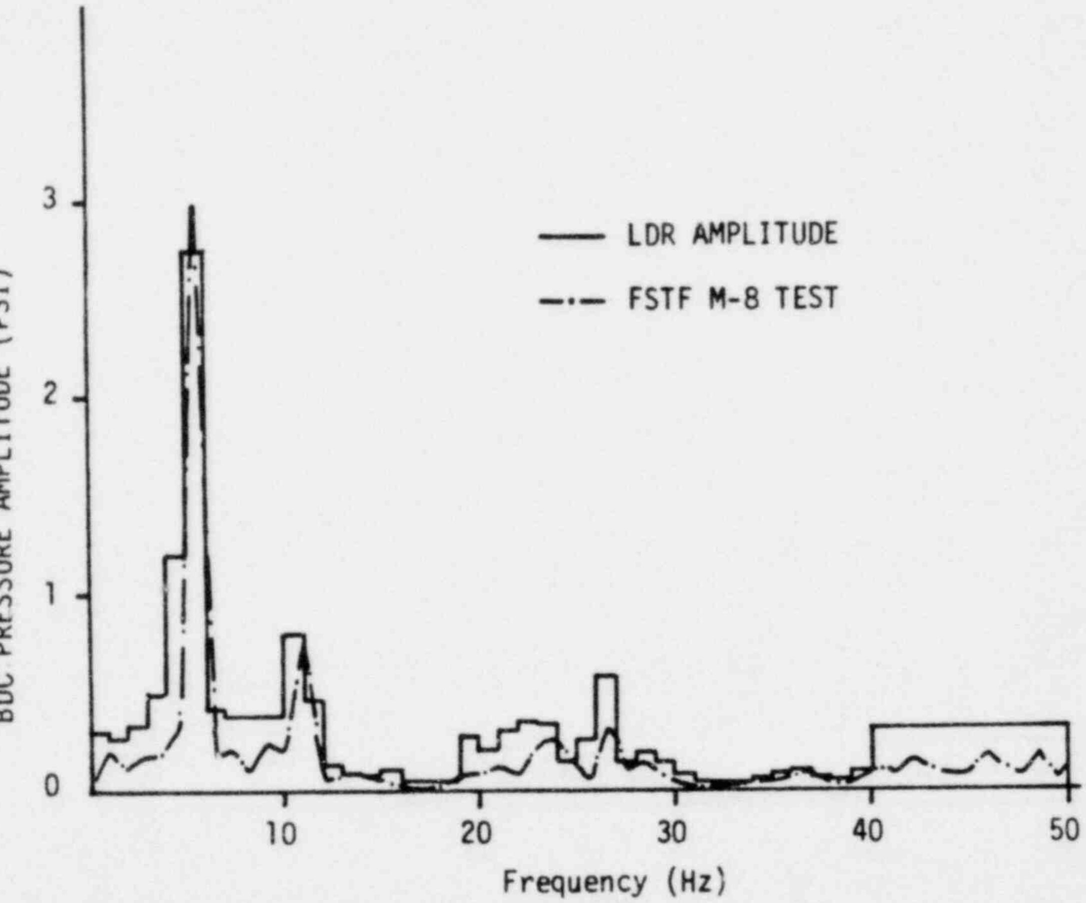
COMPARISON OF MEASURED AND FOURIER SERIES REPRESENTATION OF TOTAL INTEGRATED VERTICAL LOAD
(26.562 THROUGH 27.656 SEC)



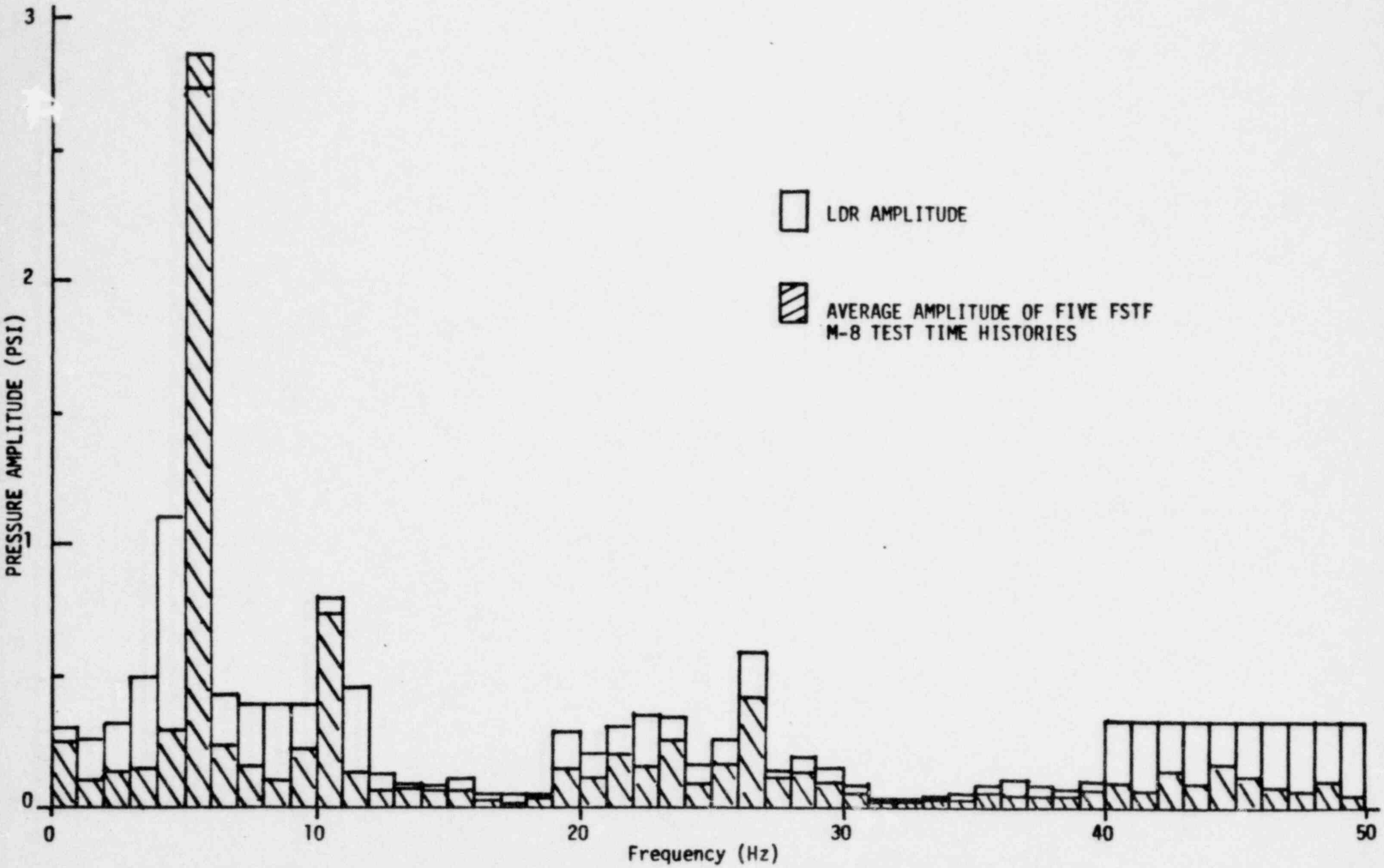
COMPARISON OF MEASURED AND FOURIER SERIES REPRESENTATION OF TOTAL INTEGRATED VERTICAL LOAD
(26.016 THROUGH 27.110 SEC)



COMPARISON OF MEASURED AND FOURIER SERIES REPRESENTATION OF TOTAL INTEGRATED VERTICAL LOAD
(26.745 THROUGH 27.839 SEC)



COMPARISON OF LDR AMPLITUDE AND FSTF RIGID WALL AMPLITUDE
(24.808 THROUGH 25.902 SEC)

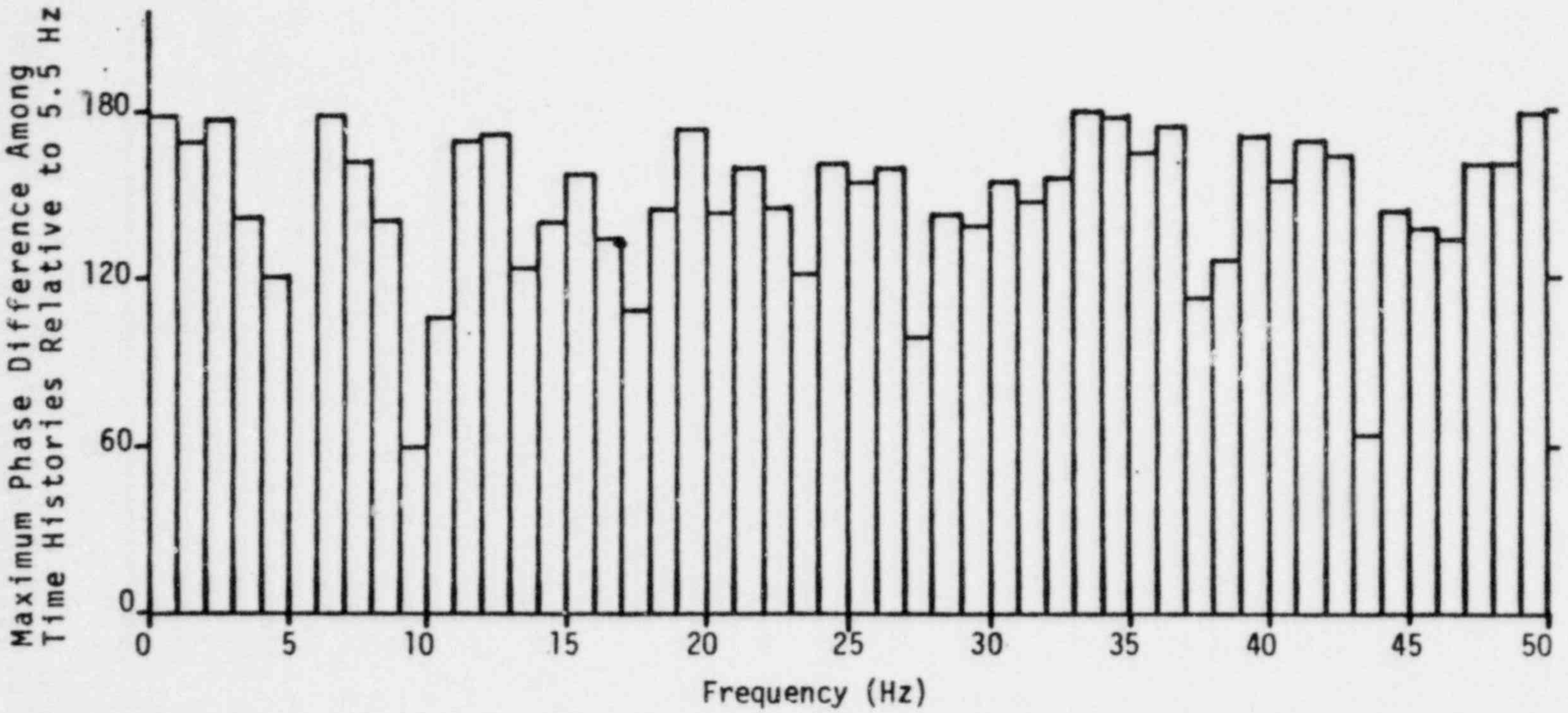


COMPARISON OF LDR AMPLITUDE AND FSTF RIGID WALL AMPLITUDES FOR FIVE TIME PERIODS

CONCLUSIONS:

- LDR AMPLITUDES ARE SLIGHTLY CONSERVATIVE COMPARED TO FSTF AMPLITUDES

- LDR AMPLITUDES ARE NOT EXCESSIVELY CONSERVATIVE AND THUS DO NOT REPRESENT THE MAJOR SOURCE OF CONSERVATISM IN CO RESPONSE EVALUATION



EVALUATION OF RELATIVE PHASING BETWEEN HARMONICS (M-8 FSTF TEST, 24 to 28 SECONDS)

CONCLUSIONS:

- FROM FSTF M-8 TEST DATA FOR INTEGRATED DOWNWARD FORCE, ALL HARMONICS HAVE RANDOM PHASING WITH RESPECT TO EACH OTHER

- OTHER INVESTIGATORS HAVE CONCLUDED THAT THERE MAY BE DETERMINISTIC PHASE RELATIONSHIPS BETWEEN THE DOMINANT HARMONIC AND THE NEXT TWO MULTIPLES. TO BE CONSERVATIVE, SMA HAS EXAMINED THE EFFECT OF ASSUMING SOME DETERMINISTIC PHASE RELATIONS IN THE CALCULATION OF CDF CURVES

COMPARISON OF FSTF MEASURED RESPONSES AND CALCULATED RESPONSES FOR DURATION FROM 24 TO 28 SECONDS

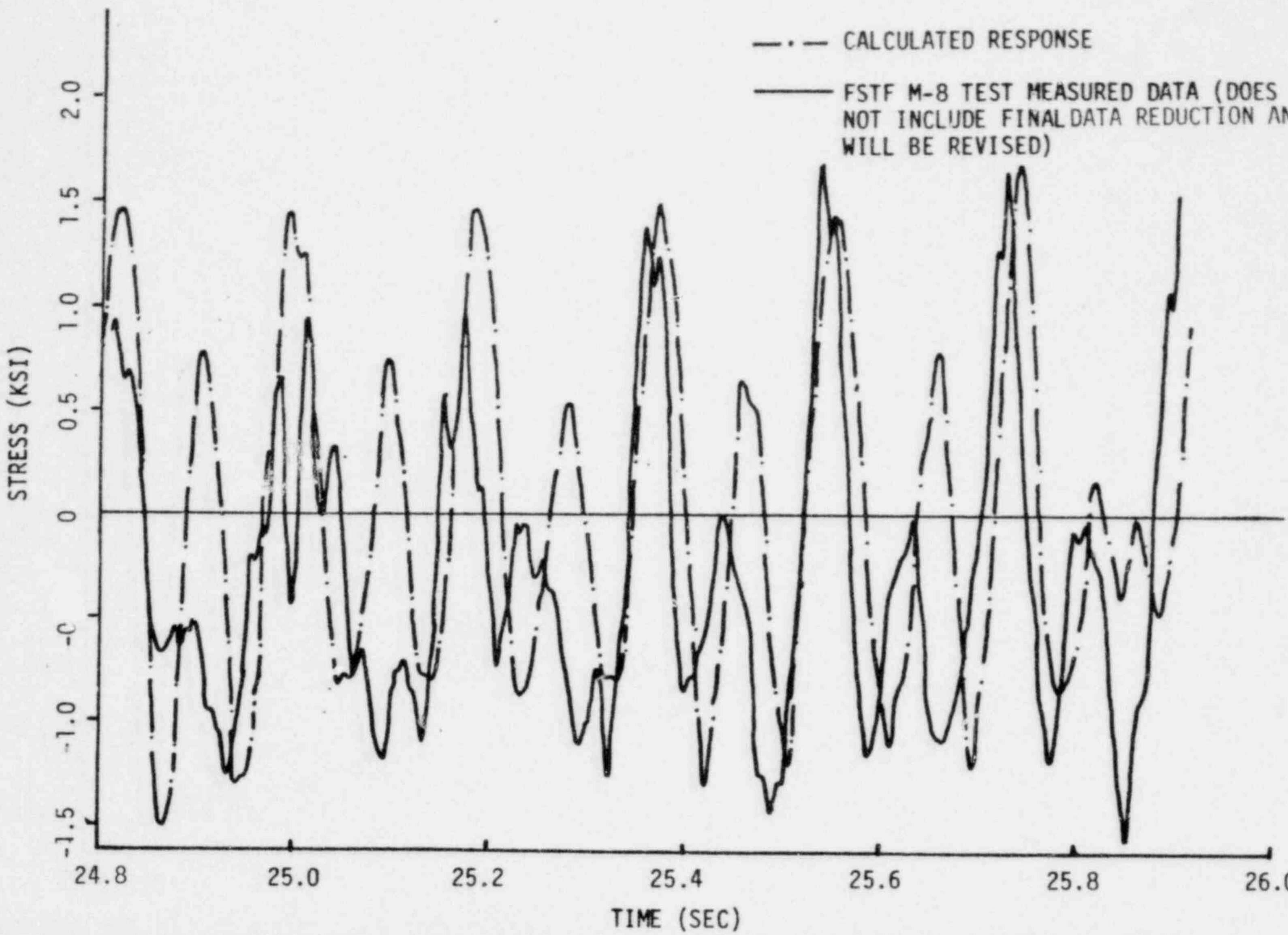
RESPONSE QUANTITY	FSTF M-8 TEST MEASURED RESPONSE					CALCULATED RESPONSE (USING FSTF RIGID WALL FOURIER AMPLITUDE AND PHASE)				
	24.001 to 25.095 SEC.	24.808 to 25.902 SEC.	26.016 to 27.110 SEC.	26.562 to 27.656 SEC.	26.745 to 27.839 SEC.	24.001 to 25.095 SEC.	24.808 to 25.902 SEC.	26.016 to 27.110 SEC.	26.562 to 27.656 SEC.	26.745 to 27.839 SEC.
BDC AXIAL MEMBRANE STRESS (KSI)	2.05	1.95	2.32	2.32	1.90	2.00	1.67	1.73	1.83	2.02
BDC HOOP MEMBRANE STRESS (KSI)	2.22	2.17	2.63	2.63	2.51	1.83	1.73	1.52	1.75	1.84
BDC RADIAL DISPLACEMENT (IN.)	0.098	0.084	0.108	0.108	0.099	0.118	0.103	0.095	0.104	0.121
INSIDE COLUMN AXIAL FORCE (KIPS)	93	92	81	91	91	98	82	88	91	91
OUTSIDE COLUMN AXIAL FORCE (KIPS)	110	107	98	98	98	107	92	93	98	102

CONCLUSIONS:

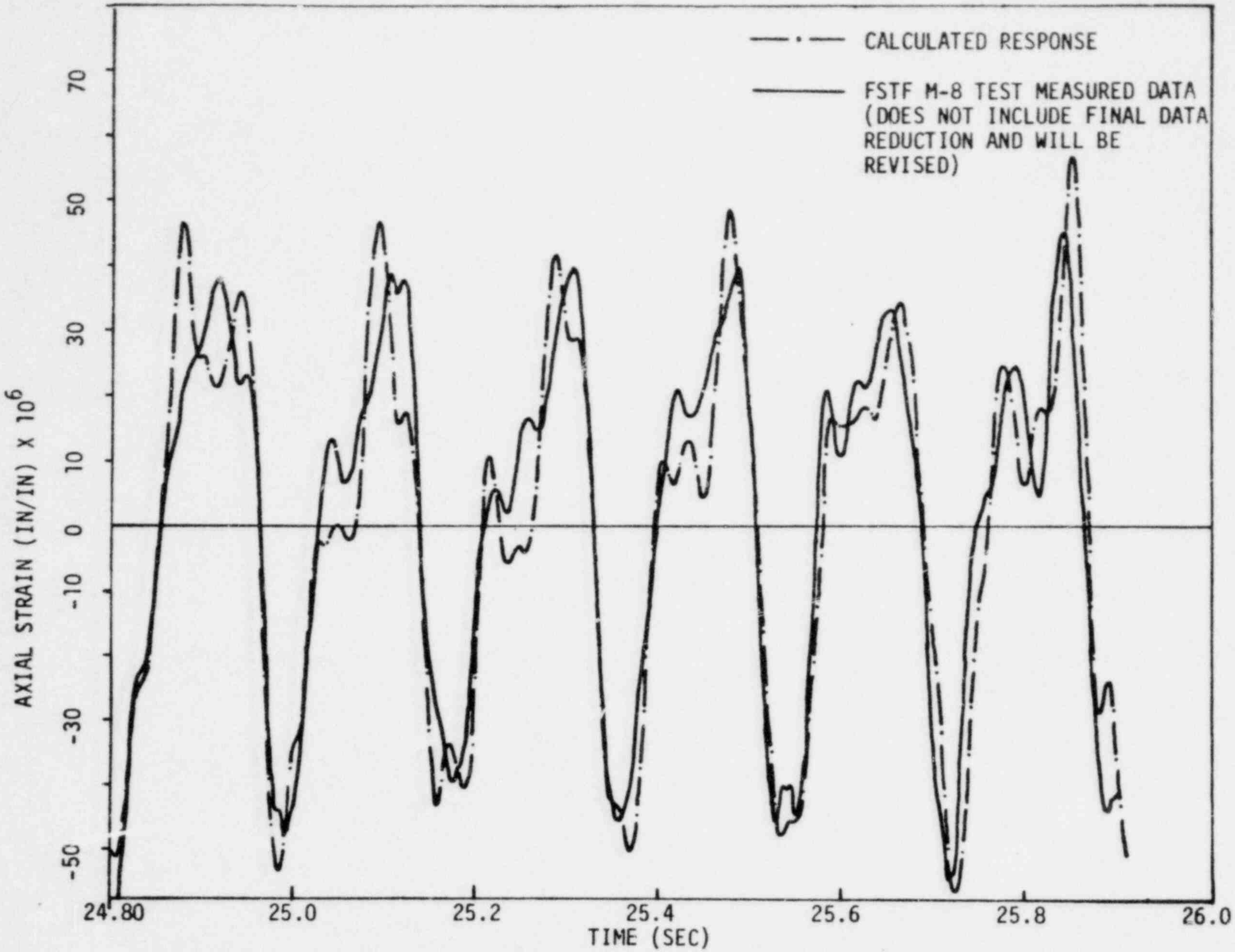
- ON THE AVERAGE, CALCULATED RESPONSE DIFFERS FROM MEASURED RESPONSE BY THE FOLLOWING AMOUNTS:

BDC AXIAL MEMBRANE STRESS	-12%
BDC HOOP MEMBRANE STRESS	-29%
BDC RADIAL DISPLACEMENT	+ 9%
INSIDE COLUMN AXIAL FORCE	0%
OUTSIDE COLUMN AXIAL FORCE	- 4%

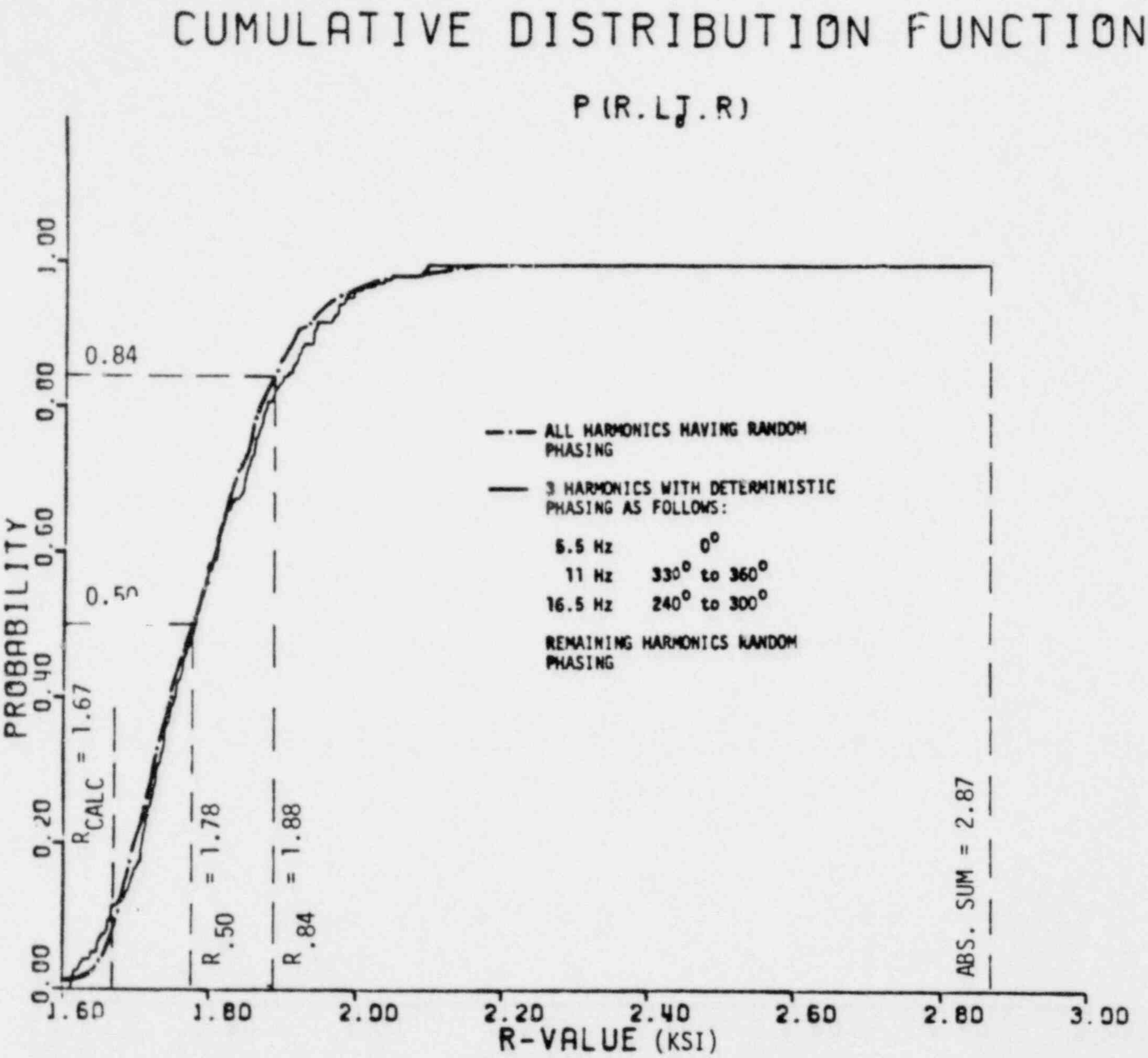
- STRUCTURAL MODEL AND ASSUMPTIONS OF 2% DAMPED, STEADY STATE RESPONSE ARE NOT A SOURCE OF CONSERVATISM IN THE PROCESS OF EVALUATING CO RESPONSE



COMPARISON OF CALCULATED (FSTF RIGID WALL FOURIER AMPLITUDE AND PHASE SPECTRA) AND MEASURED RESPONSE TIME HISTORIES -- BDC AXIAL MEMBRANE STRESS (24.808 - 25.902 SECONDS)



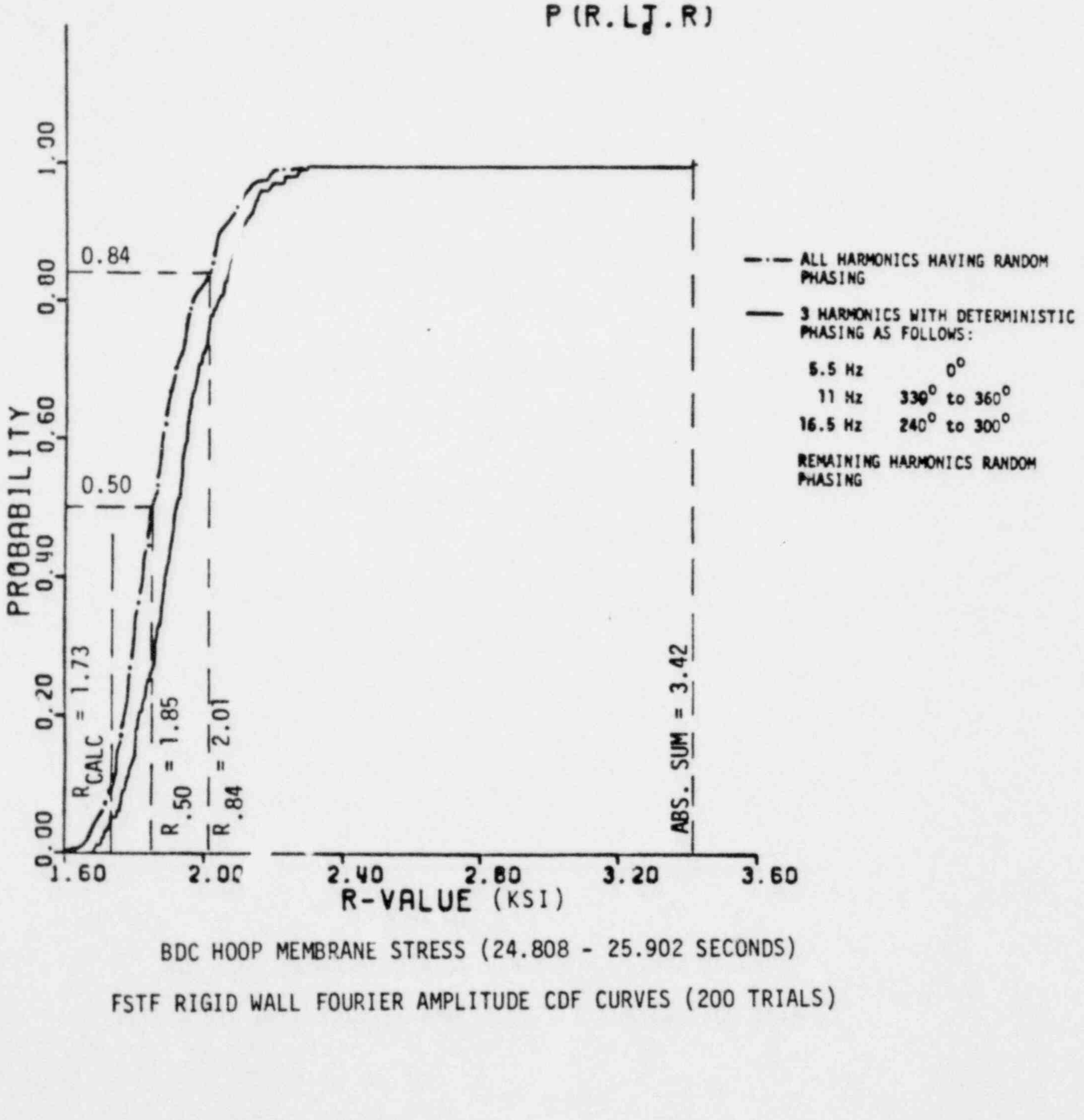
COMPARISON OF CALCULATED (FSTF RIGID WALL FOURIER AMPLITUDE AND PHASE SPECTRA) AND MEASURED RESPONSE TIME HISTORY -- INSIDE COLUMN AXIAL STRAIN (24.808 - 25.902 SECONDS)



BDC AXIAL MEMBRANE STRESS (24.808 - 25.902 SECONDS)

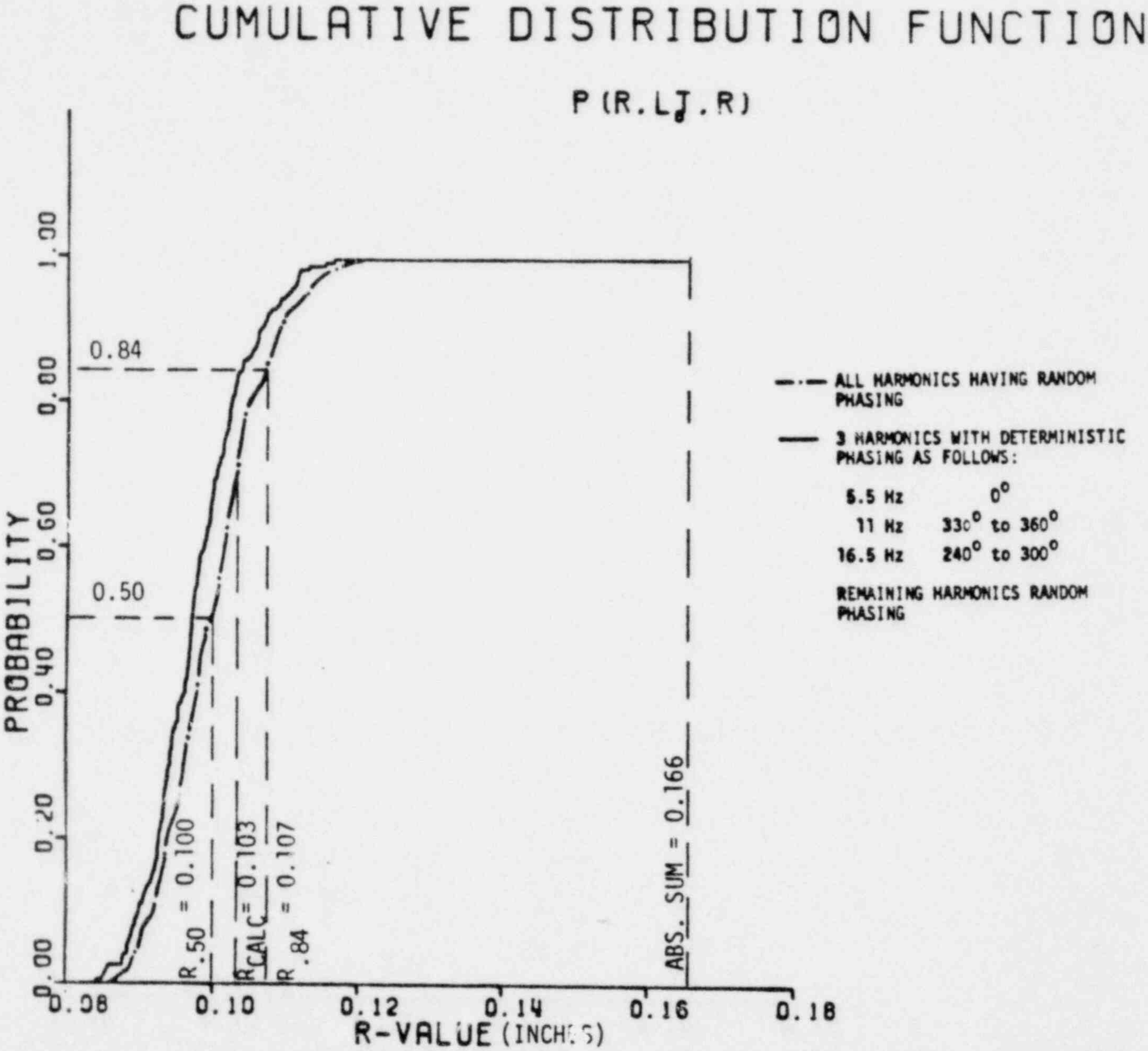
FSTF RIGID WALL FOURIER AMPLITUDE CDF CURVES (200 TRIALS)

CUMULATIVE DISTRIBUTION FUNCTION



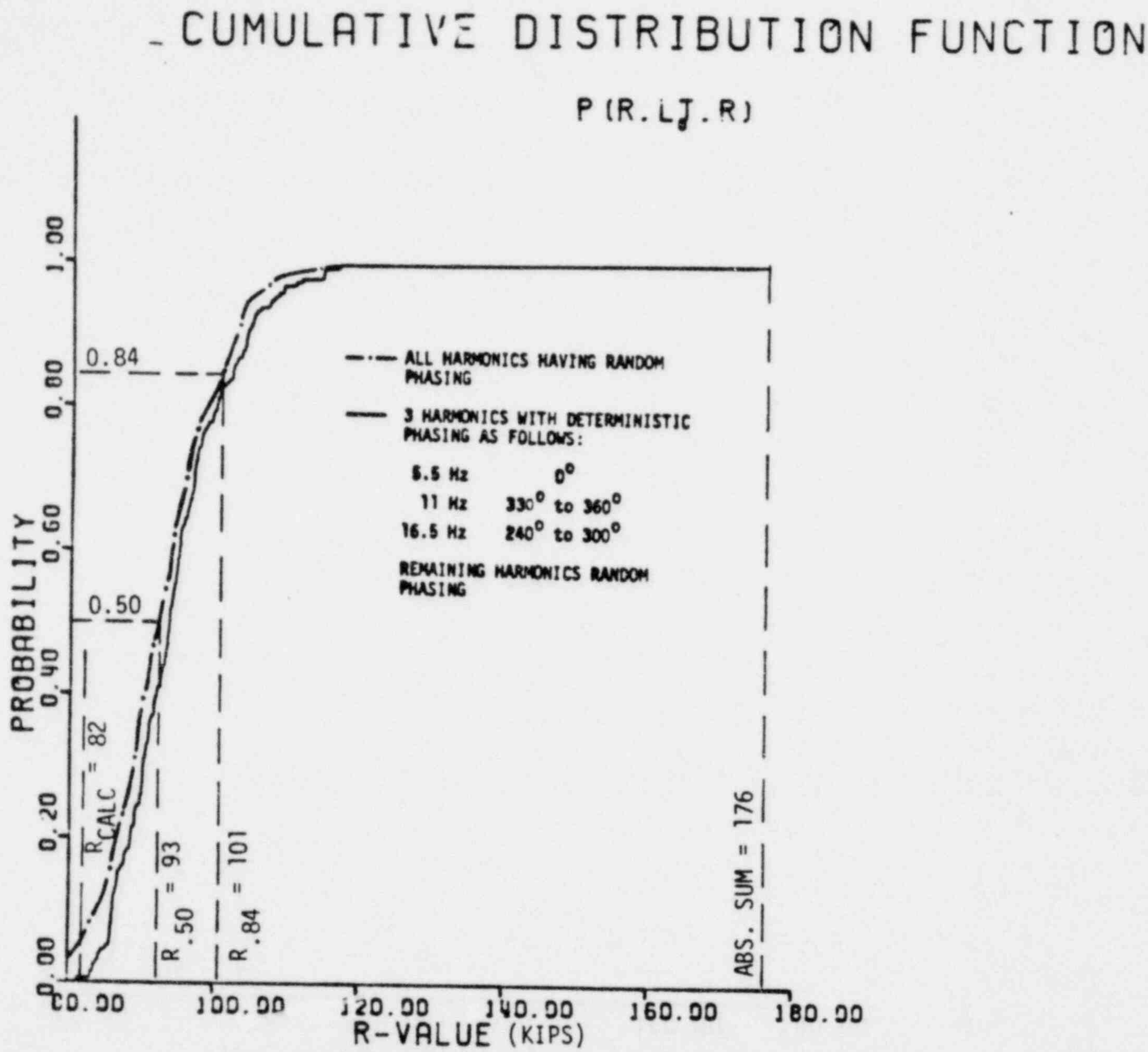
BDC HOOP MEMBRANE STRESS (24.808 - 25.902 SECONDS)

FSTF RIGID WALL FOURIER AMPLITUDE CDF CURVES (200 TRIALS)



BDC RADIAL DISPLACEMENT (24.808 - 25.902 SECONDS)

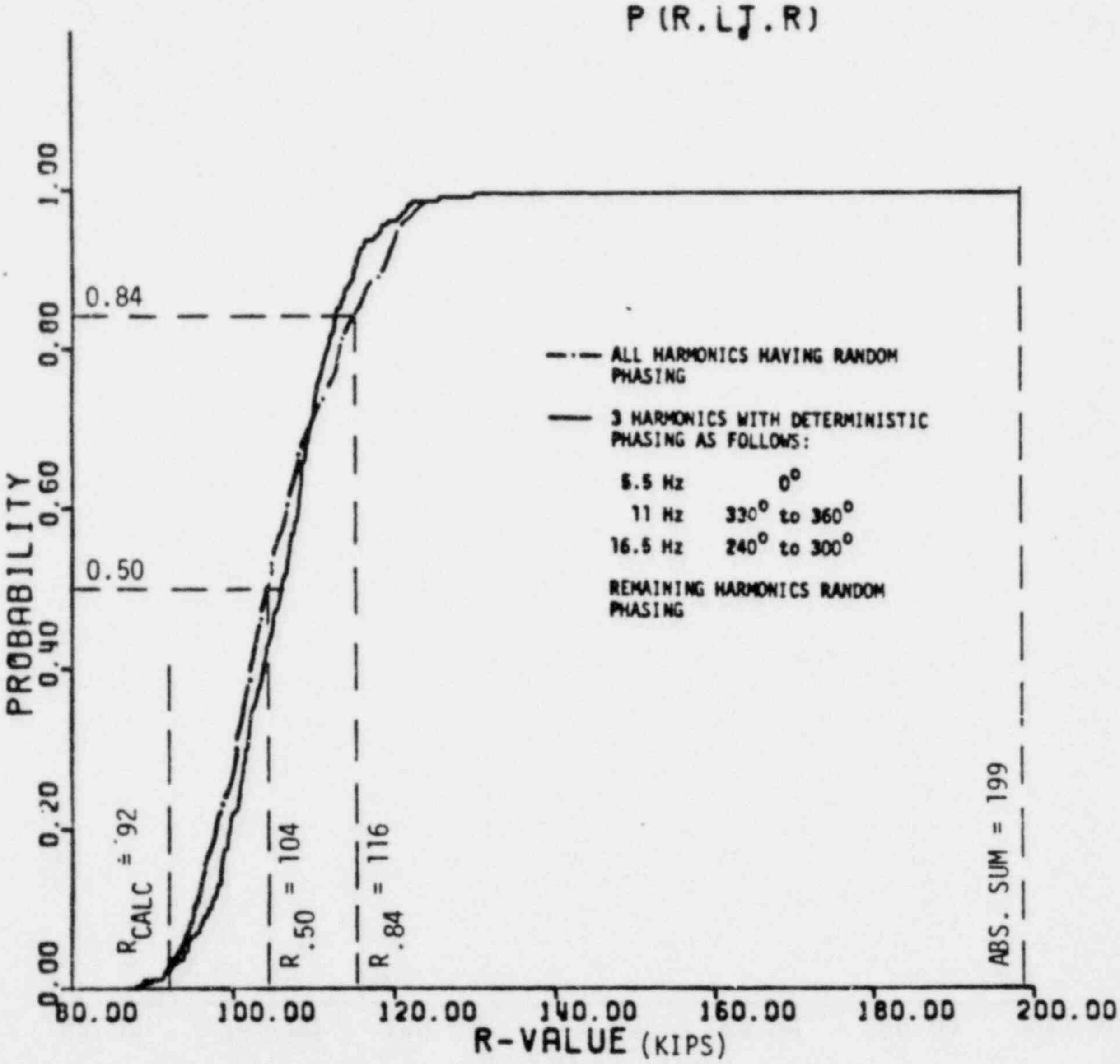
FSTF RIGID WALL FOURIER AMPLITUDE CDF CURVES (200 TRIALS)



INSIDE COLUMN AXIAL FORCE (24.808 - 25.902 SECONDS)

FSTF RIGID WALL FOURIER AMPLITUDE CDF CURVES (200 TRIALS)

CUMULATIVE DISTRIBUTION FUNCTION



OUTSIDE COLUMN AXIAL FORCE (24.808 - 25.902 SECONDS)

FSTF RIGID WALL FOURIER AMPLITUDE CDF CURVES (200 TRIALS)

CONCLUSIONS FROM FSTF RIGID WALL FOURIER AMPLITUDE CDF CURVES

- THE DIFFERENCE IN CDF CURVES ASSUMING ALL HARMONICS ARE RANDOM AND CONSIDERING CONSERVATIVE DETERMINISTIC PHASE RELATIONS FOR THREE HARMONICS IS EQUAL TO FOUR PERCENT OR LESS

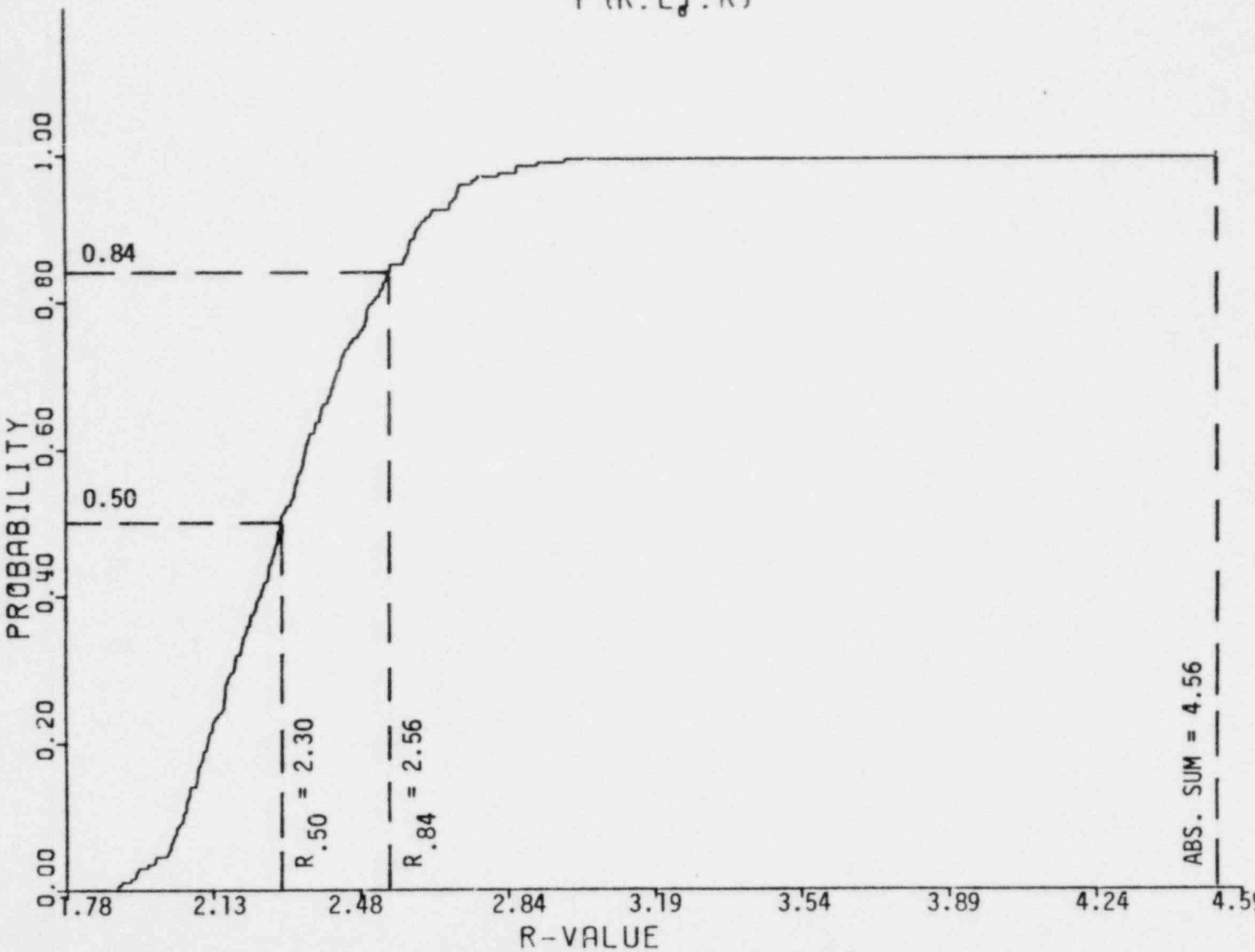
- MAXIMUM RESPONSE FROM 200 TRIALS IS, IN ALL CASES, MUCH LOWER THAN THE ABSOLUTE SUM OF HARMONIC RESPONSES

- THE ABSOLUTE SUM VALUES ARE ABOUT 1.7 TIMES THE VALUES CORRESPONDING TO 84% NEP

- CALCULATED RESPONSE IS IN THE STEEP REGION OF THE CDF CURVE BASED ON RANDOM PHASING. THIS IS FURTHER INDICATION THAT RANDOM PHASING IS ACTUAL BEHAVIOR

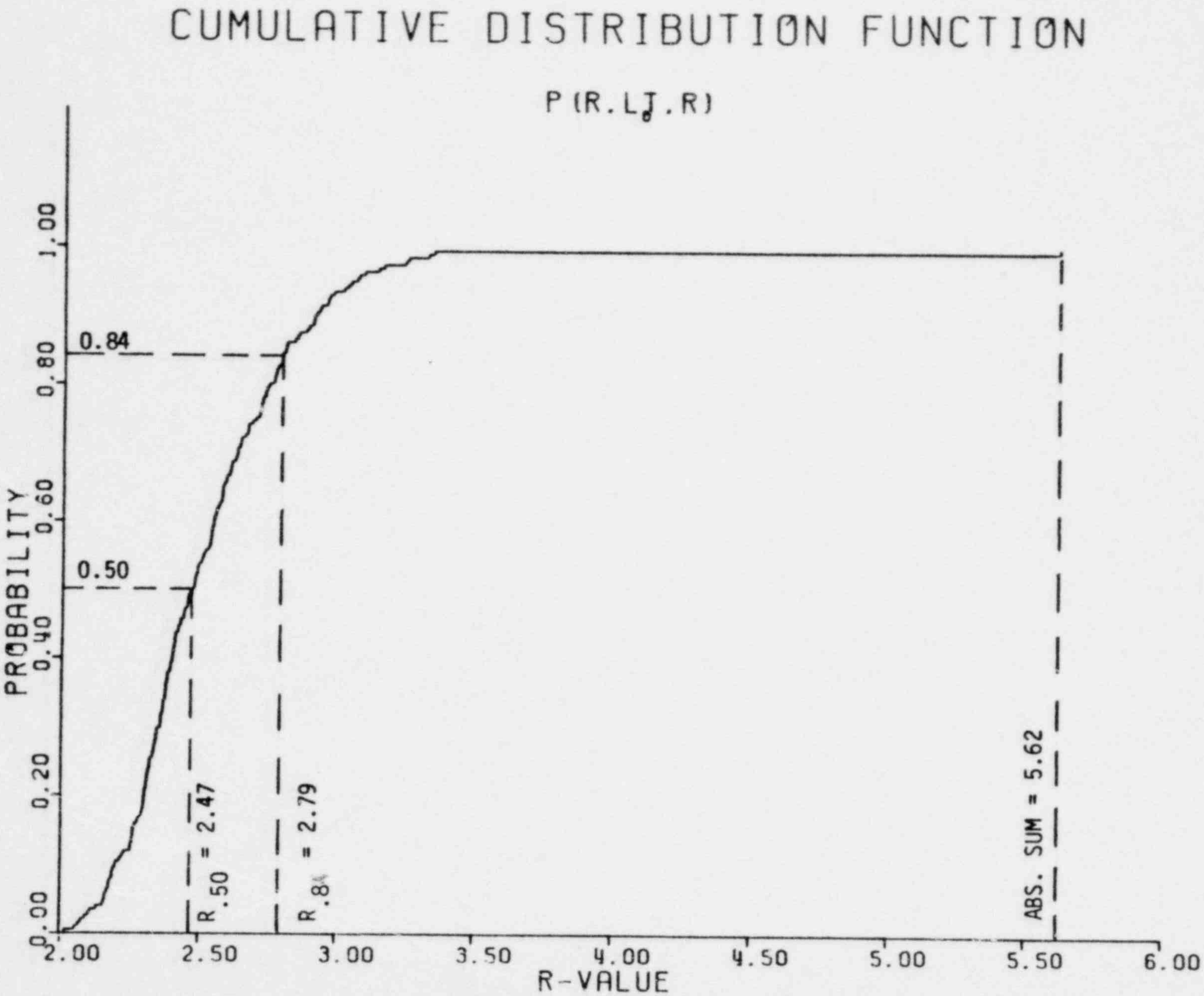
CUMULATIVE DISTRIBUTION FUNCTION

P(R.LJ.R)



BDC AXIAL MEMBRANE STRESS (KSI)

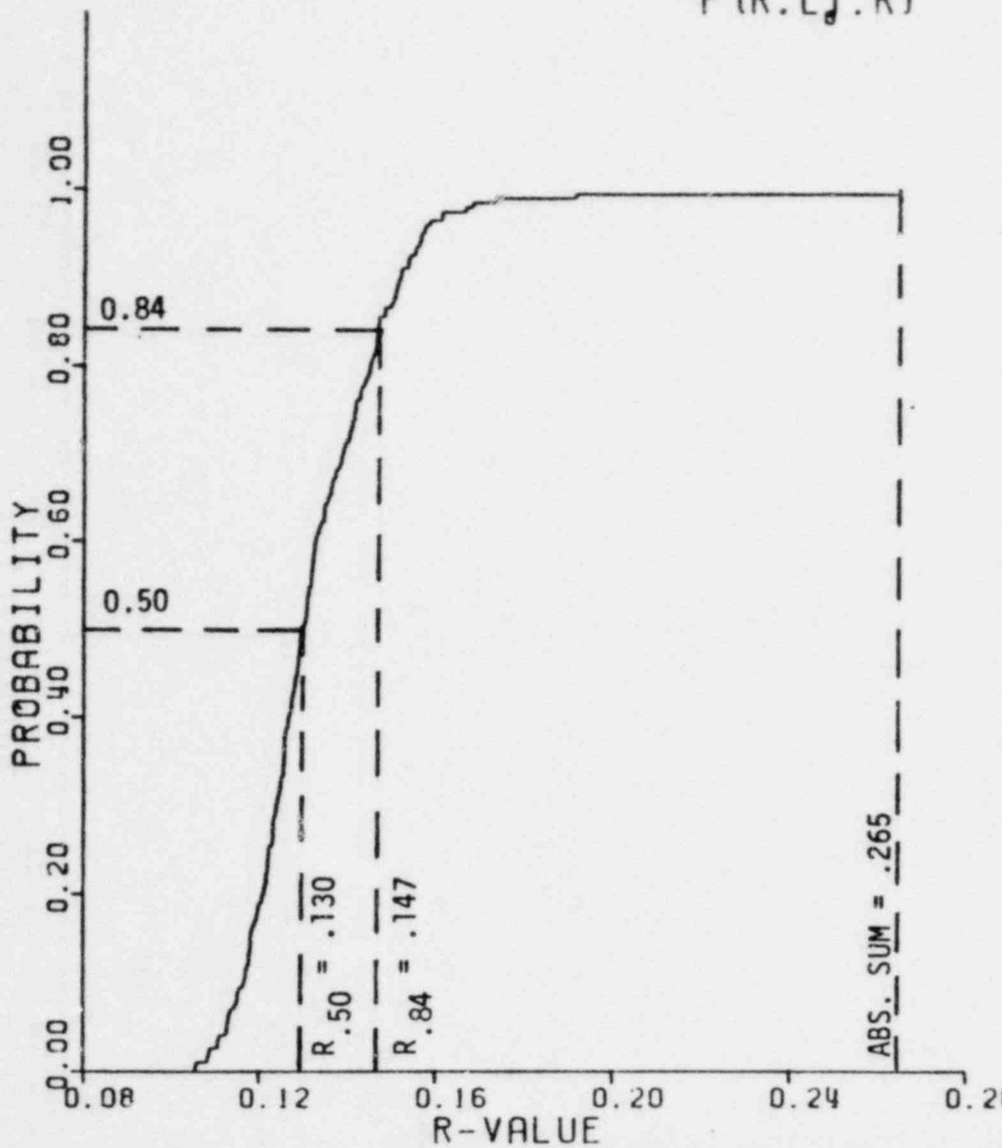
LDR AMPLITUDE CDF CURVE (200 TRIALS)



LDR AMPLITUDE CDF CURVE (200 TRIALS)

CUMULATIVE DISTRIBUTION FUNCTION

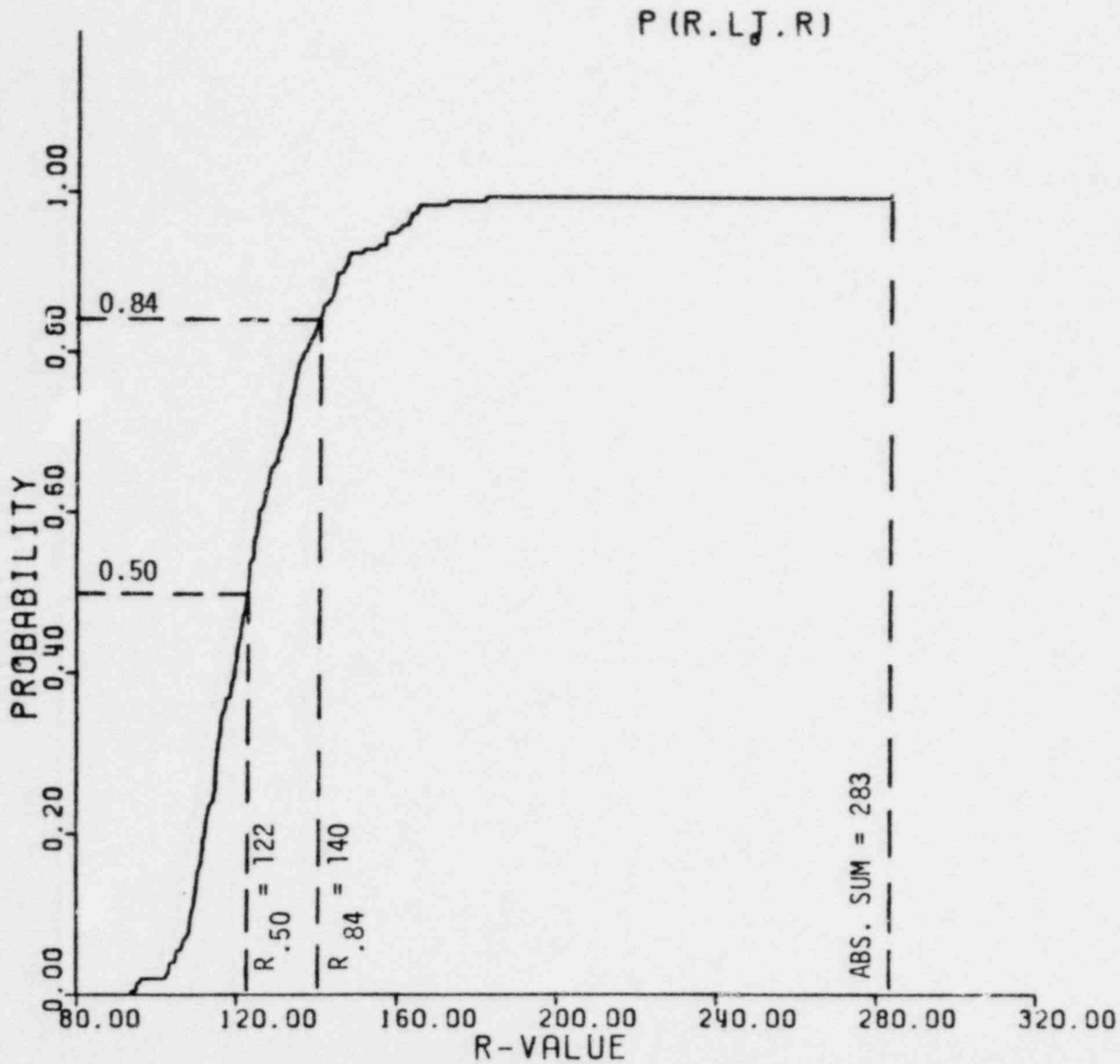
P(R.LJ.R)



BDC RADIAL DISPLACEMENT (INCHES)

LDR AMPLITUDE CDF CURVE (200 TRIALS)

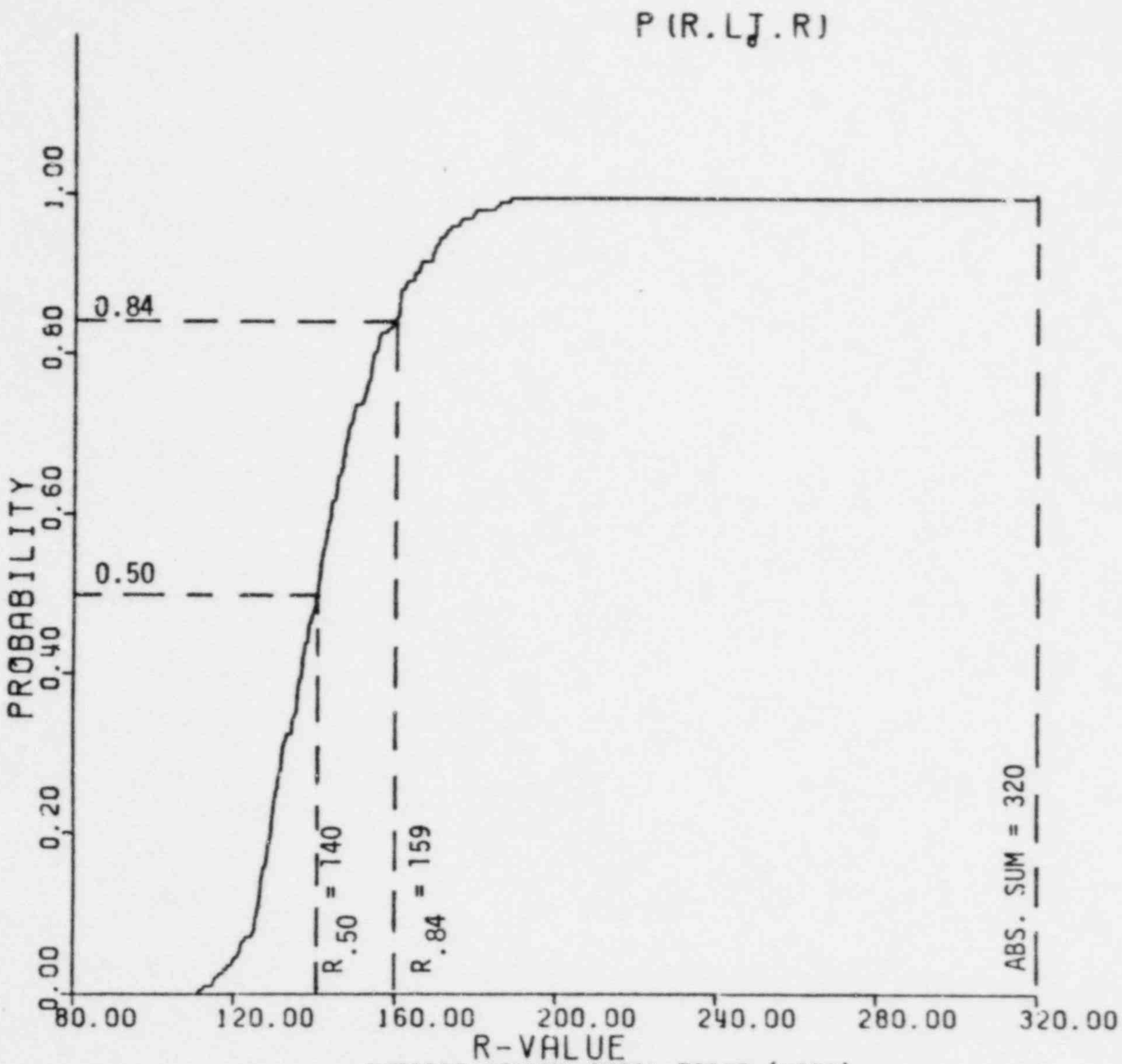
CUMULATIVE DISTRIBUTION FUNCTION



INSIDE COLUMN AXIAL FORCE (KIPS)

LDR AMPLITUDE CDF CURVE (200 TRIALS)

CUMULATIVE DISTRIBUTION FUNCTION



OUTSIDE COLUMN AXIAL FORCE (KIPS)

LDR AMPLITUDE CDF CURVE (200 TRIALS)

CONCLUSIONS FROM LDR AMPLITUDE CDF CURVES FOR FSTF RESPONSE

- MAXIMUM RESPONSE FROM 200 TRIALS IS, IN ALL CASES, MUCH LOWER THAN THE ABSOLUTE SUM OF HARMONIC RESPONSES

- THE ABSOLUTE SUM VALUES ARE ABOUT 2 TIMES THE VALUE CORRESPONDING TO 84% NEP

- THE USE OF ABSOLUTE SUM COMBINATION OF HARMONICS IS THE MAJOR SOURCE OF CONSERVATISM IN THE EVALUATION OF CO RESPONSE

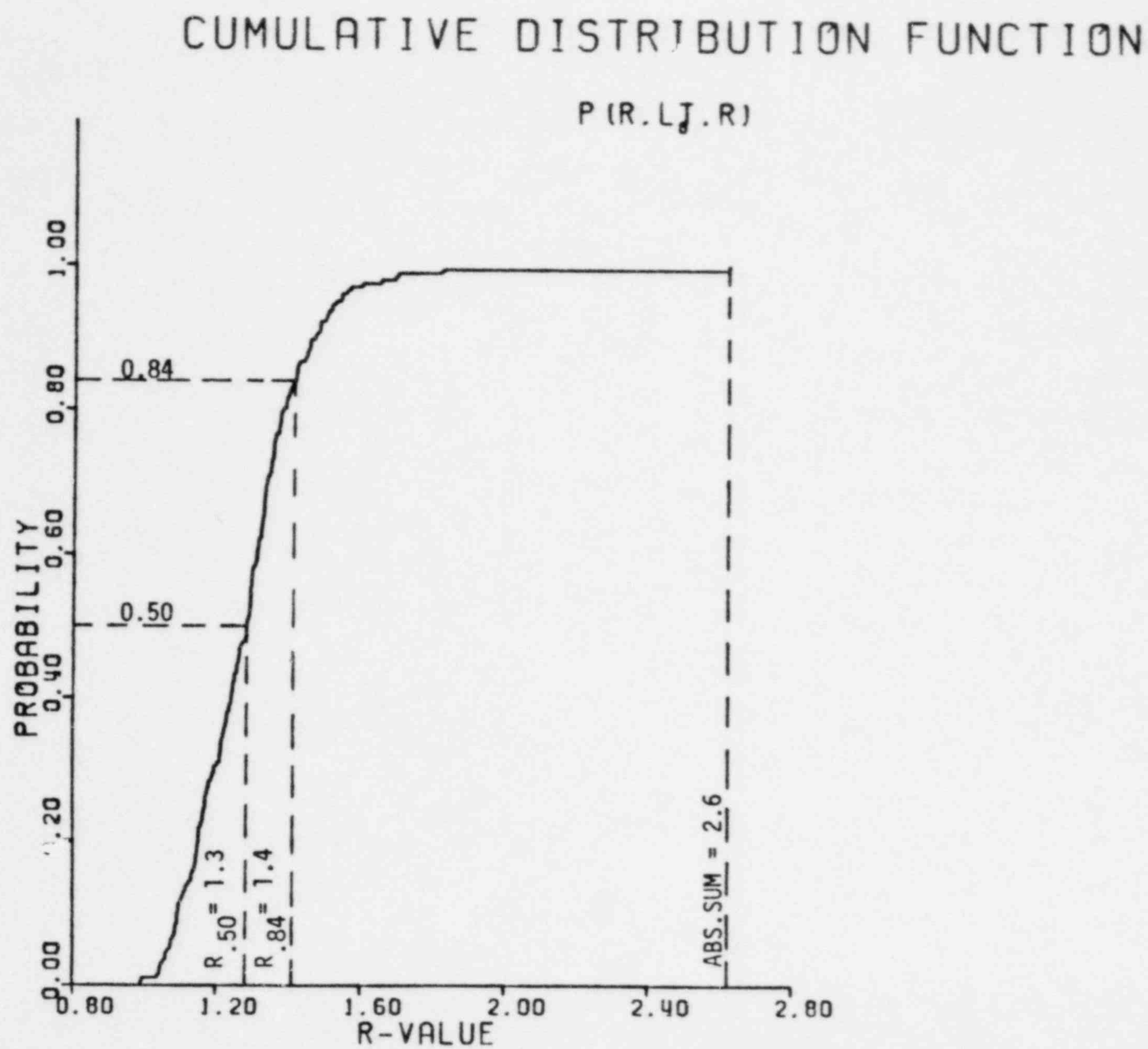


FIGURE 5-2. CDF CURVE (200 TRIALS) OF OYSTER CREEK TORUS BDC MIDBAY AXIAL STRESS (KSI)

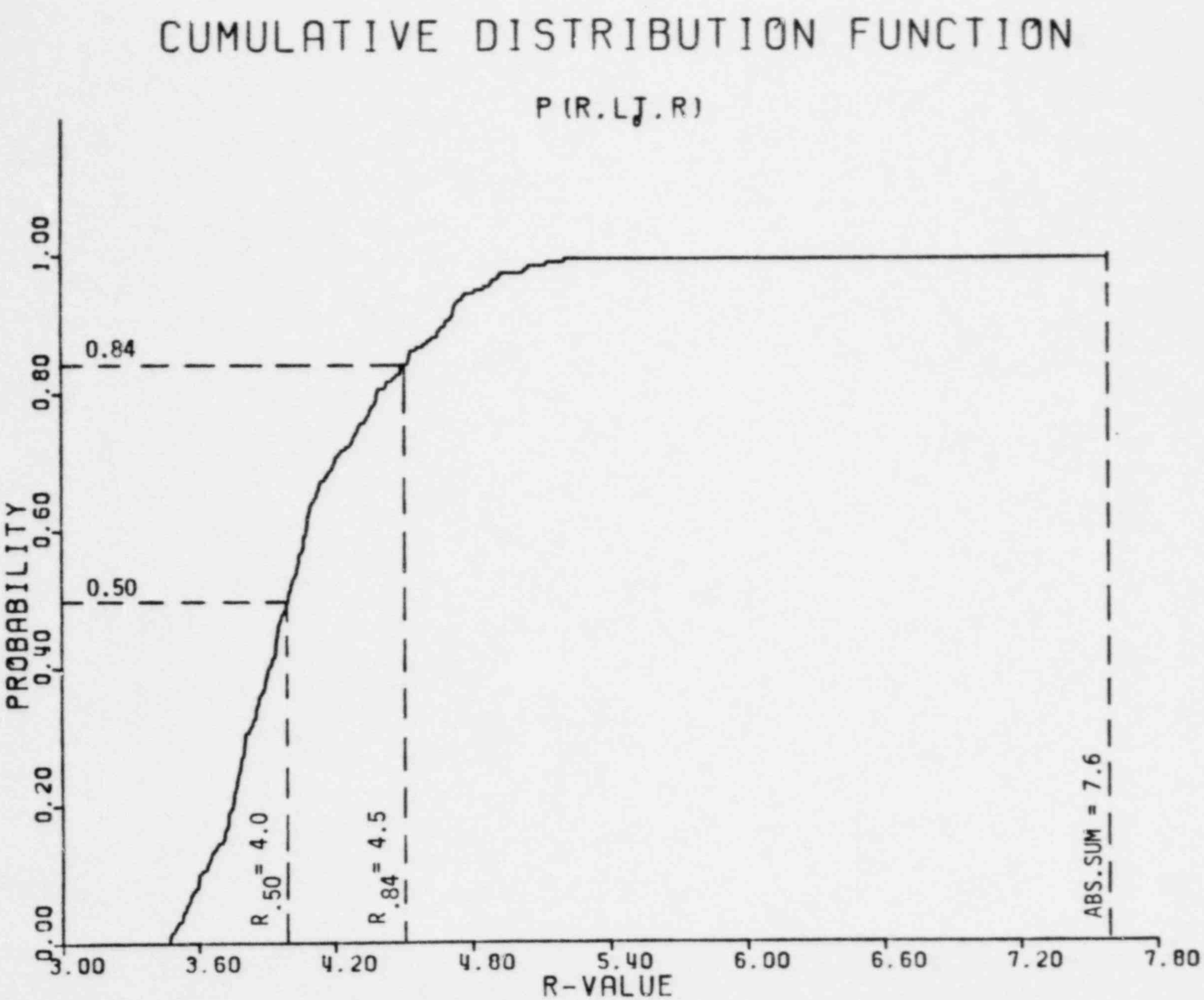


FIGURE 5-3. CDF CURVE (200 TRIALS) OF OYSTER CREEK TORUS BDC MIDBAY HOOP STRESS (KSI)

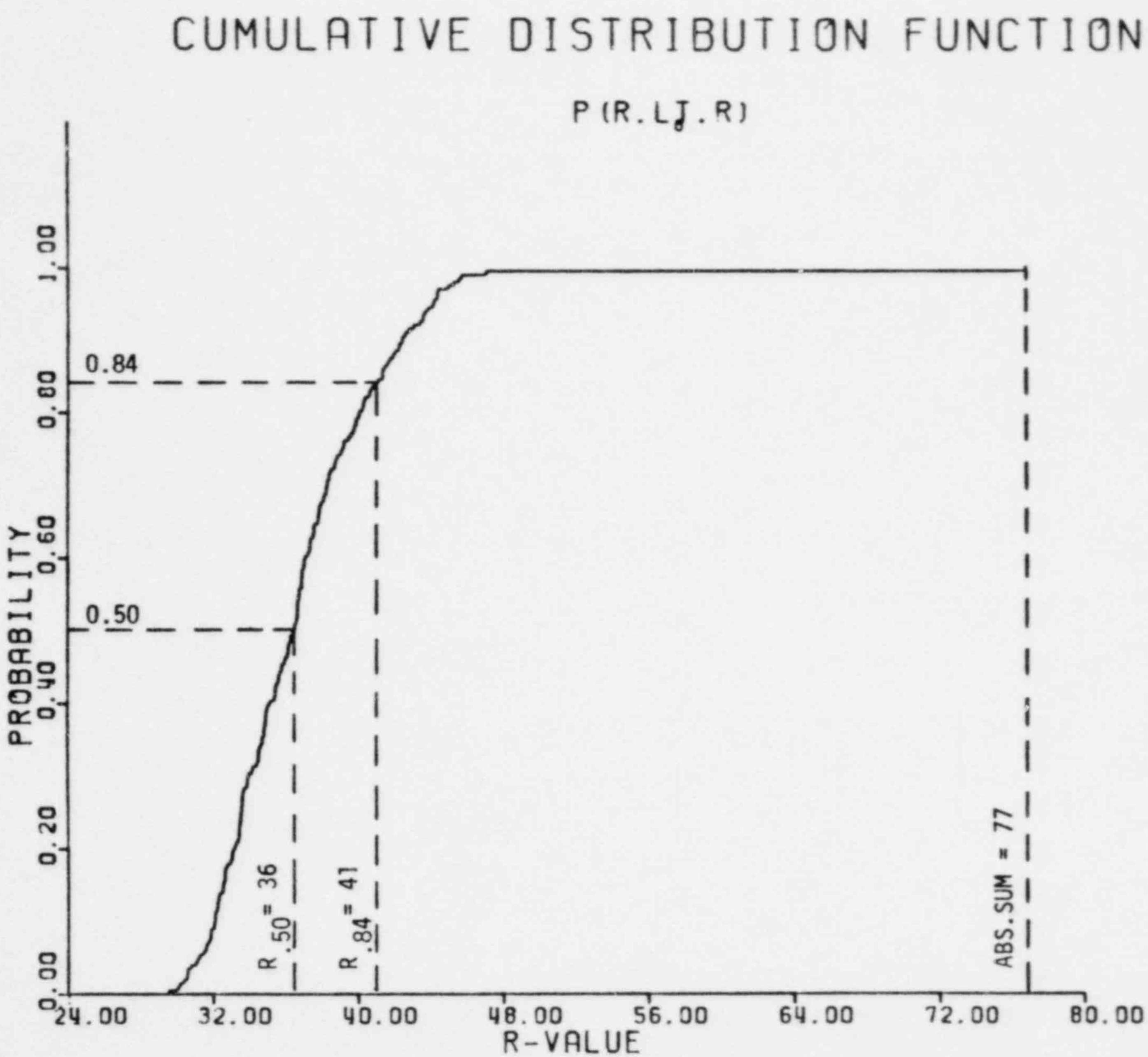


FIGURE 5-4. CDF CURVE (200 TRIALS) OF OYSTER CREEK TORUS INSIDE SUPPORT COLUMN AXIAL FORCE (KIPS)

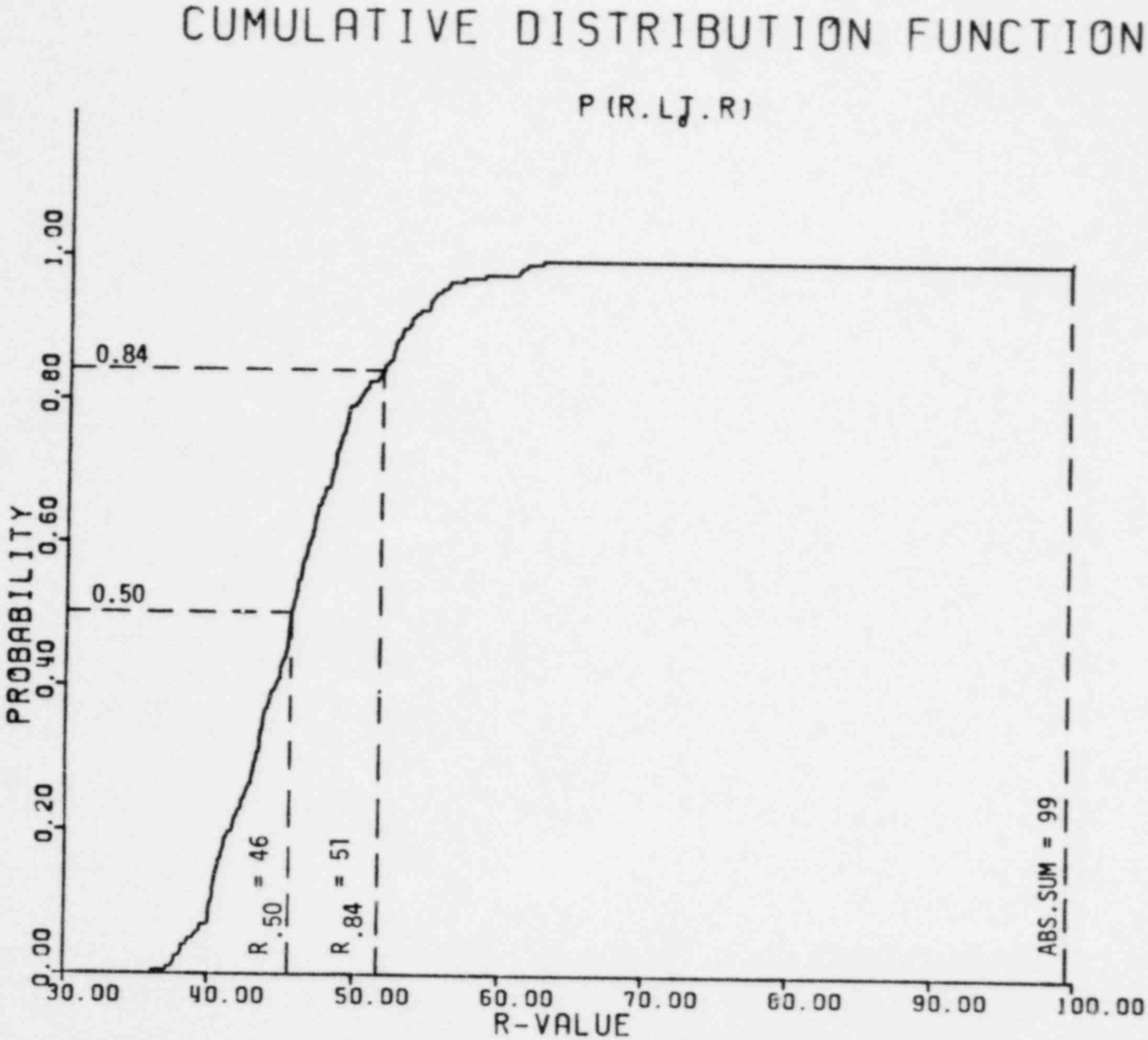


FIGURE 5-5. CDF CURVE (200 TRIALS) OF OYSTER CREEK TORUS OUTSIDE SUPPORT COLUMN AXIAL FORCE (KIPS)

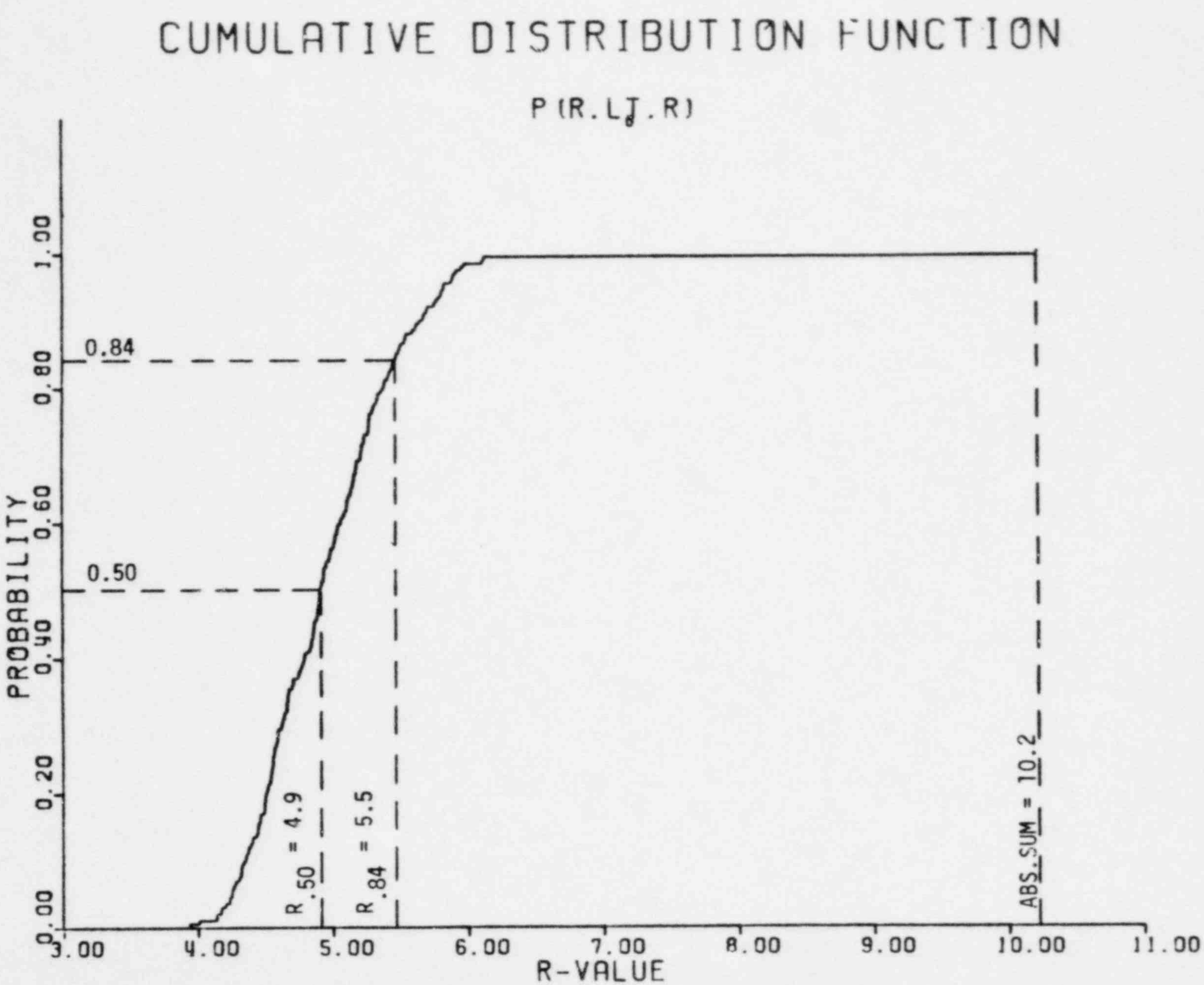


FIGURE 5-6. CDF CURVE (200 TRIALS) OF OYSTER CREEK TORUS BDC MIDBAY (ELEMENT 998) STRESS INTENSITY (KSI)

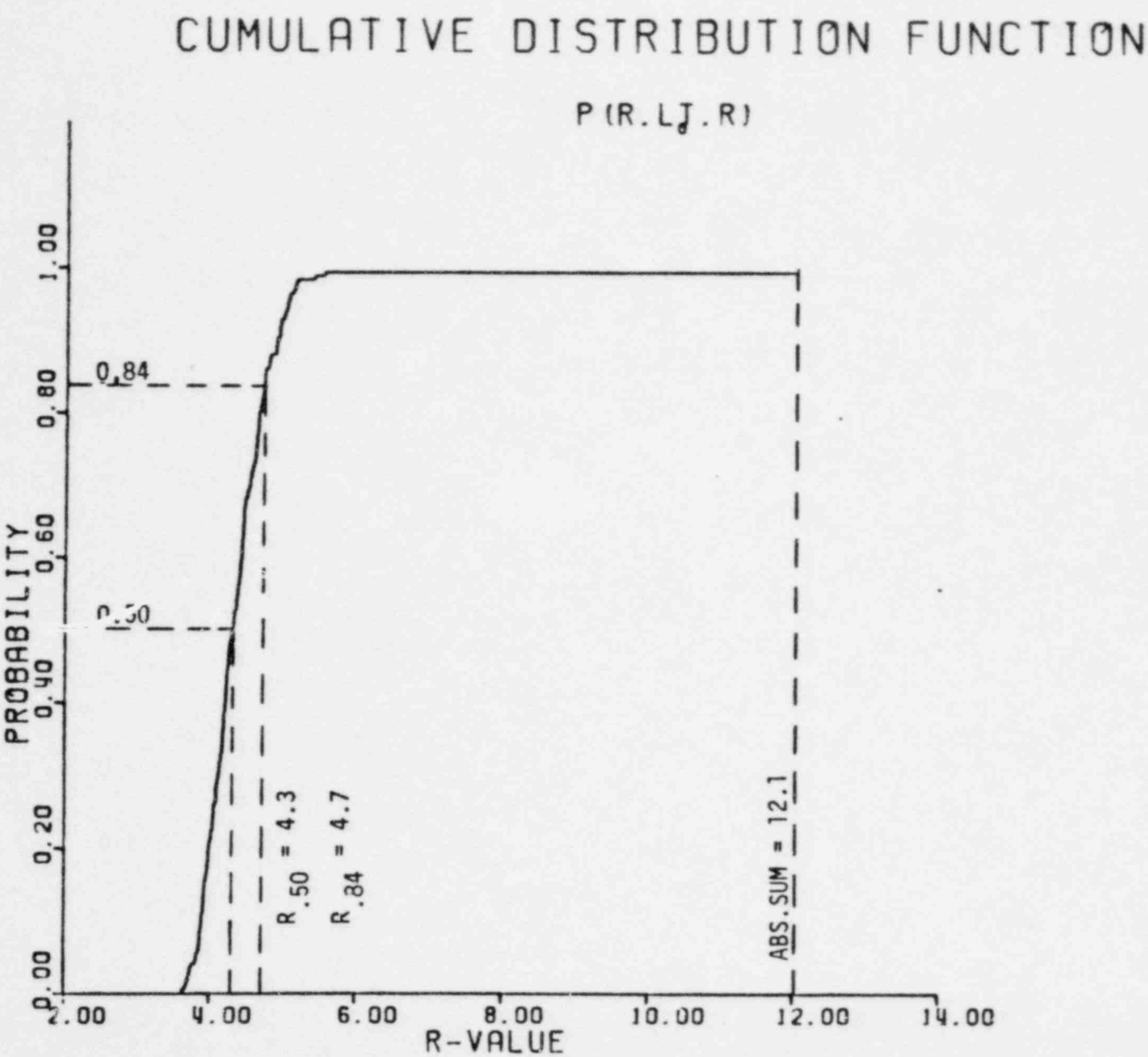


FIGURE 5-7. CDF CURVE (200 TRIALS) OF OYSTER CREEK TORUS BDC AT COLUMNS (ELEMENT 113) STRESS INTENSITY (KSI)

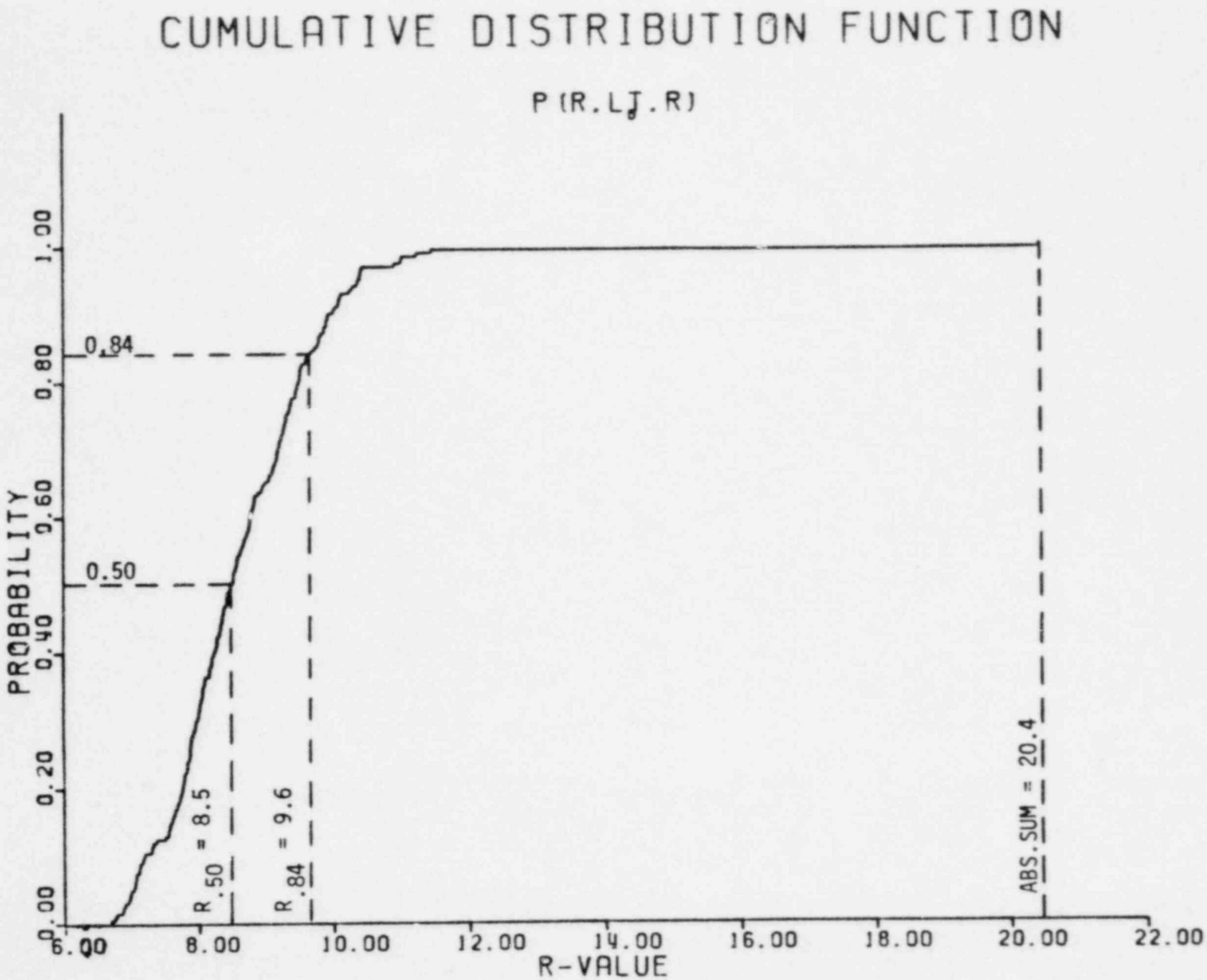


FIGURE 5-8. CDF (200 TRIALS) OF OYSTER CREEK TORUS 30° FROM BDC AT COLUMNS (ELEMENT 120) STRESS INTENSITY (KSI)

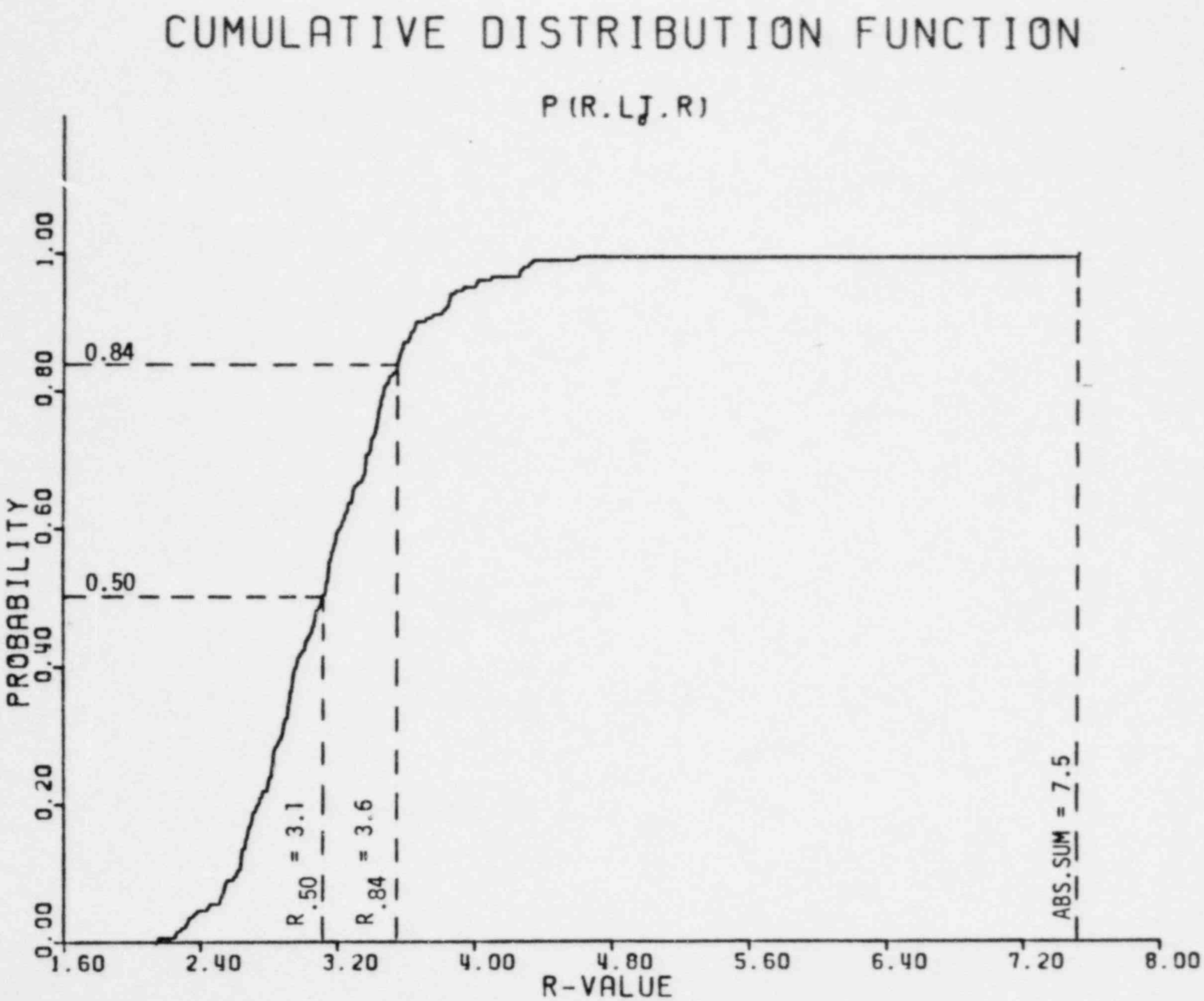


FIGURE 5-9. CDF CURVE (200 TRIALS) OF OYSTER CREEK TORUS OUTSIDE COLUMN COMBINED AXIAL AND BENDING STRESS (KSI)

CONCLUSIONS FROM LDR AMPLITUDE CDF CURVES FOR OYSTER CREEK RESPONSE

- CDF CURVES FOR OYSTER CREEK RESPONSE ARE SIMILAR TO THOSE FOR FSTF RESPONSE

- AGAIN, THE CDF CURVES ARE VERY STEEP SUCH THAT THERE IS LITTLE VARIATION IN CALCULATED RESPONSE FOR THE VARIOUS RANDOM TRIALS

- ALSO, THERE IS A LARGE MARGIN BETWEEN THE ABSOLUTE SUM COMBINATION OF HARMONICS AND THE CALCULATED RESPONSE FROM RANDOM TRIALS

- IT IS CONCLUDED THAT THE PROCEDURE OF COMBINING HARMONICS BY ABSOLUTE SUMMATION IS A MAJOR SOURCE OF CONSERVATISM AND A LARGE REDUCTION IN RESPONSE MAY BE ACHIEVED BY COMBINING HARMONICS IN A MANNER WHICH ACCOUNTS FOR RANDOM PHASING

HARMONIC RESPONSE COMBINATION RULES

FSTF RIGID WALL FOURIER AMPLITUDES (24.808 - 25.902 SEC)

RESPONSE QUANTITY	CDF CURVES 50% NEP RESPONSE	CDF CURVES 34% NEP RESPONSE	ABS. SUM	ABS. SUM 2 HIGHEST + $SRSS_{48}$	ABS. SUM 3 HIGHEST + $SRSS_{47}$	ABS. SUM 4 HIGHEST + $SRSS_{46}$
BDC AXIAL MEMBRANE STRESS (KSI)	1.78	1.83	2.87	1.79	1.93	2.02
BDC HOOP MEMBRANE STRESS (KSI)	1.85	2.01	3.42	1.83	1.95	2.06
BDC RADIAL DISPLACEMENT (INCHES)	0.100	0.107	0.166	0.100	0.108	0.114
INSIDE COLUMN AXIAL FORCE (KIPS)	93	101	176	92	98	103
OUTSIDE COLUMN AXIAL FORCE (KIPS)	104	116	199	105	111	117

LDR AMPLITUDES (FSTF RESPONSE)

RESPONSE QUANTITY	CDF CURVES 50% NEP RESPONSE	CDF CURVES 34% NEP RESPONSE	ABS. SUM	ABS. SUM 2 HIGHEST + $SRSS_{48}$	ABS. SUM 3 HIGHEST + $SRSS_{47}$	ABS. SUM 4 HIGHEST + $SRSS_{46}$
BDC AXIAL MEMBRANE STRESS (KSI)	2.30	2.56	4.56	2.13	2.40	2.63
BDC HOOP MEMBRANE STRESS (KSI)	2.47	2.79	5.62	2.20	2.49	2.75
BDC RADIAL DISPLACEMENT (INCHES)	0.130	0.147	0.265	0.122	0.139	0.154
INSIDE COLUMN AXIAL FORCE (KIPS)	122	140	283	113	129	143
OUTSIDE COLUMN AXIAL FORCE (KIPS)	140	159	320	128	145	160

TABLE 6-3

RESPONSES OF OYSTER CREEK TORUS AND SUPPORTS TO LDR CO LOAD AMPLITUDES CALCULATED BY USING DIFFERENT HARMONIC RESPONSE COMBINATION RULES

RESPONSE QUANTITY	CDF CURVES 50% NEP RESPONSE	CDF CURVES 84% NEP RESPONSE	ABS. SUM	ABS. SUM 2 HIGHEST + $SRSS_{38}$	ABS. SUM 3 HIGHEST + $SRSS_{37}$	ABS. SUM 4 HIGHEST + $SRSS_{36}$
BDC, MIDBAY AXIAL STRESS (KSI)	1.3	1.4	2.6	1.1	1.3	1.4
BDC, MIDBAY HOOP STRESS (KSI)	4.0	4.5	7.6	3.8	4.2	4.6
INSIDE COLUMN AXIAL FORCE (KIPS)	36	41	77	31	36	40
OUTSIDE COLUMN AXIAL FORCE (KIPS)	46	51	99	40	45	50

CANDIDATE DESIGN RULES FOR EVALUATING COMBINED STRESS (OYSTER CREEK RESPONSE)

	BDC Midbay Stress Intensity (ksi)		BDC Columns Stress Intensity (ksi)		30^{0} from BDC at Columns Stress Intensity (ksi)		Outside Column Axial Plus Bending Stress (ksi)	
50% NEP Response	4.9		4.3		8.5		3.1	
84% NEP Response	5.5		4.7		9.6		3.6	
Design Rules*	Worst Case Phasing	Component Phasing Retained	Worst Case Phasing	Component Phasing Retained	Worst Case Phasing	Component Phasing Retained	Worst Case Phasing	Component Phasing Retained
SRSS (40)	2.8	2.7	3.2	2.6	6.7	4.8	1.8	1.8
ABS(1) + SRSS(39)	3.9	3.8	4.4	3.7	9.2	6.6	2.5	2.5
ABS(2) + SRSS(38)	4.8	4.6	5.3	4.4	11.5	8.2	2.9	2.9
ABS(3) + SRSS(37)	5.4	5.1	6.2	5.0	13.3	9.6	3.3	3.3
ABS(4) + SRSS(36)	5.9	5.6	7.0	5.6	14.8	10.7	3.7	3.6
ABS(5) + SRSS(35)	6.4	6.0	7.6	6.2	15.8	11.3	4.1	4.0
ABS Sum	10.2	9.5	12.1	9.8	20.4	15.0	7.5	7.2

* Harmonics from 0 to 40 hz are considered.

ABS(x) + SRSS(40-x) = Absolute sum of x highest harmonic response amplitudes plus SRSS combination of the remaining harmonics.

CONCLUSIONS:

- ABSOLUTE SUM OF 3 HIGHEST + $SRSS_{47}$ ADEQUATELY APPROXIMATES 50% NEP VALUE
- ABSOLUTE SUM OF 4 HIGHEST + $SRSS_{46}$ ADEQUATELY APPROXIMATES 84% NEP VALUE
- FOR LDR ABSOLUTE SUM OF 3 HIGHEST + $SRSS_{47}$ LEADS TO ABOUT A FACTOR OF 2 REDUCTION FROM RESPONSE COMPUTED BY ABSOLUTE SUM OF ALL HARMONICS
- DIFFERENCE BETWEEN 3 HIGHEST AND 4 HIGHEST COMBINATION RULES AMOUNTS TO ABOUT 10% DIFFERENCE IN RESPONSES
- FOR COMBINED STRESS RESPONSE, HARMONIC RESPONSE AMPLITUDES SHOULD BE EVALUATED IN A MANNER WHICH RETAINS PHASING BETWEEN COMPONENT STRESSES FOR EACH HARMONIC. ASSUMING WORST CASE PHASING CAN LEAD TO EXCESSIVE CONSERVATISM
- CONSIDERING THE CONSERVATISM OF LDR AMPLITUDES, ACHIEVING 50% NEP BASED ON CONDITIONAL RANDOM PHASING ONLY CDF CURVES IS SUFFICIENT. THE ACTUAL NEP FOR COMBINED PEAK RESPONSE WILL BE MUCH GREATER THAN 50%

COMPARISON OF RESPONSE USING LDR AND FSTF AMPLITUDES

RESPONSE QUANTITY	LDR (50% NEP RESPONSE)*	FSTF FOURIER AMPLITUDE (50% NEP RESPONSE)*				
		24.001 TO 25.095 SEC	24.808 TO 25.902 SEC	26.016 TO 27.110 SEC	26.562 TO 27.656 SEC	26.745 TO 27.839 SEC
BDC AXIAL MEMBRANE STRESS (KSI)	2.40	1.92	1.93	1.76	2.11	2.38
BDC HOOP MEMBRANE STRESS (KSI)	2.49	2.00	1.95	1.77	2.04	2.18
BDC RADIAL DISPLACEMENT (INCHES)	0.139	0.114	0.108	0.102	0.117	0.134
INSIDE COLUMN AXIAL FORCE (KIPS)	129	113	98	97	108	111
OUTSIDE COLUMN AXIAL FORCE (KIPS)	145	126	111	109	121	125

* PHASING RULE: ABSOLUTE SUM AMPLITUDES OF HIGHEST 3 HARMONICS AND SRSS OF THE OTHER 47 HARMONICS

CONCLUSION: LDR AMPLITUDES ARE CONSERVATIVE IN THAT THEY ALWAYS LEAD TO GREATER RESPONSE AND AVERAGE OF ABOUT 10 PERCENT GREATER THAN THE HIGHEST FSTF FOURIER AMPLITUDE RESPONSE

COMPARISON OF RESPONSE OBTAINED FROM THE RECOMMENDED DESIGN APPROACH AND MEASURED FSTF RESPONSE

RESPONSE QUANTITY	LDR FSTF 50% NEP RESPONSE*	MAXIMUM FSTF RESPONSE (MEASURED)
BDC AXIAL MEMBRANE STRESS	2.4 KSI	2.3 KSI
BDC HOOP MEMBRANE STRESS	2.5 KSI	2.6 KSI
BDC RADIAL DISPLACEMENT	.14 INCHES	.11 INCHES
INSIDE COLUMN AXIAL FORCE	129 KIPS	93 KIPS
OUTSIDE COLUMN AXIAL FORCE	145 KIPS	110 KIPS

PHASING RULE: ABSOLUTE SUM OF HIGHEST 3 HARMONICS PLUS SRSS OF THE REMAINING 47 HARMONICS

* CONCLUSION: THE RECOMMENDED DESIGN APPROACH GENERALLY RESULTS IN A CONSERVATIVE ESTIMATE OF MEASURED FSTF RESPONSE

INFLUENCE OF HARMONICS FROM 30 TO 50 HZ (FSTF RESPONSE)

RESPONSE QUANTITY	CALCULATED RESPONSE					
	M-8 TEST AMPLITUDE AND PHASING (24.808 - 25.902 SECONDS)		M-8 TEST AMPLITUDE RANDOM HARMONIC COMBINATION RULE*		LDR AMPLITUDE RANDOM HARMONIC COMBINATION RULE*	
	UP TO 50 HZ	UP TO 30 HZ	UP TO 50 HZ	UP TO 30 HZ	UP TO 50 HZ	UP TO 30 HZ
BDC AXIAL MEMBRANE STRESS (KSI)	1.67	1.70	1.93	1.92	2.40	2.36
BDC HOOP MEMBRANE STRESS (KSI)	1.73	1.56	1.95	1.90	2.49	2.38
BDC RADIAL DISPLACEMENT (INCHES)	0.103	0.102	0.108	0.108	0.139	0.139
INSIDE COLUMN AXIAL FORCE (KIPS)	82	82	98	98	129	128
OUTSIDE COLUMN AXIAL FORCE (KIPS)	92	91	111	111	145	144

* COMBINATION RULE: ABSOLUTE SUM 3 HIGHEST HARMONICS + $SRSS_{47}$

CONCLUSION: HARMONICS ABOVE 30 HZ CONTRIBUTE LITTLE AND COULD BE IGNORED IN DESIGN.

INFLUENCE OF HARMONICS FROM 30 TO 40 HZ
(OYSTER CREEK RESPONSE)

Oyster Creek Response Quantity	Response for Harmonics up to 40 hz*	Response for Harmonics up to 30 hz*
BDC Midbay Axial Stress (ksi)	1.28	1.28
BDC Midbay Hoop Stress (ksi)	4.19	4.19
Inside Column Axial Force (kips)	36	36
Outside Column Axial Force (kips)	45	45
BDC Midbay Stress Intensity (ksi)	5.11	5.11
BDC Columns Stress Intensity (ksi)	5.03	5.03
30^{o} from BDC Columns Stress Intensity (ksi)	9.57	9.57
Outside Column Axial plus Bending Stresses (ksi)	3.25	3.25

COMBINATION RULE: ABSOLUTE SUM OF 3 HIGHEST HARMONICS + $SRSS_{47}$

* CONCLUSION: HARMONICS ABOVE 30 HZ DO NOT CONTRIBUTE SIGNIFICANTLY TO RESPONSE AND CAN BE IGNORED FOR DESIGN

CONCLUSIONS (I)

- IGNORING RANDOM PHASING OF HARMONICS HAS BEEN THE MAJOR SOURCE OF CONSERVATISM IN THE EVALUATION OF CO RESPONSE. LOAD AMPLITUDES AND STRUCTURE RESPONSE COMPUTATIONS DO NOT LEAD TO OVERCONSERVATIVE CO RESPONSE EVALUATION

- IT IS RECOMMENDED THAT FOR DESIGN THE FOLLOWING HARMONIC RESPONSE COMBINATION RULES BE EMPLOYED TO ESTIMATE 50% NEP RESPONSE, $R_{.50}$ FOR INDIVIDUAL RESPONSE QUANTITIES OR FOR COMBINED STRESS RESPONSE

  $R_{.50}$ = ABSOLUTE SUM OF THREE HIGHEST HARMONICS PLUS SRSS OF REMAINING HARMONICS

- RESPONSE AT THE 50% NEP LEVEL BASED ON CONDITIONAL RANDOM PHASING ONLY CDF CURVES AS DEFINED ABOVE IS SUFFICIENT BECAUSE DUE TO CONSERVATISM IN THE LOAD DEFINITION, THE ACTUAL NEP OF PEAK COMBINED RESPONSE WILL BE MUCH GREATER THAN 50 PERCENT

CONCLUSIONS (II)

- $R_{50\%}$ AS ESTIMATED ABOVE LEADS TO ABOUT A FACTOR OF 2 REDUCTION IN RESPONSE FROM THAT COMPUTED BY ABSOLUTE SUMMATION OF HARMONICS
- HARMONICS ABOVE ABOUT 30 HZ DO NOT CONTRIBUTE SIGNIFICANTLY TO RESPONSE AND CAN BE IGNORED FOR DESIGN
- HARMONIC RESPONSE AMPLITUDES FOR COMBINED STRESSES SHOULD BE COMPUTED IN A MANNER THAT PHASING BETWEEN COMPONENT STRESSES IS RETAINED FOR EACH HARMONIC. ASSUMING WORST CASE PHASING CAN LEAD TO EXCESSIVELY CONSERVATIVE RESPONSE

ALTERNATE TIME HISTORY APPROACH

SINGLE TIME HISTORY

- USE LDR AMPLITUDES AS FOURIER AMPLITUDES
- ASSUME ALL HARMONICS RANDOM FOR FOURIER PHASE ANGLES
- GENERATE INPUT TIME HISTORY AND CALCULATE RESPONSE TIME HISTORY
- MULTIPLY THE RESPONSE BY A SCALE FACTOR TO OBTAIN RESPONSE FOR WHICH THERE IS 90% CONFIDENCE OF BEING AT A SELECTED NON-EXCEEDANCE PROBABILITY

FSTF Response Quantity	Scale Factor for Being at 50% NEP	Scale Factor for Being at 84% NEP
BDC Axial Membrane Stress (ksi)	1.12	1.24
BDC Hoop Membrane Stress (ksi)	1.12	1.27
BDC Radial Displacement (in.)	1.12	1.27
Inside Column Axial Force (kips)	1.13	1.29
Outside Column Axial Force (kips)	1.12	1.27
Oyster Creek Response Quantity		
BDC Midbay Axial Stress (ksi)	1.17	1.29
BDC Midbay Hoop Stress (ksi)	1.11	1.25
Inside Column Axial Force (kips)	1.14	1.27
Outside Column Axial Force (kips)	1.13	1.28
BDC Midbay Stress Intensity (ksi)	1.13	1.26
BDC Columns Stress Intensity (ksi)	1.11	1.21
30^{o} from BDC Columns Stress Intensity (ksi)	1.18	1.34
Outside Column Axial Plus Bending (ksi)	1.19	1.36

CONCLUSIONS:

- FOR SINGLE TIME HISTORY APPROACH, THE SCALE FACTOR TO OBTAIN 90% CONFIDENCE OF BEING AT 50% NEP LEVEL IS 1.2
- SCALE FACTOR TO OBTAIN 90% CONFIDENCE OF BEING AT 84% NEP LEVEL IS 1.4
- FOR DESIGN, IT IS RECOMMENDED THAT SINGLE TIME HISTORY ANALYTICAL RESPONSE BE SCALED BY 1.2 TO ACHIEVE THE APPROPRIATE LEVEL OF CONSERVATISM CONSISTENT WITH THAT OBTAINED FOR THE HARMONIC COMBINATION DESIGN RULE RECOMMENDED EARLIER