AGENDA

SRSS STATUS REVIEW

AUGUST 8, 1979

• MK II OPENING REMARKS	DR. H. CHAU
• SRSS HISTORY - SUMMARY AND OVERVIEW	DR. NEWMARK
• DISCUSSION OF NEWMARK/KENNEDY CRITERIA AND RECENT EFFORTS	DR. KENNEDY
• BNL STUDY PRELIMINARY REVIEW	BNL?/DR. KENNEDY
• CONCLUSIONS	DR. KENNEDY

BASES FOR SRSS

- **RELIABILITY BASIS**

  IT HAS BEEN SHOWN THAT THE USE OF SRSS COMBINATION OF PEAK RESPONSES IN DESIGN DOES NOT SIGNIFICANTLY ALTER THE RELIABILITY OF STRUCTURAL COMPONENTS FROM THAT OBTAINED THROUGH THE USE OF ABSOLUTE SUM (AS) COMBINATION.

- **OPTIMUM DESIGN BASIS**

  THE CASE HAS BEEN PRESENTED THAT THE OPTIMUM BALANCE BETWEEN STRENGTH AND DUCTILITY, AND BETWEEN STIFFNESS UNDER DYNAMIC INERTIAL EFFECTS AND FLEXIBILITY TO WITHSTAND THERMAL AND DISPLACEMENT EFFECT IS BETTER ACHIEVED THROUGH THE USE OF SRSS COMBINATION OF DYNAMIC RESPONSE RATHER THAN AS COMBINATION.

- **DYNAMIC MARGIN BASIS**

  IT HAS BEEN SHOWN THAT THE RATIO BETWEEN THE DYNAMIC VERSUS STATIC MARGIN TO FAILURE IS GENERALLY SUFFICIENT SO THAT THERE IS A GREATER DYNAMIC MARGIN AGAINST FAILURE FOR STRUCTURES DESIGNED FOR SRSS COMBINED DYNAMIC RESPONSES THAN THE STATIC MARGIN.

- **STATISTICAL BASIS**

  THE STATISTICAL BASIS FOR THE SRSS METHOD IS THAT THE SRSS COMBINED PEAK RESPONSE SHOULD HAVE AT LEAST AS GREAT A NON-EXCEEDANCE PROBABILITY AS THE INDIVIDUAL RESPONSES BEING COMBINED. THIS MIGHT BE CALLED THE RISK-IN EQUALS RISK-OUT PRINCIPLE.

BASIC ASSUMPTION BEHIND CRITERIA FOR SRSS COMBINATION OF RESPONSES

- MANY SOURCES OF CONSERVATISM EXIST IN DESIGN AND EVALUATION PROCESS.
- ADDITIONAL CONSERVATISM DOES NOT HAVE TO BE INCORPORATED WITHIN THE RESPONSE COMBINATION PROCESS.
- IT IS NOT NECESSARY FOR THE COMBINED RESPONSE TO HAVE A LOWER PROBABILITY OF EXCEEDANCE THAN THE INDIVIDUAL RESPONSES.

CRITERIA 1 REQUIREMENTS:

- RESPONSE COMPONENTS FROM INDEPENDENT EVENTS OR RANDOM PHASING

- LIMITED NUMBER OF NEAR PEAK EXCURSION

  NO MORE THAN 5 EXCEEDING 75% OF THE MAXIMUM, OR
  NO MORE THAN 10 EXCEEDING 60% OF THE MAXIMUM

- LIMITED DURATION

  10 SECONDS OR LESS

- APPROXIMATELY ZERO MEAN

JUSTIFICATION OF CRITERION 1

- CRITERION 1 IS INTENDED TO ASSURE THAT RESPONSE IS EARTHQUAKE-LIKE

- FOR CERTAIN STATIONARY STOCHASTIC PROCESSES THE PROBABILITY OF EXCEEDANCE OF SRSS COMBINED RESPONSE CAN BE SHOWN TO BE EQUAL TO THE PROBABILITY OF EXCEEDANCE OF THE INDIVIDUAL RESPONSES

$$P\left[R \leq R_{SRSS_{84}}\right] = 84\%$$

- EARTHQUAKE-LIKE RESPONSES HAVE BEEN SHOWN TO BE REASONABLY APPROXIMATED AS STATIONARY STOCHASTIC PROCESSES AND CAN BE EVEN BETTER APPROXIMATED AS NON-STATIONARY PROCESSES

- FOR NON-STATIONARY PROCESSES:

$$P\left[R \leq R_{SRSS_{84}}\right] \geq 84\% \qquad (1)$$

- EARTHQUAKE-LIKE RESPONSE EXPECTED TO MEET EQUATION 1

- EARTHQUAKE-LIKE RESPONSE REQUIRES LESS NEAR-MAX. PEAKS (MORE NON-STATIONARY) THAN FOR EARTHQUAKE RESPONSE, APPROXIMATELY ZERO MEAN, AND RANDOM PHASING

- RANDOM PHASING AUTOMATICALLY ACHIEVED BY RANDOM START TIME. TO BE CONSIDERED RANDOM, RELATIVE START TIMES MUST BE CONSIDERED UNKNOWN WITHIN A TIME INTERVAL GREATER THAN ABOUT 2 TO 5 TIMES THE NATURAL PERIOD OF THE STRUCTURE

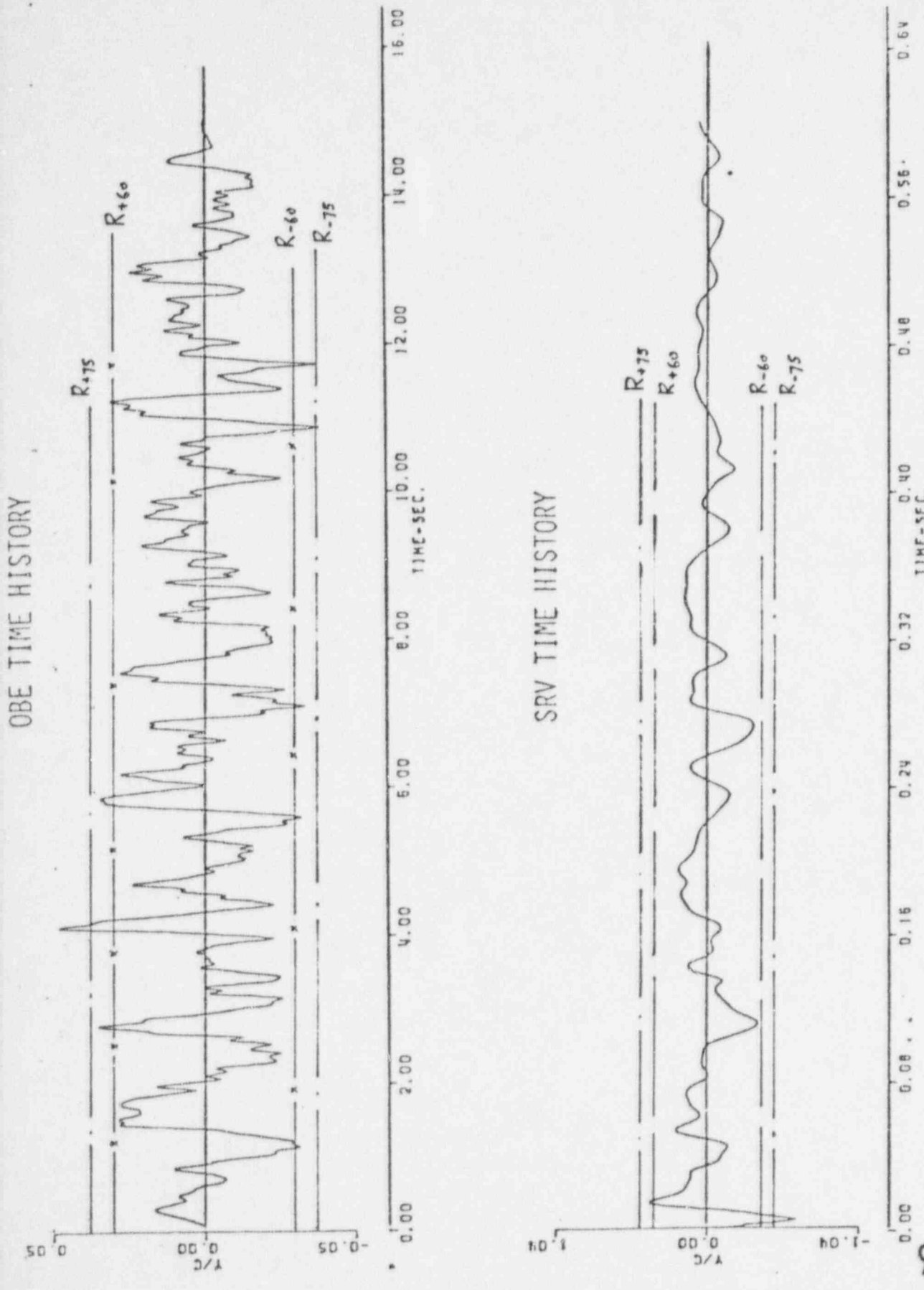

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FIGURE 1-1. DYNAMIC EVENT LOADING FUNCTIONS

EDRG

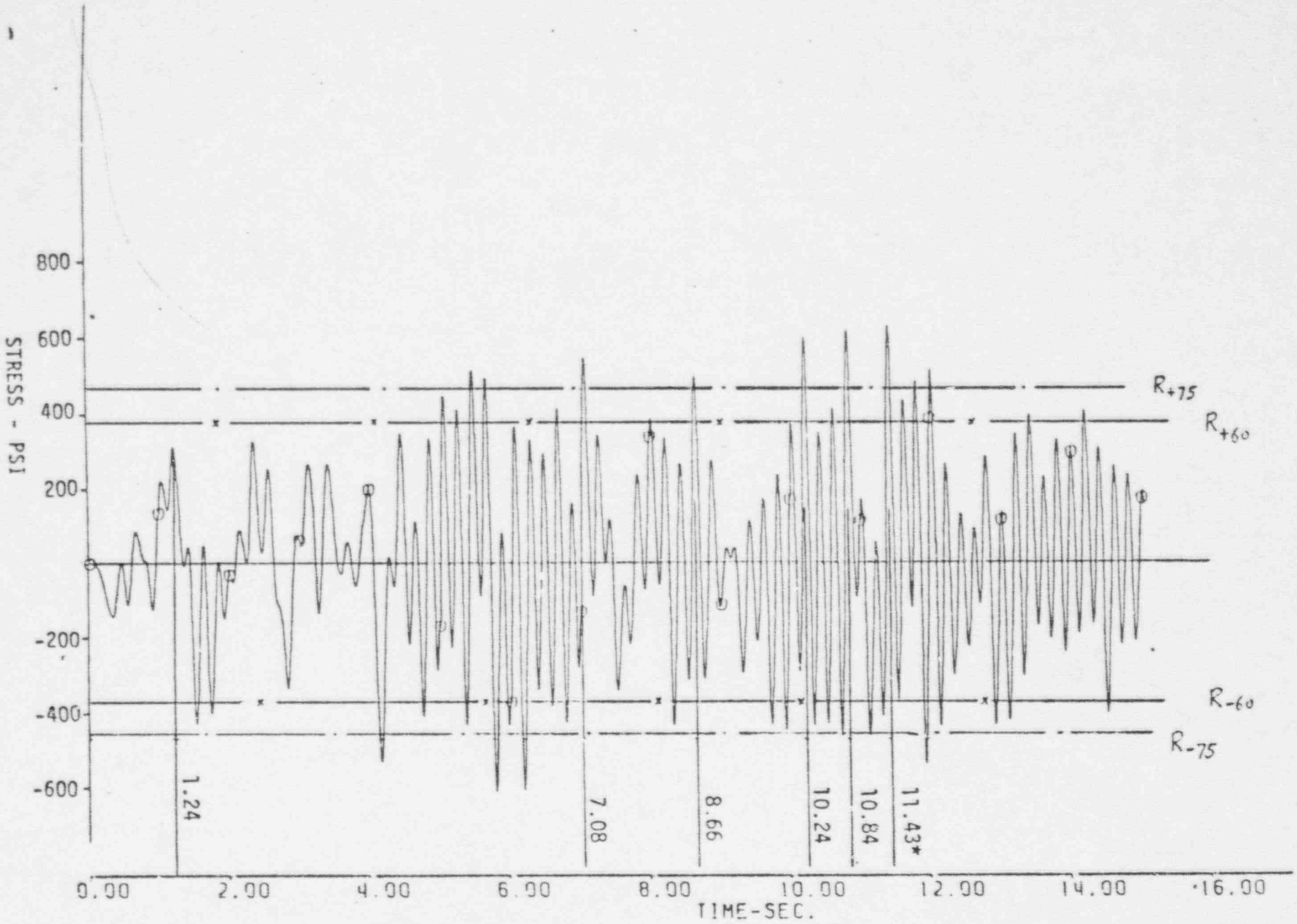


FIGURE 3-6. ELASTIC RESPONSE TO UNSCALED OBE, 5 Hz MODEL, 2 PERCENT DAMPING

* Time for peak elastic response.

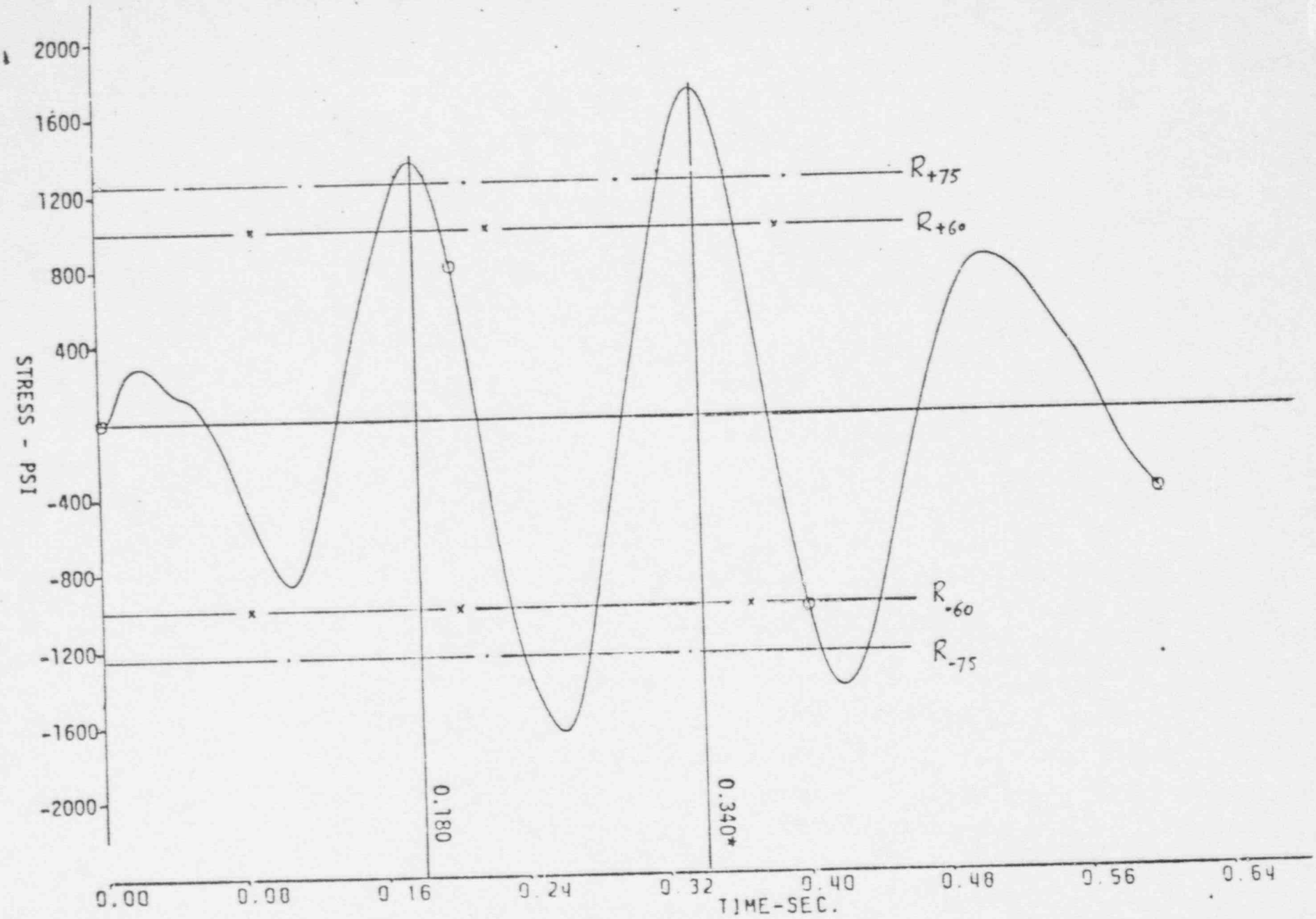


FIGURE 3-7. ELASTIC RESPONSE TO UNSCALED SRV, 5 Hz MODEL, 2 PERCENT DAMPING

* Time for peak elastic response.

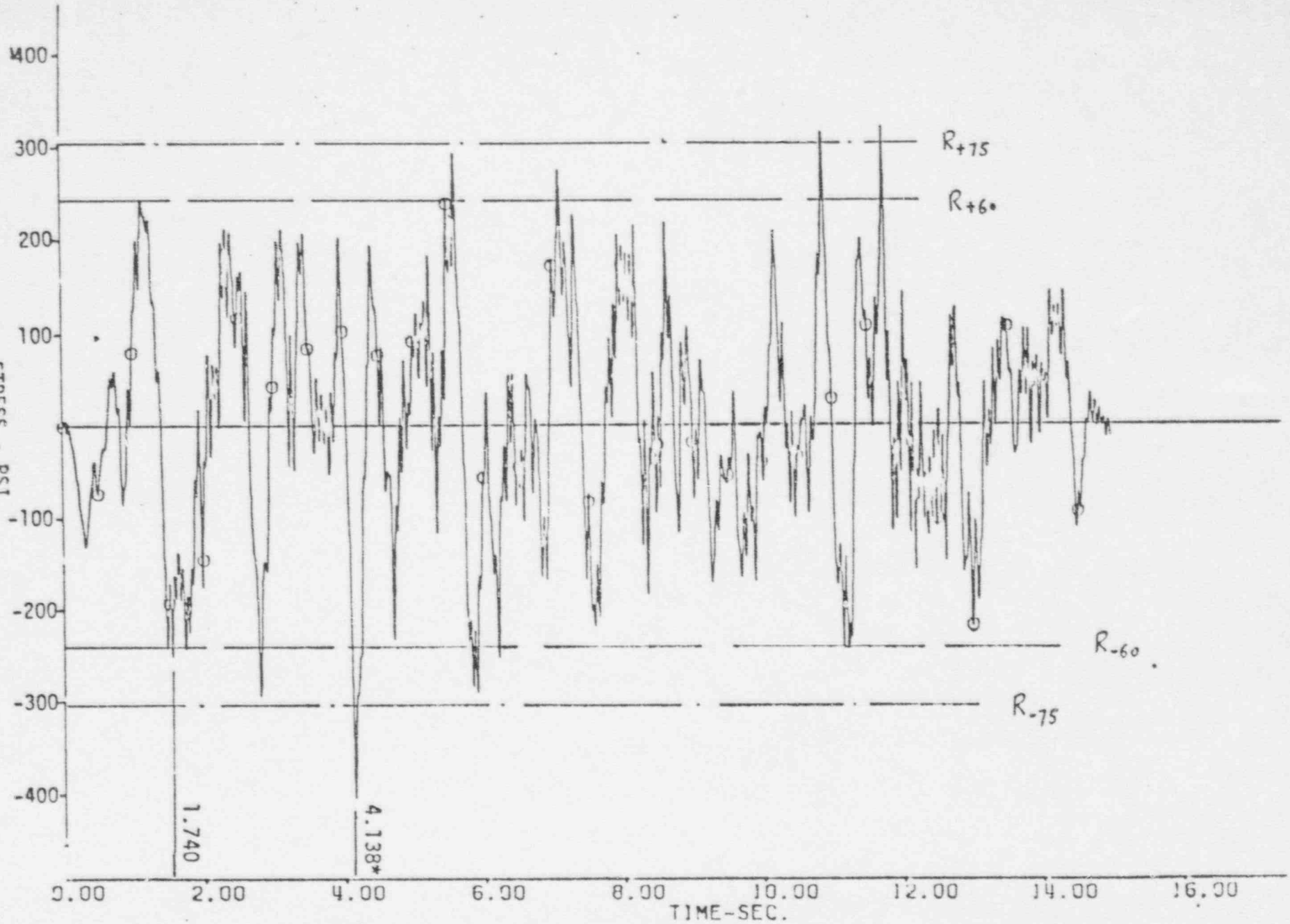


FIGURE 3-8. ELASTIC RESPONSE TO UNSCALED OBE, 16 Hz MODEL, 2 PERCENT DAMPING

* Time for peak elastic response.

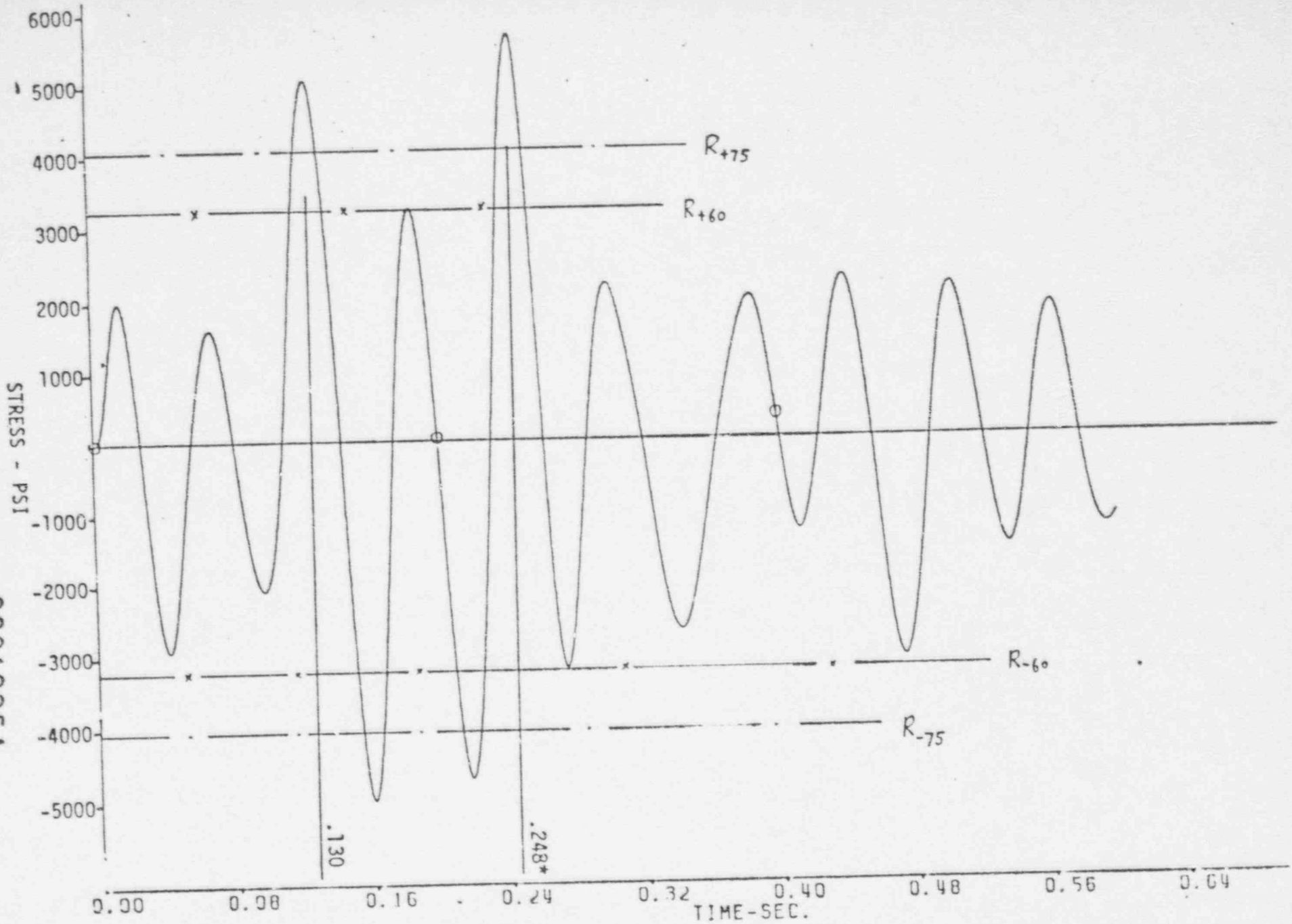


FIGURE 3-9. ELASTIC RESPONSE TO UNSCALED SRV, 16 Hz MODEL, 2 PERCENT DAMPING

* Time for peak elastic response.

TIME HISTORY	INPUT OR RESPONSE / NO. OF PEAKS	LOADING	RESPONSE	
			SDOF, 5 HZ 0.02 DAMPING	SDOF, 16 HZ 0.02 DAMPING
OBE	N_{60}	5	23	9
	N_{75}	1	9	2
SRV	N_{60}	1	2	2
	N_{75}	1	2	3

CRITERION 2

$R_{SRSS_{84}}$ = SRSS COMBINED RESPONSE WHERE EACH INDIVIDUAL RESPONSE HAS BEEN DEFINED CONSERVATIVELY AT 84TH PERCENTILE OR F•MEDIAN.

$R_{T_{84}}$ = RANDOM TIME PHASE COMBINED RESPONSE WHERE ALL AMPLITUDES DEFINED AT 84TH PERCENTILE.

R = COMBINED RESPONSE CONSIDERING BOTH RANDOM AMPLITUDE AND TIME PHASING.

GOAL OF SRSS COMBINATION

$$P\left[R \leq R_{SRSS_{84}}\right] \geq 84\% \qquad (1)$$

CRITERION 2 REQUIREMENT

$$P\left[R_{T_{84}} \leq R_{SRSS_{84}}\right] \geq 50\% \qquad (2)$$

&

$$P\left[R_{T_{84}} \leq 1.2\ R_{SRSS_{84}}\right] \geq 85\% \qquad (3)$$

JUSTIFICATION OF CRITERION 2

1. THE GOAL OF SRSS COMBINATION (EQU. 1) CAN BE MATHEMATICALLY PROVEN FOR CERTAIN INDEPENDENT STOCHASTIC INPUT FORCING FUNCTIONS.

2. FOR REAL EARTHQUAKE TIME HISTORIES IT HAS BEEN DEMONSTRATED THAT EQUATIONS (1), (2), ARE MET.

3. JUDGED THAT MEETING EQUATIONS (2) AND (3) ARE SUFFICIENT TO REASONABLY ASSURE EQUATION (1) IS REASONABLY MET. THIS JUDGEMENT IS BOLSTERED BY APPROXIMATE, SIMPLIFIED, MATHEMATICAL DEVELOPMENT.

4. DEMONSTRATION ANALYSES WERE PERFORMED TO DEMONSTRATE THAT CASES MEETING CRITERION 2 (EQUATIONS (2) AND (3)) DO MEET GOAL (EQU. 1) WHEN:

$$R_{i_{84}} = \left\{ \begin{array}{l} R_{84\%} \\ \text{or} \\ F \cdot R_{50\%} \end{array} \right\}$$

$$1.05 \leq F \leq 1.2$$

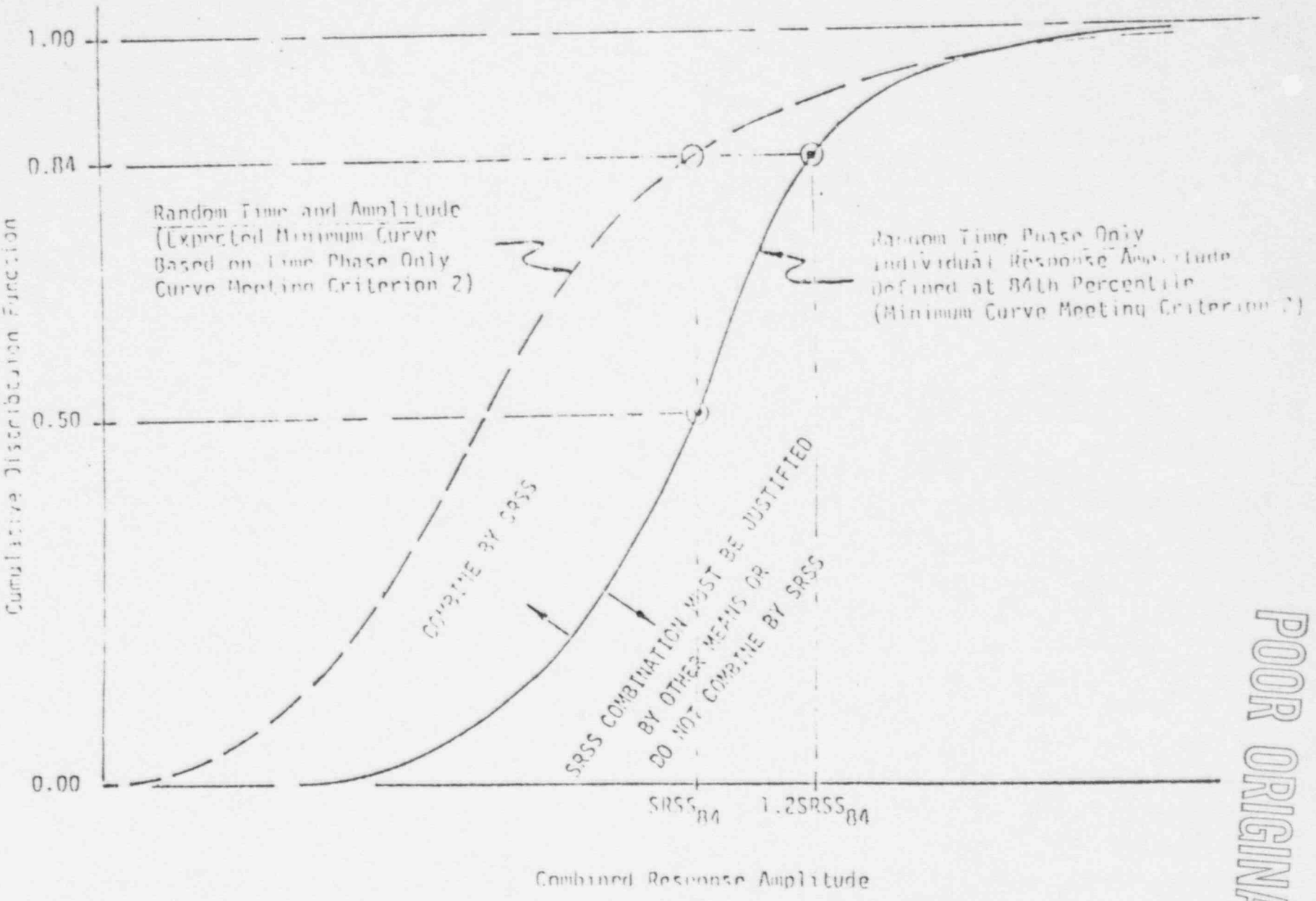


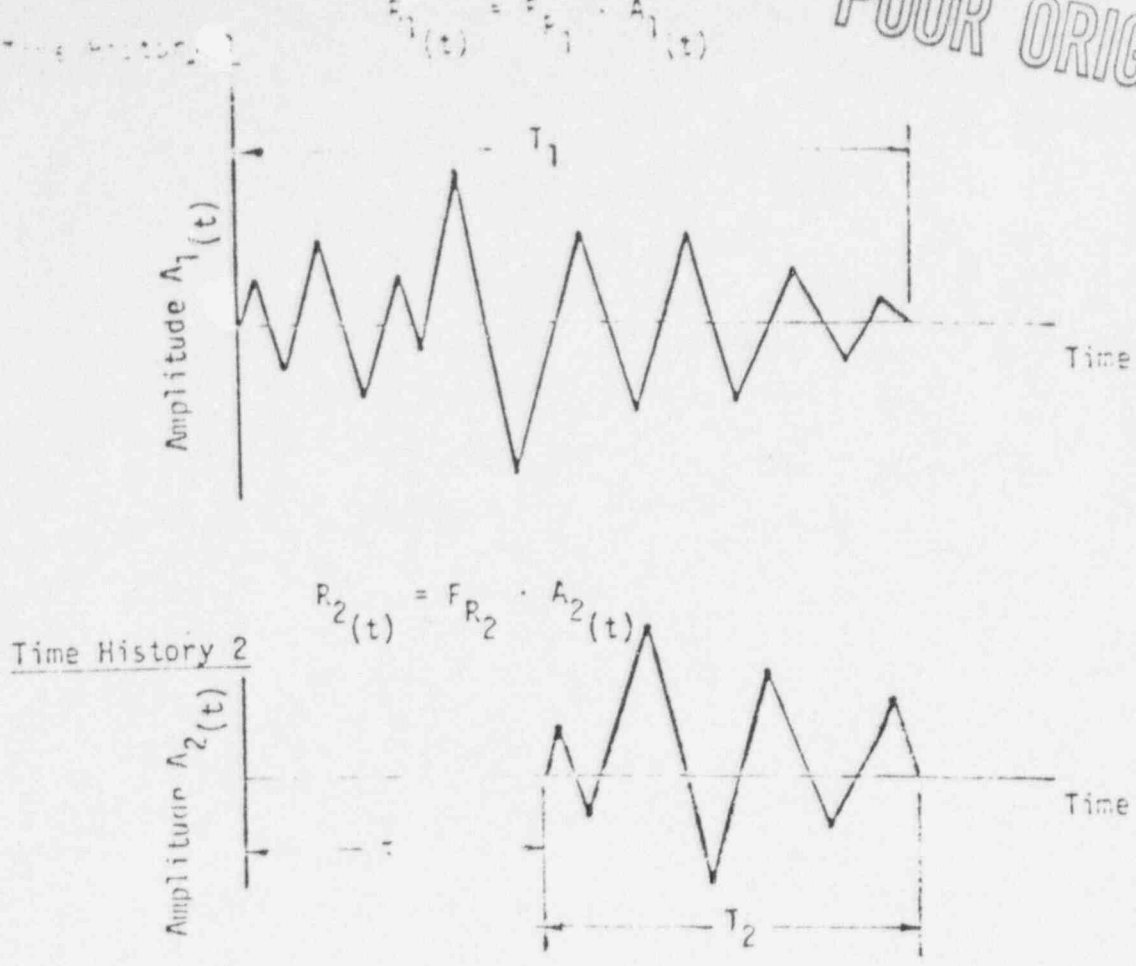
FIGURE 2-1. COMPARISON OF RANDOM TIME PHASE ONLY CDF CURVES WITH RANDOM TIME PHASE AND AMPLITUDE CDF CURVES

The intent of the Newmark-Kennedy Criteria for SRSS combination of transient responses is to provide reasonable confidence that a nonexceedance probability of approximately 84 percent is achieved for the peak combined response.

Important issues studied:

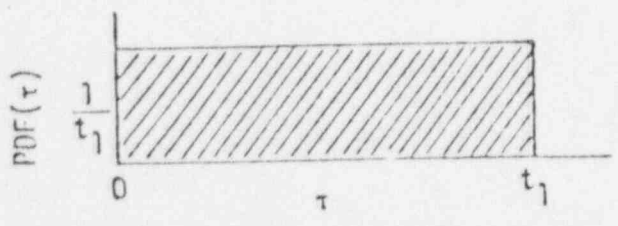
1. To demonstate that meeting Criterion 2 provides high confidence that approximately the SRSS combined response achieves a nonexceedance probability of approximately 84 percent or greater. It has already been demonstrated that meeting Criterion 1 provides high confidence that Criterion 2 would also be met. Therefore, the demonstration bolsters the confidence in both Criterion 1 and 2.

2. To more accurately specify the required level of conservatism for individual responses being combined (i.e., in the requirement that the individual responses be specified at approximately the 84th percentile or at F times the median level, it is desired to determine the necessary value for F).

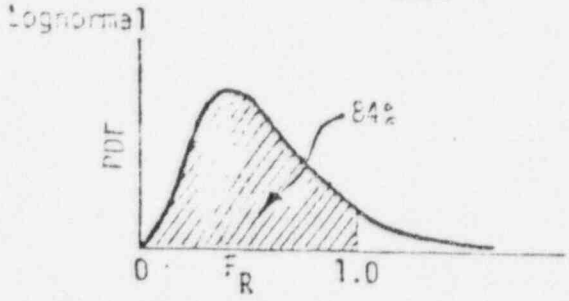


Random Variables

Time Lag: Uniform



Amplitude Factor: F_R



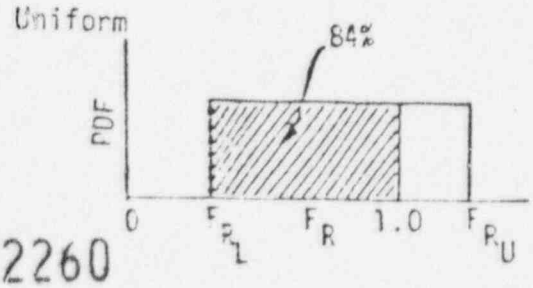


FIGURE 2-2. RESPONSE COMBINATION ASSUMPTIONS

1. Only cases in which the absolute sum (AS) combined response exceeded the SRSS combined response by more than 25 percent were considered. It was judged that when the difference was less than this amount then the impact of using an SRSS combination versus an AS combination was not very significant, and that such cases were not very interesting.

2. Three cases should be ones for which the time phase CDF curve marginally passes the first part of Criterion 2, i.e., the time phase NEP for the SRSS value should lie between 0.4 and 0.6.

3. Three cases should be ones for which the time phase CDF curve marginally passes the second part of Criterion 2, i.e., the time phase only NEP for 1.2 times SRSS should lie as close to 85 percent as possible.

4. One case should be a three response combination case.

TABLE 2-2. RESPONSE RATIOS FOR STUDY CASES

CASE	SIGN	AS/SRSS	TIME PHASE ONLY NEP	
			SRSS	1.2 * SRSS
1	+	1.27	0.40	0.98
	-	1.26	0.47	1.0
2	+	1.26	0.66	1.0
	-	1.26	0.61	1.0
3	+	1.28	0.54	0.95
	-	1.35	0.74	0.99
4	+	1.41	0.70	0.91
	-	1.37	0.90	0.99
5	+	1.41	0.74	0.91
	-	1.38	0.94	1.00
6	+	1.56	0.73	0.96
	-	1.50	0.97	1.00

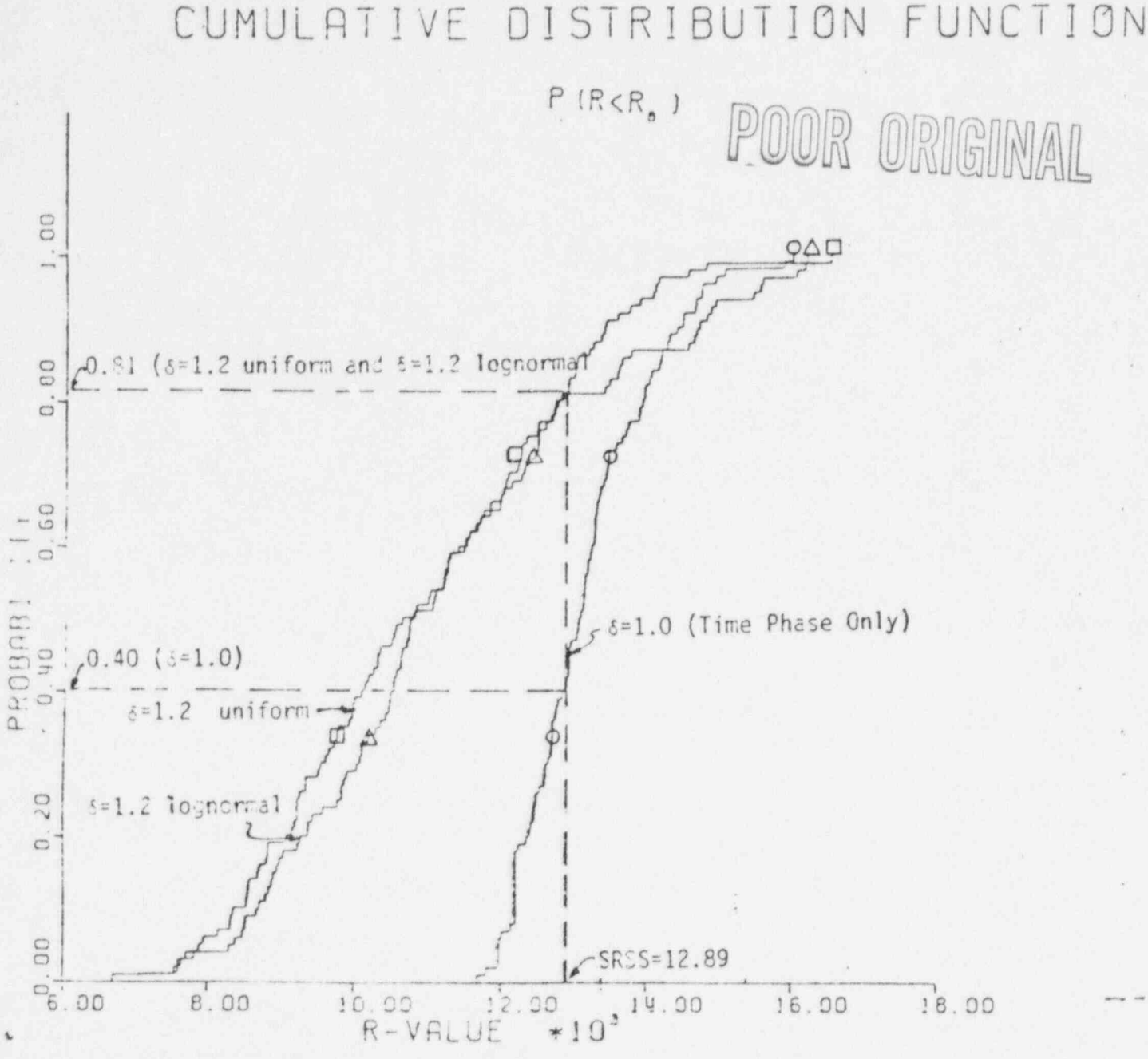


FIGURE 2-52. CASE 1: MAIN STEAM-46I OBE + SRVBDG M_a(POSITIVE)
INFLUENCE OF SHAPE OF AMPLITUDE PDF

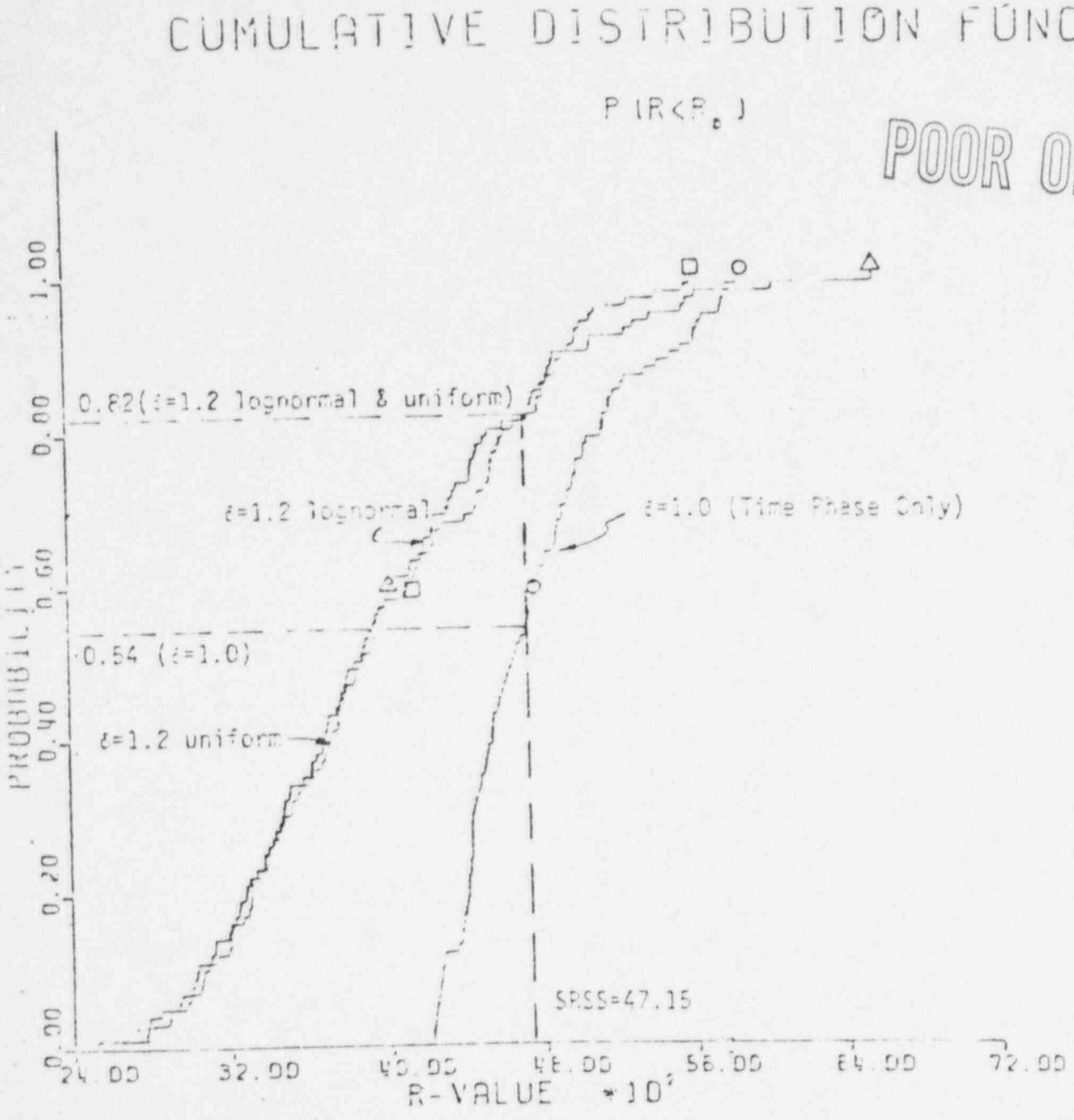


FIGURE 2-56 CASE 3: RHR-WETWELL OBE + SRVBUB M_a (POSITIVE)
INFLUENCE OF SHAPE OF AMPLITUDE

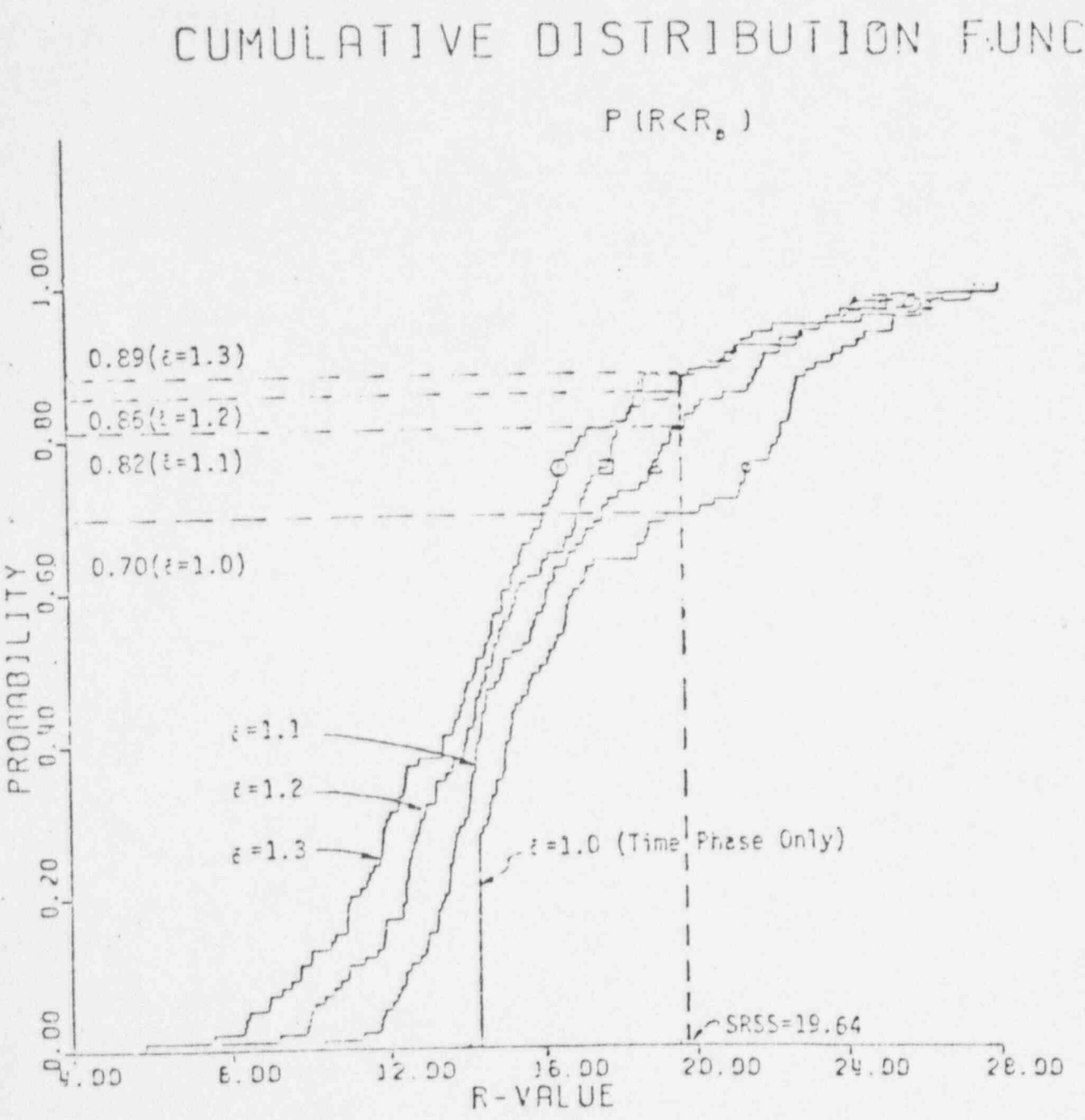


FIGURE 2-34. CASE 4: ZIMMER PLANT OBE(NS) + SRV (ALL),
CONTAINMENT WALL AT DRYWELL FLOOR ELEVATION.
LOGNORMAL AMPLITUDE PDF-ALL DISPERSIONS EQUAL

TABLE 2-3. RESULTS OF INCREASED DISPERSION OF RANDOM AMPLITUDE SCALE FACTOR WHEN INDIVIDUAL RESPONSES ARE DEFINED AT 84% NEP

CASE	SIGN	TIME PHASE ONLY, NEP		NEP FOR SRSS VALUE WITH RANDOM AMPLITUDE		
		SRSS	1.2 SRSS	$\delta = 1.1$	$\delta = 1.2$	$\delta = 1.3$
1	+	0.40	0.98	0.74*	0.81	0.82
	-	0.47	1.00	0.77*	0.81	0.84
2	+	0.66	1.00	0.80	0.85	0.85
	-	0.61	1.00	0.78*	0.83	0.82
3	+	0.54	0.95	0.79*	0.82	0.87
	-	0.74	0.99	0.86	0.86	0.87
4	+	0.70	0.91	0.82	0.86	0.89
	-	0.90	0.99	0.94	0.93	0.92
5	+	0.74	0.91	0.86	0.88	0.88
	-	0.94	0.98	0.96	0.93	0.93
6	+	0.73	0.96	0.84	0.90	0.90
	-	0.97	1.00	0.96	0.93	0.91

* Unacceptably Low NEP

TABLE 2-4. RESULTS OF LOW DISPERSION OF THE RANDOM AMPLITUDE SCALE FACTOR WHEN INDIVIDUAL RESPONSES ARE DEFINED AT THE 84% NEP OR F TIMES THEIR MEDIAN, WHICHEVER IS GREATER

CASE	SIGN	δ = 1.0						δ = 1.1					
		F = 1.1		F = 1.15		F = 1.2		F = 1.1		F = 1.15		F = 1.2	
		$SRSS_D$	NEP	$SRSS_D$	NEP	$SRSS_D$	NEP	$SRSS_D$	NEP	$SRSS_D$	NEP	$SRSS_D$	NEP
1	+	14.18	0.85	14.82	0.96	15.47	0.98	12.89	0.74*	13.48	0.81	14.06	0.90
	-	14.60	0.89	15.26	0.95	15.92	1.0	13.27	0.77*	13.87	0.82	14.48	0.92
2	+	8.918	0.95	9.323	0.99	9.728	1.00	8.107	0.80	8.475	0.92	8.844	0.97
	-	8.672	0.93	9.066	0.98	9.460	1.00	7.884	0.78*	8.242	0.92	8.600	0.95
3	+	51.87	0.85	54.22	0.89	56.58	0.95	47.15	0.79*	49.29	0.84	51.44	0.90
	-	49.02	0.89	51.24	0.93	53.47	0.99	44.56	0.86	46.58	0.89	48.61	0.93
4	+	21.61	0.77*	22.59	0.88	23.57	0.91	19.64	0.82	20.54	0.86	21.43	0.87
	-	22.99	0.96	24.04	0.99	25.08	0.99	20.90	0.94	21.85	0.95	22.80	0.97
5	+	21.39	0.83	22.36	0.89	23.33	0.91	19.44	0.86	20.33	0.88	21.21	0.90
	-	22.62	0.95	23.64	0.98	24.67	0.98	20.56	0.96	21.49	0.97	22.43	0.98
6	+	21.38	0.87	22.36	0.92	23.33	0.96	19.44	0.84	20.32	0.92	21.20	0.94
	-	24.78	0.98	25.90	0.98	27.02	1.00	22.52	0.96	23.55	0.99	24.57	1.00

* Unacceptably Low NEP

TABLE 3-3. MAXIMUM POSSIBLE RATIO OF 84% NON-EXCEEDANCE PROBABILITY PEAK COMBINED RESPONSE TO SRSS COMBINED RESPONSE FOR ANY CASE WHICH CAN PASS CRITERION 2 AS A FUNCTION OF AMPLITUDE DISPERSION AND FACTOR F.

Factor of Conservatism on Median Response, F	RATIO $K = \frac{C_{P_{84_{max}}}}{SRSS}$				
	δ = 1.0	1.1	1.15	1.2	1.3
1.0	1.19*	1.11	1.09	1.07	1.06
1.1	1.08	1.11*	1.09	1.07	1.06
1.15	1.04	1.06	1.09*	1.07	1.06
1.2	0.99	1.02	1.04	1.07*	1.06
1.3	0.92	0.94	0.96	0.99	1.06*

*The worst case dispersion at which the maximum ratio is maximized.

JUSTIFICATION OF CRITERION 1 (CON'T.)

- JUSTIFICATION OF CRITERION 1 CONSIDERABLY BOLSTERED BY FACT THAT OUT OF 235 MARK II RESPONSE COMBINATIONS WHICH MEET CRITERION 1, 100% OF CASES (ALL 235) ALSO MET CRITERION 2

  ∴ MEETING CRITERION 1 PROVIDES HIGH CONFIDENCE THAT CRITERION 2 WOULD BE MET

REVISED CRITERION 1

Dynamic or transient responses of structures, components, and equipment arising from combinations of dynamic loading or motions may be combined by SRSS provided that each of the dynamic inputs or responses has characteristics similar to those of earthquake ground motions, and that the individual component inputs can be considered to be relatively uncorrelated. This similarity involves a limited number of peaks of force or acceleration, with approximately zero mean.

- UNCORRELATED OR RANDOM START TIME
- NEAR ZERO MEAN
- ANY OF THE FOLLOWING:

1) RESPONSES

$$\text{ALL} \quad \frac{T_{50}}{\Delta T} \leq 0.08 \qquad \text{AND} \qquad \frac{T_{75}}{\Delta T} \leq 0.02$$

2) INPUT (LOAD)

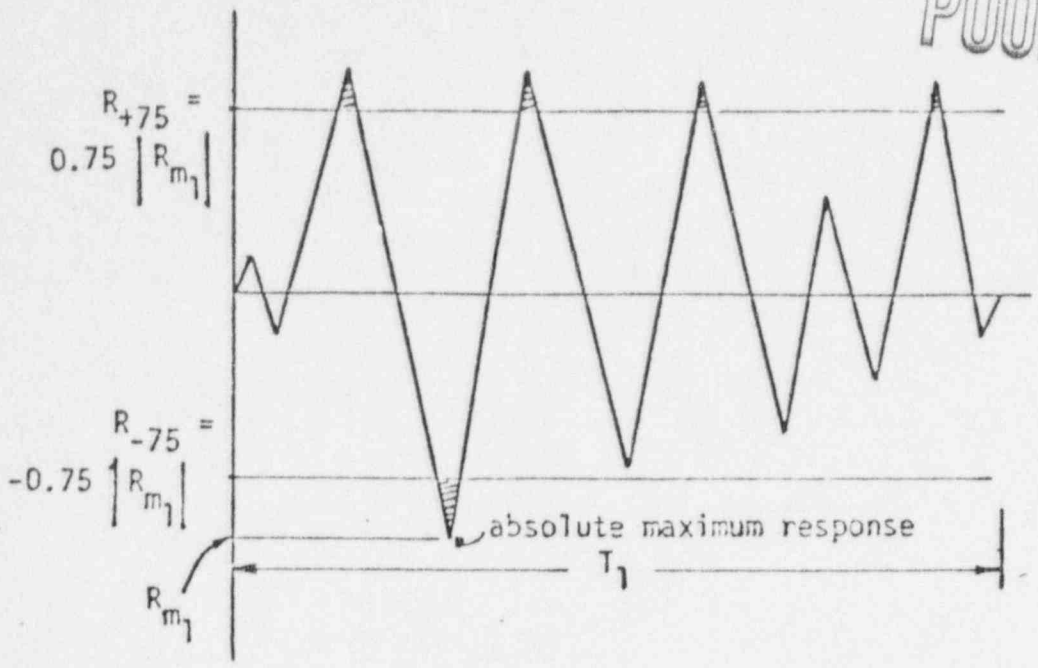
$$\text{ALL} \quad \frac{T_{50}}{\Delta T} \leq 0.04 \qquad \text{AND} \qquad \frac{T_{75}}{\Delta T} \leq 0.01$$

3) RESPONSES

$$\left(\frac{T_{50}}{\Delta T}\right)_e \leq 0.08\,, \qquad \left(\frac{T_{75}}{\Delta T}\right)_e \leq 0.02$$

WHERE

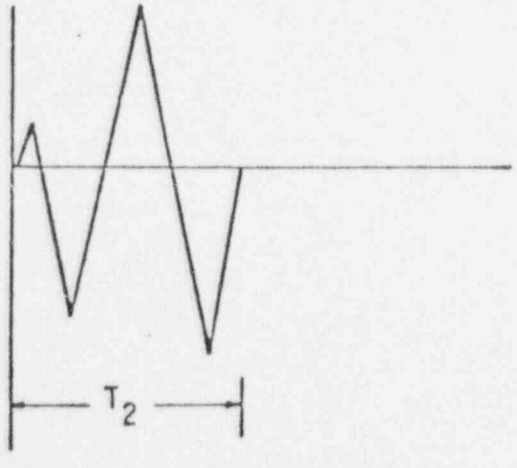
$$\left(\frac{T_{75}}{\Delta T}\right)_e = \frac{\sqrt{\sum_{i=1}^{N}\left(R_m T_{75}/\Delta T\right)_i^2}}{\sqrt{\sum_{i=1}^{N}\left(P_m\right)_i^2}}$$



T_{+75} = $\sum$ time that response exceeds R_{+75}

T_{-75} = $\sum$ time that response less than R_{-75}

T_{75} = $\sum$ larger of T_{+75} or T_{-75}



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$T_1 \geq T_2$; $\Delta T = T_1$

FIGURE 1: Definition of Notation

FROM BROOKHAVEN

$$\frac{\sigma}{R_{max}} \lesssim 0.36 \quad \text{FOR SRSS COMBINATION}$$

REQUIREMENT OF CRITERION 1

- RESPONSE HAS MEAN ZERO CENTERED

  IF NORMALLY DISTRIBUTED :

$$R_x = f_x \cdot \sigma$$

IF $\sigma = 0.36\, R_{max}$

$$f_x = \frac{R_x}{\sigma} = \left(\frac{R_x}{R_{max}}\right)\frac{1}{0.36} = \left(\frac{R_x}{R_{max}}\right)(2.78)$$

$\therefore$ FOR $R_{50}/R_{max} = .50 \longrightarrow f_{50} = 1.39 \longrightarrow P\left[\frac{R_{50}}{R_{max}} > 0.50\right] = 0.082$

$$\longrightarrow \boxed{\frac{T_{50}}{\Delta T} \leq 0.08}$$

FOR $R_{75}/R_{max} = 0.75 \longrightarrow f_{75} = 2.08 \longrightarrow P\left[\frac{R_{75}}{R_{max}} > 0.75\right] = 0.019$

$$\longrightarrow \boxed{\frac{T_{75}}{\Delta T} \leq 0.02}$$

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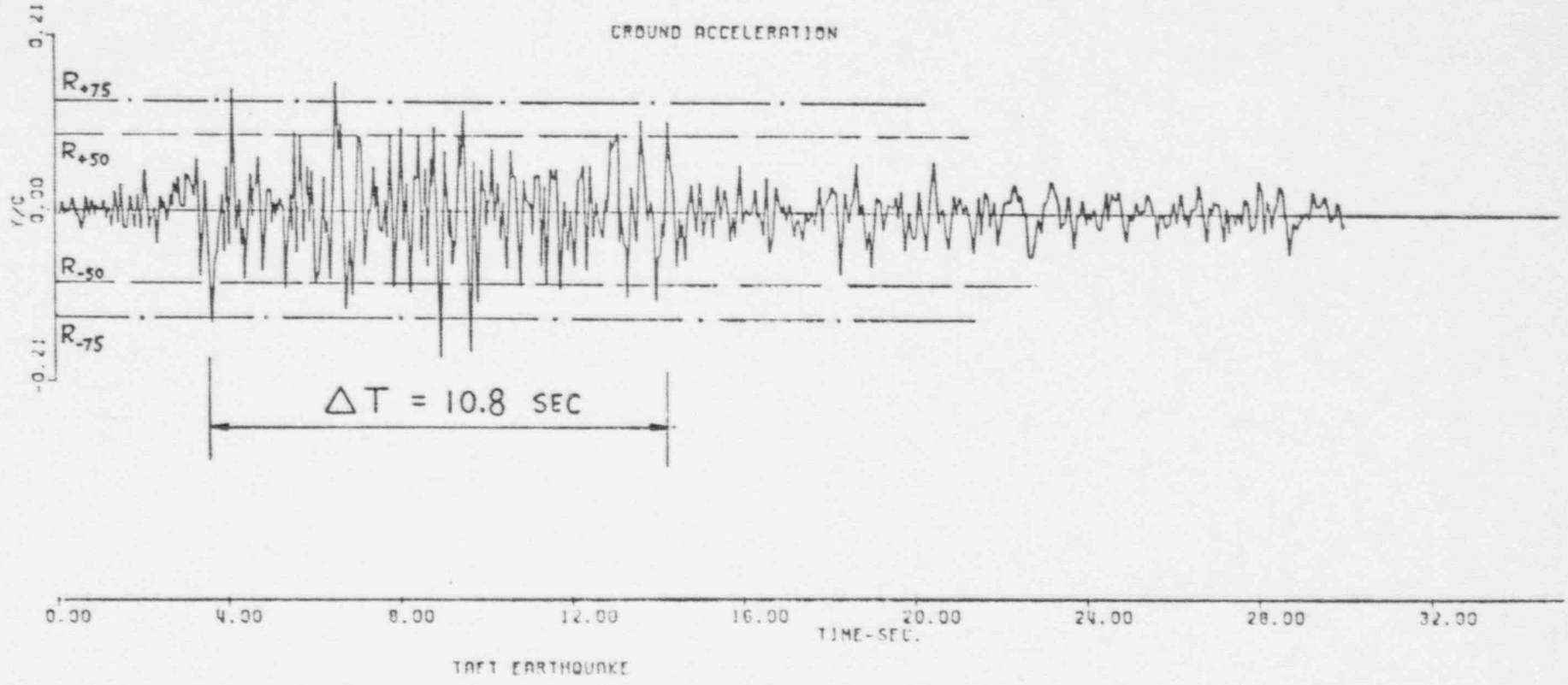
DERIVATION OF NEW CRITERION 1



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$$\begin{cases} \dfrac{T_{75}}{\Delta T} = 0.0083 \\ \dfrac{T_{50}}{\Delta T} = 0.0420 \end{cases}$$

CASES SELECTED FOR SRSS DEMONSTRATION STUDIES:

- MAIN STEAM - 46 I - SRSS 2 MOMENT AT A -- OBE + SRVBDG
- MAIN STEAM - 46 I - SRSS 2 MOMENT AT C -- OBE + SRVBDG
- RHR WETWELL - 11 - SRSS 1 -- OBE + SRVBUB
- ZIMMER PLANT - CONTAINMENT WALL AT DRYWELL FLOOR ELEVATION -- OBE (NS) + SRV (ALL)
- ZIMMER PLANT - CONTAINMENT WALL AT DRYWELL FLOOR ELEVATION -- OBE (EW) + SRV (ALL)
- LASALLE - 1 CONTAINMENT WALL AT DRYWELL FLOOR ELEVATION -- OBE (NS) + SRV (ADS) + CHUG (30HZ)

	CASE NO. / RE-SPONSE NO.	1		2		3		4		5		6	
NEW CRITERION 1		$\frac{T_{50}}{\Delta T}$	$\frac{T_{75}}{\Delta T}$	$\frac{T_{50}}{\Delta T}$	$\frac{T_{75}}{\Delta T}$	$\frac{T_{50}}{\Delta T}$	$\frac{T_{75}}{\Delta T}$	$\frac{T_{50}}{\Delta T}$	$\frac{T_{75}}{\Delta T}$	$\frac{T_{50}}{\Delta T}$	$\frac{T_{75}}{\Delta T}$	$\frac{T_{50}}{\Delta T}$	$\frac{T_{75}}{\Delta T}$
	1	0.059	0.012	0.057	0.011	0.067	0.003	0.071	0.010	0.046	0.010	0.009	0.005
	2	0.027	0.013	0.025	0.009	0.014	0.003	0.015	0.009	0.015	0.009	0.017	0.007
	3											0.004	0.003
	Effective Time Ratio	0.032	0.013	0.030	0.009	0.031	0.003	0.057	0.010	0.038	0.010	0.012	0.006
OLD CRITERION 1	NO. OF PEAKS / RE-SPONSE NO.	N_{60}	N_{75}	N_{60}	N_{75}	N_{60}	N_{75}	N_{60}	N_{75}	N_{60}	N_{75}	N_{60}	N_{75}
	1	[8]	5	[9]	[5]	7	1	5	1	[7]	2	1	1
	2	[8]	[7]	8	[5]	[15]	[6]	[7]	[5]	[7]	[5]	[7]	[5]
	3											2	2

NEW CRITERION 1 $\left(\frac{T_{50}}{\Delta T}\right)_{\text{ave}} \leq 0.08, \quad \left(\frac{T_{75}}{\Delta T}\right)_{\text{ave}} < 0.02$

OLD CRITERION 1 $N_{60} \leq 10, \quad N_{75} \leq 5$

CONCLUSIONS

- RECENT SUPPORTIVE MK II/G.E. EFFORTS HAVE CONFIRMED THAT NEWMARK/KENNEDY CRITERION 2 REPRESENTS A CONSERVATIVE BASIS FOR JUDGING THE ACCEPTABILITY FOR THE SRSS COMBINATION OF RESPONSES.

- PREVIOUS STUDIES USING REAL MK II RESPONSE TIME HISTORIES HAVE DEMONSTRATED THAT THE NEWMARK/ KENNEDY CRITERION 1 IS MORE CONSERVATIVE THAN CRITERION 2. MEETING CRITERION 1 PROVIDES GOOD ASSURANCE OF MEETING CRITERION 2 FOR THE TYPES OF DYNAMIC LOADS EVALUATED IN THE MK II SRSS STUDY.

- RECENT FINDINGS HAVE INDICATED SOME POTENTIAL AMBIGUTIES IN CRITERION 1 IF THE NEWMARK/KENNEDY CRITERIA IS TO BE APPLIED AS A GENERIC STANDARD. HOWEVER, N/K CRITERION 1 STILL REMAINS A CONSERVATIVE JUSTIFIABLE BASIS FOR JUDGING THE ACCEPTABILITY OF SRSS FOR THE TYPES OF LOADING COMBINATIONS CONSIDERED IN THE MK II SRSS STUDY.