ATTACHMENT C

CRITERIA FOR COMBINATIONS OF EARTHQUAKE AND/OR OTHER TRANSIENT RESPONSES

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R. P. Kennedy

2.1 PREAMBLE

The intent of the methods proposed for combinations of transient, dynamic responses is to achieve a nonexceedance probability of approximately 84% for the peak combined response of the system, component, or element considered. This goal is achieved by compliance with any one of the following criteria, or any alternative method that meets the intent stated above, provided that the intensity of loads or accelerations for each input are conservatively represented (approximately at the level of the 84th percentile, or the mean plus one standard deviation, of the expected input intensity).

2.2 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; i.e., the individual dynamic inputs or responses considered are either from independent events or have random peak phasing. This similarity involves a limited number of peaks of force or acceleration (not more than 5 exceeding 75% of the maximum, or not more than 10 exceeding 60% of the maximum), with approximately zero mean and a total duration of strong motion (i.e., exceeding 50% of the maximum) of 10 seconds or less.

Explanation. Since earthquake motions in various directions produce responses which are combined conservatively by the use of SRSS, the descriptions of dynamic or transient inputs are based on those applicable to earthquake motions. The coefficient of correlation for these is less than 0.4, and the pattern of peaks is based on Table 2 of Circular 672 of the U.S. Geological Survey describing earthquake ground motions for use in the design of the Alaska oil pipeline.

The probability distribution for the responses to earthquake motions is based on the concepts underlying U.S. NRC Regulatory Guide 1.60, where the standard deviation is 30 to 40% of the median value.

It was proved some decades ago that modal responses to earthquake motions may be conservatively combined by SRSS methods with the same degree of conservatism as that of the motions. If each of such responses is considered to be at the level of mean plus one standard deviation, the SRSS value is also at this level. For the same reasons, responses from the three component directions of earthquake motions may also be conservatively combined by SRSS methods.

2.3 CRITERION 2

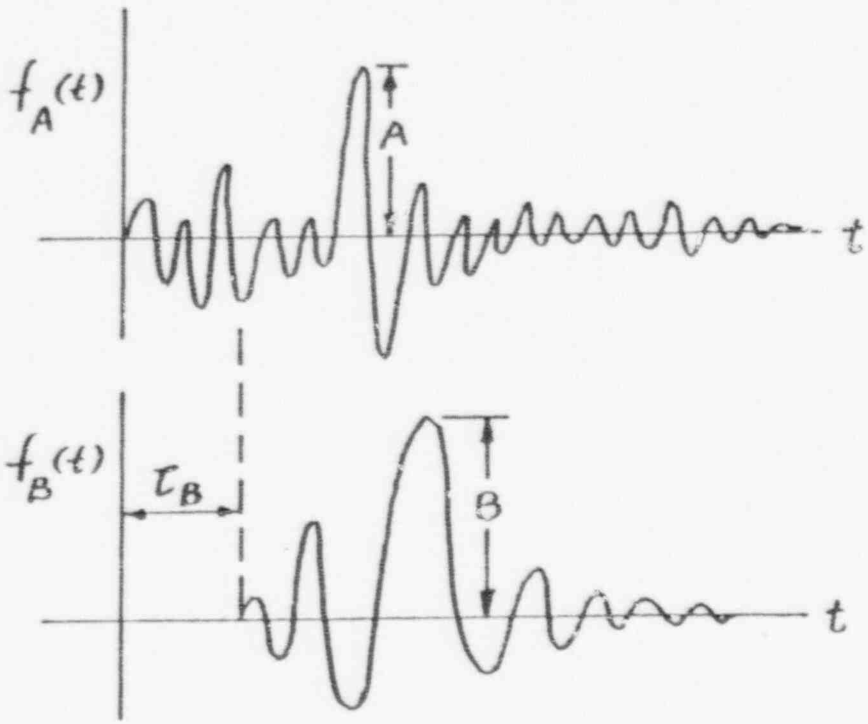
When response time histories are available for all multiple dynamic loadings being combined, SRSS methods may be used for peak combined response when CDF calculations, using appropriate assumptions on the range of possible time lags between the response time histories, show the following criteria are met:

1. There is estimated to be less than approximately a 50% conditional probability that the actual peak combined response from these conservatively defined loadings exceeds approximately the SRSS calculated peak response, and

2. There is estimated to be less than approximately a 15% conditional probability that the actual peak combined response exceeds approximately 1.2 times the SRSS calculated peak response.

ATTACHMENT D

BACKGROUND INFORMATION ON COMBINATION OF DYNAMIC RESPONSES
(STAFF PRESENTATION)



$$f_R(t) = f_A(t) + f_B(t+\tau_B) + \cdots$$

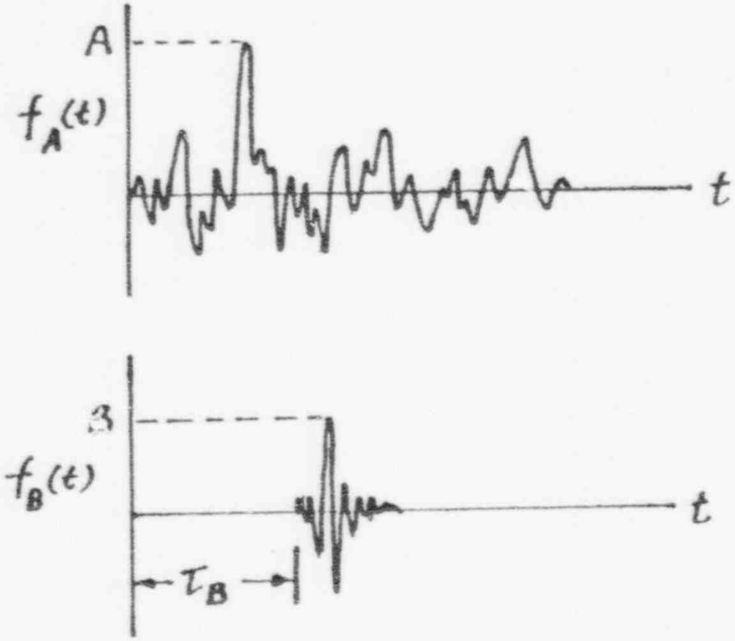
DYNAMIC RESPONSE:

- RAPID VARYING
- SHORT DURATION
- DISTINCT FEW PEAKS
- VAR. FREQ. CONTENT
- NOT ALWAYS GET $f(t)$

RESPONSE COMBINATION:

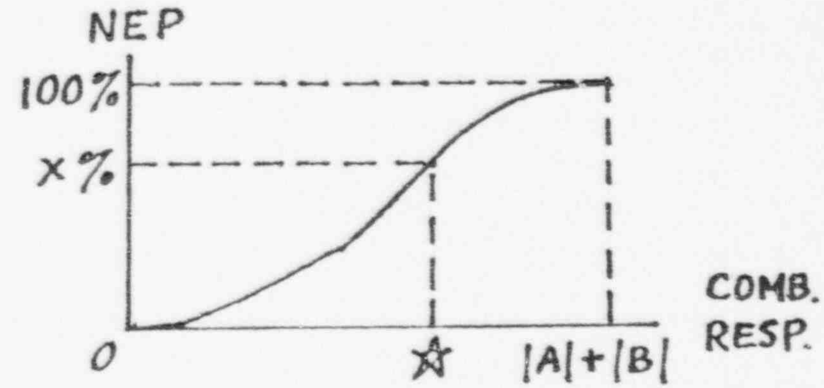
- RULE OF SUPERPOSITION
  - — LINEAR
  - — ELASTIC
- STRUCTURAL FILTERING
- UNCERTAIN τ

GENERAL PRACTICE IN RESPONSE COMBINATION



I. ABS: $R = |A| + |B| + \cdots$

II. CDF: R = ☆



x% — ACCEPTABLE NON-EXCEEDANCE PROBABILITY

- NOT ALWAYS GET f(t)
- CURVE MAY NOT BE UNIQUE
- DETERMINATION OF x%

- TIME CONSUMING
  - STUDYING TOOL
  - NOT PRACTICAL FOR DESIGN
  - BAD FOR MORE THAN TWO FUNCTIONS TO COMB.

III. SRSS: $R = \sqrt{A^2 + B^2 + \cdots}$

D-2

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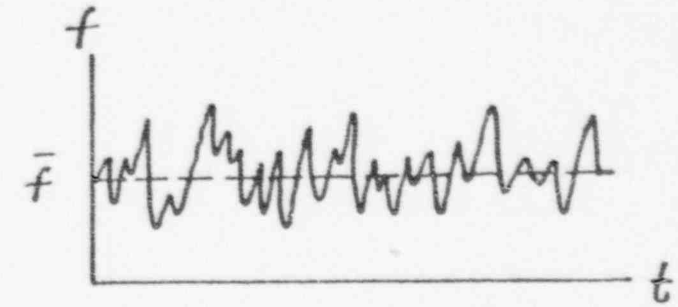
THEORETICAL BASIS OF SRSS



- VARIANCE $= \sigma^2 = E[(f-\bar{f})^2]$

  FOR ZERO MEAN: $\bar{f} = 0$

  $$\sigma^2 = E[f^2]$$

- FOR $f_R(t) = f_A(t) + f_B(t+\tau_B) + \cdots$

  ASSUME ZERO MEAN FOR ALL FUNCTIONS:

  $$\sigma_R^2 = E[f_R^2(t)] = E[\{f_A(t) + f_B(t+\tau_B) + \cdots\}^2]$$

  $$= E[f_A^2(t) + f_B^2(t+\tau_B) + \cdots + 2 f_A(t) f_B(t+\tau_B) + \cdots]$$

  $$= E[f_A^2(t)] + E[f_B^2(t+\tau_B)] + \cdots + 2E[f_A(t) f_B(t+\tau_B)] + \cdots$$

  ASSUME FUNCTIONS ARE STATIONARY:

  $$E[f(t)] = E[f(t+\tau)] \quad E[f^2(t)] = E[f^2(t+\tau)] \quad \cdots$$

  ASSUME FUNCTIONS ARE NON-CORRELATED: (ie. Gaussian)

  $$E[f_A(t) f_B(t+\tau_B)] = 0$$

  $$\sigma_R^2 = E[f_A^2(t)] + E[f_B^2(t)] + \cdots = \sigma_A^2 + \sigma_B^2 + \cdots$$

  $$\therefore \quad \sigma_R = \sqrt{\sigma_A^2 + \sigma_B^2 + \cdots}$$

D-3

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WHAT IS THE REAL WORLD ?

- DOES IT CONFORM WITH SRSS RULES ?
  - COMBINATION OF EXTREM PEAKS (NOT σ s)
  - ZERO MEAN ?
  - STATIONARY ?
  - NON-CORRELATION ?

- FOR COMBINING MORE THAN TWO FUNCTIONS BY NORMALIZING PEAKS TO 1

NO. OF FUNC.	SRSS	WORST POSSIBLE RATIO
2	$\sqrt{2} = 1.41$	$(2-1.41)/2 = 30\%$
3	$\sqrt{3} = 1.73$	$(3-1.73)/3 = 42\%$
4	$\sqrt{4} = 2.$	$(4-2.0)/4 = 50\%$

- STRUCTURAL DESIGN MARGIN
- EVENT PROBABILITY

D-4

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Nov., 1978

ATTACHMENT E

NRC INTERIM ACCEPTANCE CRITERIA FOR SRSS

1. EACH OF THE RESPONSE TIME FUNCTIONS TO BE COMBINED BY SRSS SHOULD MEET THE FOLLOWING CHARACTERISTICS:

   A. FUNCTION IS RAPIDLY VARYING WITH TIME

   B. DURATION OF THE STRONG MOTION PORTION IS SHORT

   C. FUNCTION CONSISTS OF A FEW DISTINCT HIGH PEAKS IN RANDOM APPEARANCE

   D. RESPONSE IS NOT ASSOCIATED WITH NORMAL PLANT OPERATION EVENT

   E. PHASING RELATIONSHIP AMONG FUNCTIONS TO BE COMBINED ARE RANDOM.

   F. RESPONSE IS CALCULATED ON LINEAR ELASTIC BASIS

2. SRSS MAY BE USED IN COMBINING RESPONSES TO THREE PERPENDICULAR COMPONENT LOADINGS IF THE COMPONENT LOADINGS ARE RELATIVELY UNCORRELATED.

3. SRSS MAY BE USED IN COMBINING MODAL RESPONSES PROVIDED THAT THEIR FREQUENCIES ARE NOT CLOSELY SPACED AS DELINEATED IN REGULATORY GUIDE 1.92.

4. SRSS MAY BE USED IN COMBINING TWO RESPONSES IF THE SRSS LEVEL REPRESENTS A NON-EXCEEDANCE PROPABILITY EQUAL OR GREATER THAN 84 %. IF THE PROBABILITY IS LESS THAN 84 %, THE LEVEL AT 84 % MAY BE USED

5. FOR COMBINING MORE THAN TWO RESPONSES, SRSS MAY BE USED IN COMBINING ANY TWO OF THE RESPONSES, PROVIDED ALL RESPONSE TIME FUNCTIONS HAVING CHARACTERISTICS AS DELINEATED IN ITEM 1. THE REMAINING RESPONSES HAVE TO BE COMBINED IN ABSOLUTE SUM.

6. SRSS MAY BE USED TO COMBINE MORE THAN TWO RESPONSES IF THE NON-EXCEEDANCE PROBABILITY EQUAL OR GREATER THAN 84 % CAN BE DEMONSTRATED.

7. SRSS MAY BE USED IF IT CAN BE VERIFIED THAT THE DYNAMIC MARGINS AT THE SPECIFIC STRUCTURAL LOCATION CAN ADEQUATELY COMPENSATE FOR THE UNCERTAINTY OF SRSS AS INDICATED IN THE EXCEEDANCE PROBABILITY.

8. SRSS MAY BE USED IF IT CAN BE VERIFIED THAT THE OVERALL DESIGN MARGINS AT THE SPECIFIC STRUCTURAL LOCATION CAN ADEQUATELY COMPENSATE FOR THE UNCERTAINTY OF SRSS AS INDICATED IN THE EXCEEDANCE PROBABILITY.

9. SRSS MAY BE USED IF IT CAN BE VERIFIED THAT THE OVERALL STRESS RESULTANT IS FAR GREATER THAN THE DYNAMIC PORTION OF THE STRESS AND THE UNCERTAINTY PORTION INDUCED BY USING SRSS CAN BE COMPENSATED BY JUSTIFIABLE MEANS.

10. SRSS MAY BE USED TO COMBINE RESPONSES OF LOCA & SSE IN THE MAIN LOOPS OF THE LIGHT WATER PLANT.

ATTACHMENT F

Dr. Kennedy's Presentation

A Response to Staff Comments

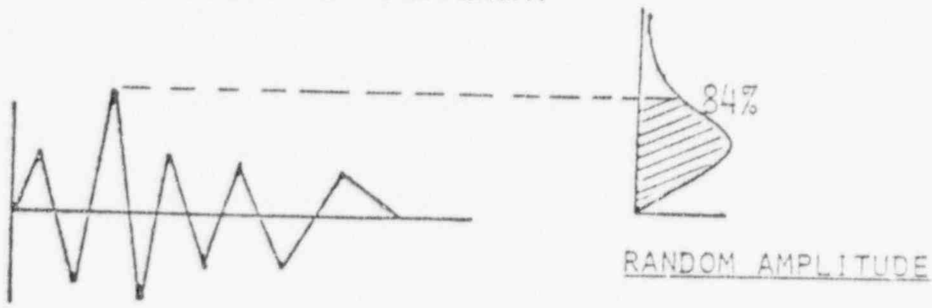
MULTIPLE RESPONSE TIME HISTORIES

1. TIME HISTORIES HAVE RANDOM RELATIVE START TIMES. (UNCORRELATED)

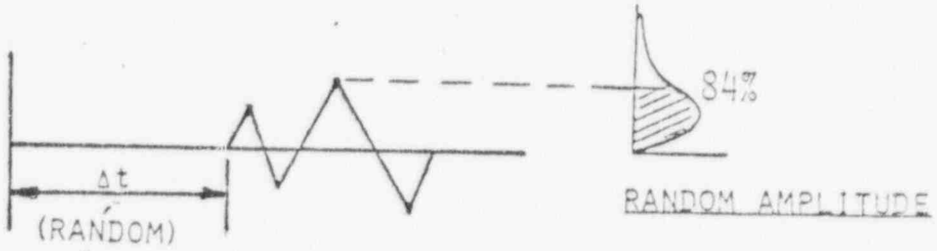
2. TIME HISTORIES ALSO HAVE RANDOM AMPLITUDES.

3. DESIGN AMPLITUDES ARE DEFINED TO BE AT THE 84% NON-EXCEEDANCE PROBABILITY BY CRITERIA.

(A)



(B)



4. HOW SHOULD PEAK INDIVIDUAL RESPONSE BE COMBINED?

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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.

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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

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

&

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

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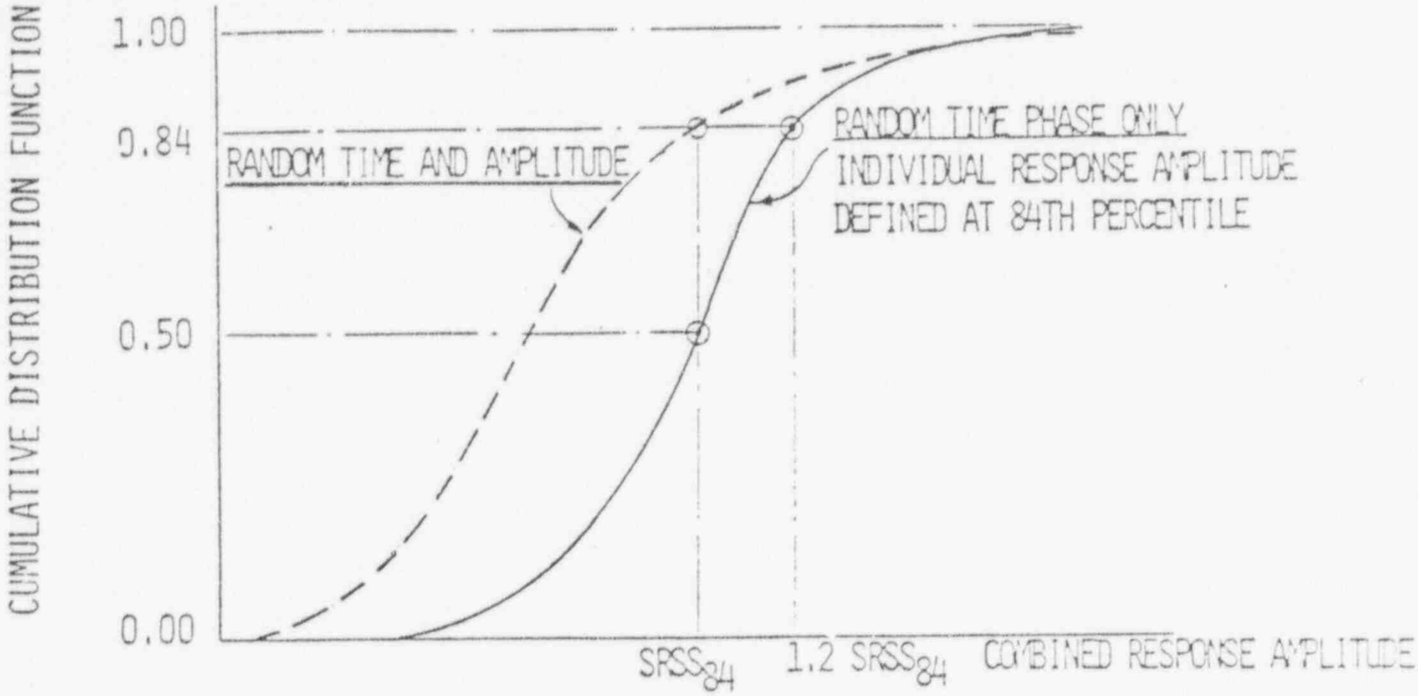
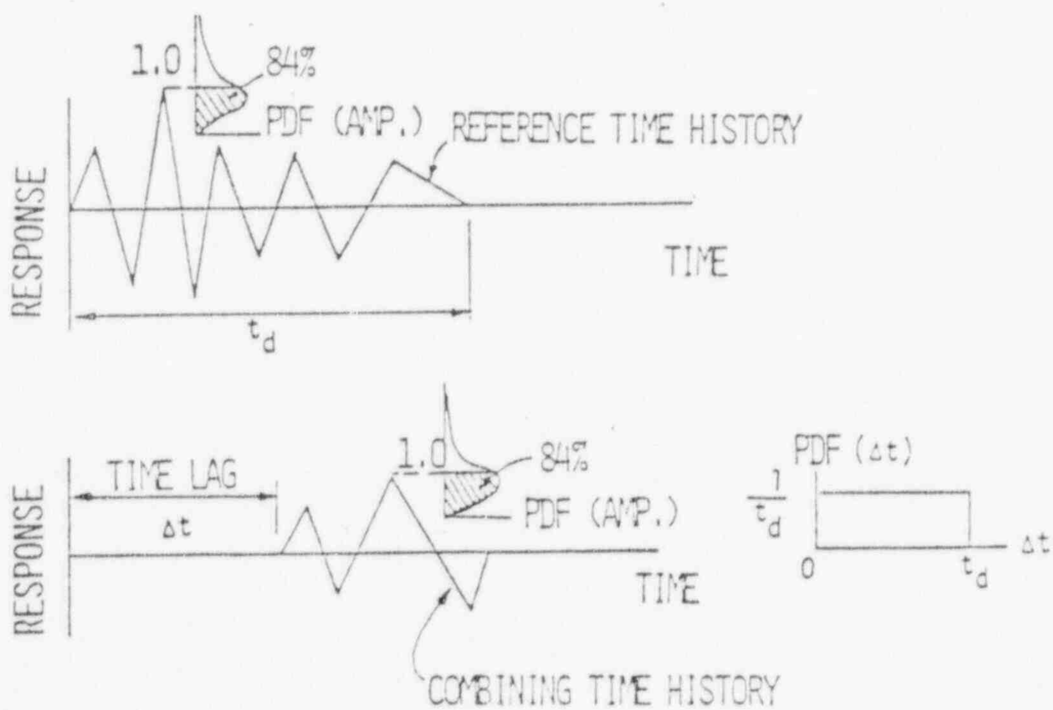


COMPARISON OF RANDOM TIME PHASE ONLY CDF CURVE
WITH RANDOM TIME PHASE AND AMPLITUDE CDF CURVE



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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 CURRENTLY BEING PERFORMED TO DEMONSTRATE THAT CASES MEETING CRITERION 2 (EQUATIONS (2) AND (3)) DO MEET GOAL (EQU. 1) WHEN:

$$R_{i_{84}} = \begin{Bmatrix} R_{84\%} \\ \text{OR} \\ F \cdot R_{50\%} \end{Bmatrix}$$

$$1.05 \leq F \leq 1.2$$

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DISCUSSION OF CRITERION 2

- CRITERION 2 BASED UPON USE OF CDF CURVE

- PROBLEMS
  - COSTLY & DIFFICULT TO USE SINCE REQUIRES GENERATION OF RESPONSE TIME HISTORIES AND CDF CURVE - INTENDED ONLY AS A FINAL ARBITRATOR FOR CASES WHICH CANNOT BE CONCLUSIVELY SHOWN TO PASS CRITERIA 1.

  - SELECTION OF PDF FOR RELATIVE TIME PHASING IS ARBITRARY - NOT CONSIDERED MAJOR PROBLEM SO LONG AS REASONABLE PDF IS USED SINCE GE "RED-BOOK" STUDY SHOWS THAT CDF CURVE IS NOT SENSITIVE TO PDF USED.

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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

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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 <u>LESS</u> 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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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

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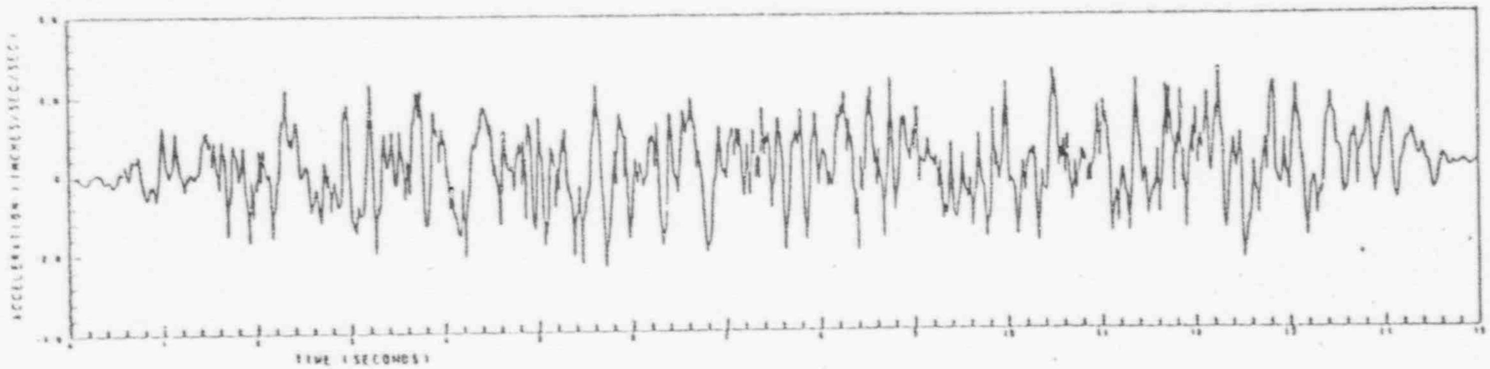
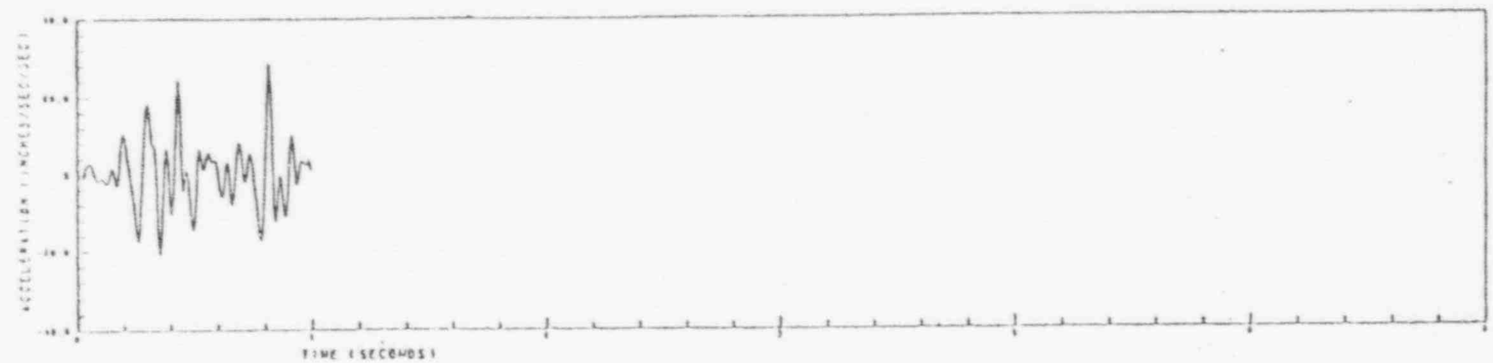


RESPONSE A - EARTHQUAKE



RESPONSE B - SRV

COMPARISON OF EARTHQUAKE TRANSIENT RESPONSE
WITH SRV TRANSIENT RESPONSE

FIGURE 1

F-10

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RESPONSES TO QUESTIONS ON CRITERION 1

1. HOW TO ASSURE SUFFICIENTLY RAPID VARIATION OF TIME HISTORIES.

   - RAPID VARIATION IS ASSURED BY:

     A) LIMITING THE NUMBER OF NEAR MAXIMUM PEAKS

        AND

     B) ASSURING A NEAR ZERO RATIO OF MEAN TO MAXIMUM RESPONSE OVER A TIME DURATION LESS THAN THE UNCERTAINTY IN THE LAG TIME.

   - A RATIO OF MEAN TO MAXIMUM LESS THAN ABOUT 0.1 TO 0.2 MEETS REQUIREMENT OF NEAR ZERO MEAN.

2. WHY CAN LOADING TIME HISTORY BE USED IN LIEU OF RESPONSE TIME HISTORY.

   - IF LOADING TIME-HISTORY IS EARTHQUAKE-LIKE THEN RESPONSE TIME-HISTORY WILL AUTOMATICALLY BE EARTHQUAKE-LIKE FOR LINEAR ELASTIC STRUCTURES (I.E.) IF LOADING HAS LESS NEAR PEAK EXCURSIONS THAN FOR EARTHQUAKE, THE RESPONSE TO LOADING WILL AUTOMATICALLY HAVE LESS NEAR PEAK EXCURSION THAN IT WOULD HAVE FROM EARTHQUAKE TIME HISTORY.

   - IF LOADING HAS NEAR-ZERO MEAN, RESPONSE AUTOMATICALLY HAS NEAR-ZERO MEAN FOR LINEAR ELASTIC SYSTEMS.

   - NOT PRACTICAL TO LIMIT CRITERIA TO RESPONSE. FOR MANY CASES, RESPONSE TIME HISTORIES ARE NOT GENERATED. NEED A CRITERIA WHICH CAN BE APPLIED AT THE LOADING LEVEL.

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RESPONSE TO QUESTIONS ON CRITERION 1 (CONT.)

3. HOW TO DEMONSTRATE WEAK CORRELATION BETWEEN PEAK RESPONSES.

- SO LONG AS RELATIVE TIME PHASING BETWEEN TIME HISTORIES IS UNKNOWN (RANDOM) WITHIN A TIME INTERVAL AT LEAST AS GREAT AS 2 TO 5 TIMES THE PREDOMINANT NATURAL PERIOD OF THE STRUCTURE, THE TIME OF PEAK RESPONSES ARE AUTOMATICALLY WEAKLY CORRELATED FROM A PRACTICAL STANDPOINT.

4. WHAT TO DO WHEN RESPONSES DO NOT HAVE NEAR ZERO MEAN

- THE MEAN RESPONSES SHOULD BE COMBINED ALGEBRAICALLY (NOT ABSOLUTELY) SINCE SIGN OF RESPONSE IS KNOWN.

- THE DIFFERENCES BETWEEN PEAK RESPONSE AND MEAN RESPONSE CAN BE COMBINED SRSS IF THESE DIFFERENT TIME HISTORIES MEET CRITERIA 1, OR 2.

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ATTACHMENT G

BNL PROGRESS REPORT

GENERIC STUDY

WORK SCOPE

1. INVESTIGATE THE KEY PARAMETERS WHICH CAN BE UTILIZED TO FULLY CHARACTERIZE DYNAMIC RESPONSES IN THE TIME AND FREQUENCY DOMAIN. PARAMETERS SHOULD INCLUDE (BUT NOT NECESSARILY LIMITED TO) AMPLITUDE, FREQUENCY, PHASING, AND DURATION.

   THE TIME DOMAIN RESPONSE SHOULD BE A TIME VARYING FUNCTION.

2. DEVELOP THE DYNAMIC RESPONSES TO TWO DYNAMIC INPUTS FOR COMBINATION STUDIES, BOTH IN THE TIME AND FREQUENCY DOMAINS, USING THE VARIOUSLY QUANTIFIED PARAMETERS SPECIFIED IN ITEM 1. CONDUCT SENSITIVITY STUDIES BY VARYING ONE OR MORE THAN ONE OF THE PARAMETERS. THE DEGREE OF INFLUENCE OF PARAMETER VARIATION ON THE RESULTS OF RESPONSE

COMBINATION SHOULD BE QUANTIFIED. THE METHOD USED TO QUANTIFY THE COMBINATION RESULTS MAY BE IN TERMS OF NON-EXCEEDANCE PROBABILITY OR OTHER APPROPRIATE MEANS ACCEPTABLE TO THE STAFF.

3. BASED ON KNOWLEDGE OBTAINED IN SENSITIVITY STUDIES, DEVELOP RECOMMENDATIONS FOR THE COMBINATION OF TWO DYNAMIC RESPONSES, EITHER EXPRESSED IN THE FREQUENCY DOMAIN OR IN THE TIME DOMAIN. THE RECOMMENDATIONS SHOULD INCLUDE BUT NOT NECESSARILY BE LIMITED TO THE FOLLOWING:

   A) QUANTIFY THE CONDITIONS UNDER WHICH THE ABSOLUTE SUM (ABS) METHOD OF COMBINATION SHOULD BE USED;
   B) QUANTIFY THE CONDITIONS UNDER WHICH THE SQUARE-ROOT-OF SUM SQUARE (SRSS) METHOD OF COMBINATION MAY BE USED, AND

C) QUANTIFY THE CONDITIONS UNDER WHICH THE CUMULATIVE DISTRIBUTION FUNCTION (CDF) METHOD FOR RESPONSE COMBINATIONS MAY BE USED INCLUDING THE SPECIFICATION OF POSSIBLE NON-EXCEEDANCE PROBABILITIES OF 50% OR HIGHER LEVEL.

WORK PLAN FOR THE EVALUATION OF MARK II SRSS LOAD COMBINATION CRITERIA

BACKGROUND

GENERAL ELECTRIC TOPICAL REPORT NEDO-24010-2, ENTITLED "BASIS FOR CRITERIA FOR COMBINATION OF EARTHQUAKE AND OTHER TRANSIENT RESPONSES BY THE SQUARE ROOT SUM OF THE SQUARE METHOD," SUPPLEMENT 2, WAS ISSUED IN DECEMBER OF 1978, ADDRESSING THIS PROBLEM. THIS REPORT PROPOSES TWO CRITERIA AS A BASIS FOR DYNAMIC LOAD COMBINATIONS.

BACKGROUND, CONTINUED

THE TWO CRITERIA CAN BE SUMMARIZED AS FOLLOWS:

1. SQUARE ROOT SUM OF THE SQUARES (SRSS) CAN BE USED IF EACH OF THE TIME FUNCTIONS, IN EITHER LOADING OR RESPONSE IS SIMILAR TO THE EARTHQUAKE GROUND MOTIONS, AND

2. SRSS MAY BE USED IF CUMULATIVE DISTRIBUTION FUNCTION (CDF) OF COMBINED RESPONSE TIME FUNCTIONS SATISFIES THE CONDITIONS:

   A) SRSS REPRESENTS AT LEAST 50% (±) NON-EXCEEDANCE PROBABILITY (NEP),

   B) 1.2 SRSS REPRESENTS AT LEAST 85% (±) NEP.

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OBJECTIVE

THE OBJECTIVE OF THE BNL PROGRAM IS TO OBTAIN AN EVALUATION OF THE AREAS OF VALIDITY, ADEQUACY, LIMITATIONS, AND APPLICABILITY OF THE TWO CRITERIA IN NEDO-24010-2.

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TASKS TO BE CARRIED OUT FOR EVALUATION OF CRITERION 1

1. REVIEW THE REFERENCES CITED IN NEDO-24010-2.

2. CLARIFY THE EXTENT TO WHICH COMBINATIONS OF RESPONSES SHOULD ONLY BE BASED ON THE CHARACTERISTICS OF THE RESPONSE TIME FUNCTIONS AS OPPOSED TO THE LOADING TIME FUNCTIONS.

3. USING MONTE CARLO SIMULATION INVESTIGATE THE EXTENT TO WHICH DEPARTURES FROM ZERO MEAN AFFECT THE ACCEPTABILITY OF CRITERION 1.

4. USING MONTE CARLO SIMULATION VERIFY WITH REAL AND SIMULATED RESPONSE FUNCTIONS WHETHER THE BASES OF LIMITED NUMBER OF HIGH PEAKS IS ALWAYS ACCEPTABLE. IF NOT ACCEPTABLE, DETERMINE ALTERNATE LIMITATIONS.

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TASKS TO BE CARRIED OUT FOR EVALUATION OF CRITERION 1, CONTINUED

5. USING MONTE CARLO SIMULATION INVESTIGATE THE EFFECT OF THE VARIATION OF SIGNAL DURATION TIME ON THE APPLICABILITY OF CRITERION 1.

6. USING MONTE CARLO SIMULATION, INVESTIGATE THE ACCEPTABILITY OF AN EQUAL OR LESS THAN 0.4 VALUE OF CORRELATION COEFFICIENT FOR THE SRSS METHODOLOGY.

TASKS TO BE CARRIED OUT FOR EVALUATION OF CRITERION 2

1. FROM THE REVIEW OF THE REFERENCES PERFORMED UNDER TASK 1 OF CRITERION 1 ESTABLISH THE APPLICABILITY OF THESE REFERENCES TO CRITERION 2.

2. USING MONTE CARLO SIMULATION VERIFY WITH REAL AND SIMULATED RESPONSE FUNCTIONS THE DEGREE OF CONSERVATISM (OR NON-CONSERVATISM) OBTAINED BY ACCEPTING A 50% CONDITIONAL PROBABILITY THAT THE ACTUAL PEAK COMBINED RESPONSE EXCEEDS APPROXIMATELY THE SRSS CALCULATED PEAK RESPONSE.

3. USING MONTE CARLO SIMULATION VERIFY WITH REAL AND SIMULATED RESPONSE FUNCTIONS THE DEGREE OF CONSERVATISM (OR NON-CONSERVATISM) OBTAINED BY ACCEPTING A 15% CONDITIONAL PROBABILITY THAT THE ACTUAL PEAK COMBINED RESPONSE EXCEEDS APPROXIMATELY 1.2 TIMES THE SRSS CALCULATED PEAK RESPONSE.

4. EXAMINE THE EFFECTS OF NON-UNIFORM PEAK PHASING DENSITY FUNCTIONS UPON THE ACCEPTABILITY OF CRITERION.

GENERIC STUDIES OF COMBINATION OF DYNAMIC RESPONSES

DSS COGNIZANT ENGINEER: S.N. HOU

OVERALL OBJECTIVE

ASSIST MECHANICAL ENGINEERING BRANCH IN INVESTIGATING METHODS AND IN DEVELOPING CRITERIA FOR APPROPRIATE COMBINATIONS OF DYNAMIC RESPONSES IN PIPING SYSTEMS AND COMPONENTS OF LWR PLANTS UNDER:

1. PLANT OPERATING TRANSIENTS
2. POSTULATED ACCIDENTS
3. SEISMIC EVENTS

PARAMETRIC STUDIES TO DETERMINE THE EFFECT ON RESPONSE COMBINATIONS

1. FREQUENCY
2. FREQUENCY BANDWIDTH
3. AMPLITUDE
4. DURATION TIME
5. DISTRIBUTION OF TIME LAG OR PHASE (I.E., UNIFORM, NORMAL TRIANGULAR, ETC.)
6. DAMPING

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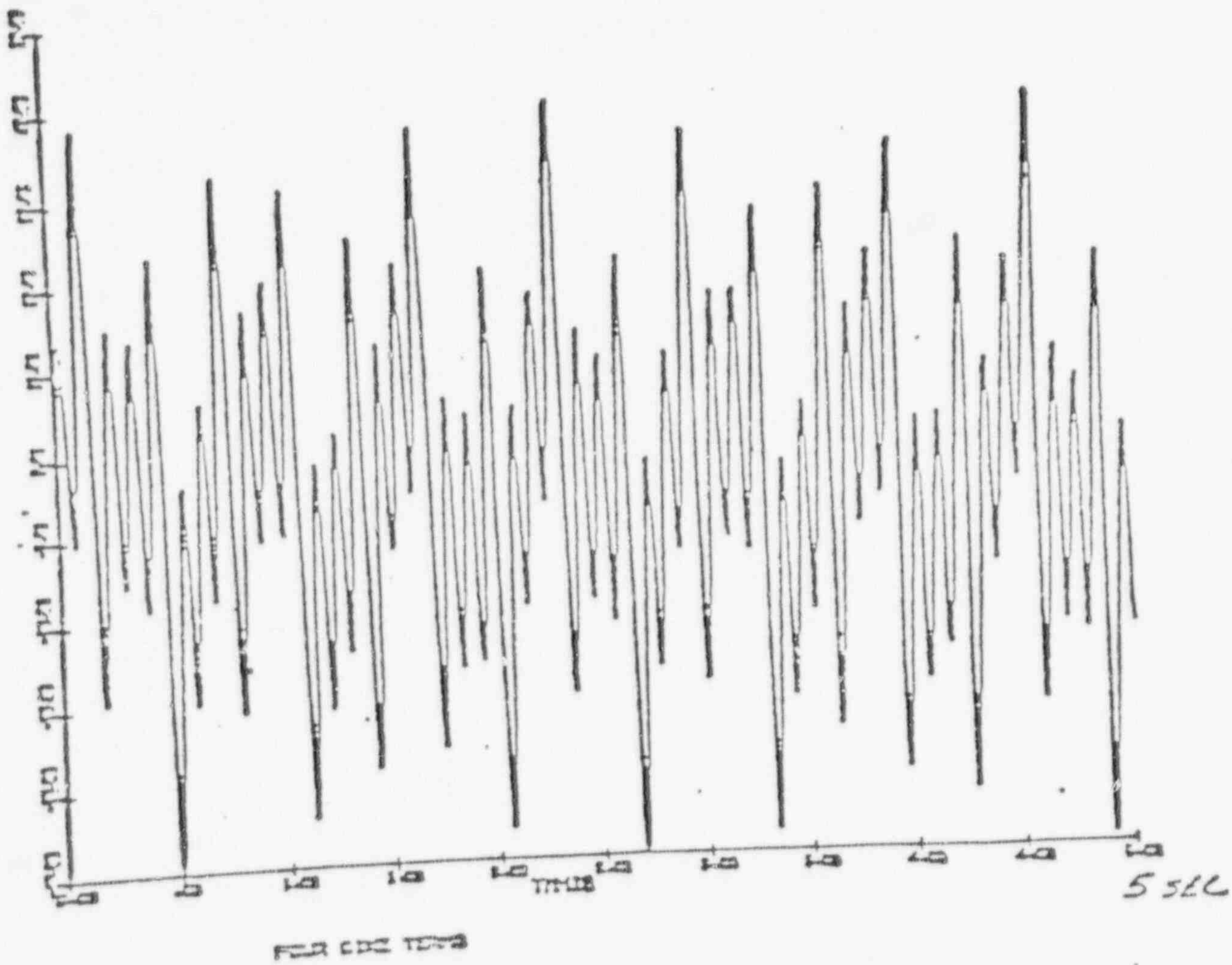
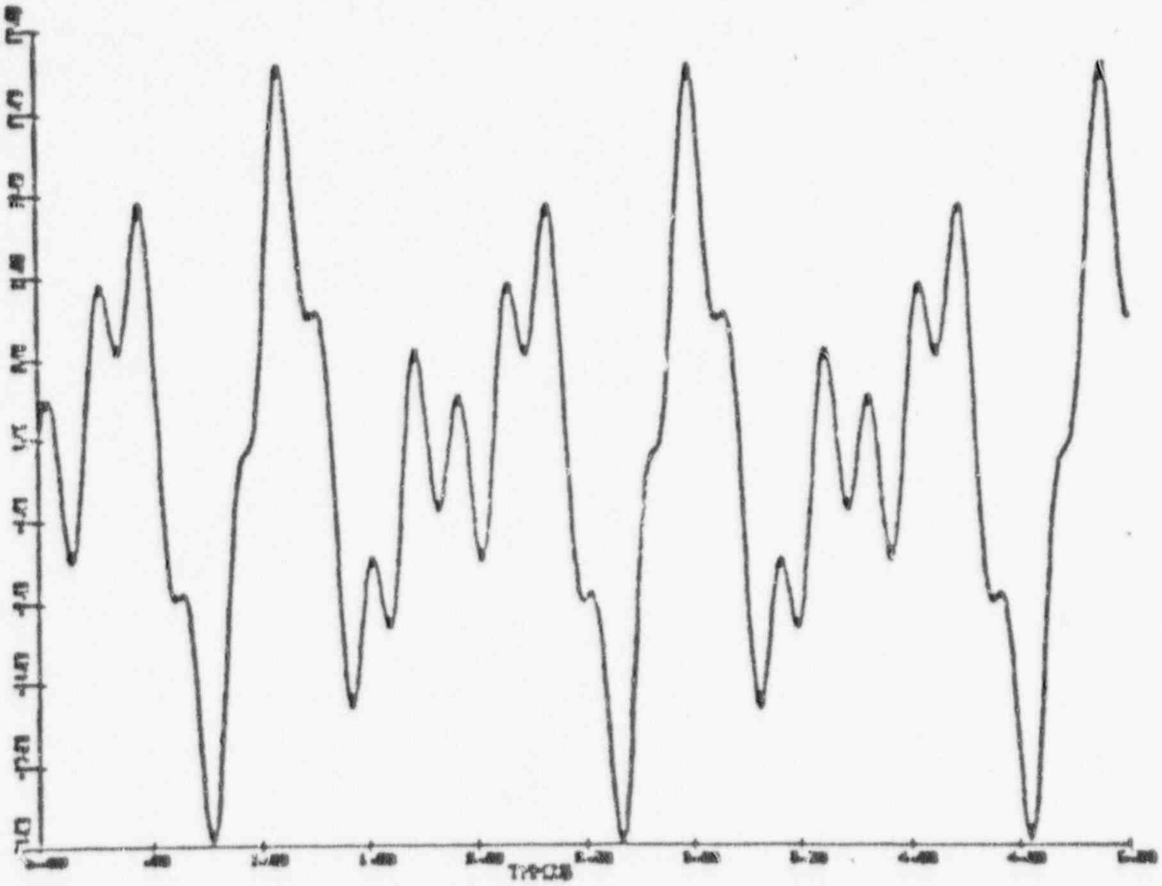
$x_2(t) = 10 \sin 9.75t + 10 \sin 10t - 10 \sin 20t + 20 \sin 50t$

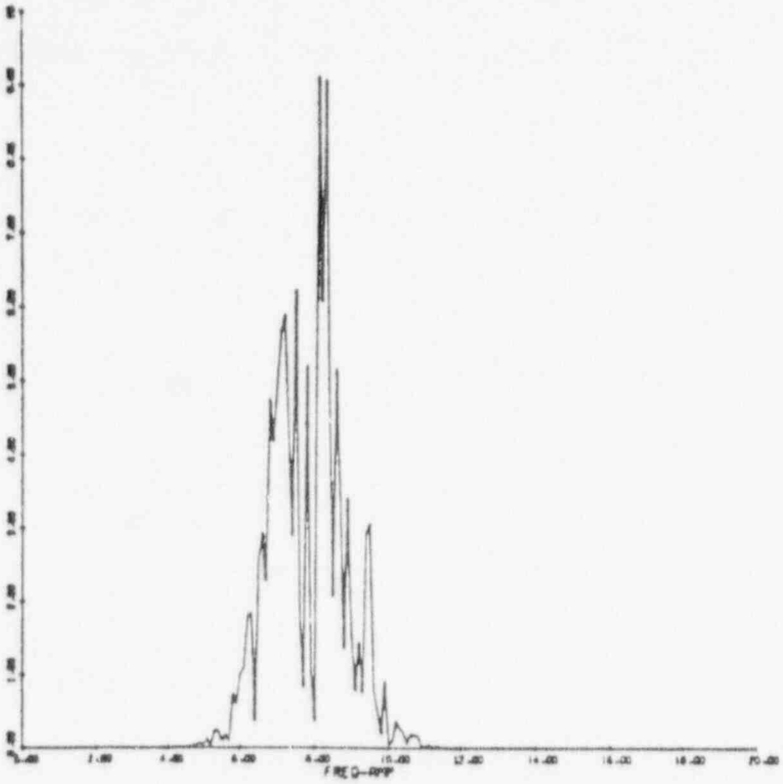


90011225

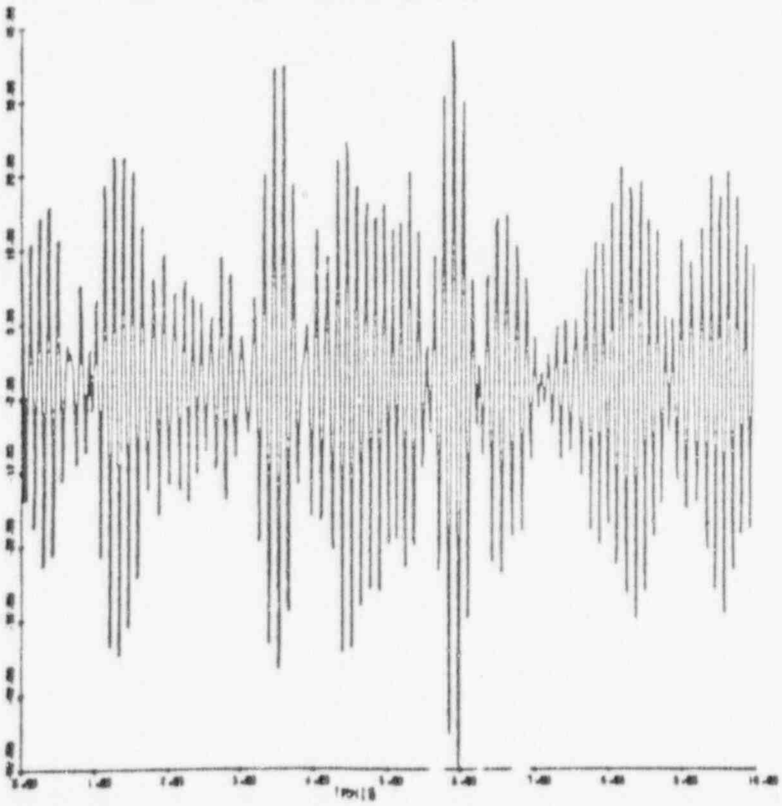
$x(t) = 10 \sin 6.67t - 10 \sin 10t + 15 \sin 30t$



90011226

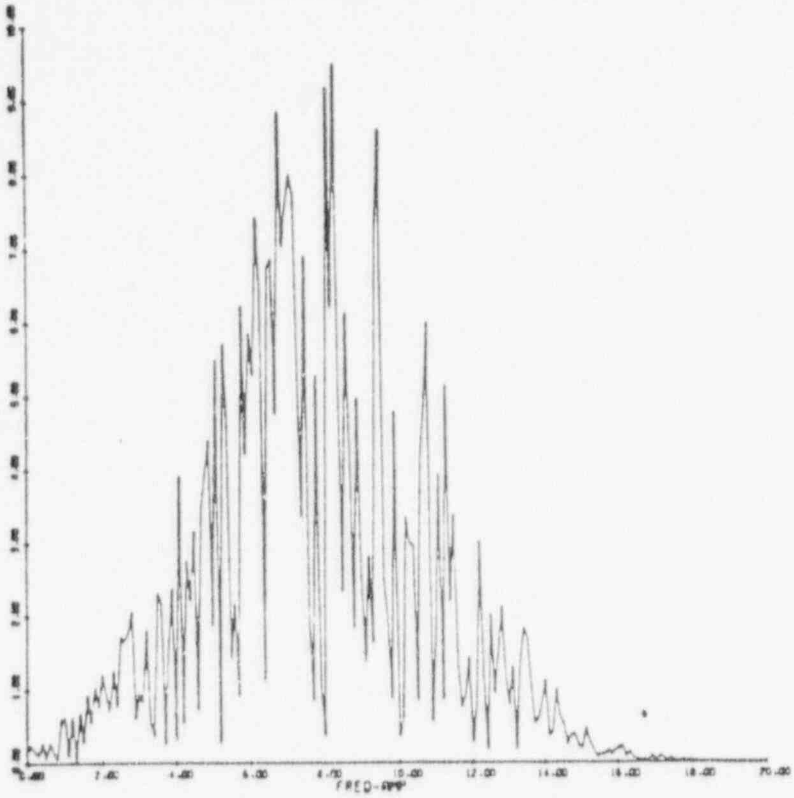


CASE A-1 FREQ=8.8 SIGMA=1.1 DUR=10.10.

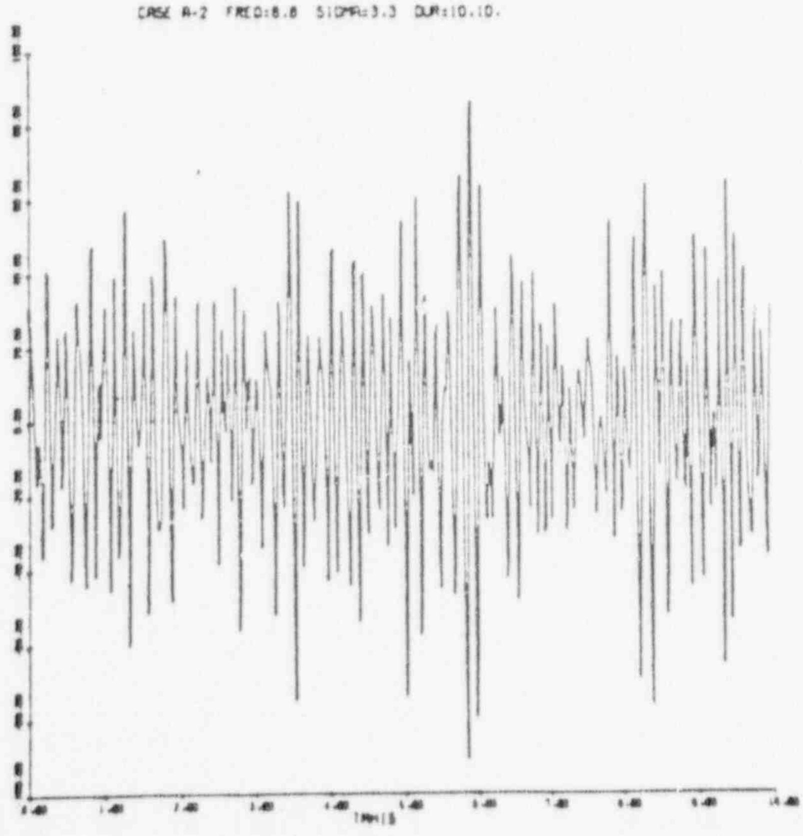


90011227

CASE A-1 FREQ=8.8 SIGMA=1.1 DUR=10.10.



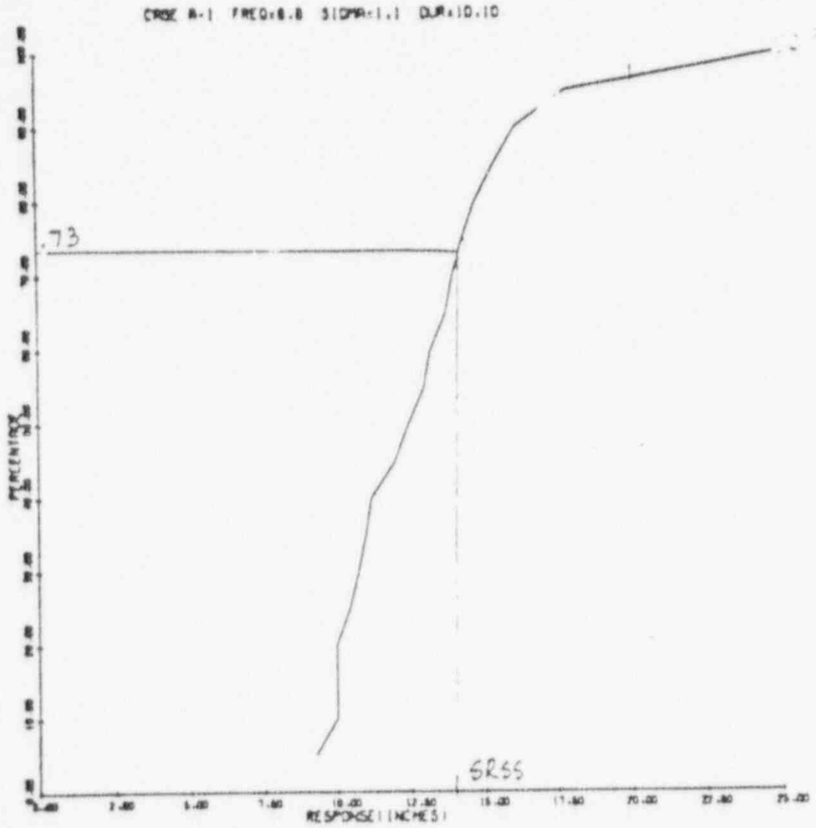
CASE A-2 FREQ=8.8 SIGMA=3.3 DUR=10.10.



CASE A-2 FREQ=8.8 SIGMA=3.3 DUR=10.10.

90011228

CASE A-1 FREQ=8.8 SIGMA=1.1 DUR=10.10



CASE A-1 FREQ=8.8 SIGMA=1.1 DUR=10.10.

CASE A-1 FREQ=8.8 SIGMA=1.1 DUR=10.10.

90011229

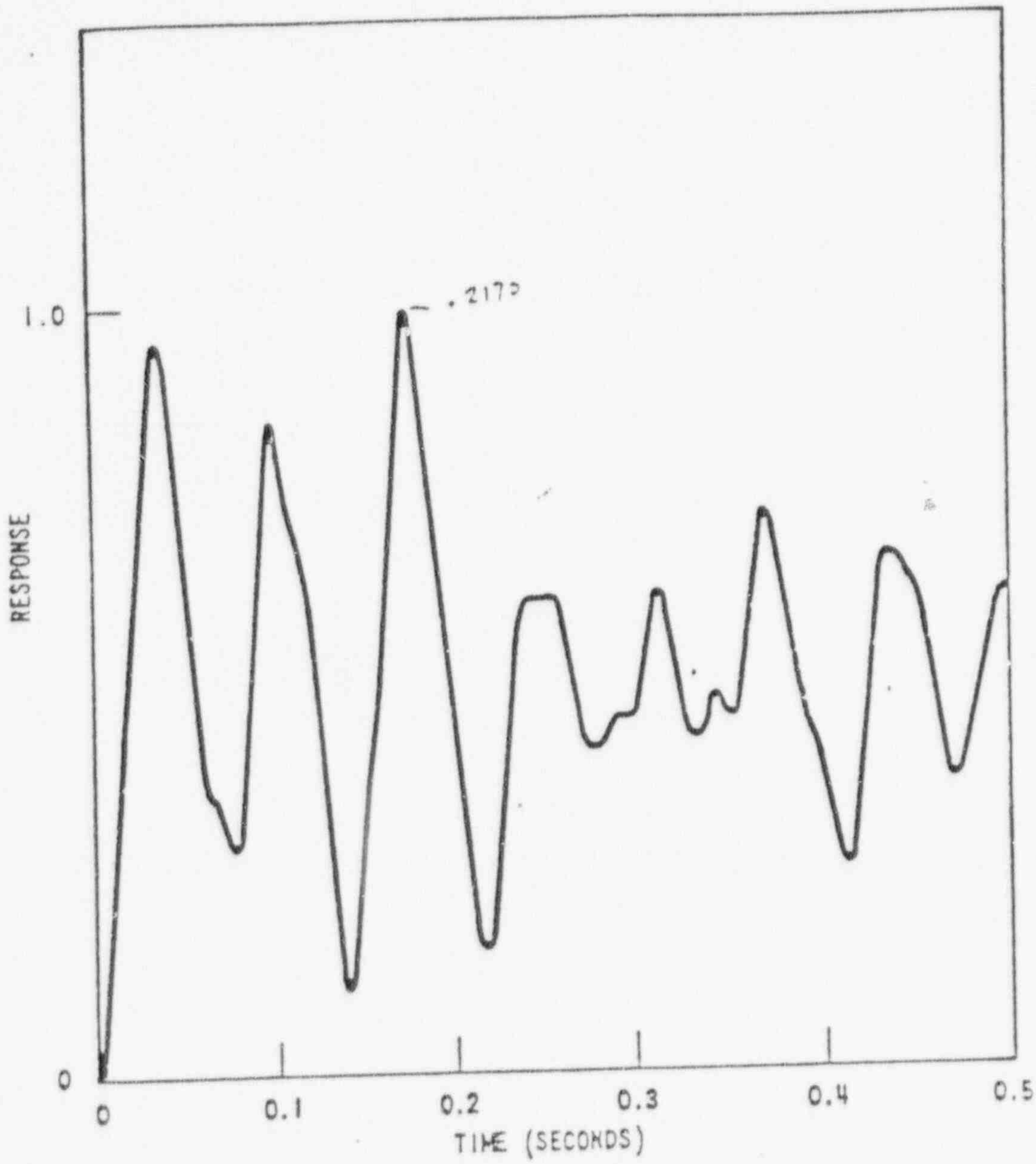


Figure B-23. LOCA Response Number 22

90011230

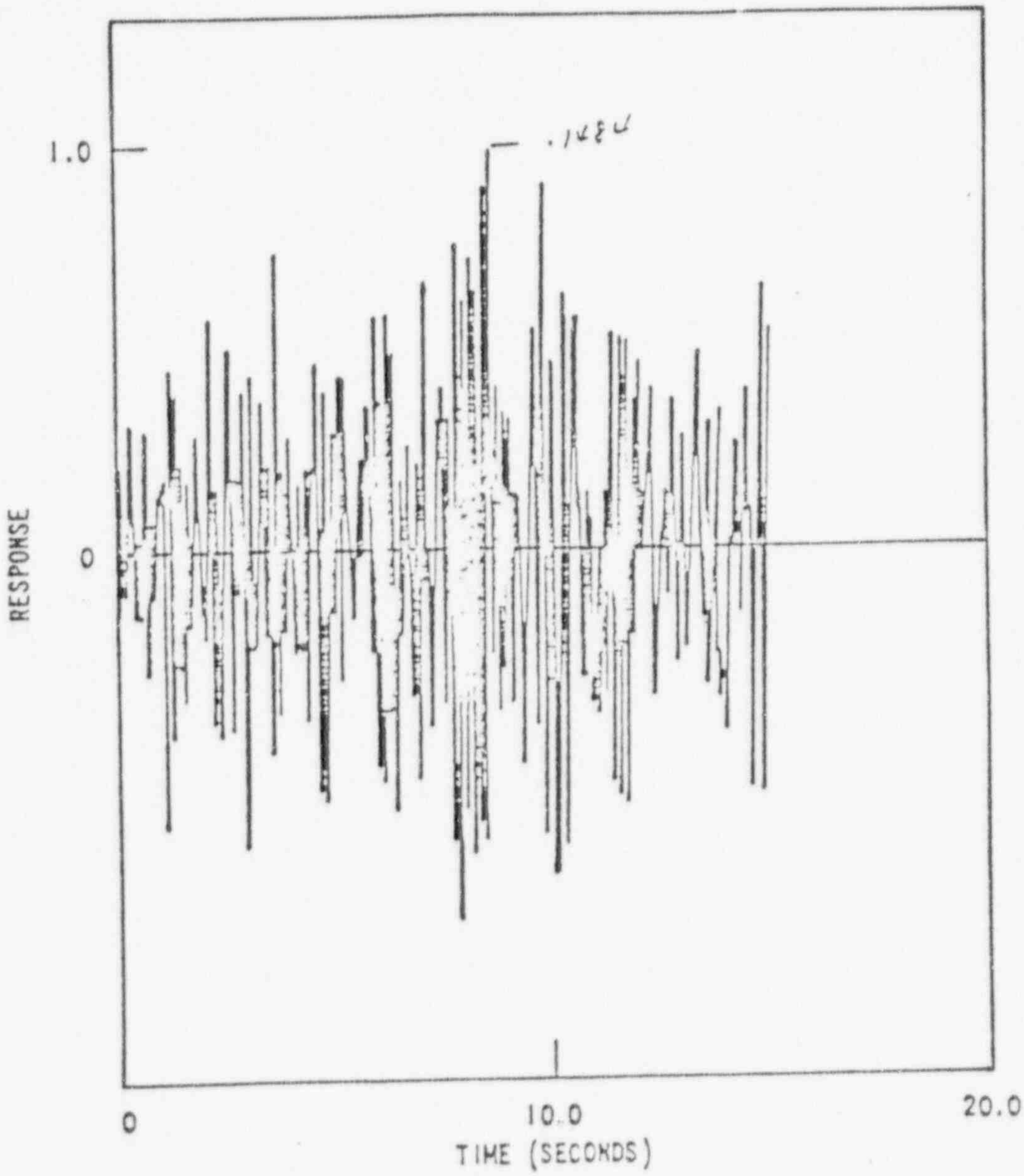
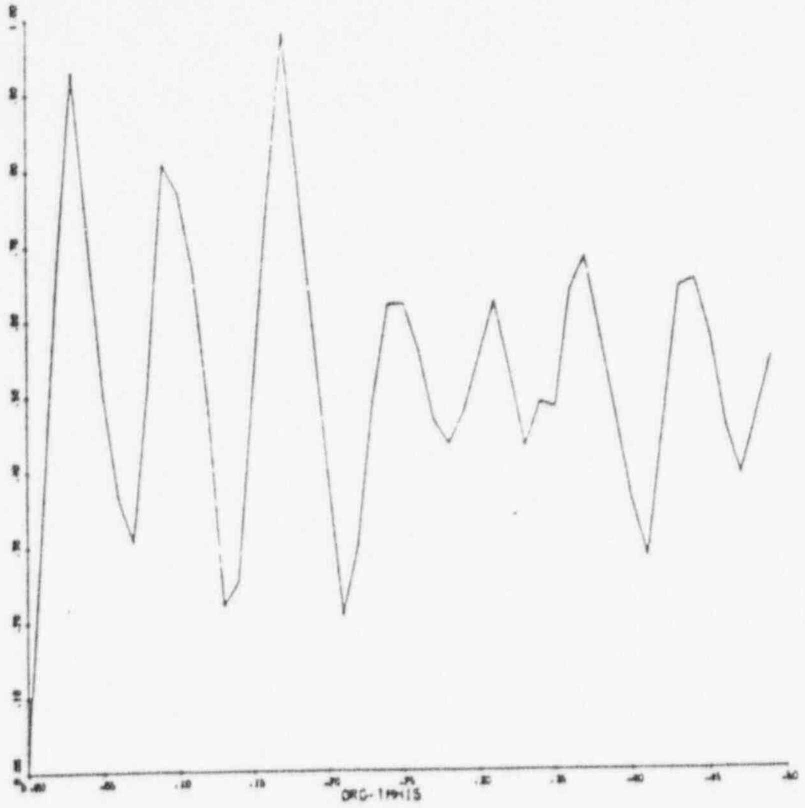
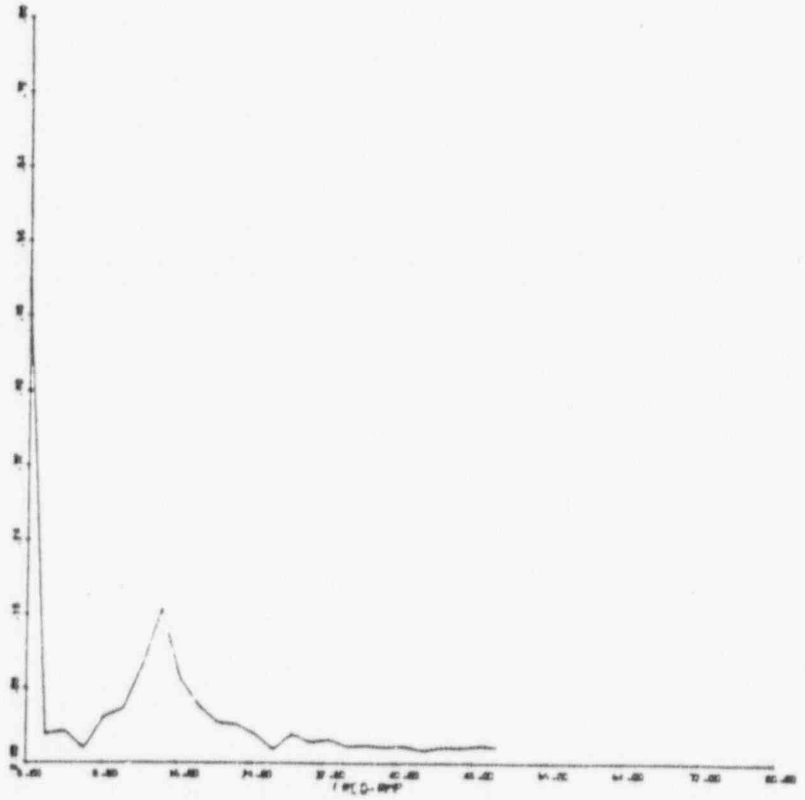


Figure B-24. SSE Response Number 22

90011231

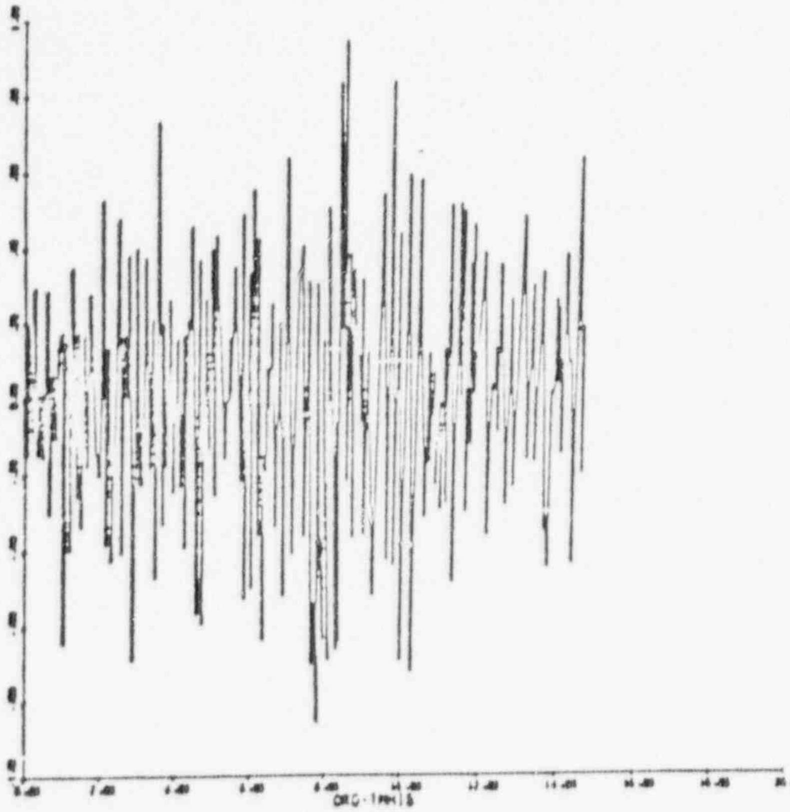


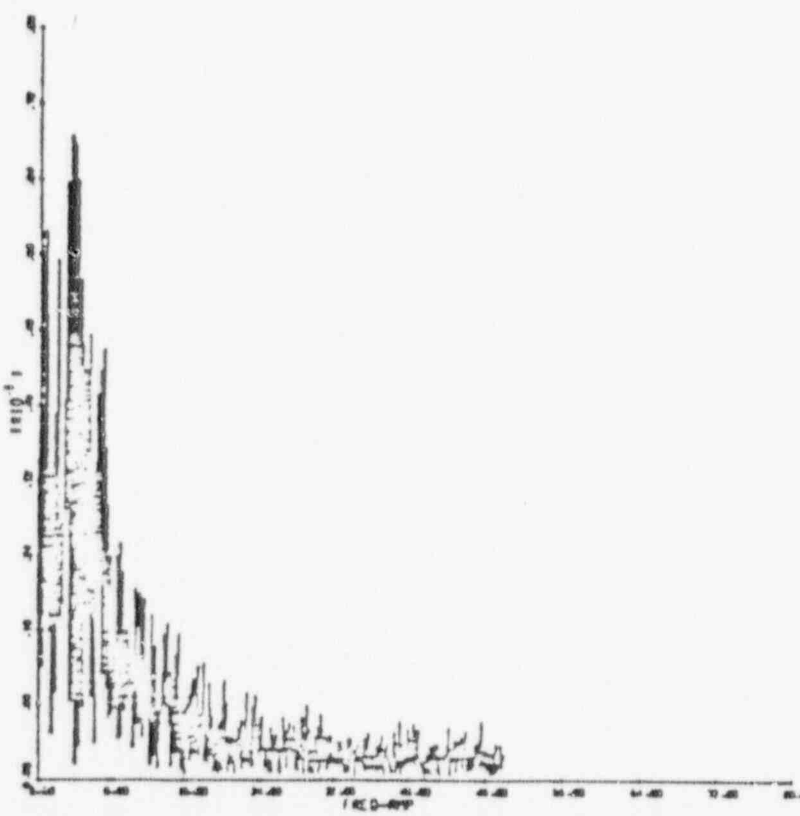
B23



90011232

G-19

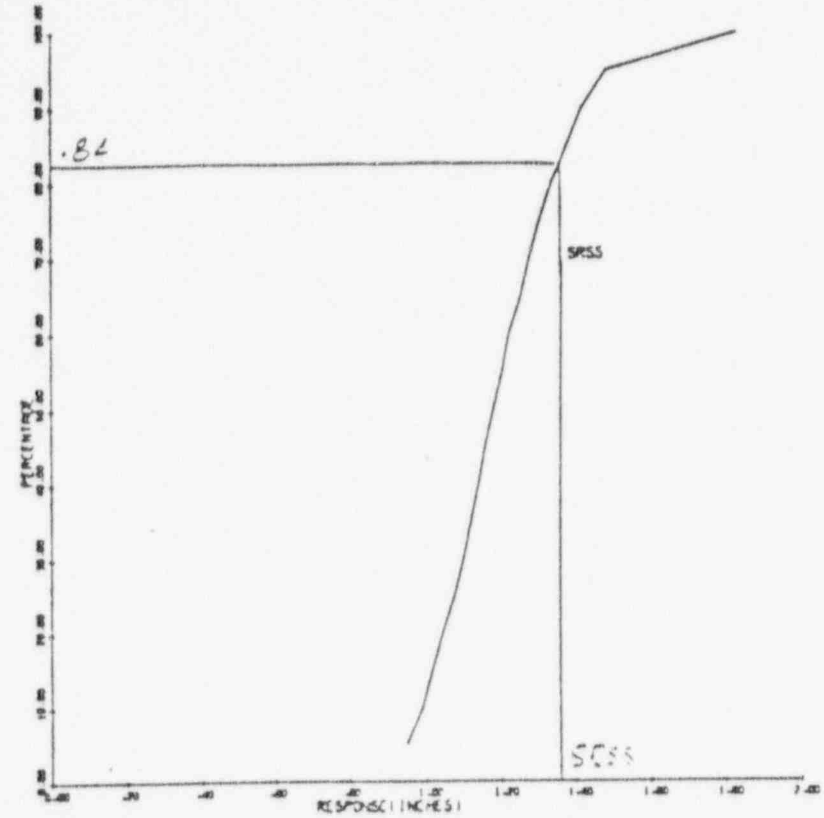




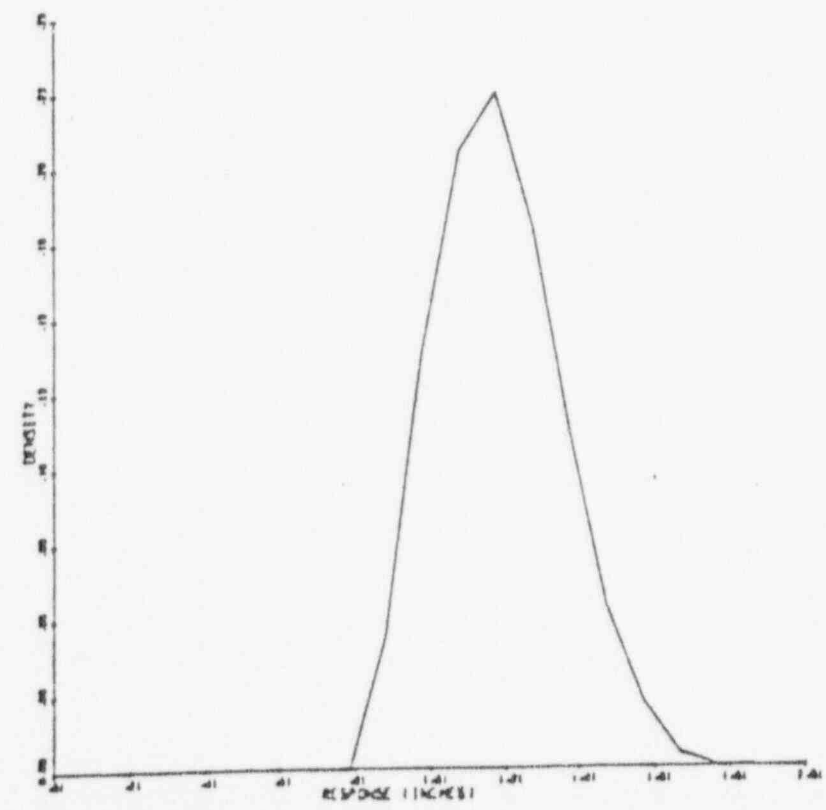
B24

G-20

90011233



EARTHQUAKE SRV B-23.24



EARTHQUAKE SRV B-23.24

90011234

METHODS EMPLOYED

MONTE CARLO

NUMERICAL SOLUTIONS

CLOSED FORM SOLUTIONS

90011235

REMAINING ITEMS:

1. EFFECTS OF MORE THAN TWO RESPONSE COMBINATIONS.
2. MORE RUNS WITH ARTIFICIAL TIME DOMAIN.
3. MORE RUNS WITH REAL EXCITATION COMBINATIONS.
4. SOME INVESTIGATION REGARDING INTERMIX OF LOADING AND RESPONSE.

9001123б

SUMMARY

CONCLUSIONS FOR REAL TIME HISTORIES, FOR ARTIFICIAL FREQUENCY, AS WELL AS TIME DOMAIN, AND MULTI-SINUSOIDAL COMBINATIONS HAVE BEEN PRESENTED. WHAT REMAINS IS TO QUANTIFY THE RESULTS. THIS IS ESSENTIALLY THE WORK OF ITEM C, IN THE WORK SCOPE.

FOR MULTISINUSOIDAL RESPONSES

1. FREQUENCY RELATIONS OF MAJOR COMPONENTS WILL AFFECT PERCENT OF NON-EXCEEDANCE, AS IS INDICATED IN CONCLUSIONS FOR SINE RESPONSE.

2. NUMBER OF PEAKS PRIMARY FACTOR IN DETERMINING PERCENT OF NON-EXCEEDANCE.

3. RESPONSES WITH SAME COMPONENTS CAN GIVE VERY DIFFERENT PERCENT OF NON-EXCEEDANCE DEPENDING ON PHASE ANGLE OF COMPONENTS.

90011238

CONCLUSIONS FOR COMBINING SINE RESPONSES

1. TWO IDENTICAL SINUSOIDS HAVE COMBINED RESPONSES AT 50% NON-EXCEEDANCE LEVEL,

2. TWO DIFFERENT FREQUENCIES ARE A PRIMARY FACTOR IN REDUCING THE PERCENT OF NON-EXCEEDANCE,

3. AMPLITUDE RATIO IS NOT A PRIMARY FACTOR IN CHANGING THE PERCENT OF NON-EXCEEDANCE,

4. DIFFERENT DURATION TIMES WILL LOWER PERCENT OF NON-EXCEEDANCE,

5. INCREASED DAMPING WILL RAISE PERCENT OF NON-EXCEEDANCE,

6. DENSITY FUNCTION FOR RANDOM PHASE ANGLE IS NOT A PRIMARY FACTOR,

7. FOR RANDOM FREQUENCIES WITH NORMAL DISTRIBUTION, AN INCREASE IN σ LOWERS THE PERCENT OF NON-EXCEEDANCE,

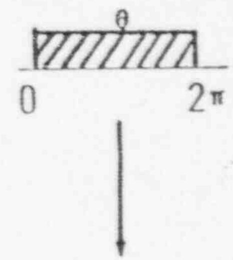
CONCLUSIONS FOR COMBINING SINE RESPONSES, CONTINUED

8. MORE OF THE SAME SINE WAVES WILL RAISE THE PERCENT OF NON-EXCEEDANCE.

G-28

RESPONSE COMBINATIONS CASES

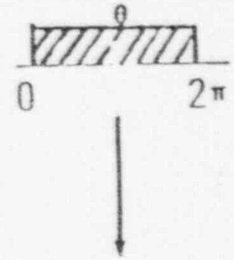
2 SINUSOIDS

NO.	AMPLITUDES A_1, A_2, A_3, A_4	FREQUENCIES RAD/SEC $W_I \rightarrow$	DURATIONS TIME, SEC $t_I \rightarrow$	SRSS %	C/CC %	PHASE ANGLE
(1)	10, 10	10, 10	5, 5	52	---	
2)	10, 10	10, 10	5, 4	53	---	
(3)	10, 10	$W_{\mu_1} = W_{\mu_2} = 7.5$	5, 5	19	---	
		$\sigma_1 = \sigma_2 = .5$		23	---	
(4)	10, 10	$\sigma_1 = \sigma_2 = .4$		33	---	
(5)	10, 10	$\sigma_1 = \sigma_2 = .2$		42	---	
(6)	10, 10	$\sigma_1 = \sigma_2 = .1$		24	---	
(7)	10, 10	$W_{\mu_1} = W_{\mu_2} = 7.5$	5,4	16	---	
		$\sigma_1 = \sigma_2 = .5$				

90011241

RESPONSE COMBINATIONS CASES, CONTINUED
3 OR 4 SINUSOIDS

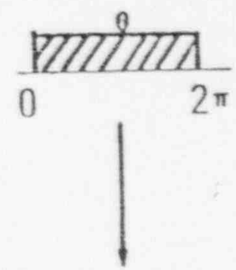
NO.	AMPLITUDES A_1, A_2, A_3, A_4	FREQUENCIES RAD/SEC $W_I \rightarrow$	DURATIONS TIME, SEC $t_I \rightarrow$	SRSS %	C/CC %	PHASE ANGLE
(8)	10, 10, 10	7.5, 7.5, 7.5	5, 5, 5,	62	---	
(9)	10, 10, 10	7.5, 7.5, 7.5	5, 4, 3	52	---	
(10)	10, 10, 10	$W_{\mu_1} = W_{\mu_2} = W_{\mu_3} = 7.5$ $\sigma_1 = \sigma_2 = \sigma_3 = .5$	5, 5, 5,	28		
(11)	10, 10, 10	$W_{\mu_1} = W_{\mu_2} = W_{\mu_3} = 7.5$ $\sigma_1 = \sigma_2 = \sigma_3 = .5$	5, 4, 3	22	---	
(12)	10, 10, 10, 10	7.5, 7.5, 7.5, 7.5	5, 5, 5, 5,	66	---	
(13)	10, 10, 10, 10	7.5, 7.5, 7.5, 7.5	5, 4, 3, 2,	51	---	
(14)	10, 10, 10, 10	$W_{\mu_1} = W_{\mu_2} = W_{\mu_3} = W_{\mu_4} = 7.5$ $\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 = .5$	5, 5, 5, 5,	35	---	
(15)	10, 10, 10, 10	$W_{\mu_1} = W_{\mu_2} = W_{\mu_3} = W_{\mu_4} = 7.5$ $\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 = .5$	5, 4, 3, 2,	35	---	



RESPONSE COMBINATIONS CASES, CONTINUED

2 SINUSOIDS

NO.	AMPLITUDES $A_I \rightarrow$	FREQUENCIES RAD/SEC $W_I \rightarrow$	DURATIONS TIME, SEC $t_I \rightarrow$	SRSS %	C/CC %	PHASE ANGLE
DAMPED RESPONSES						
(16)	10, 10	7.5, 7.5	5, 5	55	2	
(17)	10, 10	7.5, 7.5	5, 4	54	2	
(18)	10, 10	$W_{\mu_1} = W_{\mu_2} = 7.5$ $\sigma_1 = \sigma_2 = .5$	5, 5	47	2	
(19)	10, 10	$W_{\mu_1} = W_{\mu_2} = 7.5$ $\sigma_1 = \sigma_2 = .5$	5, 4	45	2	



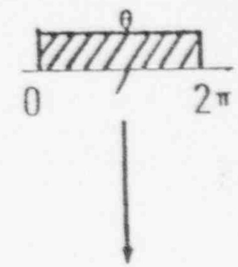
G-30

90011243

RESPONSE COMBINATIONS CASES, CONTINUED

3 OR 4 SINUSOIDS

NO.	AMPLITUDES $A_I \rightarrow$	FREQUENCIES RAD/SEC $W_I \rightarrow$	DURATIONS TIME, SEC $t_I \rightarrow$	SRSS %	C/CC %	PHASE ANGLE
	DAMPED RESPONSES					
(20)	10, 10, 10	7.5, 7.5, 7.5	5, 5, 5	62	2	
(21)	10, 10, 10	7.5, 7.5, 7.5	5, 4, 3	65	2	
(22)	10, 10, 10	$W_{\mu_1} = W_{\mu_2} = W_{\mu_3} = 7.5$ $\sigma_1 = \sigma_2 = \sigma_3 = .5$	5, 5, 5,	57	2	
(23)	10, 10, 10	$W_{\mu_1} = W_{\mu_2} = W_{\mu_3} = 7.5$ $\sigma_1 = \sigma_2 = \sigma_3 = .5$	5, 4, 3	53	2	
(24)	10, 10, 10, 10	7.5, 7.5, 7.5, 7.5	5, 5, 5, 5	67	2	
(25)	10, 10, 10, 10	7.5, 7.5, 7.5, 7.5	5, 4, 3, 2	63	2	
(26)	10, 10, 10, 10	$W_{\mu_1} = W_{\mu_2} = W_{\mu_3} = W_{\mu_4} = 7.5$ $\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 = .5$	5, 5, 5, 5,	56	2	
(27)	10, 10, 10, 10	$W_{\mu_1} = W_{\mu_2} = W_{\mu_3} = W_{\mu_4} = 7.5$ $\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 = .5$	5, 4, 3, 2,	48	2	

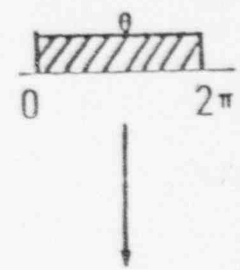


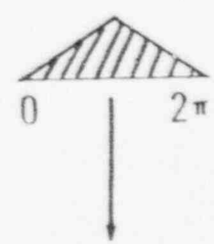
RESPONSE COMBINATIONS CASES, CONTINUED

3 OR 4 SINUSOIDS

NO.	AMPLITUDES $A_I \rightarrow$	FREQUENCIES RAD/SEC $W_I \rightarrow$	DURATIONS TIME, SEC $t_I \rightarrow$	SRSS %	C/CC %
DAMPED RESPONSES					
(28)	10, 10, 10, 10	$\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 = .4$	5, 4, 3, 2	44	2
(29)	10, 10, 10, 10	$\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 = .2$	5, 4, 3, 2	48	2
(30)	10, 10, 10, 10	$\sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 = .1$	5, 4, 3, 2	51	2
(31)	10, 10	7.5, 7.5	5, 5	52	---
(32)	10, 5	7.5, 7.5	5, 5	52	---
(33)	10, 1	7.5, 7.5	5, 5	52	---
(34)	10, 10	10, 5	5, 5	14.1	---
(35)	10, 5	10, 5	5, 5	11.8	---
(36)	10, 10	7.5, 7.5	5, 5	42	---
(37)	10, 5	7.5, 7.5	5, 5	40	---
(38)	10, 1	7.5, 7.5	5, 5	40	---
(39)	10, 10	10, 5	5, 5	14.1	---

PHASE ANGLE

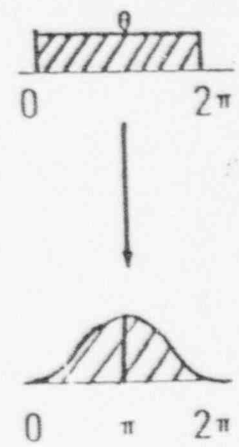




RESPONSE COMBINATIONS CASES, CONTINUED

3 OR 4 SINUSOIDS

NO.	AMPLITUDES A_I →	FREQUENCIES RAD/SEC W_I →	DURATIONS TIME, SEC t_I →	SRSS %	C/CC %	PHASE ANGLE
DAMPED RESPONSES						
(40)	10, 5	10, 5	5, 5	11.1	---	
(41)	10, 10	10, 10	5, 5	52	---	
(42)	10, 10		5, 5	50	---	



$\sigma = \frac{\pi}{4}$

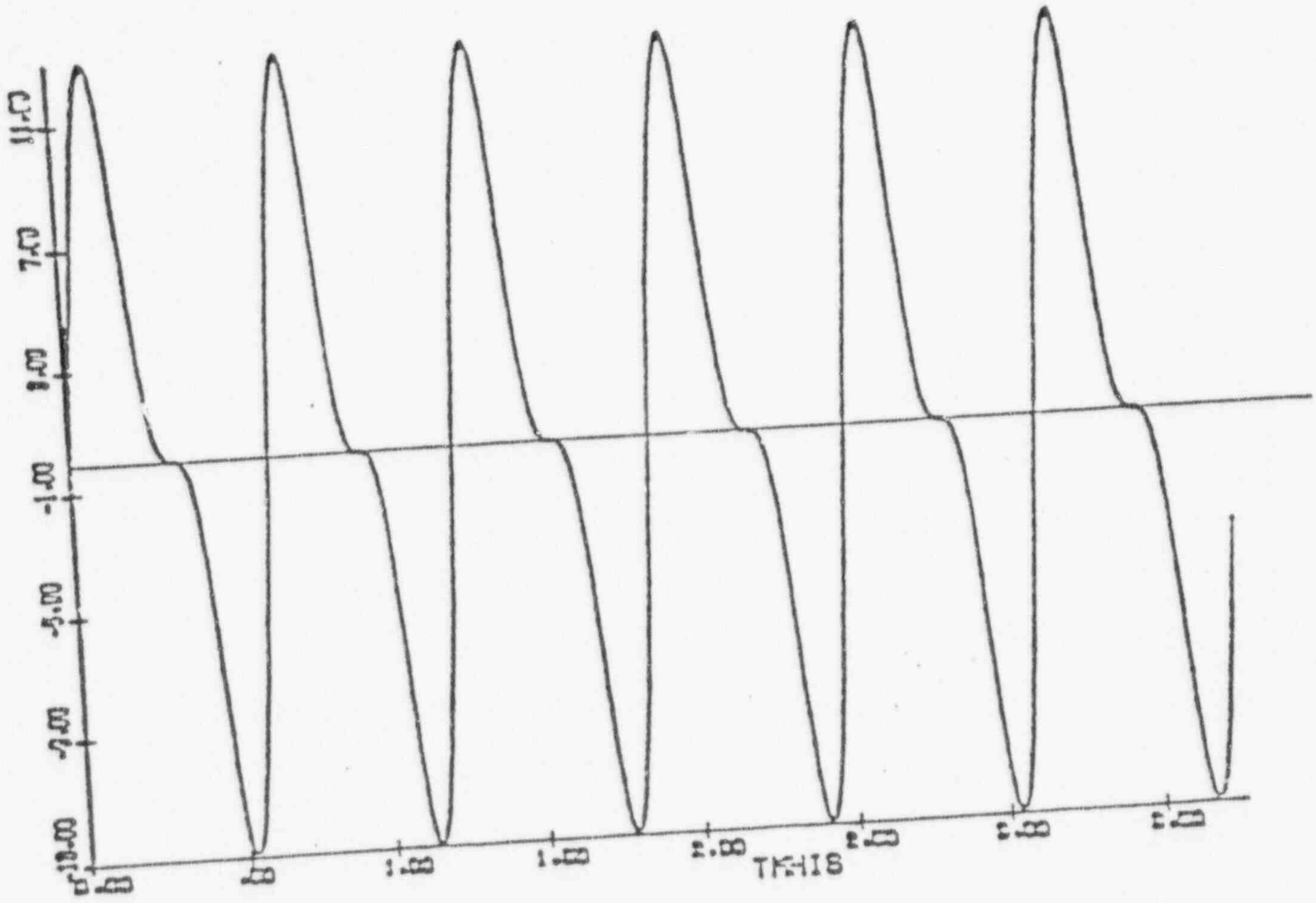
$\sigma = \frac{\pi}{4}$

G-33

90011246

P(R<SRSC) @ 62%

X(T) = 10 SIN 10T + 5 SIN 20T

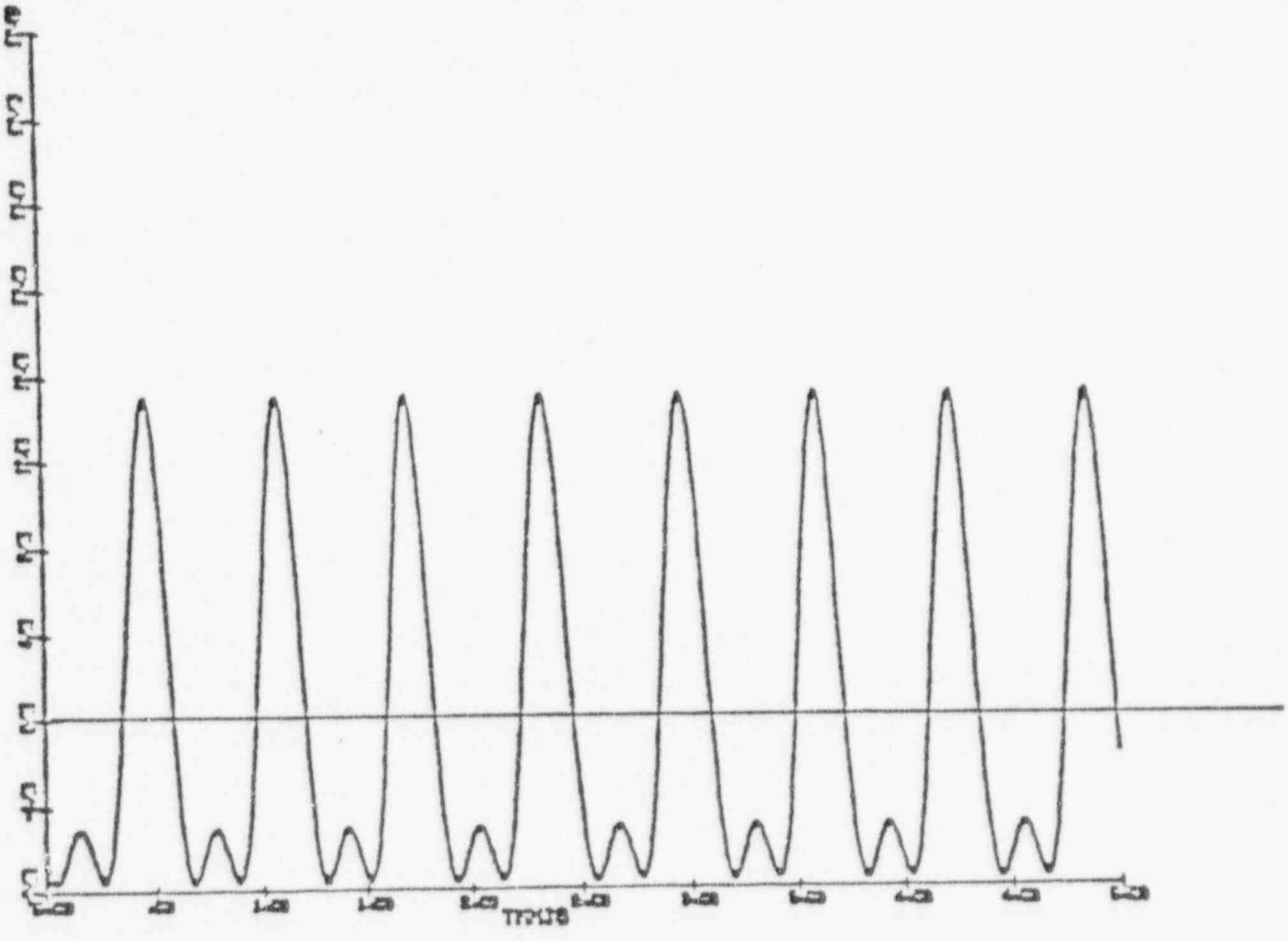


FOUR SINE TERMS

90011247

P(R<SRSS) @ 68%

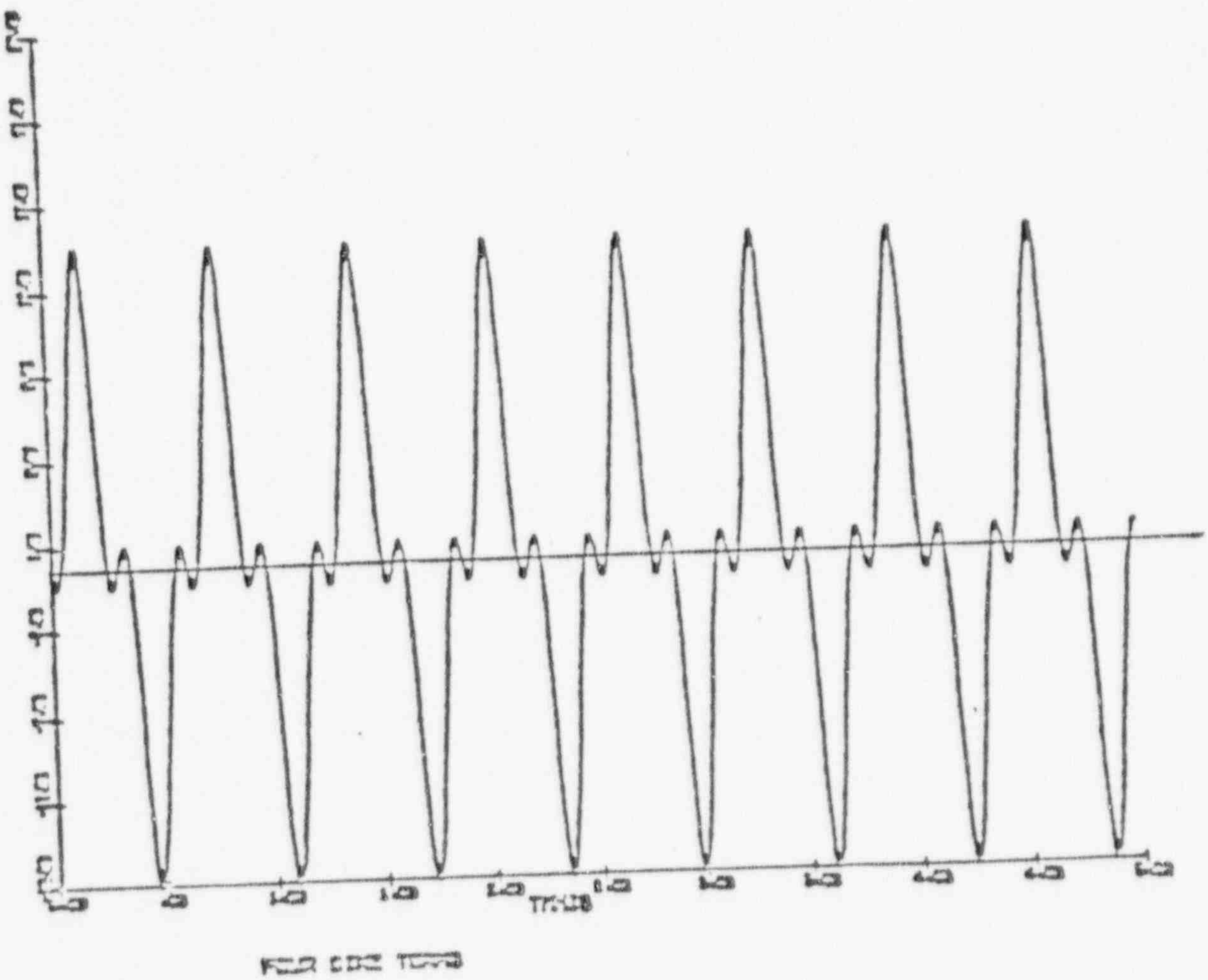
$X(\tau) = 10 \sin 10\tau + 5 \sin (20\tau - \pi/2)$



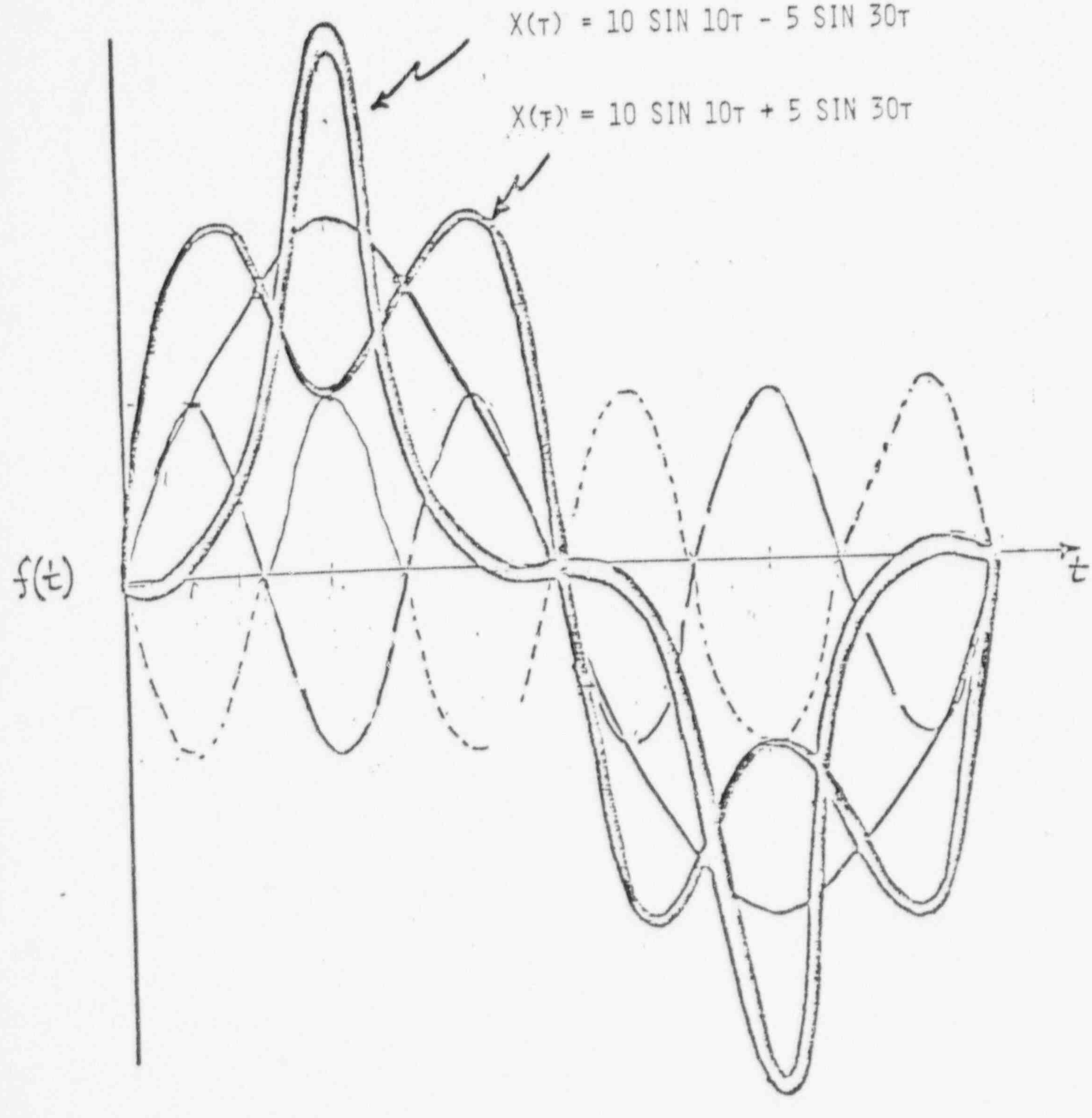
90011248

P(R<SRSS) @ 72%

$$X(T) = 10 \sin 10T - 5 \sin 30T$$



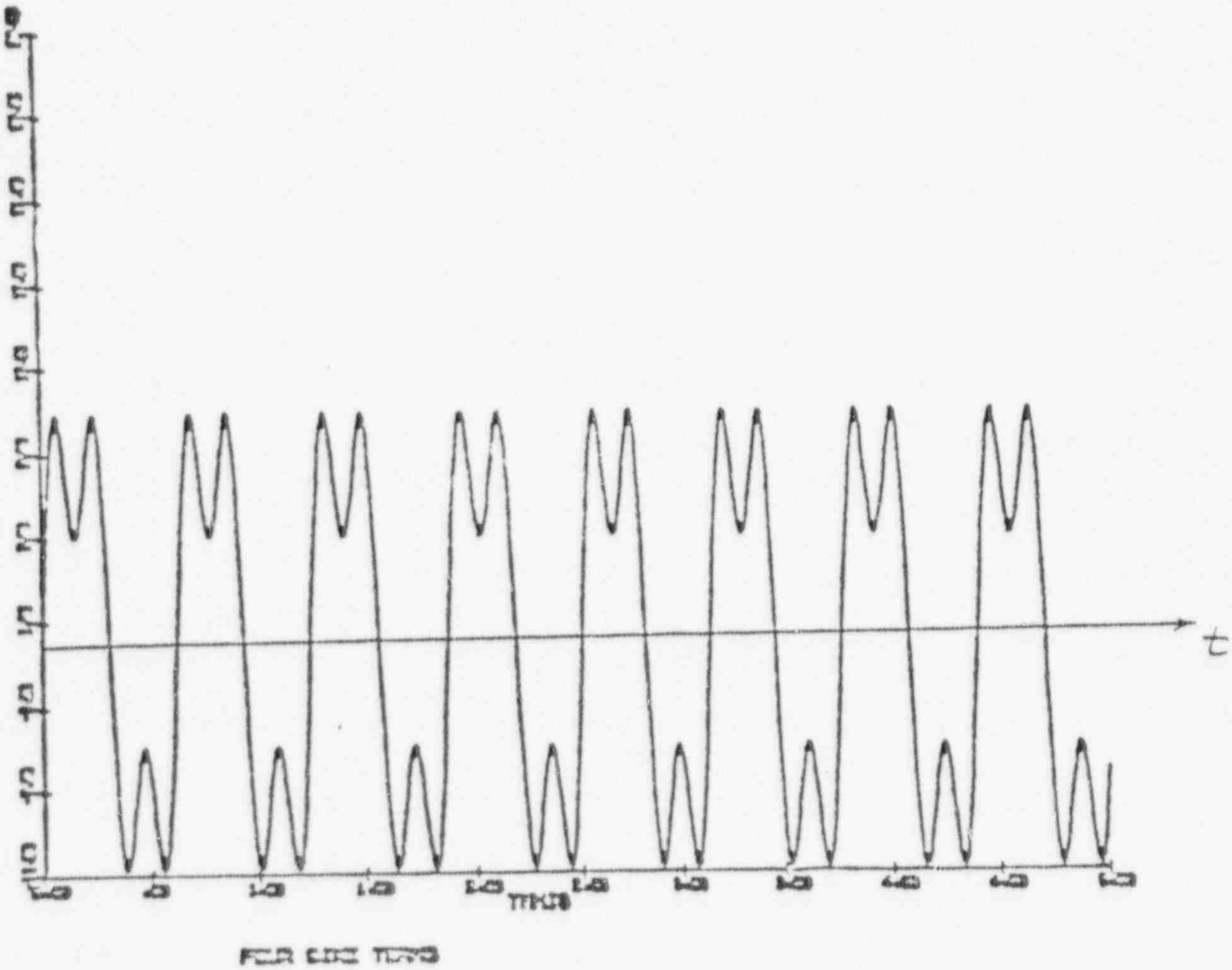
90011249



90011250

P(R<SRSS) @ 28%

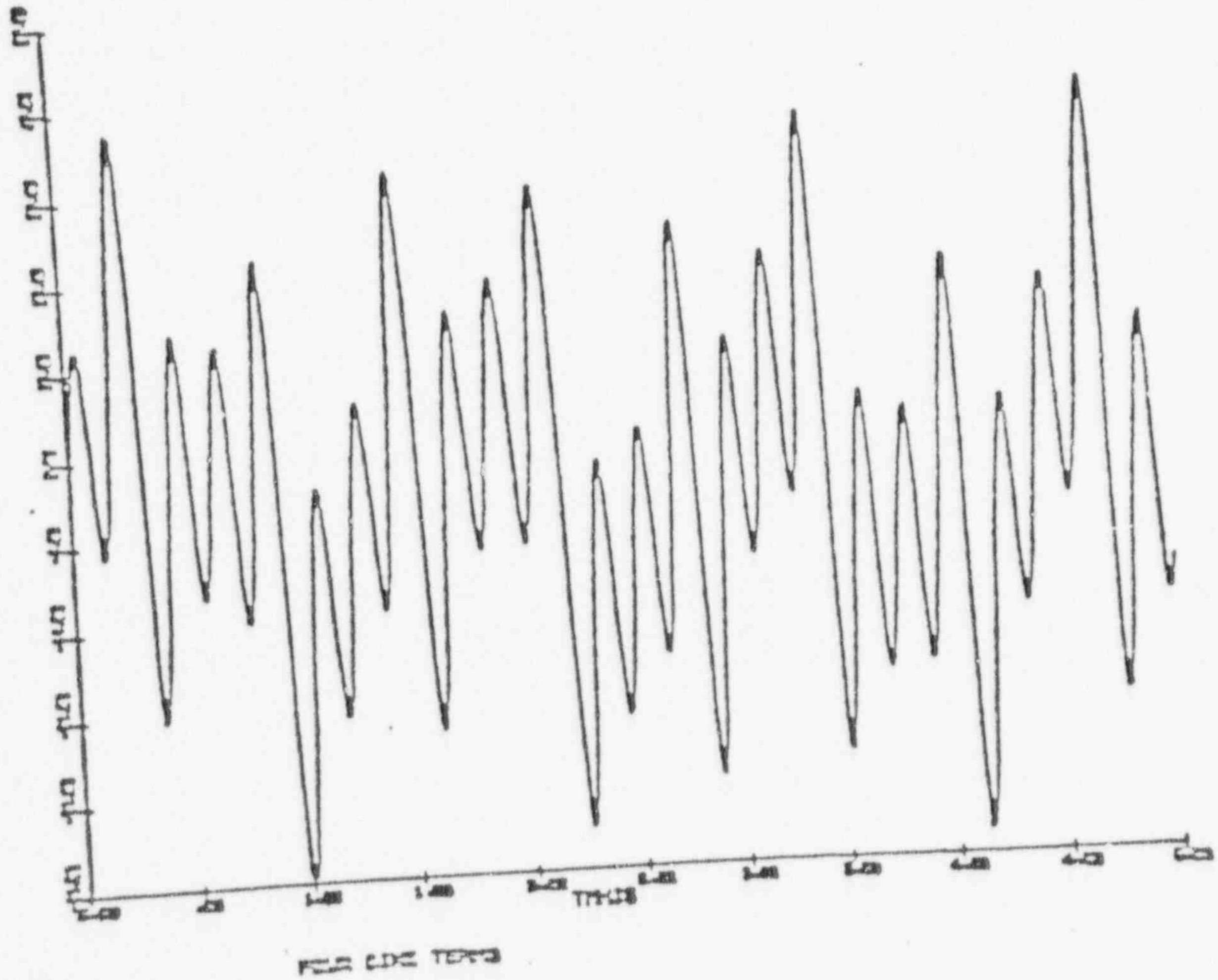
$X(T) = 10 \sin 10T + 5 \sin 30T$



90011251

P(R<SRSS) @ 72%

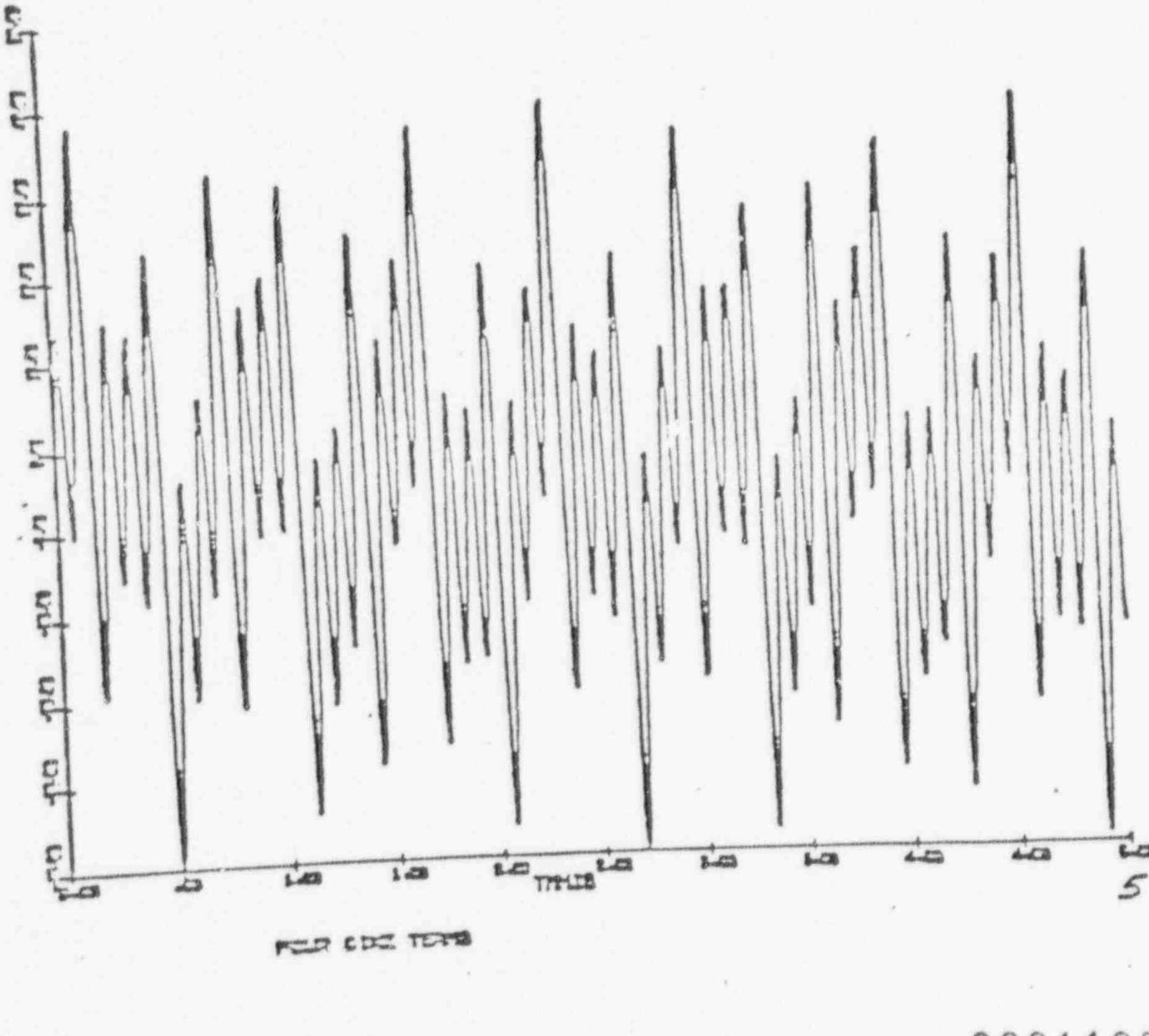
$X_1(\tau) = 10\ \mathrm{SIN}\ 4.375\tau + 10\ \mathrm{SIN}\ 10T - 10\ \mathrm{SIN}\ 20\tau + 20\ \mathrm{SIN}\ 30\tau$



90011252

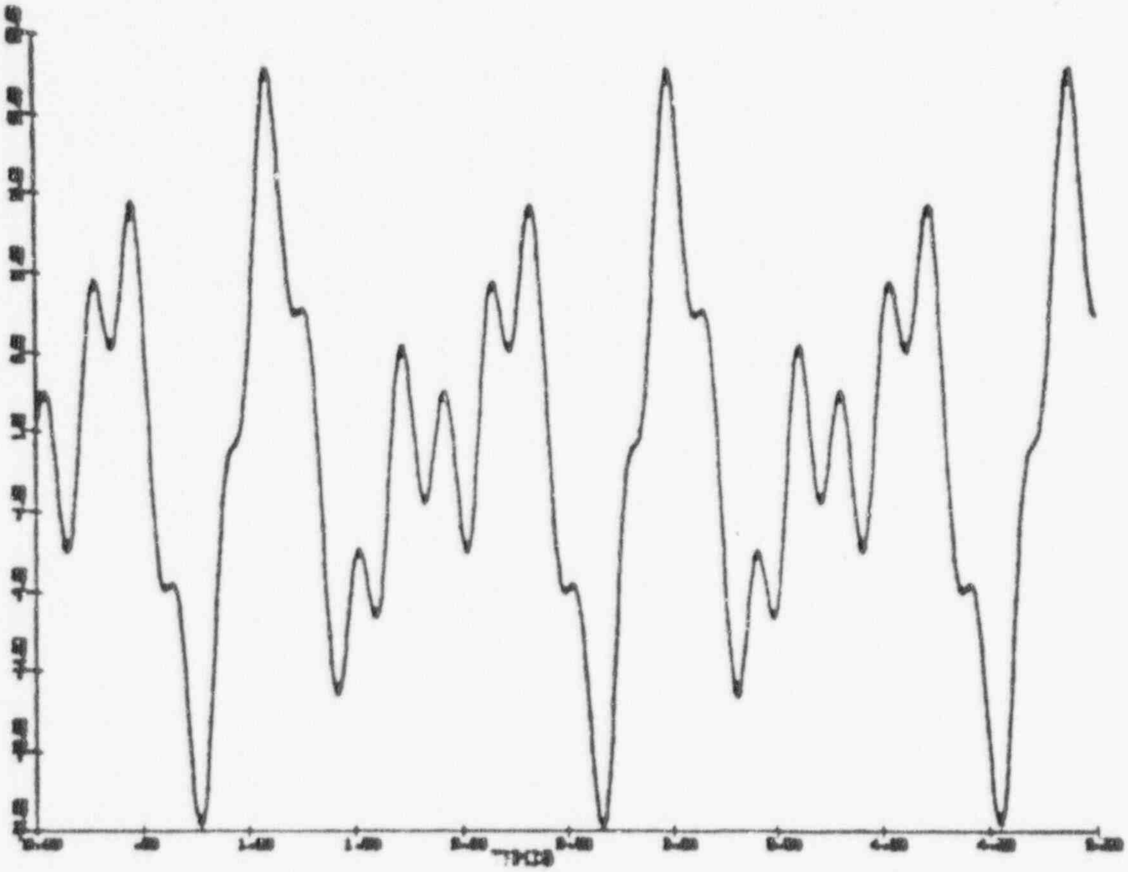
P(R<SRSS) @ 13%
WITH $X_1(T)$.

$$X_2(T) = 10 \sin 8.75T + 10 \sin 10T - 10 \sin 20T + 20 \sin 30T$$



5 SEC

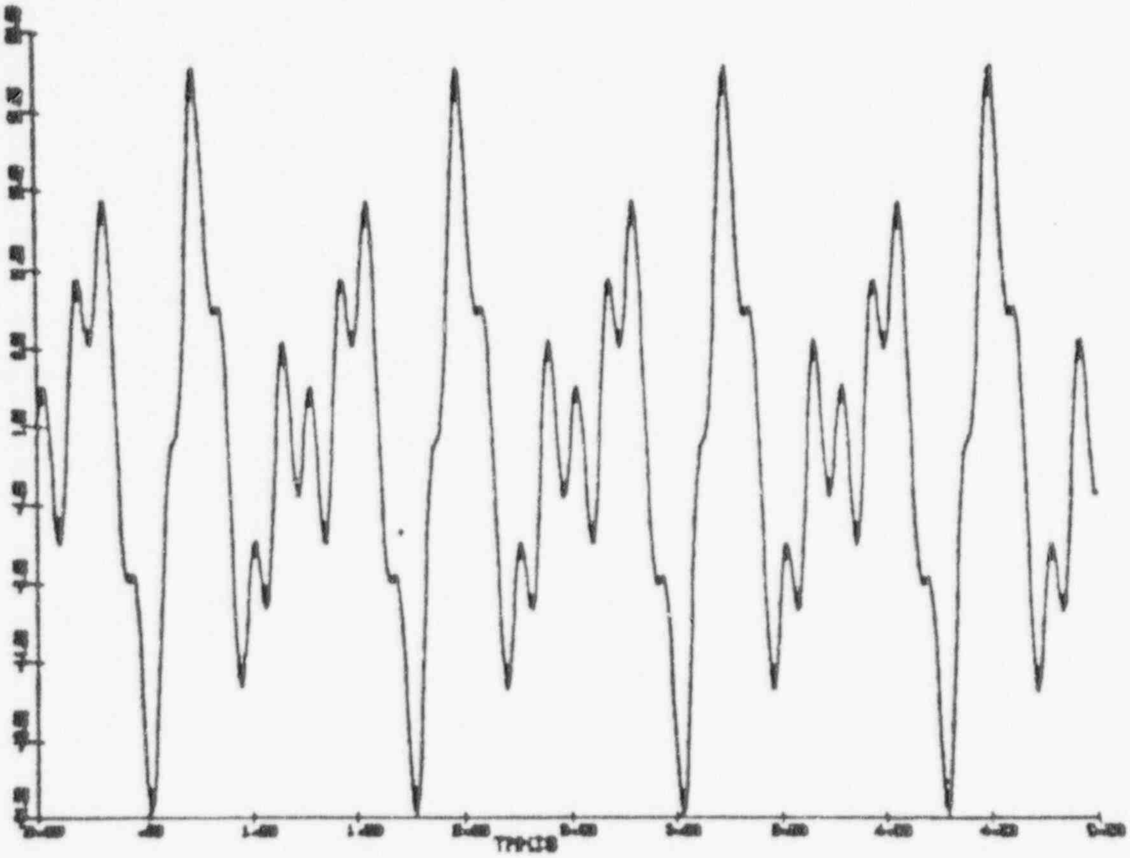
90011253



FOUR SINE TERMS

90011254

(2)



FOUR SINE TERMS

90011255

(5)

COMBINATION

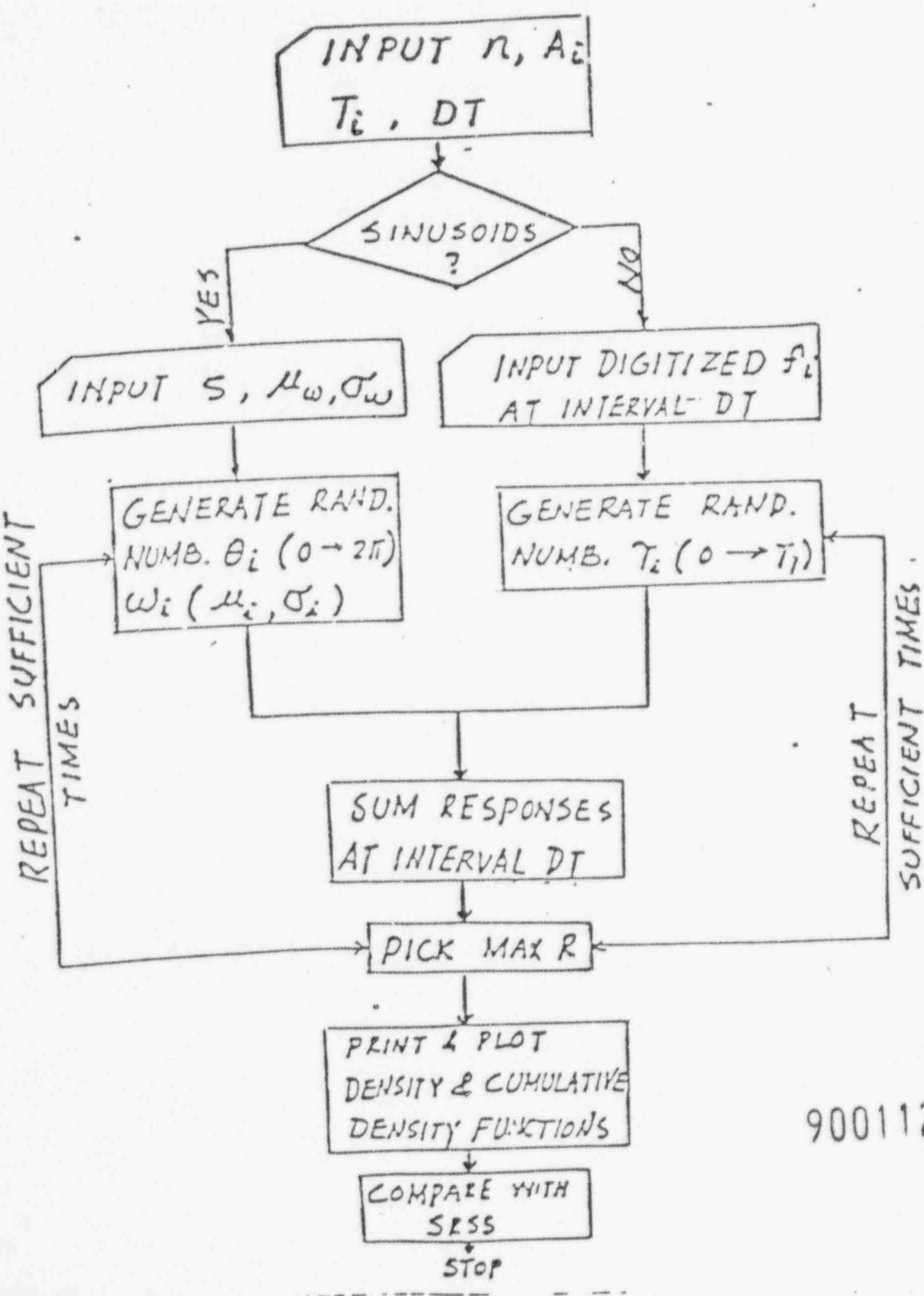
OF

1. REAL RESPONSES
2. ARTIFICIAL RESPONSES IN FREQUENCY DOMAIN
3. ARTIFICIAL RESPONSES IN TIME DOMAIN

$$R(T) = \sum_{I=1}^{N} F_I(T + \tau_I)$$

90011256

MONTE CARLO COMBINATION OF DYNAMIC RESPONSES



90011257

COMBINATION OF REAL RESPONSES

- DIGITIZE RESPONSE CURVES FROM:
  - WESTINGHOUSE REPORT
  - G. E. REPORT
- FOURIER TRANSFORMATION TO INVESTIGATE FREQUENCY CONTENT
- COMBINE RESPONSES WITH TIME LAG (UNIF. DIST.)
- PLOT CDF OF THE COMBINED PEAKS
- LOCATE NON-EXCEEDANCE PROBABILITY OF SRSS

CASE NO.	RESPONSES	SOURCE	P(R ≤ SRSS)	REMARKS
1	LOCA NO. 22 SSE NO. 22	W	.84	SKEWED + " 0
2	LOCA NO. 23 SSE NO. 23	W	.72	" + " +
3	LOCA NO. 24 SSE NO. 24	W	.98	" + " -
4	LOCA NO. 25 SSE NO. 25	W	.48	" - " -
5.	LOCA NO. 26 SSE NO. 26	W	.89	" + " -
6.	LOCA NO. 28 SSE NO. 28	W	.68	" + " 0
7.	LOCA NO. 29 SSE No. 29	W	.81	" + SPARSE " 0
8.	LOCA NO. 30 SSE NO. 30	W	.98	" - " + SPARSE
9.	LOCA NO. 31 SSE NO. 31	W	.98	" - " + SPARSE
10.	FIG. B-36 OBE FIG. B-37 SRV	G.E.	.71	SKEWED 0 0

W - WESTINGHOUSE
G.E. - GENERAL ELECTRIC

90011259

CONCLUSION:

1. SPARSITY OF PEAKS:

   P (R < SRSS) INCREASES WITH SPARSITY OF PEAKS.

2. SKEWNESS OF MEAN RESPONSE

   P (R < SRSS) INCREASES WITH OPPOSITE SKEWNESS BUT DECREASES WITH SAME SKEWNESS.

3. $0.48 \leq P\ (R \leq STRSS) \leq 0.98$

   FROM TEN CASES OF

90011260

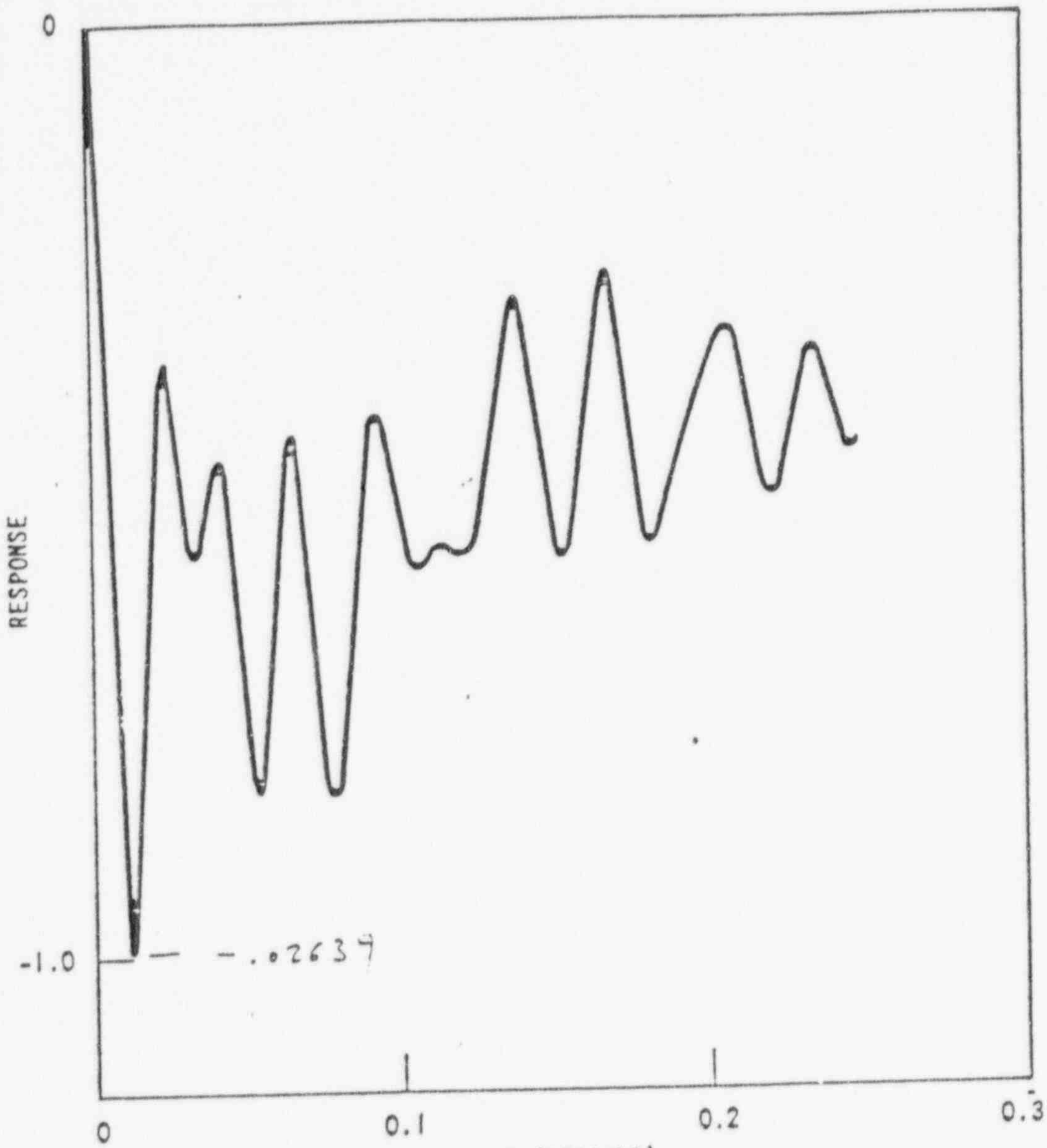


Figure B-29. LOCA Response Number 25
(Original)

90011261

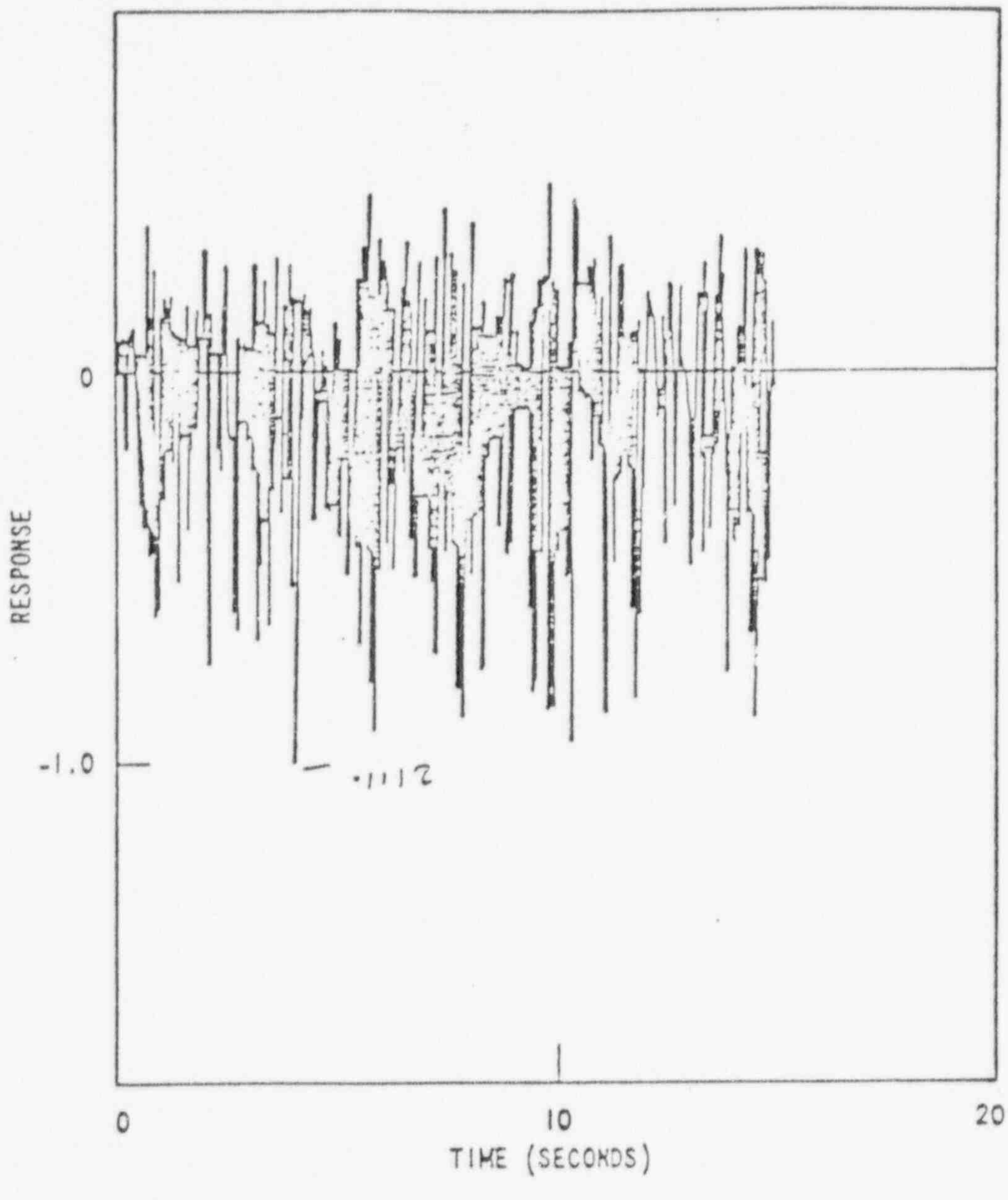
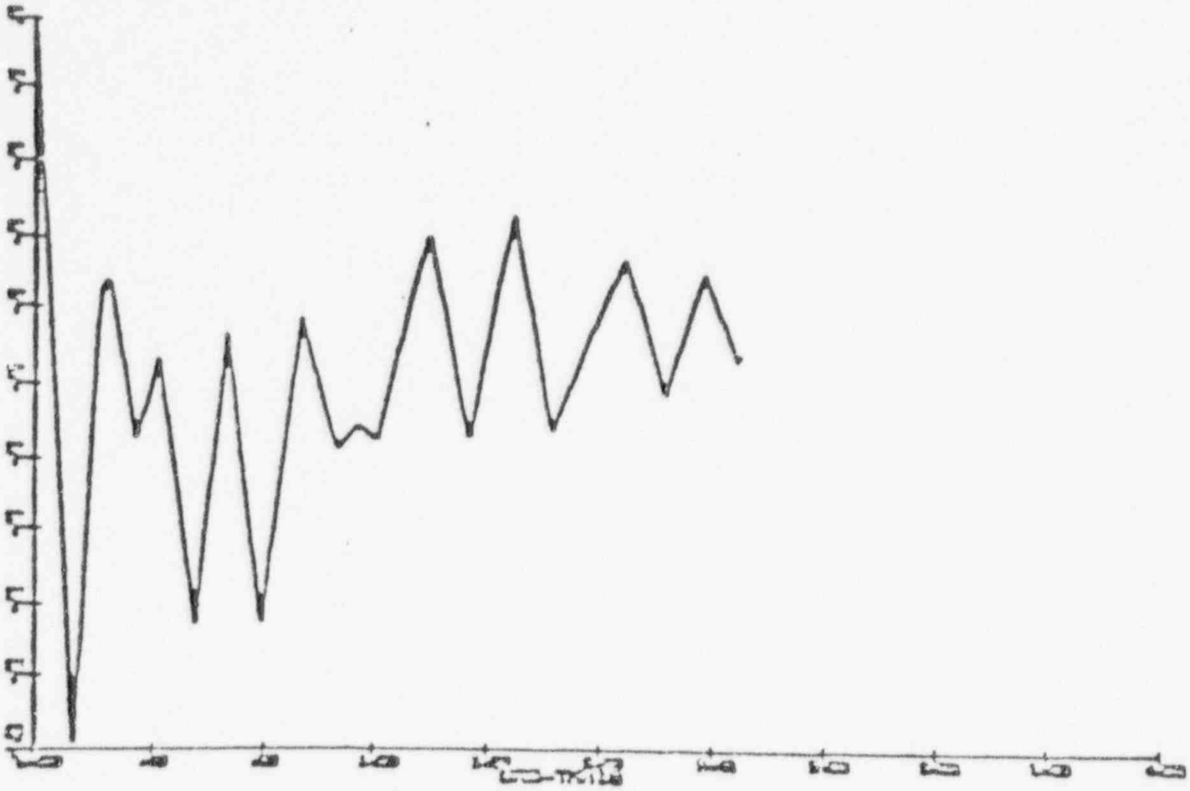


Figure B-30. SSE Response Number 25
(original)

90011262

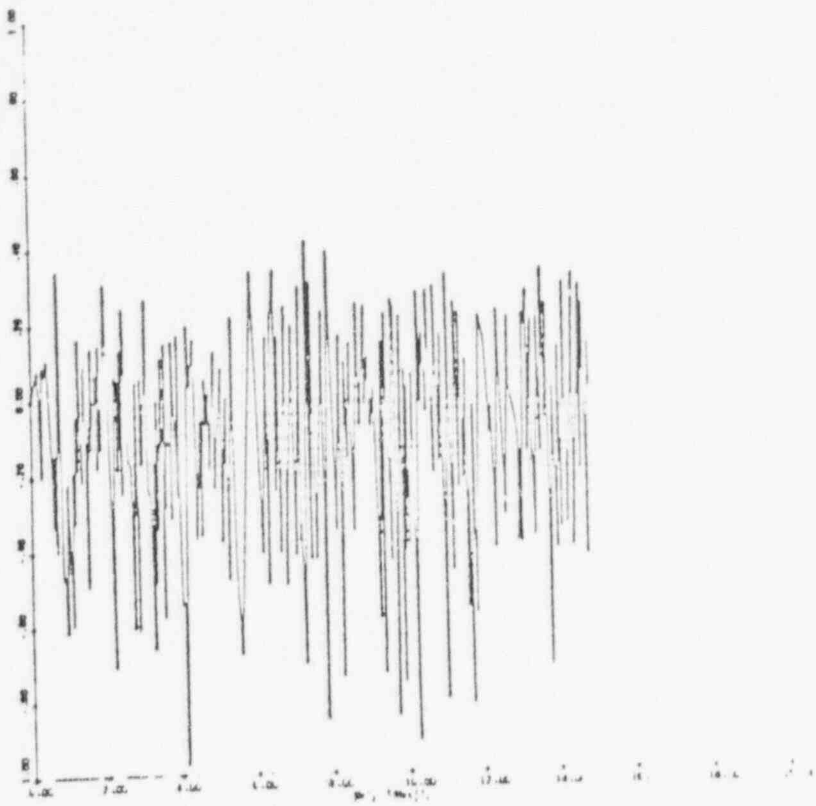


(Digitized)

90011263

FOURIER SPECTRUM

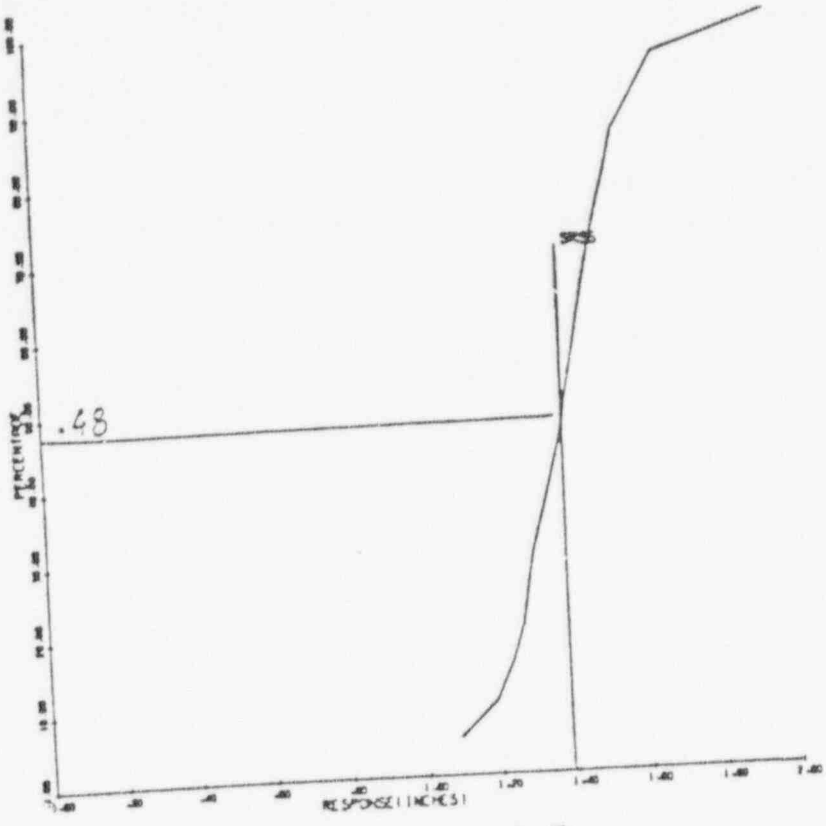
G-55



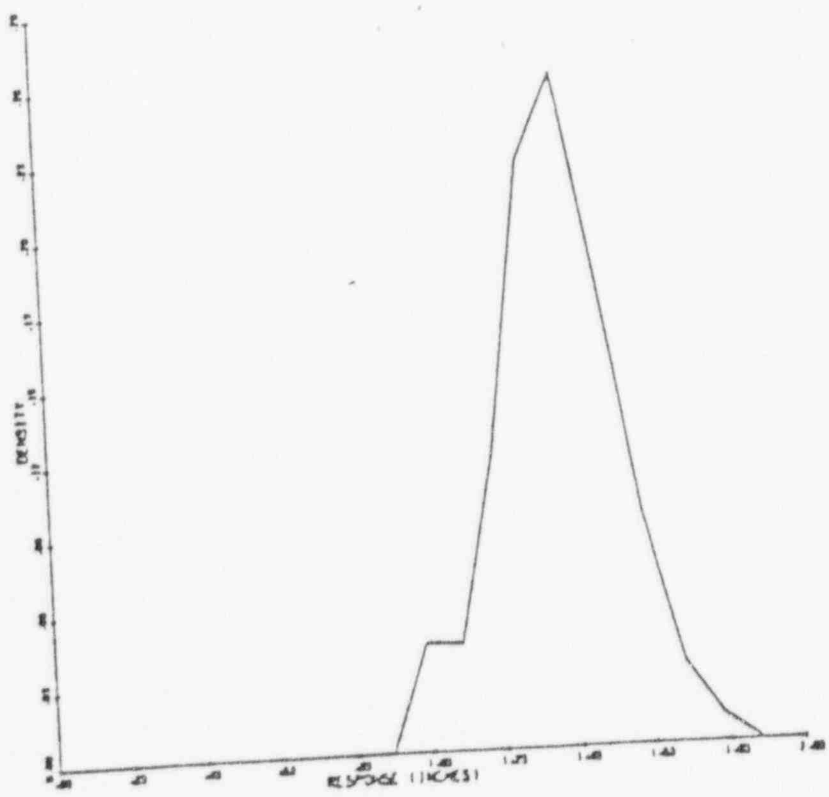
(Digitized)

90011264

FOURIER SPECTRUM



CDF



DENSITY

90011265

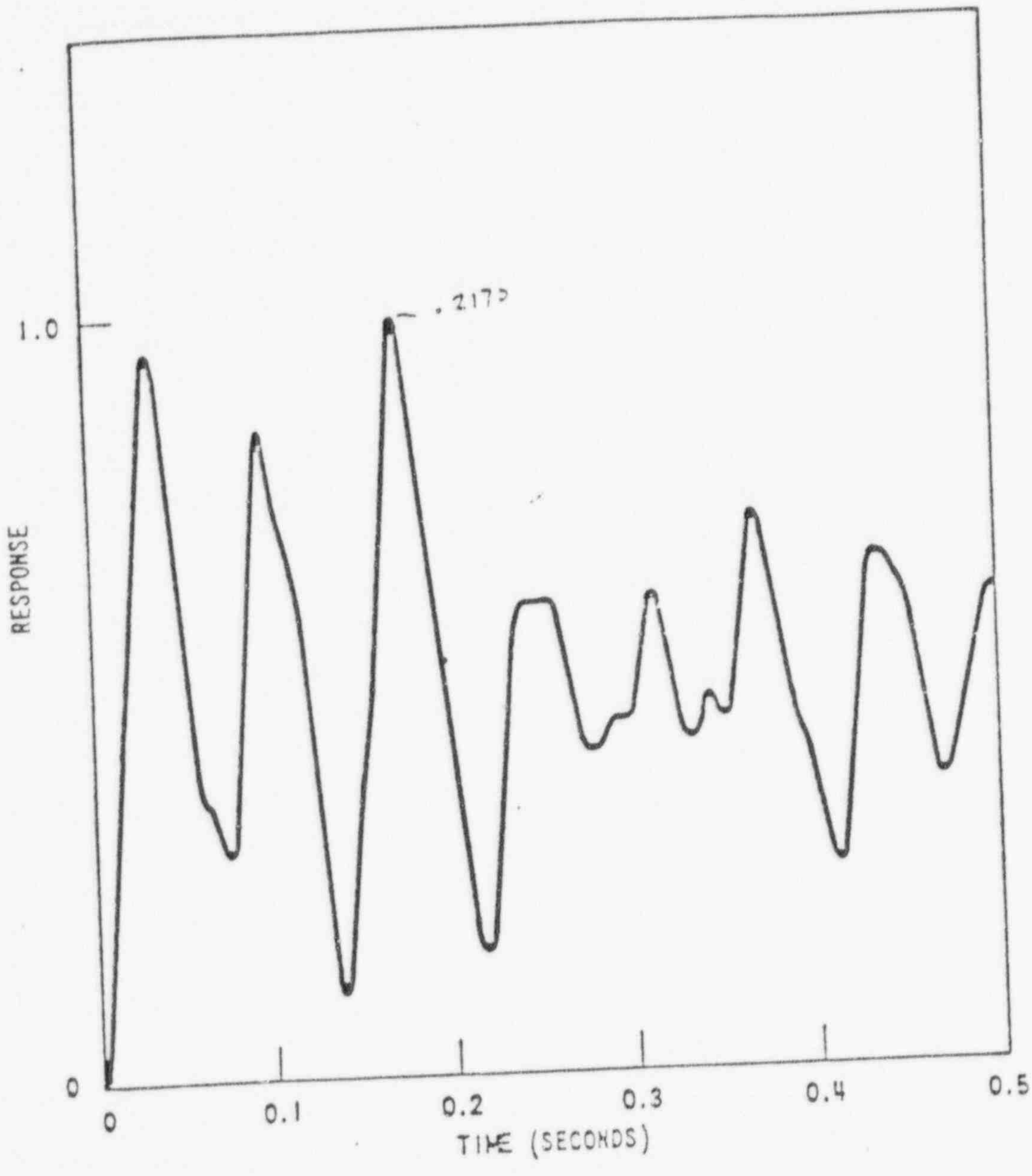


Figure B-23. LOCA Response Number 22
(original)

90011266

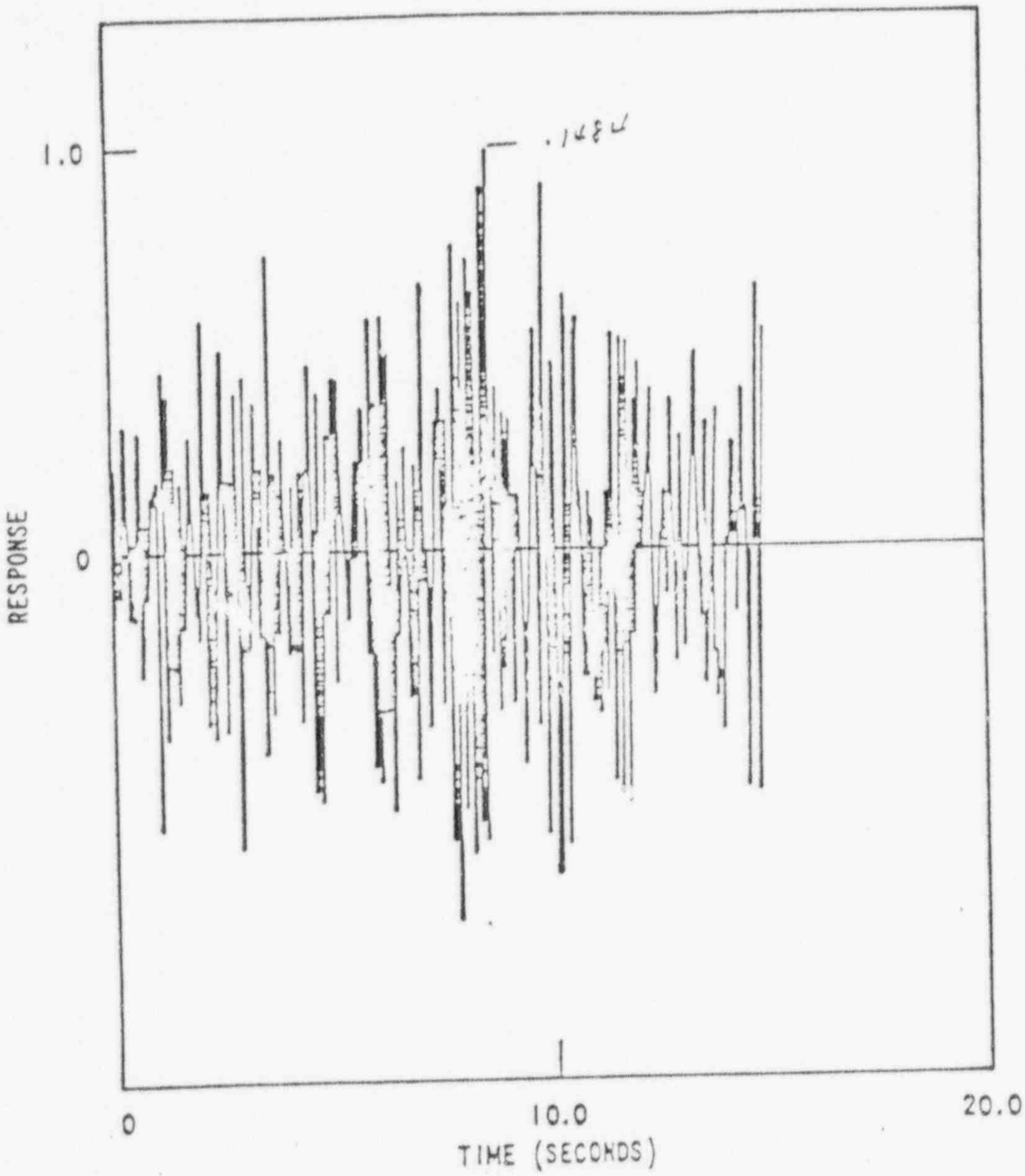
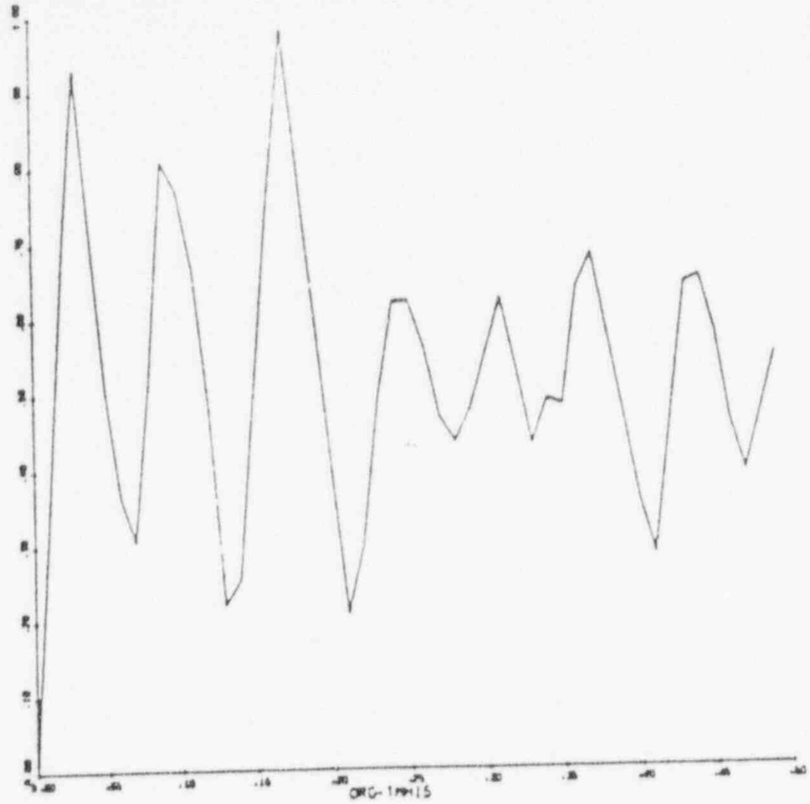


Figure B-24. SSE Response Number 22

(original)

9001†267

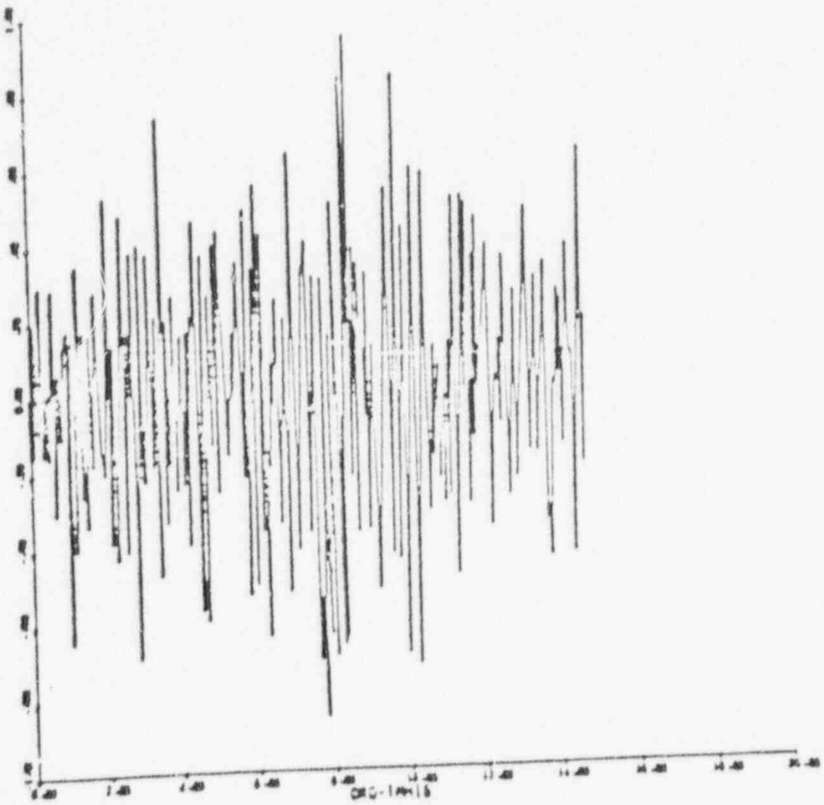


(Digitized) B23

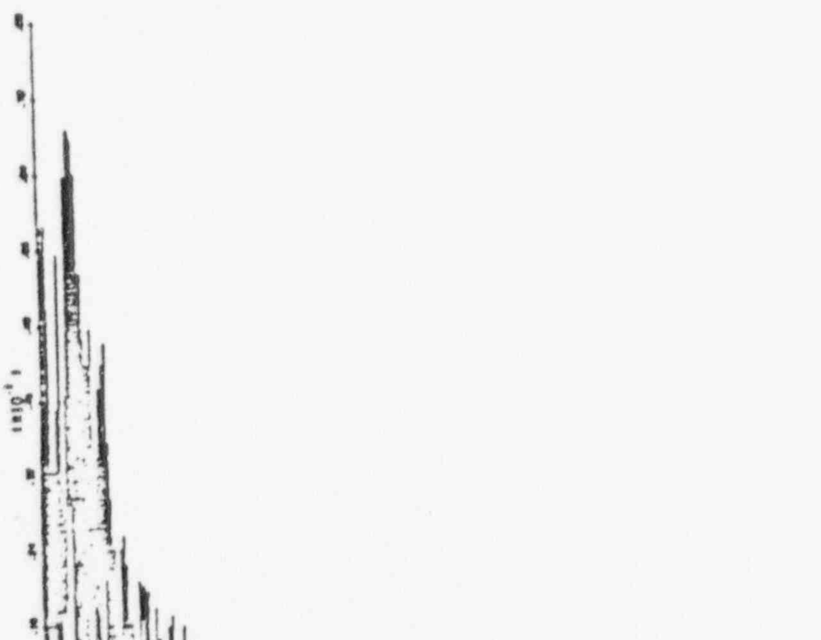
FOURIER SPECTRUM

G-55

14



(Digitized)   B24



FOURIER SPECTRUM

G-56   90011269

COMBINATION OF ARTIFICIAL RESPONSES IN FREQUENCE DOMAIN

PURPOSE

- TO GENERATE ARTIFICIAL RESPONSES WITH SPECIFIC FOURIER SPECTRA:

  AMPLITUDE OF PREDOMINENT FREQUENCIES OF PREDOMINENT AMPLITUDES

  FREQUENCY BANDWIDTH

  RELATIVE POSITION OF PREDOMINENT FREQUENCIES

- TO COMBINE ARTIFICIAL RESPONSES WITH RANDOM TIME LAG (UNIF. DISTRIBUTION)
- TO COMPUTE THE CDF OF THE COMBINED PEAKS
- TO COMPARE WITH THE SRSS VALUE
- TO OBTAIN NON-EXCEEDANCE PROBABILITY OF SRSS

DERIVATION OF FORMULAS

$$R(\tau) = \sum_{K=1}^{N} (A_K \cos(K w_0 T) + B \sin(K w_0 T)$$

$$= \sum_{K=L}^{N} C_K \cos(K w_0 T - \phi_K)$$

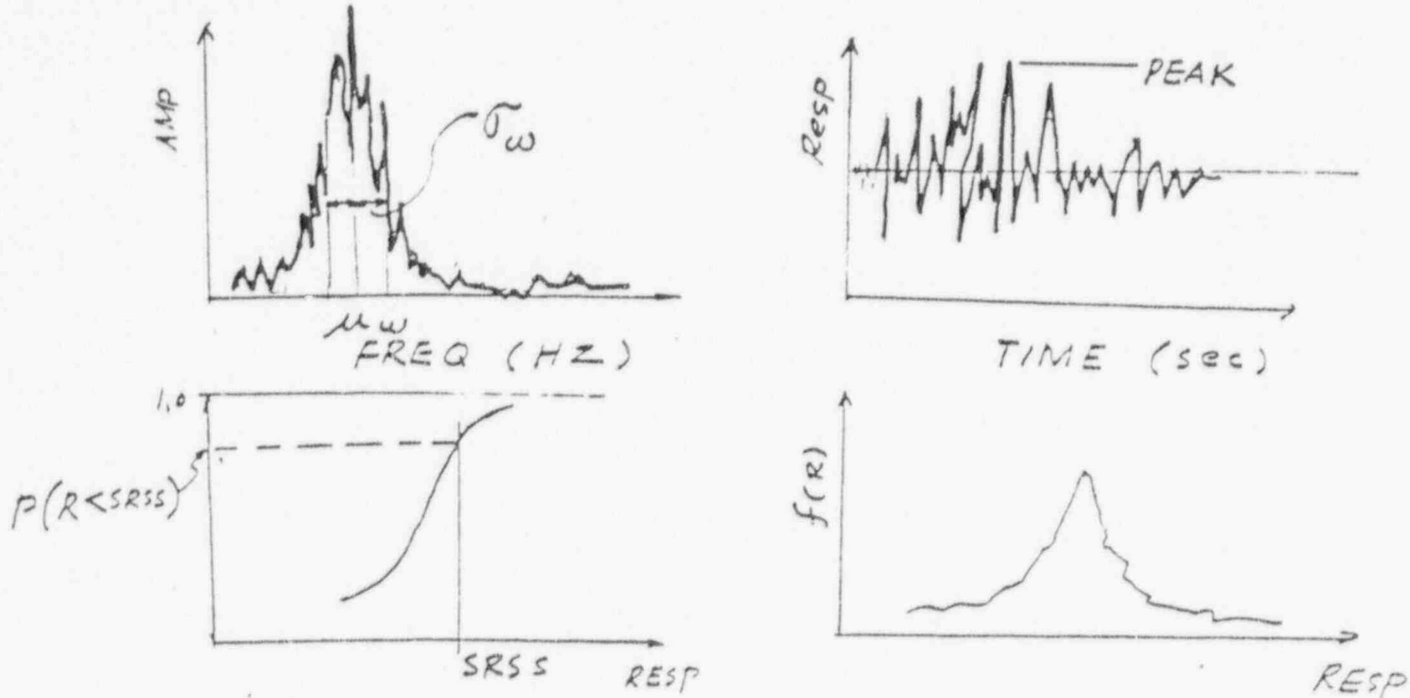
TO GENERATE ARTIFICIAL $R(\tau)$:

- $C_K = N_K \cdot E^{-(K w_0 - \mu_W)/2 \tau_W^2}$

  WHERE N_K IS A RANDOM NUMBER BETWEEN 0 AND $C_{K,MAX}$

- μ_W -- THE PREDOMINANT FREQUENCY
- σ_W -- FREQUENCY BAND VARIANCE
- ϕ_K -- RANDOM PHASE ANGLE

RESULTS $R(t) = R_1(t) + R_2(t+\tau)$, wher τ is random time la



CUMULATIVE DENSITY FUCTION

DENSITY FUNCTION

	CASE NO.	RESP. NO.	MAX. FOUR AMP	MEAN FREQ. (μ_W)	FREQ. DEV. (σ_W)	DURAT. (SEC)	P (R < SRSS)	REMARK
	1	1	10.	8.0	1.0	10.	.88	
		2	10.	8.0	1.0	10.		
A	2	3	10.	8.0	3.0	10.	.81	
		4	10.	8.0	3.0	10.		
	3	5	10.	8.0	5.0	10.	.75	
		6	10.	8.0	5.0	10.		
	4	7	10.	6.0	1.0	10.	.91	
		8	10.	6.0	1.0	10.		
	5	9	10.	6.0	3.0	10.	.78	
		10	10.	6.0	3.0	10.		

	Case No.	Resp No.	Max. Four. Amp.	Mean Freq. (μ_ω)	Freq. Dev. (σ_ω)	Durat. (sec)	P(R<SRSS)	Remark
	6	11	10	6	5	10	.78	
		12	10	6	5	10		
	7	13	10	8	1	10	.74	
		14	10	8	1	5		
B	8	15	10	8	3	10	.62	
		16	10	8	3	5		
	9	17	10	8	5	10	.51	
		18	10	8	5	5		
	10	19	10	6	1	10	.91	
		20	10	6	1	5		
	11	21	10	6	3	10	.68	
		22	10	6	3	5		
	12	23	10	6	5	10	.57	
		24	10	6	5	5		
	13	25	10	6	1	10	.64	
		26	10	12	1	5		
	14	27	10	6	3	10	.47	
		28	10	12	3	5		
C	15	29	10	6	5	10	.58	
		30	10	12	5	5		
	16	31	10	4	1	10	.46	
		32	10	12	1	5		
	17	33	10	4	3	10	.32	
		34	10	12	3	5		

Case No.	Resp No.	Max. Four. Amp.	Mean Freq. (μ_ω)	Freq. Dev. (σ_ω)	Durat. (sec)	P(R<SRSS)	Remark
18	35	10	4	5	10	.51	
	36	10	12	5	5		
19	37	10	8	0.1	10	.56	
	38	10	8	0.1	10		

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CONCLUSIONS:

1. P(R<SRSS) DECREASES WITH INCREASING FREQUENCY BANDWIDTH WHEN PREDOMINENT FREQUENCIES ARE SAME.
2. P(R<SRSS) INCREASES SOMEWHAT WITH SMALLER PREDOMINENT FREQUENCIES.
3. P(R<SRSS)DECREASES WHEN PREDOMINENT FREQUENCY DIFFERENCES INCREASES.
4. P(R<SRSS) DECREASES WHEN THE SECOND RESPONSE DECREASES IN DURATION.
5. WHEN BOTH FREQUENCY AND DURATION DIFFERENCES OCCUR, P(R<SRSS) MAY REACH .30 TO .40.

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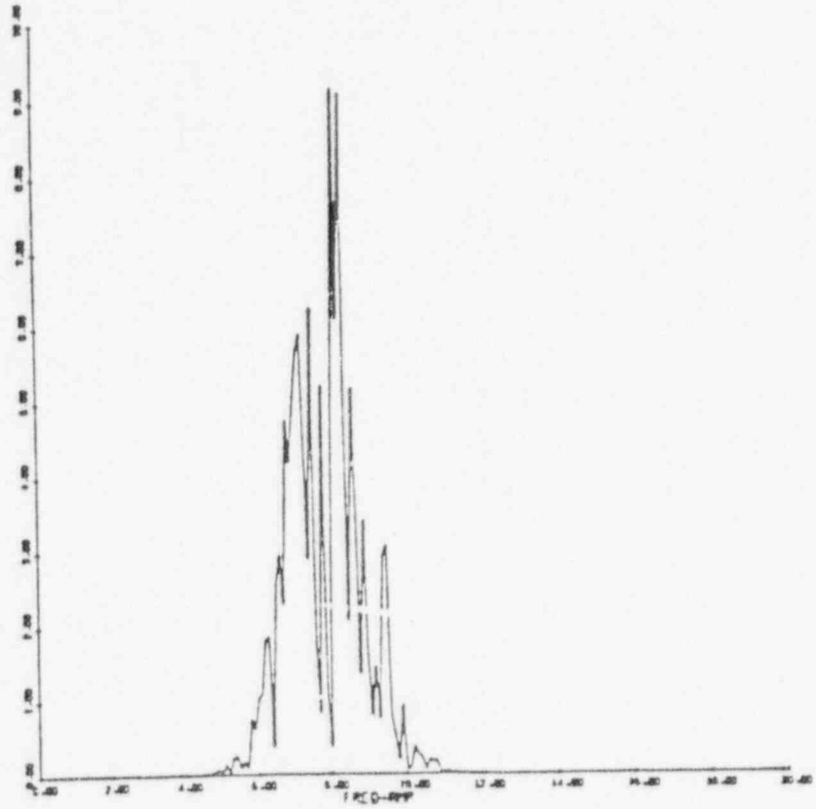
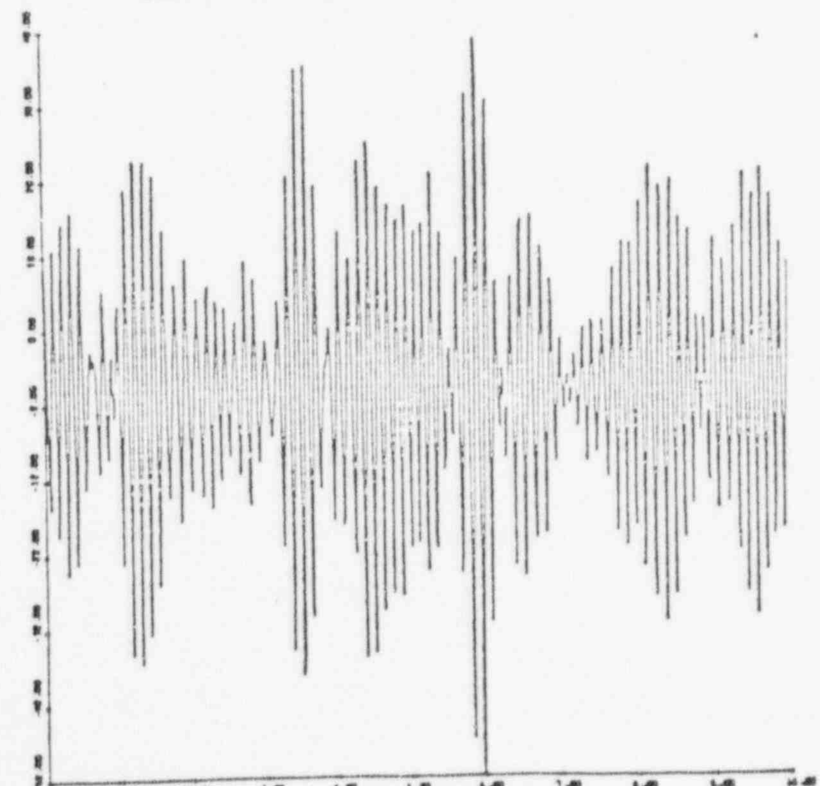
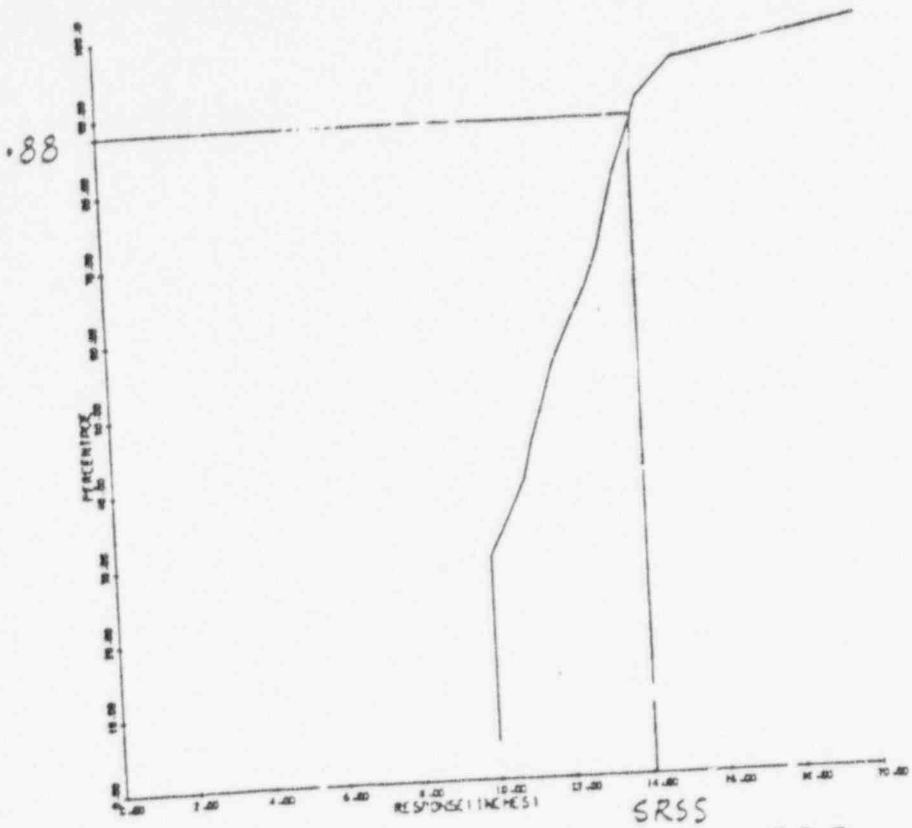


CASE A-1 FREQ:8.8 SIGMA:1.1 DUR:10.10.

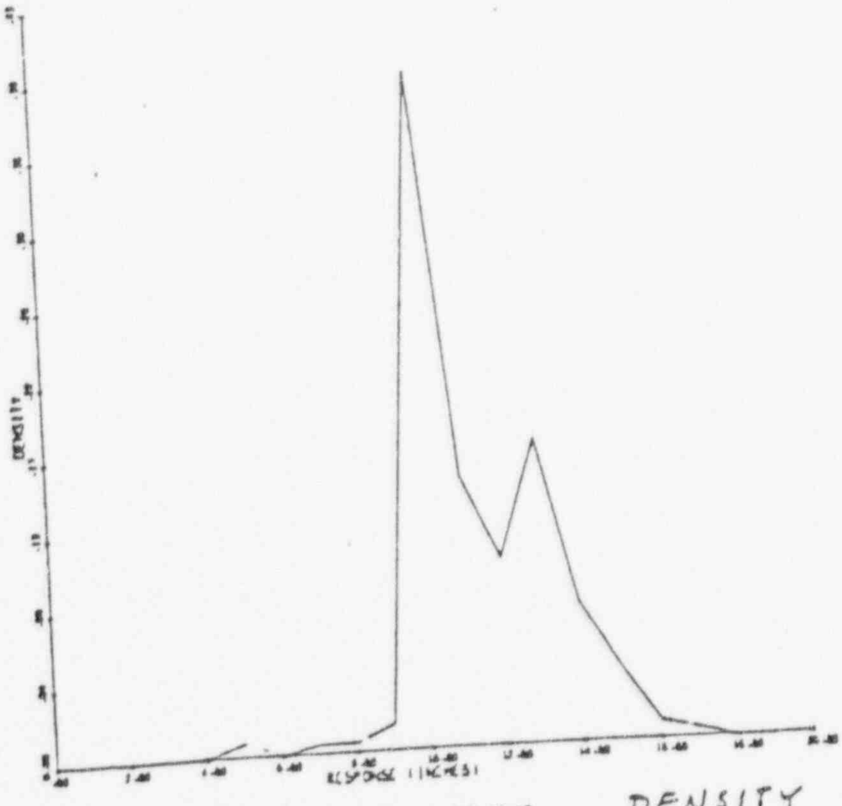


CASE A-1 FREQ:8.8 SIGMA:1.1 DUR:10.10.

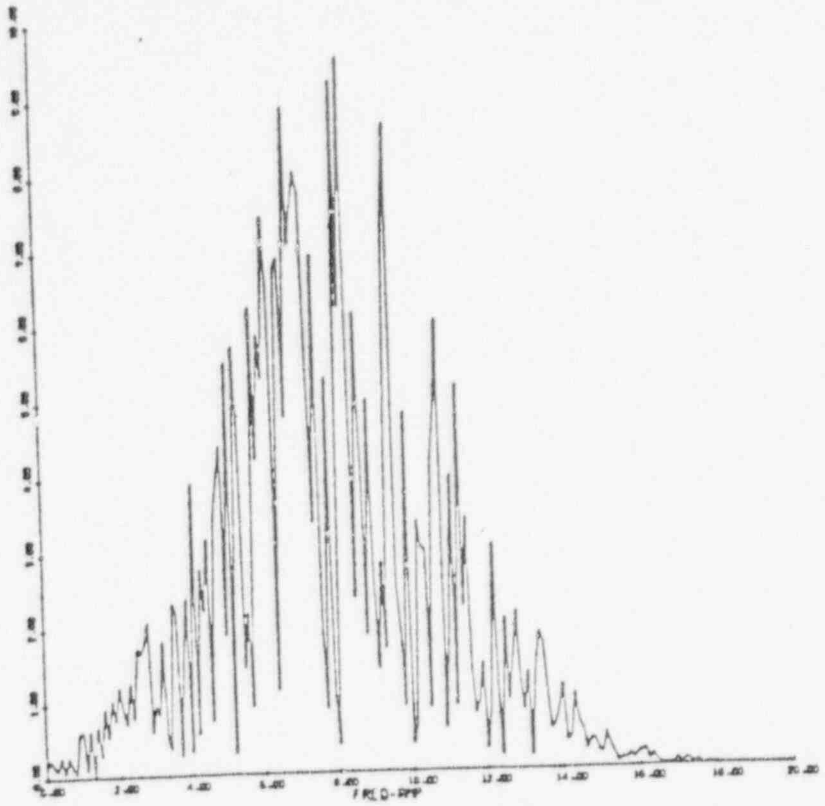
90011276



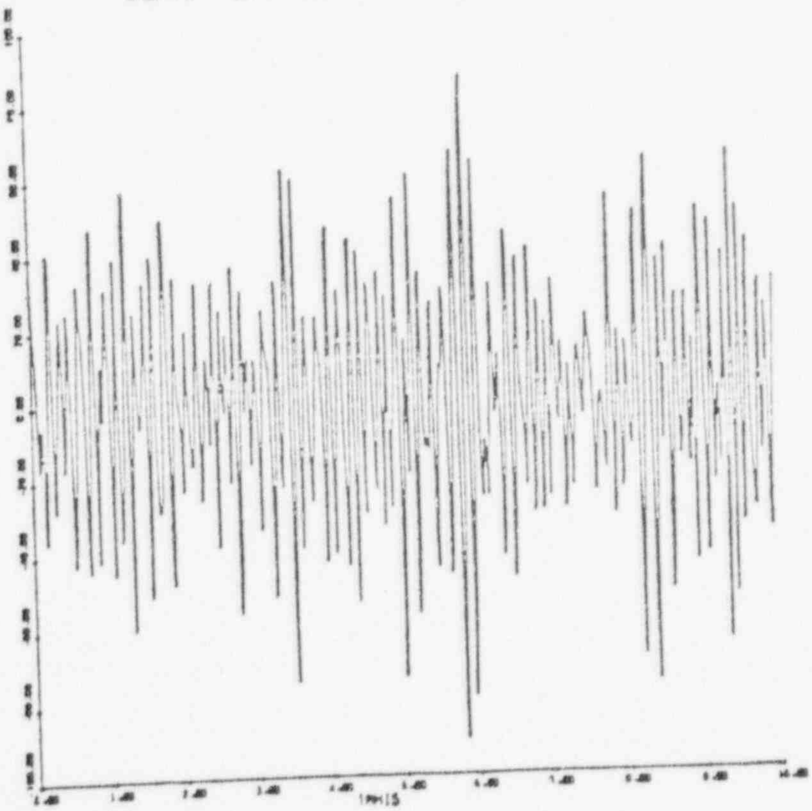
CASE A-1 FREQ:8.8 SIGMA:1.1 DUR:10.10.



CASE A-1 FREQ:8.8 SIGMA:1.1 DUR:10.10.

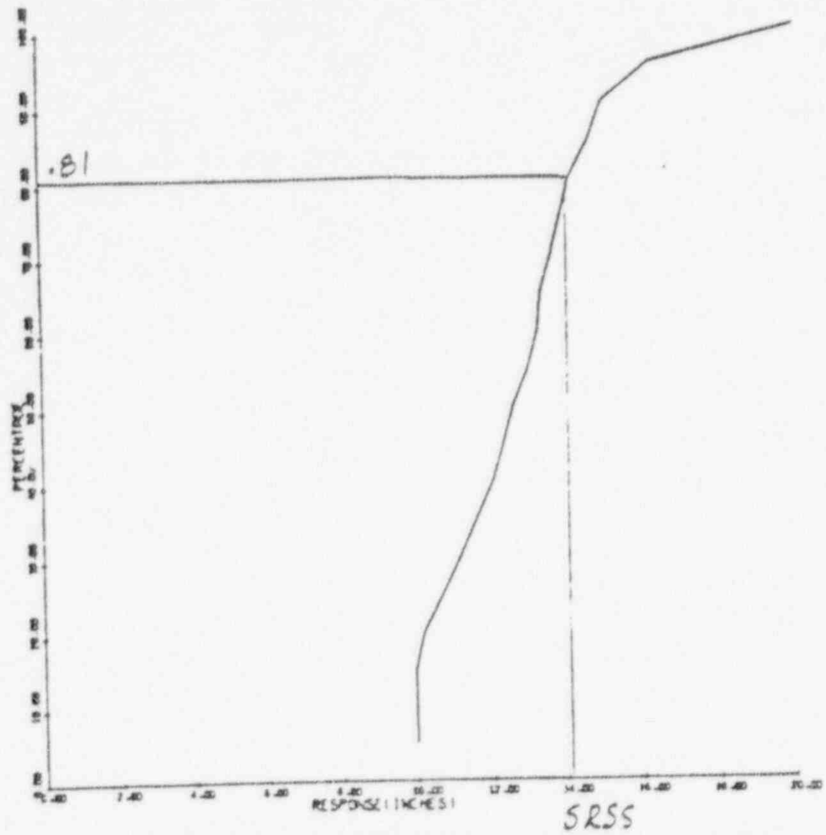


CASE A-2 FREQ:8.8 SIGMA:3.3 DUR:10.10.



CASE A-2 FREQ:8.8 SIGMA:3.3 DUR:10.10.

90011278



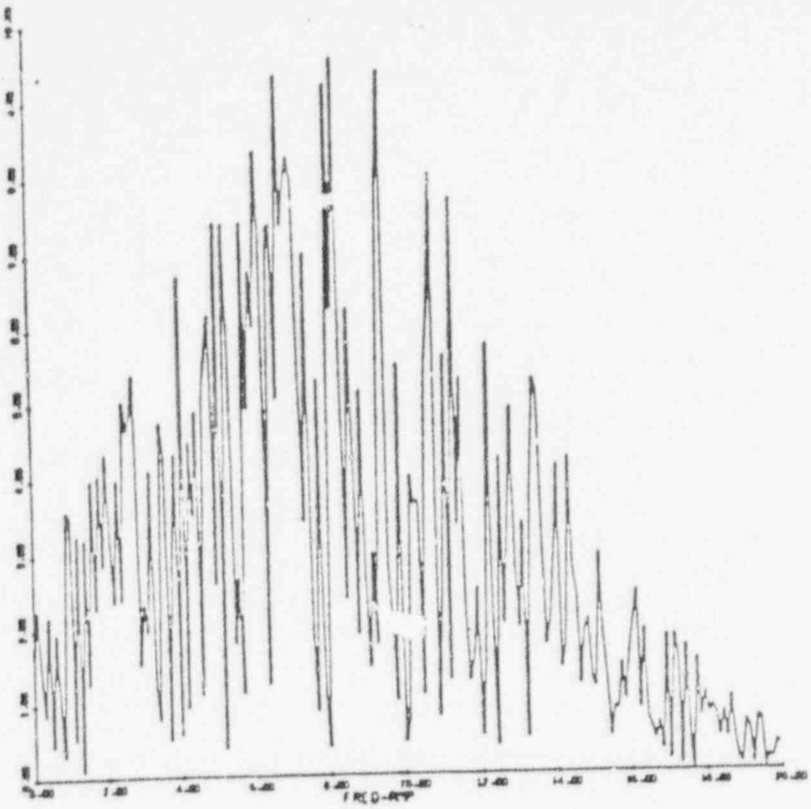
CASE A-2 FREQ:8.8 SIGMA:3.3 DUR:10.10.

CDF

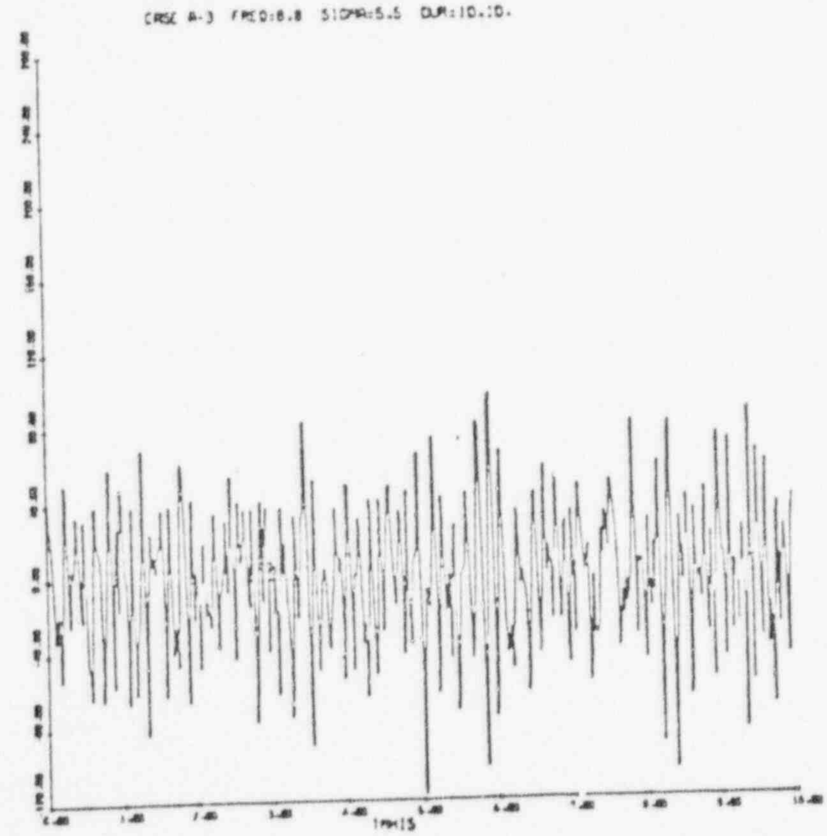
CASE A-2 FREQ:8.8 SIGMA:3.3 DUR:10.10.

Density

90011279

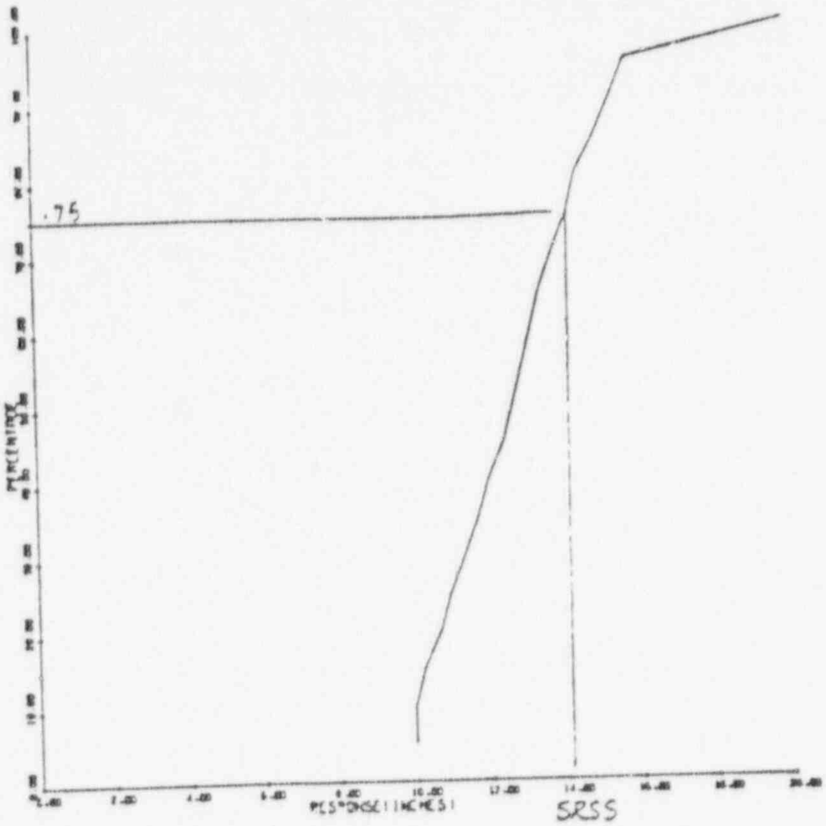


CASE A-3 FREQ:8.8 SIGMA:5.5 DUR:10.10.

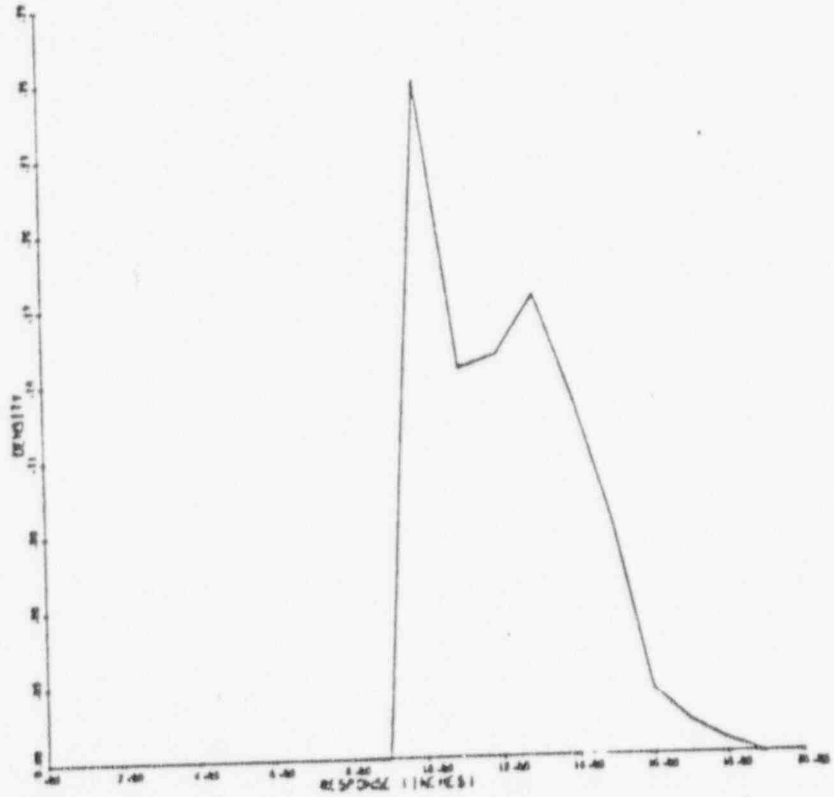


CASE A-3 FREQ:8.8 SIGMA:5.5 DUR:10.10.

90011280

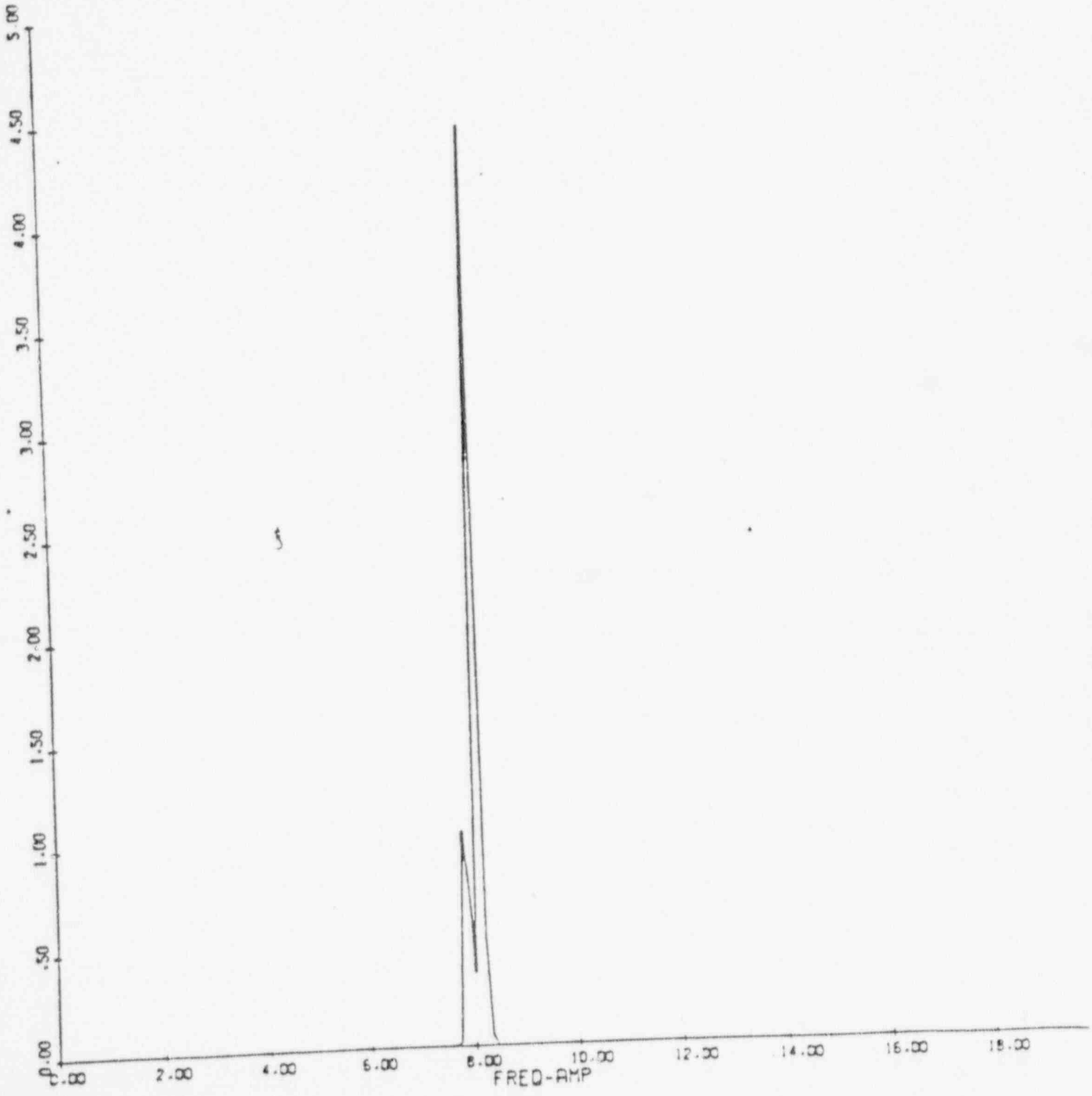


CASE A-3 FREQ:8.8 SIGMA:5.5 DUR:10.10. CDF



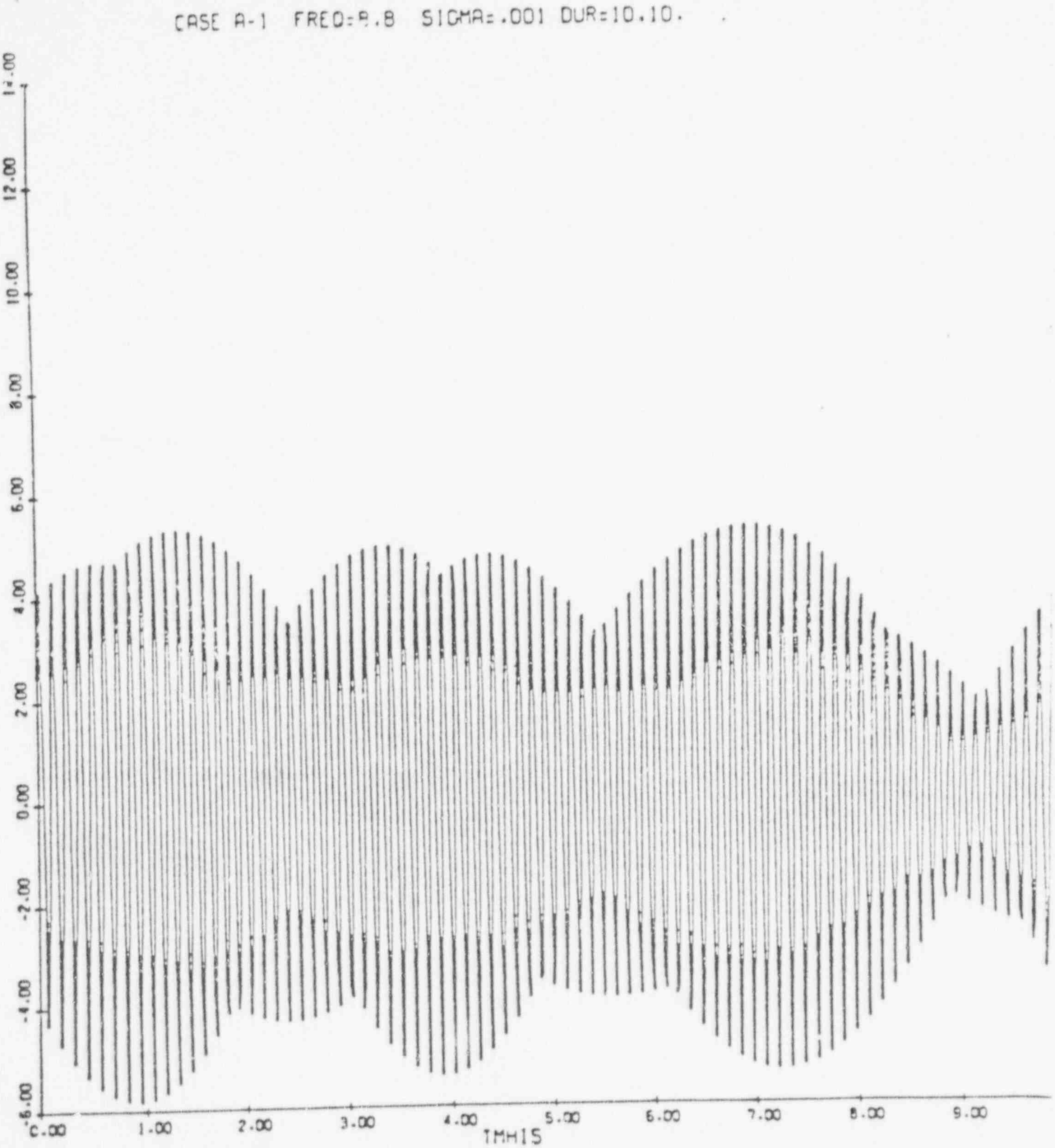
CASE A-3 FREQ:8.8 SIGMA:5.5 DUR:10.10. Density

90011281



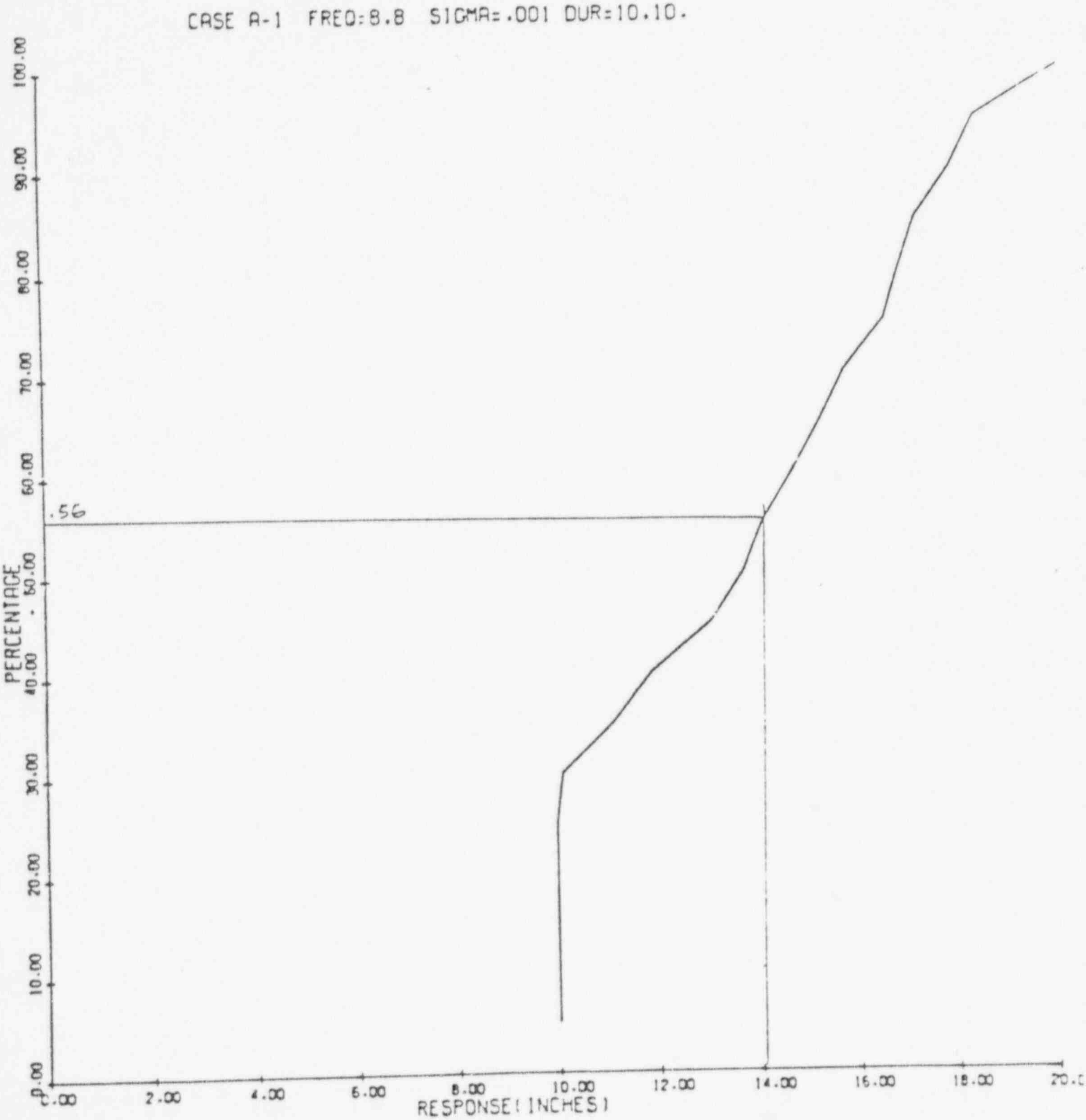
CASE A-1 FREQ=8.8 SIGMA= .1 DUR=10.10.

90011282

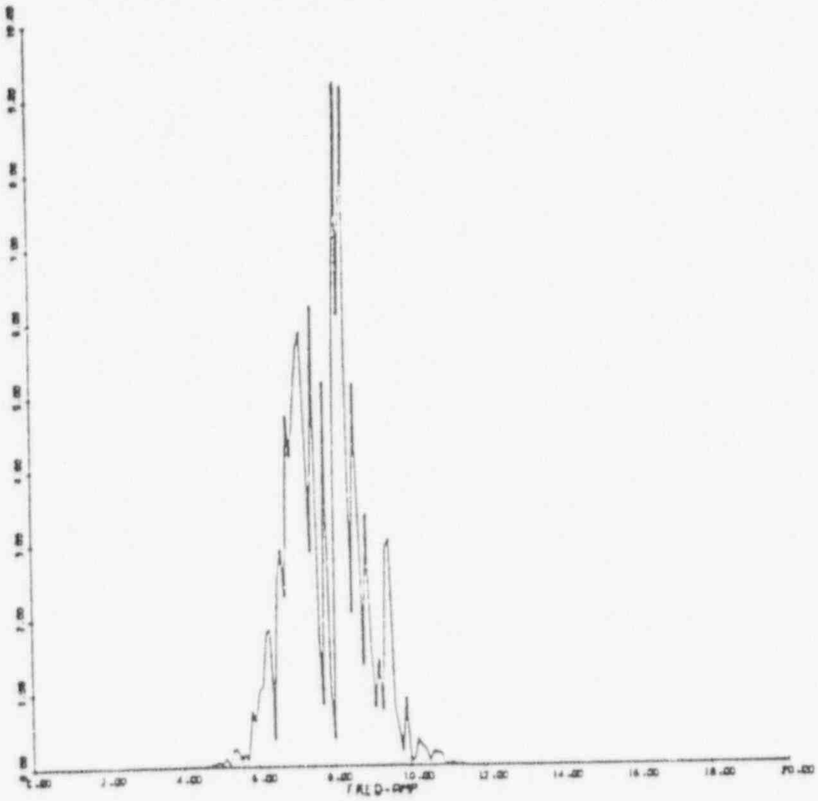


CASE A-1 FREQ=8.8 SIGMA= 4 DUR=10.10.

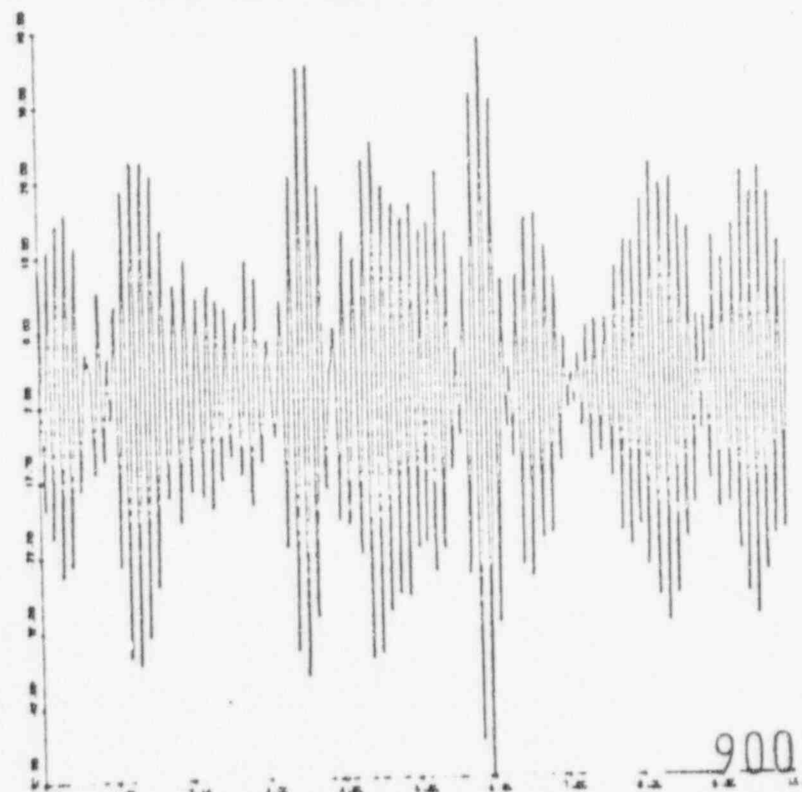
90011283



CASE A-1 FREQ:8.8 SIGMA=.001 DUR=10.10. CDF



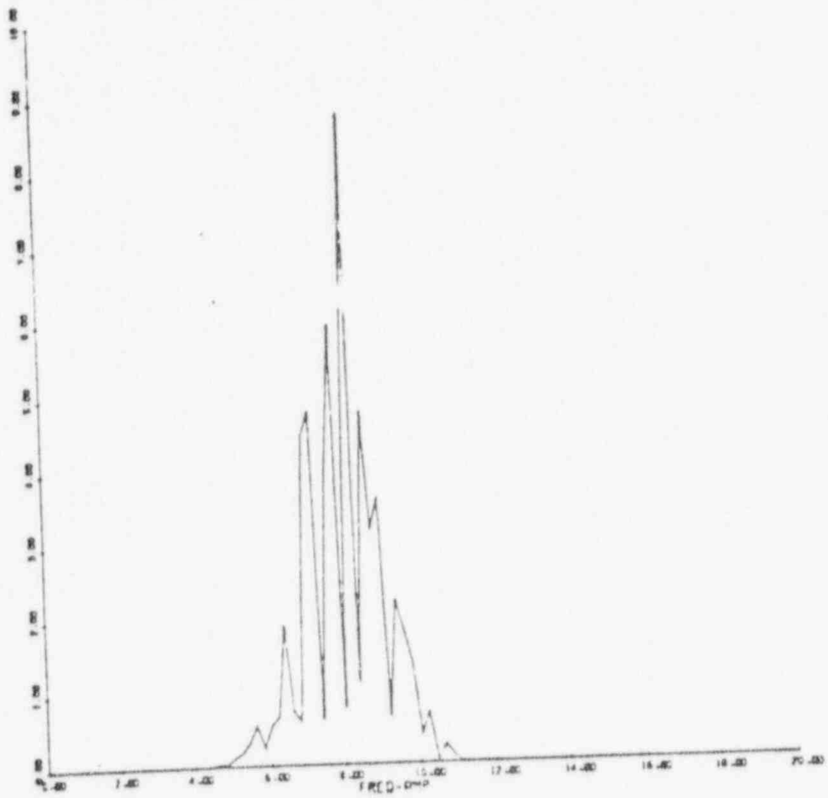
CASE B-1 FREQ:8.8 SIGMA:1.1 DUR:10.5.



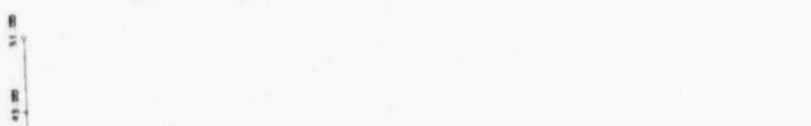
B-1 FREQ 8.8 SIGMA:1.1 DUR:10.5.

9001128 5

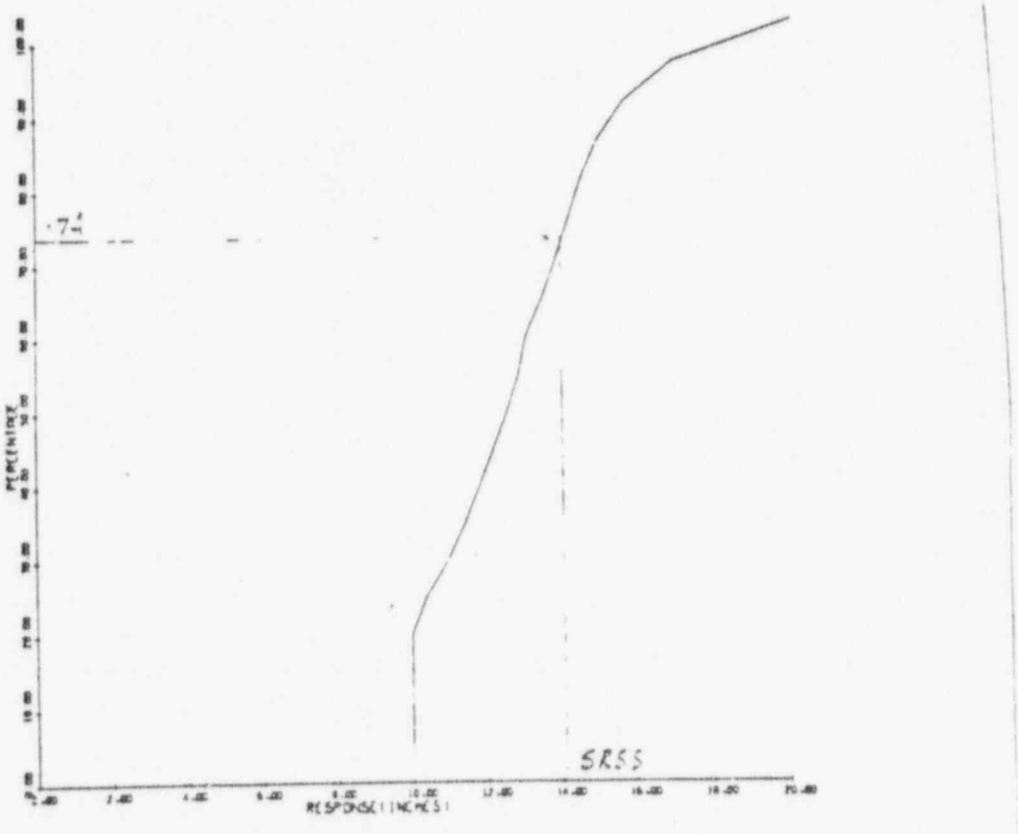
CASE B-1 FREQ:8.8 SIGMA:1.1 DUR:10.5.



CASE B-1 FREQ:8.8 SIGMA:1.1 DUR:10.5.

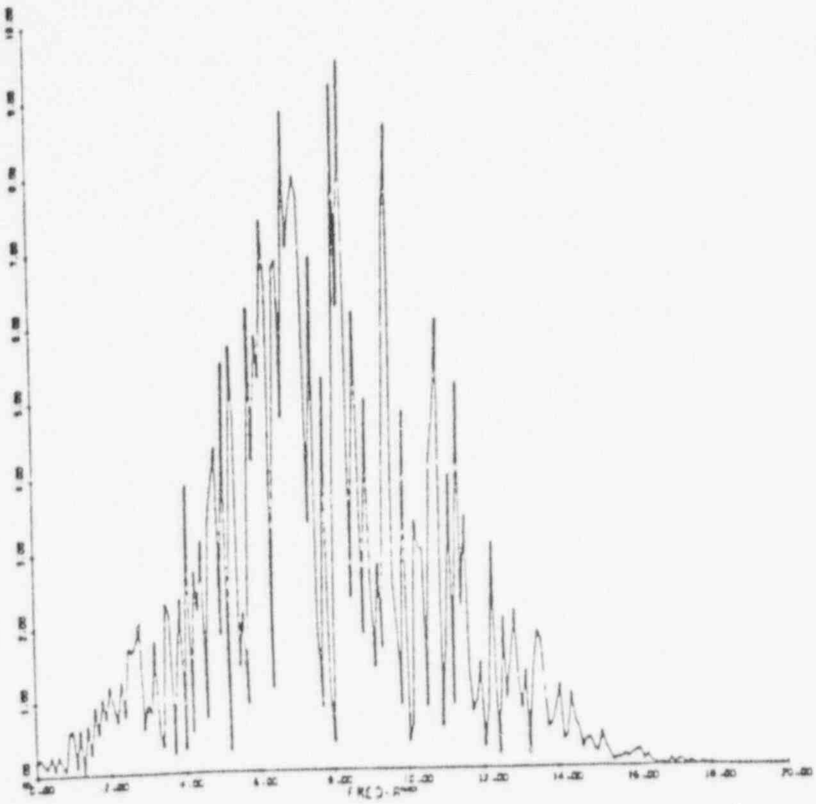


90011286

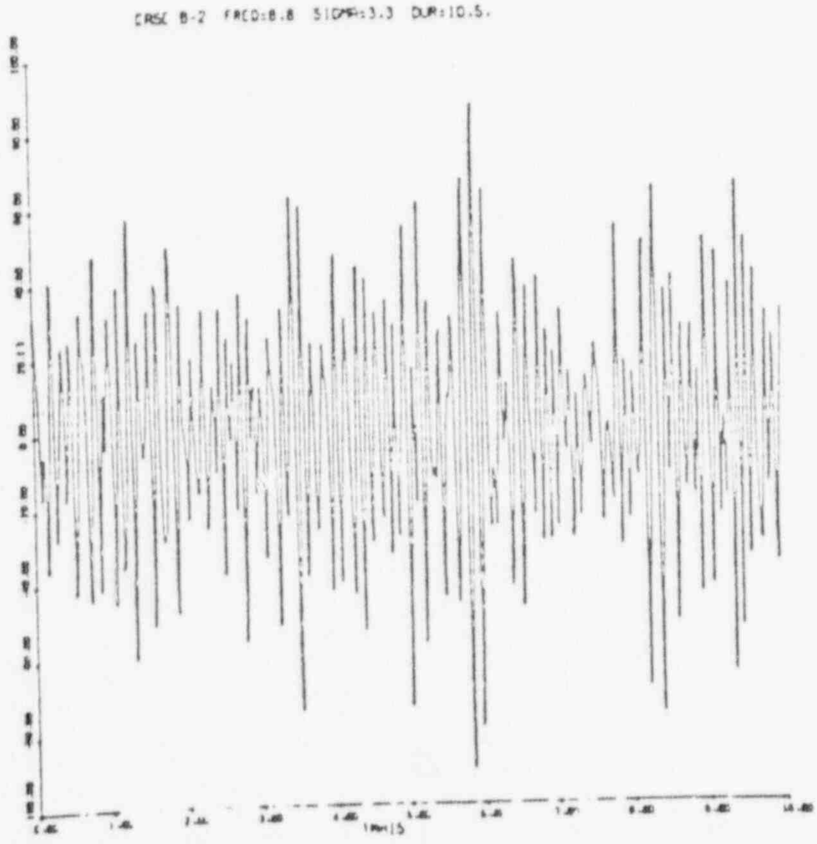


CASE B-1 FREQ:8.8 SIGMA:1.1 DUR:10.5. CPF

90011287

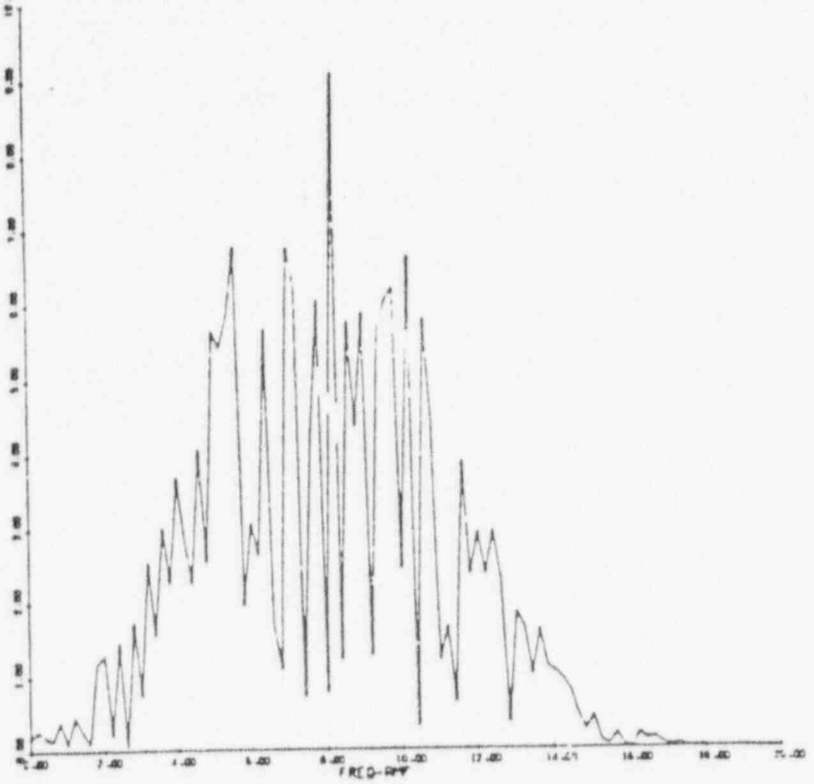


CASE B-2 FREQ:8.8 SIGMA:3.3 DUR:10.5.

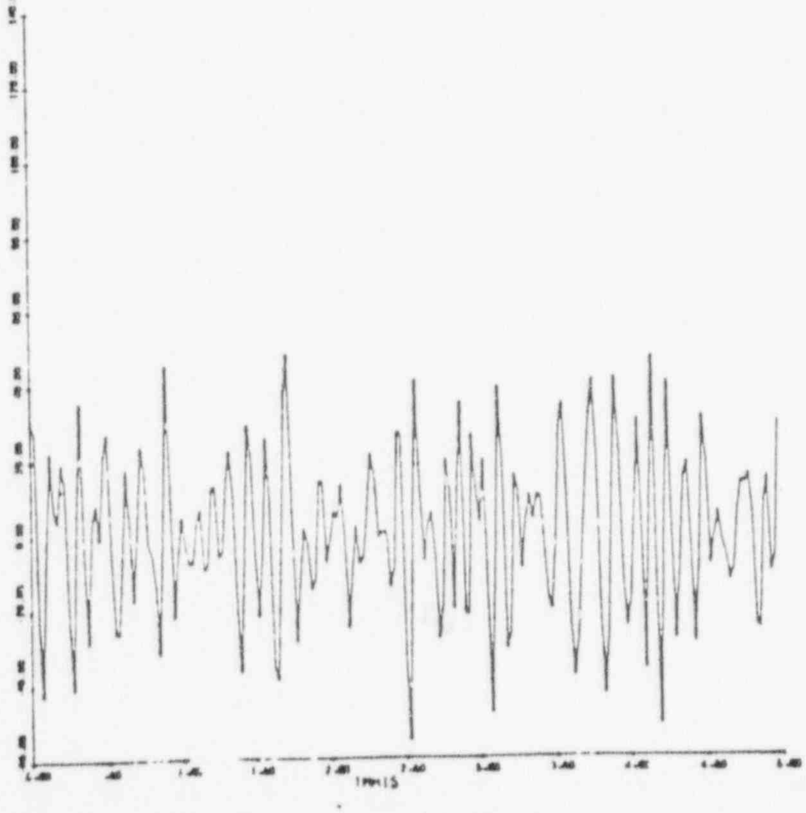


CASE B-2 FREQ:8.8 SIGMA:3.3 DUR:10.5.

90011288

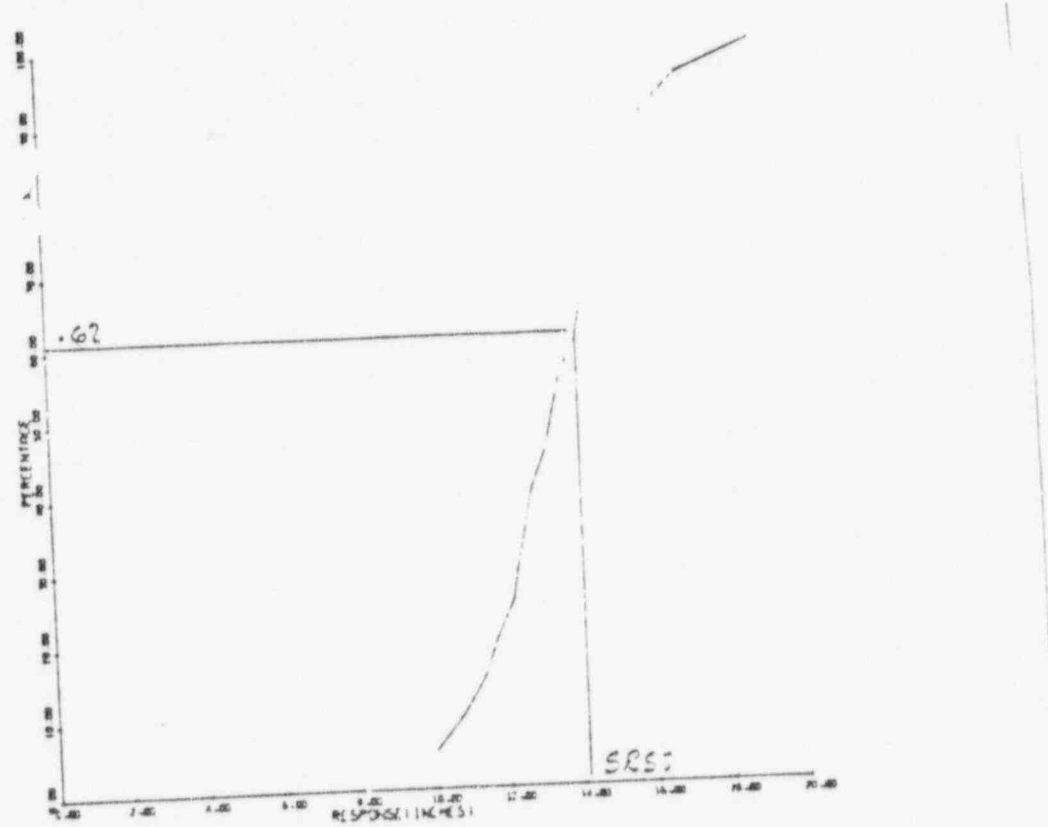


CASE B-2 FREQ:8.8 SIGMA:3.3 DUR:10.5.



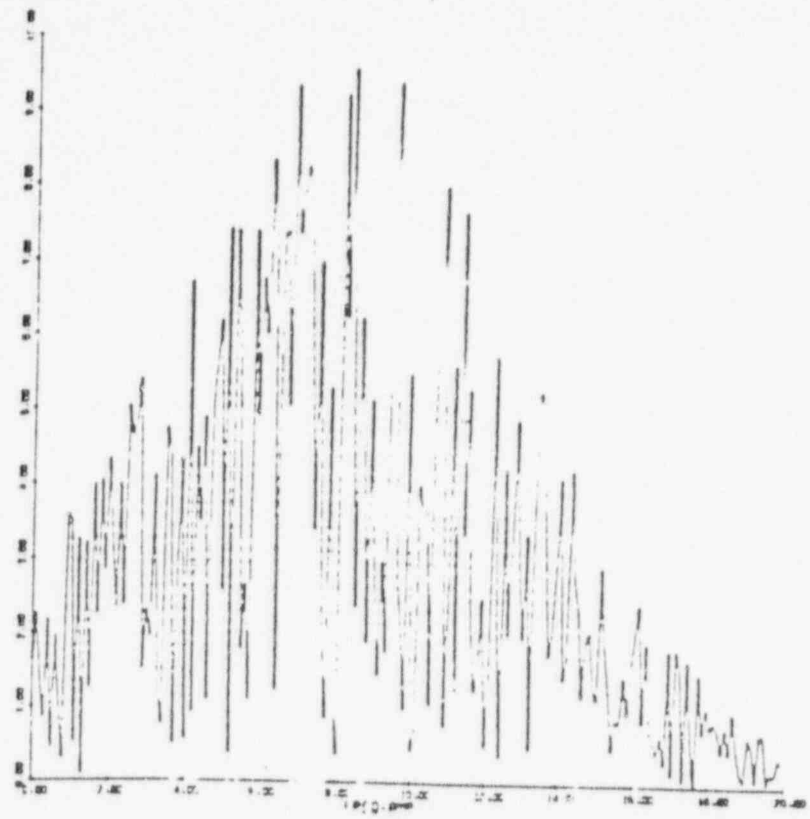
CASE B-2 FREQ:8.8 SIGMA:3.3 DUR:10.5.

90011289

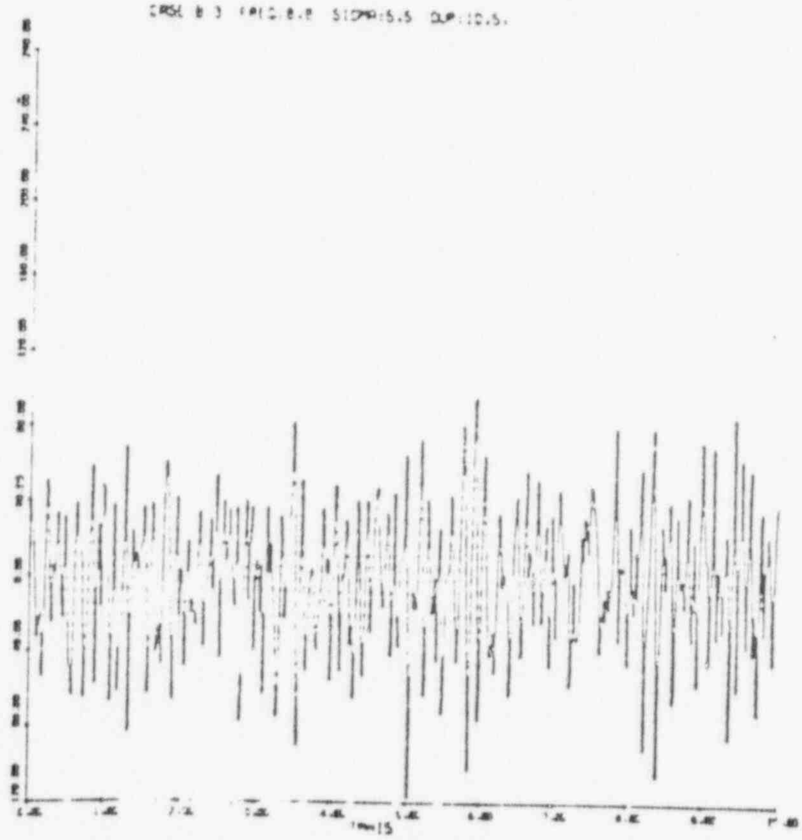


CASE B-2 FREQ:8.8 SIGMA:3.3 DUR:10.5. CDF

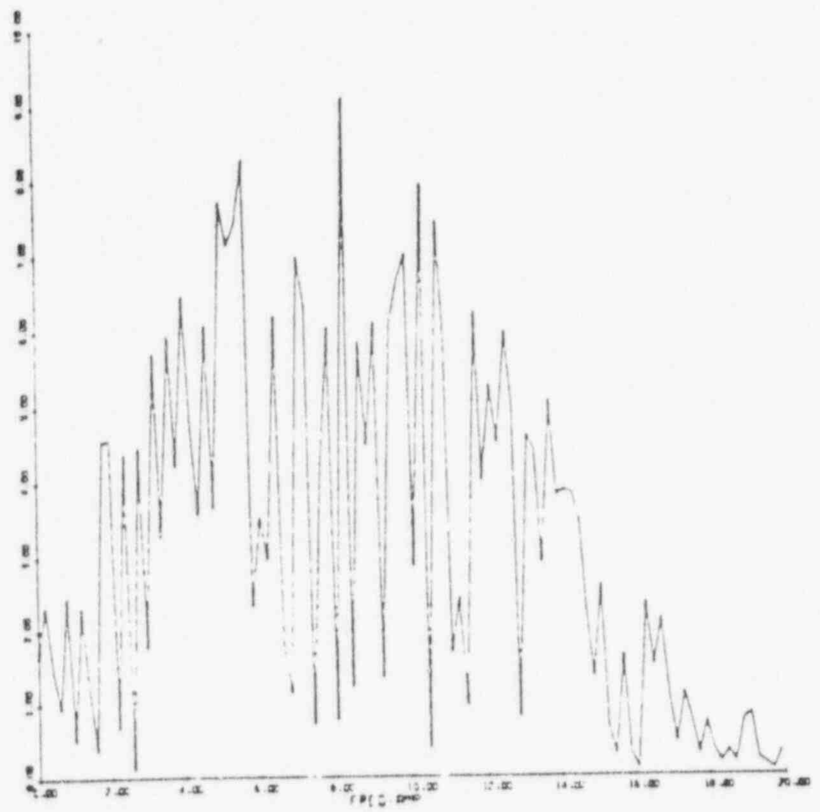
90011290



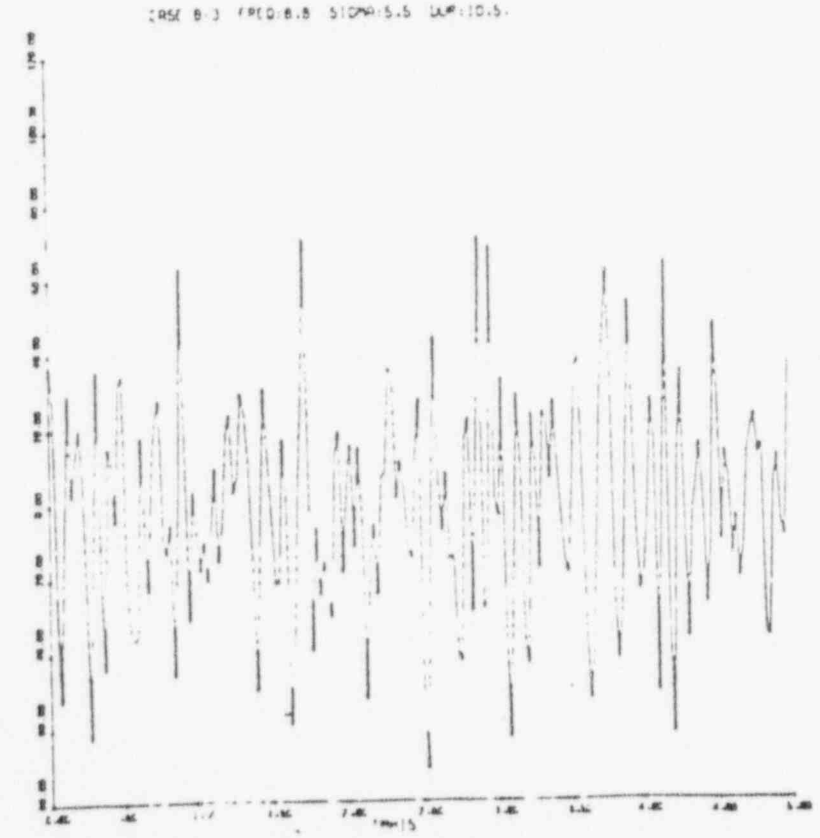
CASE 8.3 FREQ:8.8 SIGMA:5.5 DUR:10.5.



CASE 8.3 FREQ:8.8 SIGMA:5.5 DUR:10.5.



CASE B-3 FREQ:8.8 SIGMA:5.5 DUR:10.5.



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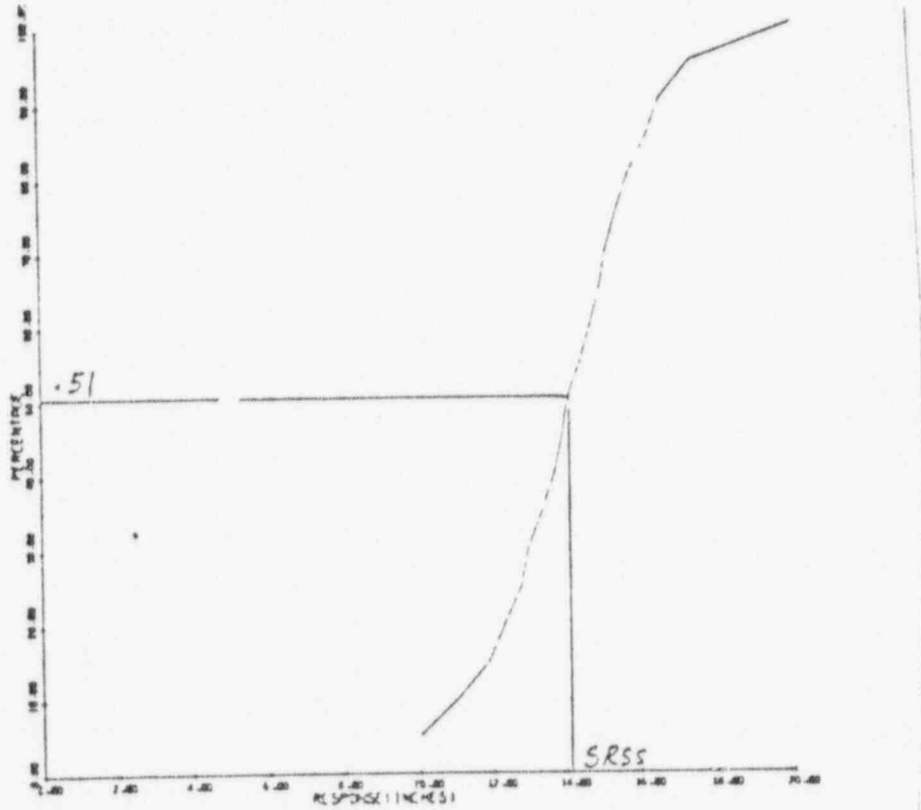
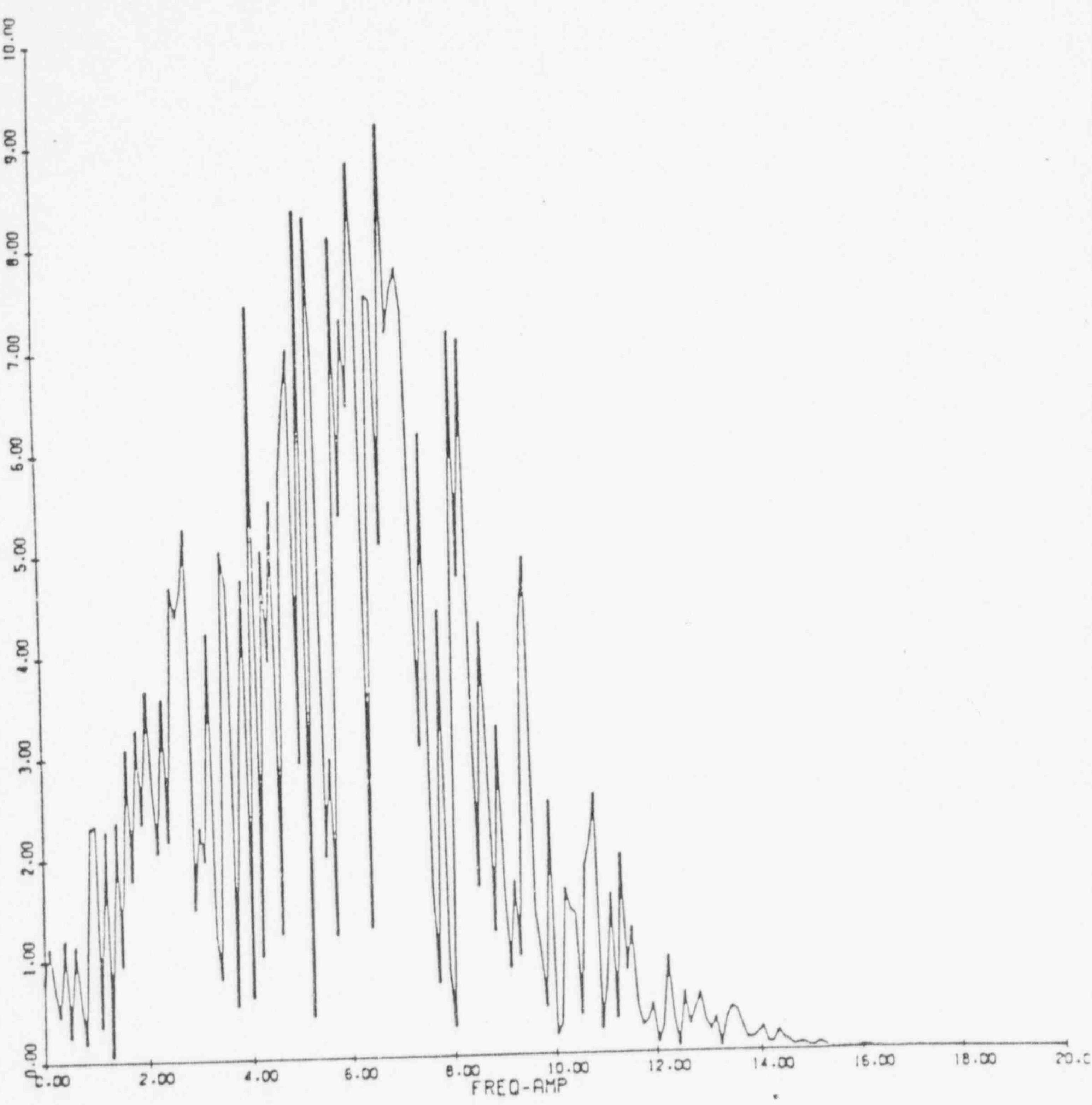
90011292



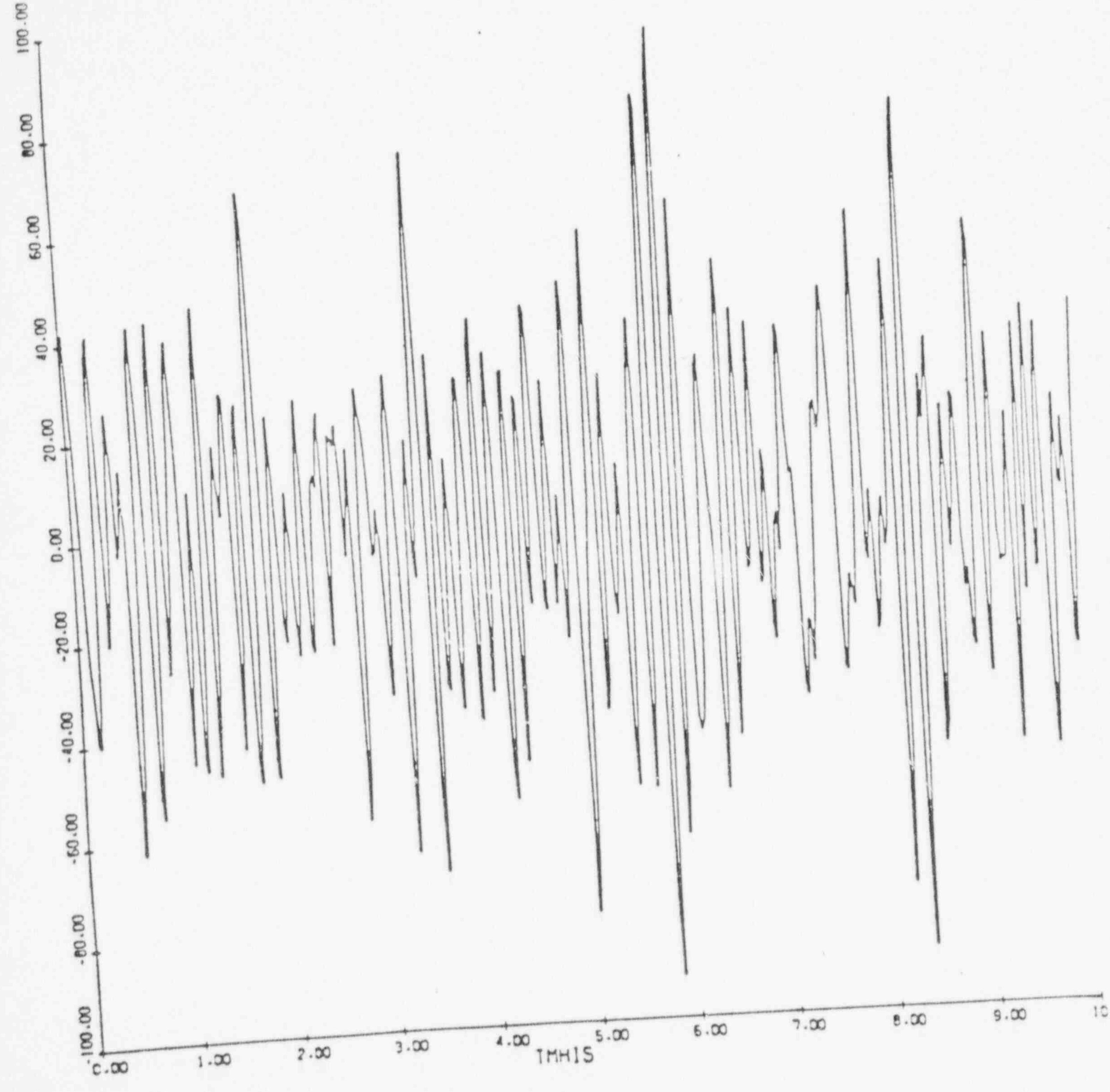
CASE B-3 FREQ:8.8 SIGMA:5.5 DUR:10.5. CDF

90011293

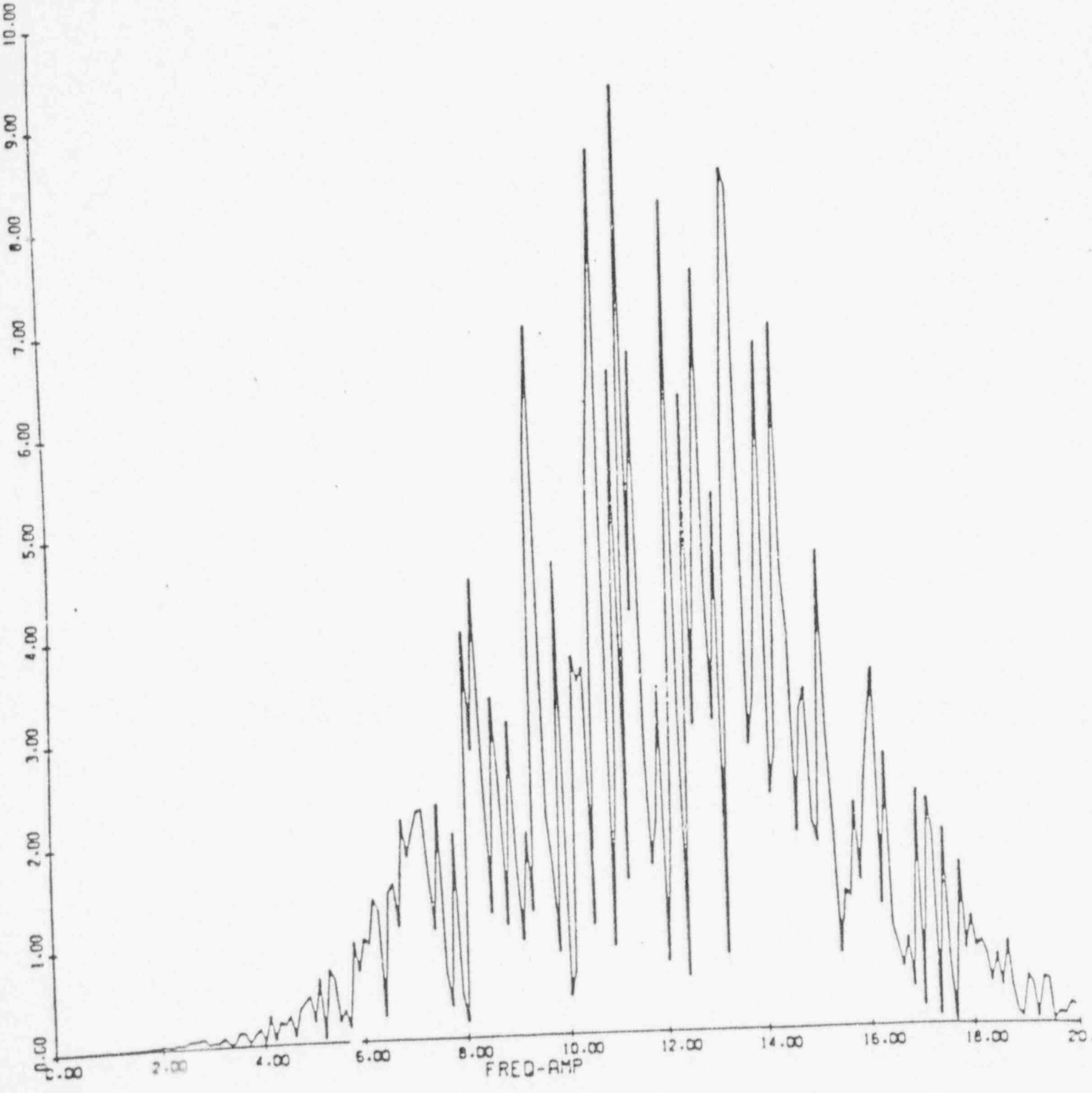


CASE C-2 FREQ=6.12 SIGMA=3.3 DUR=10.

90011294

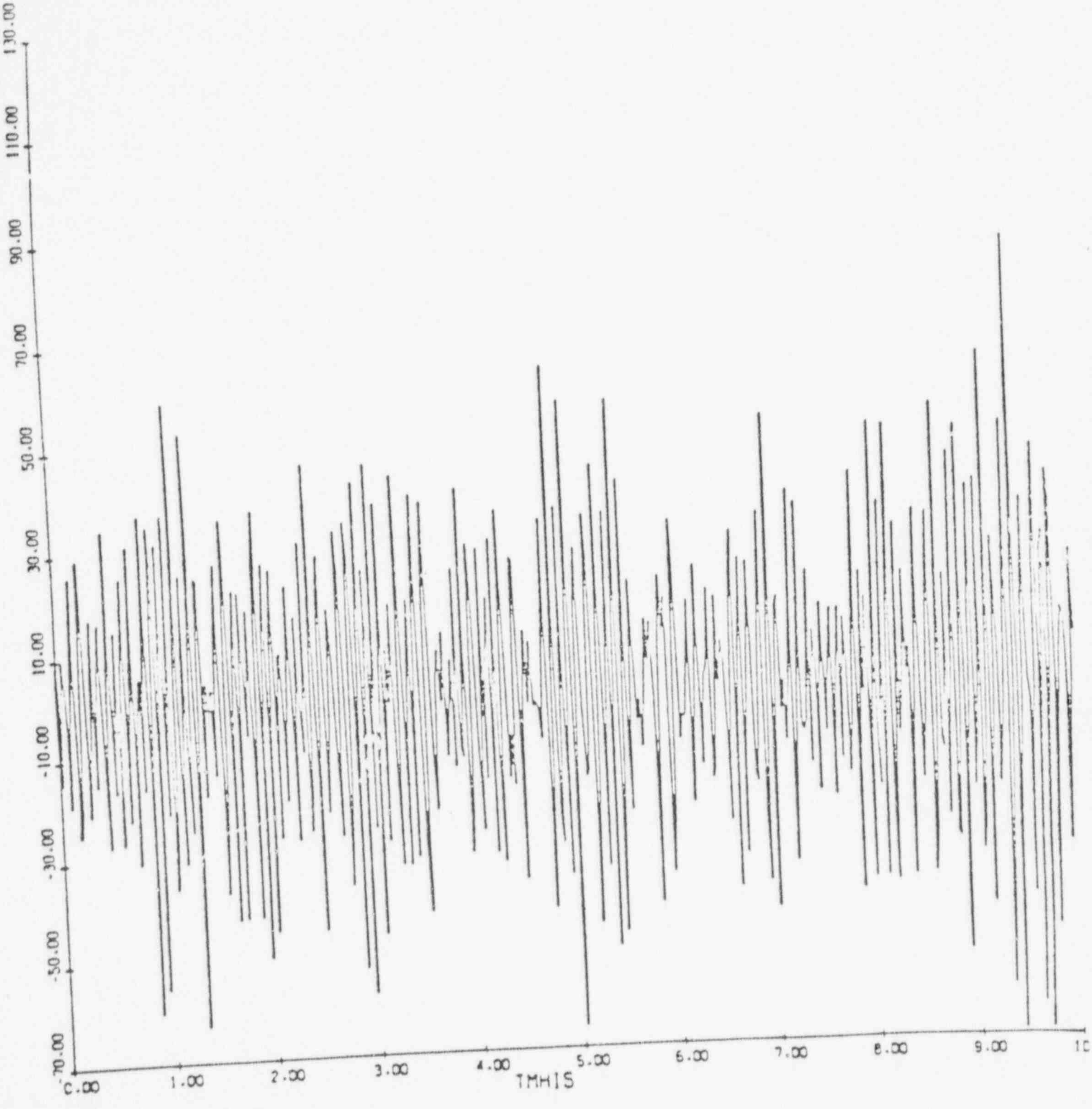


CASE L'-2 FREQ=6.12 SIGMA=3.3 DUR=10.5.



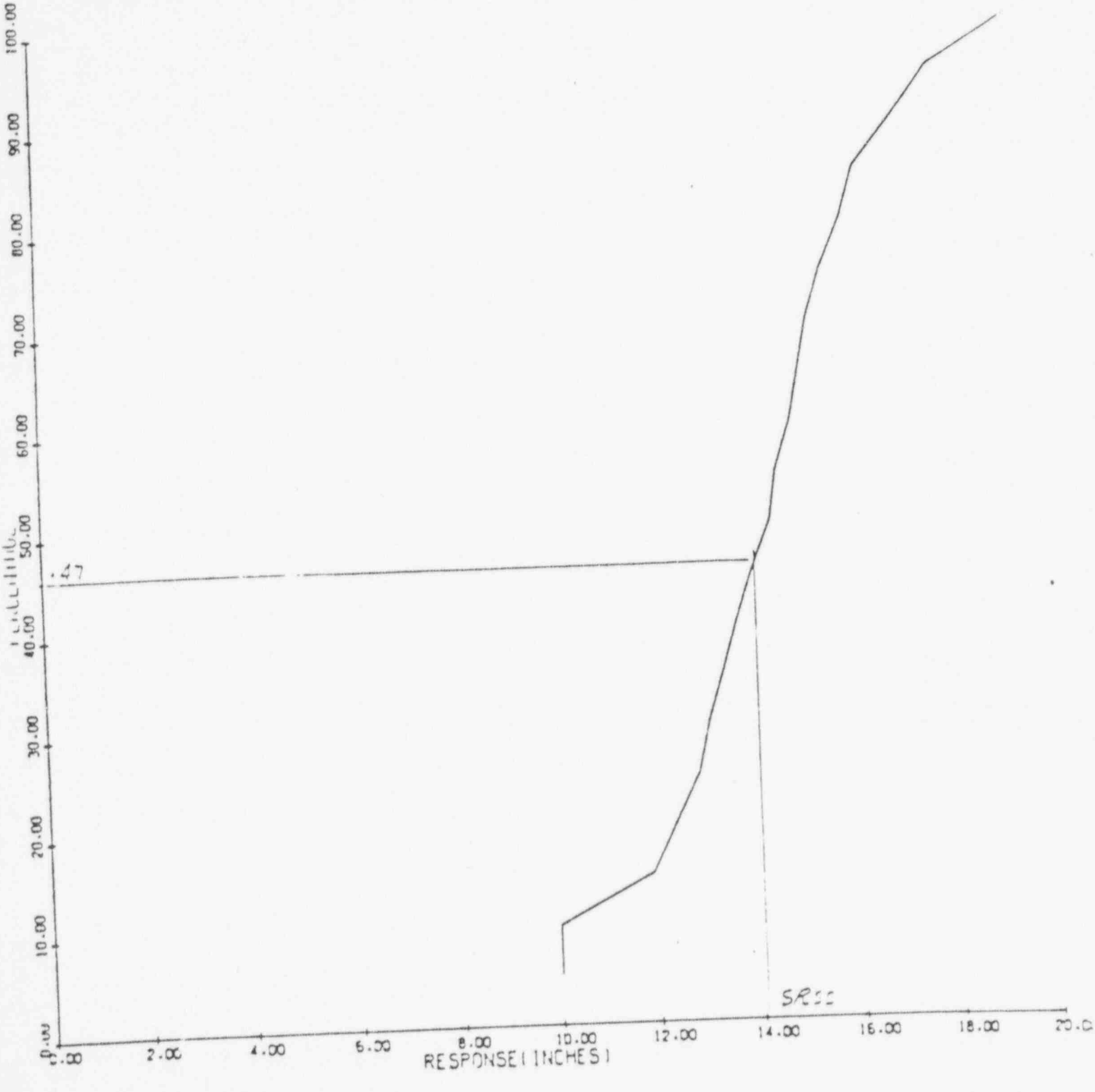
CASE C-2 FREQ=6.12 SIGMA=3.3 DUR=10.5.

90011296



CASE C-2 FREQ=6.12 SIGMA=3.3 DUR=10.5

90011297



CASE D-2 FREQ=6.'2 SIGMA=3.3 DUR=10.5

90011298

COMBINATION OF ARTIFICIAL RESPONSES IN TIME DOMAIN

PURPOSE

- TO GENERATE ARTIFICIAL RESPONSES WITH TIME DEPENDENT PARAMETERS:

  OCCURRENCE TIME OF PEAKS;

  PROBABILITY OF PEAK OCCURRENCES;

  ENVELOPE SHAPE OF RESPONSE CURVE;

  SPARSITY OF PEAKS;

  FILTERING FREQUENCIES.
- FOURIER TRANSFORM.
- COMBINE RESPONSES WITH TIME LAG.
- PLOT CDF OF COMBINED PEAKS.
- LOCAL NON-EXCEEDANCE PROBABILITY OF SRSS.

90011299

. FORMULATION

$$R(T) = \int_0^T H(T-\tau)\ \psi(\tau)\ V(\tau)\ D\tau$$

H(T) - FREQUENCY CONTROL FILTER (IMPULSE RESPONSE)

ψ(T) - SHAPE FUNCTION

V(T) - RANDOM NUMBER

EXPERIMENTAL FUNCTIONS

$$H(T) = E^{-\xi WT}\left(\cos W_D T - \xi \frac{W}{W_D} \sin W_D T\right)$$

$$\psi(T) = E^{-\alpha T} - E^{-\beta T}$$

V(T) = GAUSSIAN RANDOM NUMBER OR UNIF. DIST. RANDOM NUMBER.

90011300

. RESULTS:

1. TWO IDENTICAL RESPONSES, DUR = 10 SEC

   UNIF. DIST. OF PEAK

   NO FILTER

   MAX PEAK AT ± 5 SEC

   P (R < SRSS) = 0.29

2. TWO IDENTICAL RESPONSES, DUR = 10 SEC

   GAUSSIAN DIST. OF PEAK

   NO FILTER

   MAX. PEAK AT ± 5 SEC

   P (R < SRSS) = 0.60

3. TWO IDENTICAL RESPONSES, DUR = 10 SEC

   GAUSSIAN DIST. OF PEAK

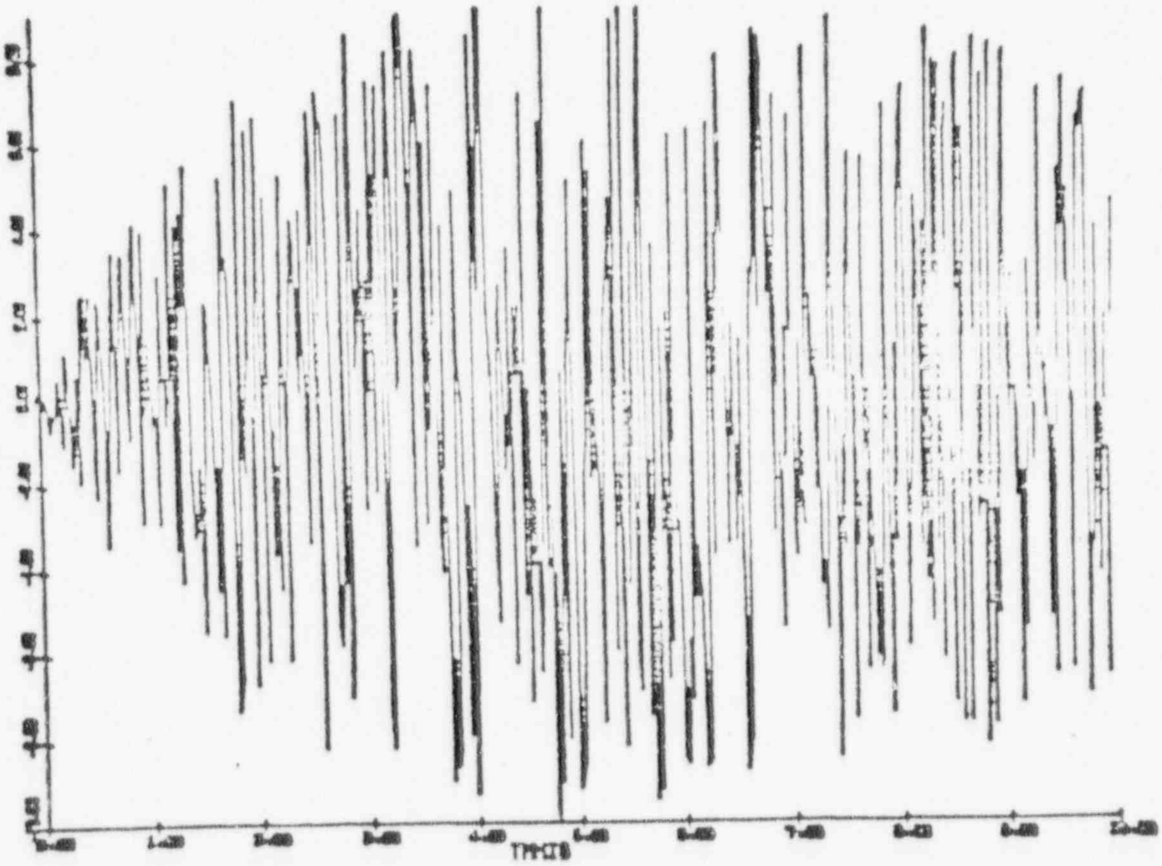
   FILTER WITH IMPULSE RESPONSES

   MAX PEAK AT 3 SEC - 6 SEC

   P (R < SRSS) = 0.72

9001130 1

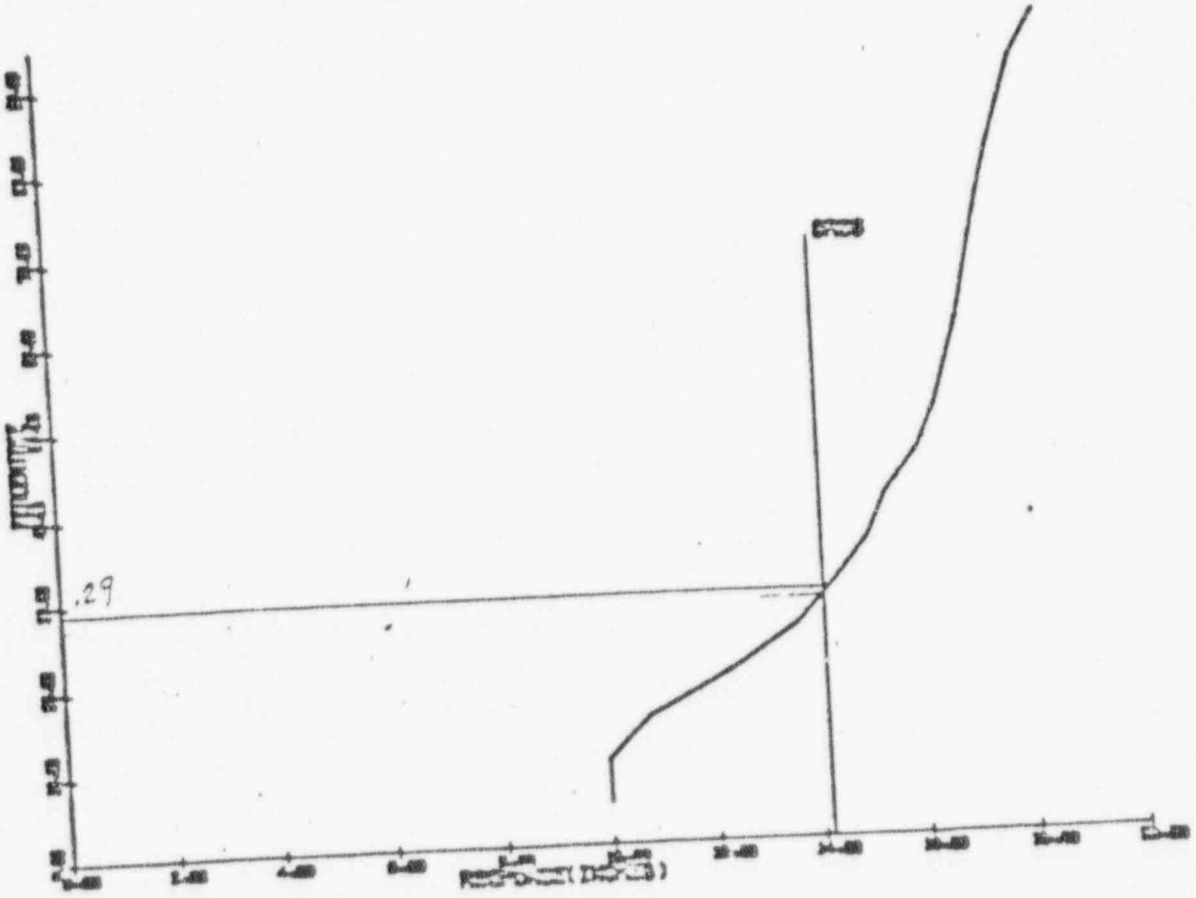
CONCLUSION: PENDING



ARTIFICIAL TIME RESPONSE SIMULATION

1. UNIF. DIST OF PEAK
NO FILTER

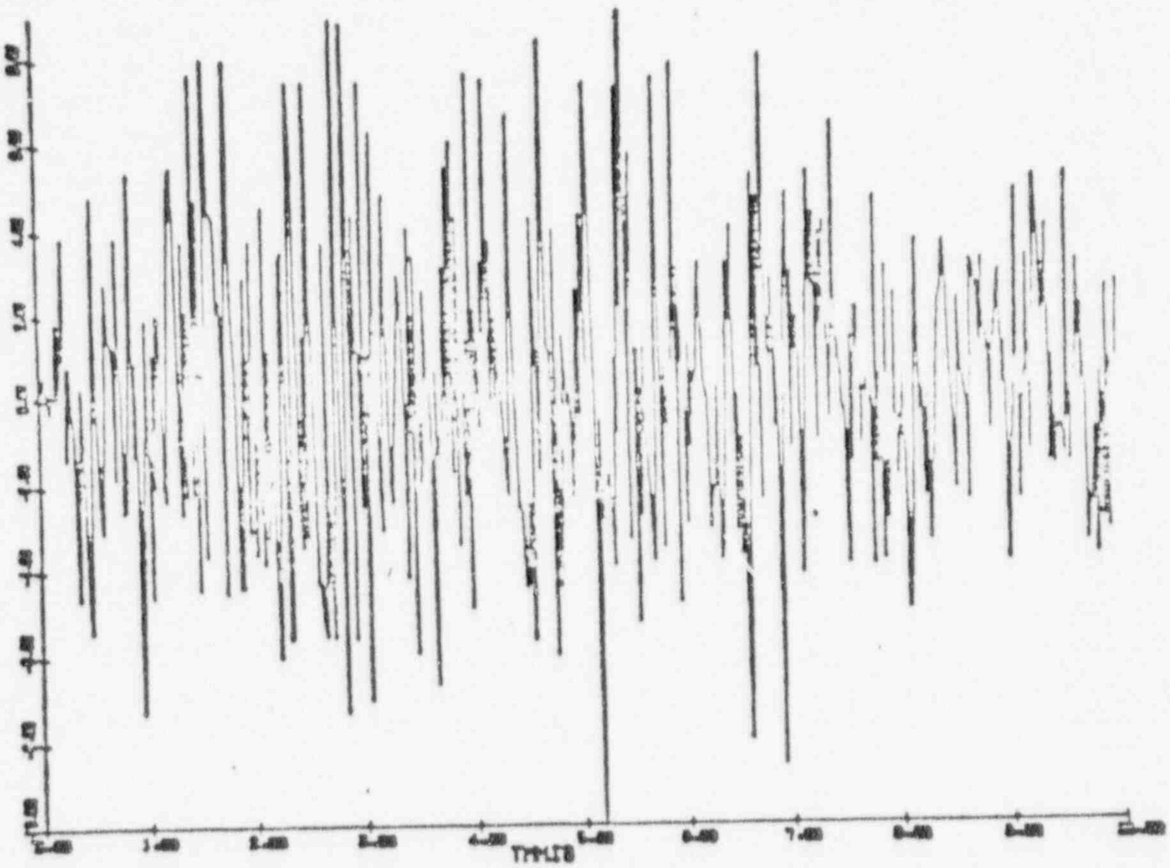
90011302



ARTIFICIAL TIME RESPONSE SIMULATION

1. UNIF. DIST. OF PEAK CDF
NO FILTER

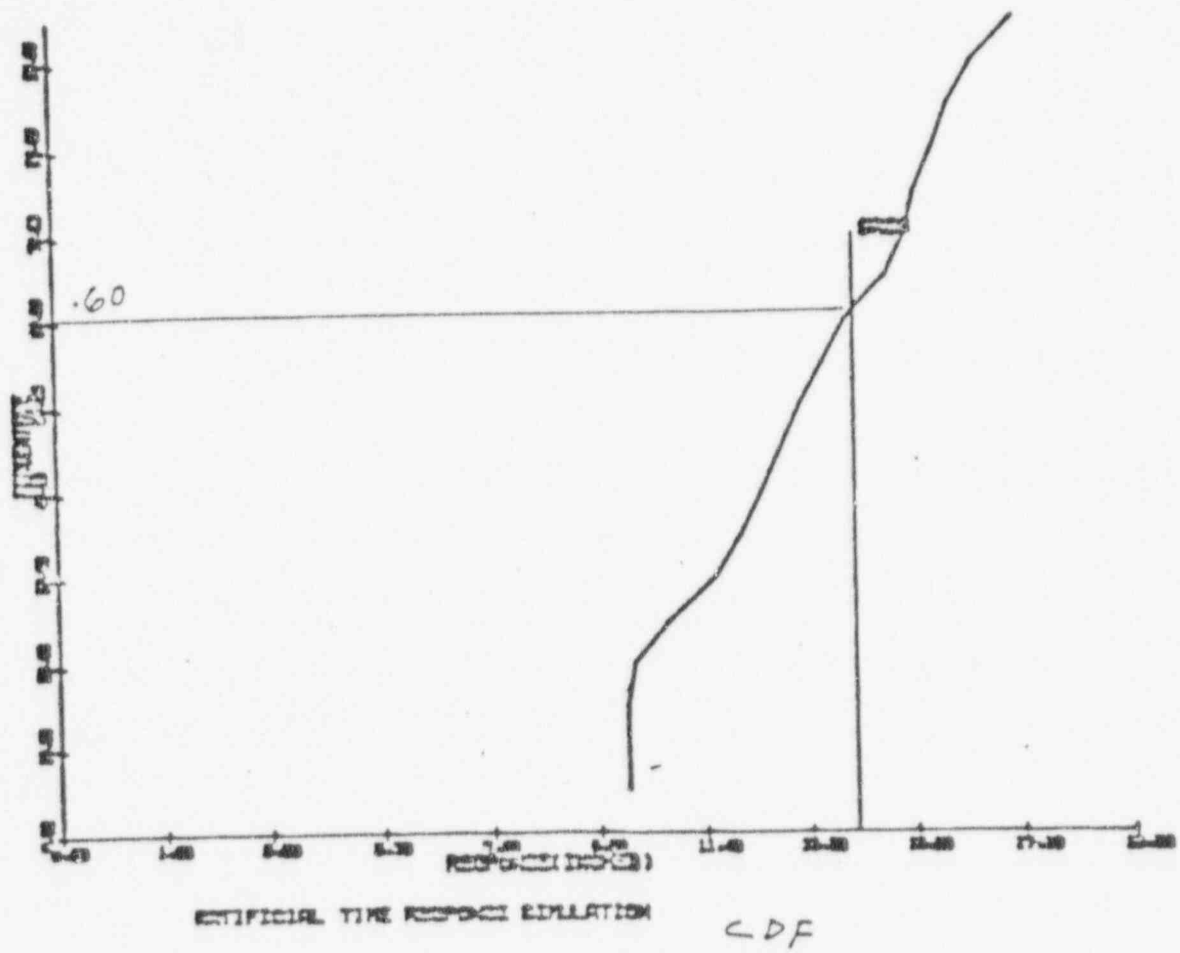
90011303



ARTIFICIAL TIME RESPONSE SIMULATION

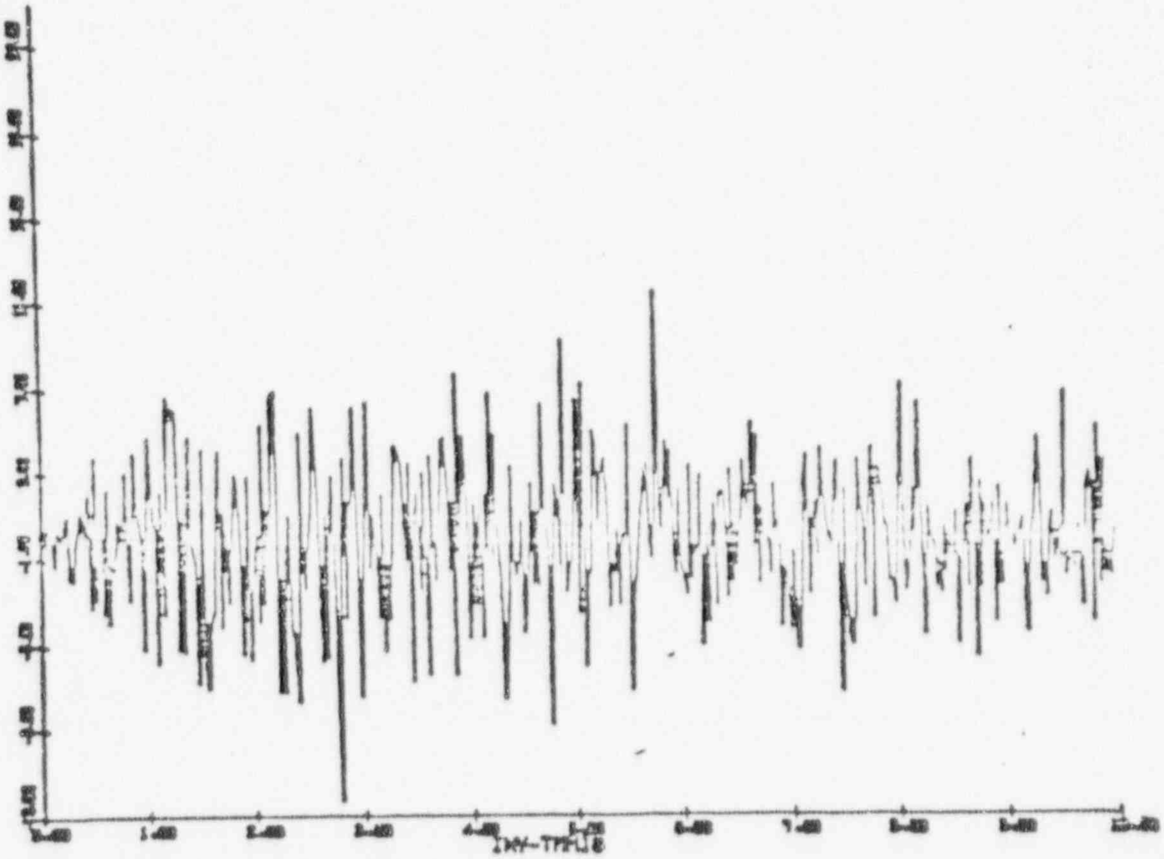
2. GAUSSIAN DIST OF PEAK
NO FILTER

90011304



2. GAUSSIAN DIST OF PEAK
NO FILTER

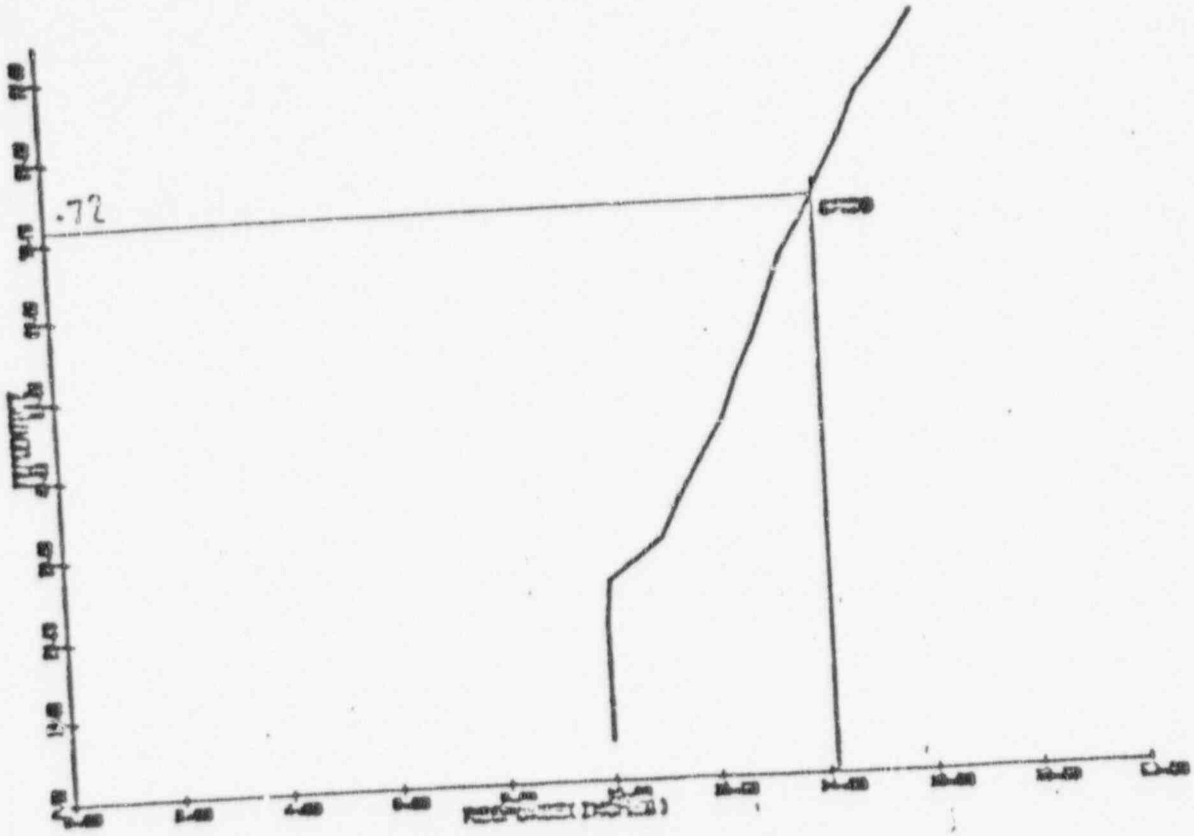
90011305



ARTIFICIAL TIME RESPONCE SIMULATION

3. GAUSSIAN PEAK DIST.
FILTERED

90011306



ARTIFICIAL TIME RESPONSE SIMULATION CDF

3. GAUSSIAN PEAK DIST.
FILTERED

90011307