RECEIVED
DEC 26 1978
S. V. TASHJIAN

SAN ONOFRE UNITS 2 AND 3

DOCKETS 50-361 AND 362

SLIDES DEPICTING STRUCTURAL ANALYSIS METHODS TESTING, PROPERTIES AND ANALYSIS AND TEST RESULTS FOR THE C-E 16X16 FUEL ASSEMBLY FOR SAN ONOFRE UNITS 2 AND 3.

NON-PROPRIETARY VERSION

PRESENTATION TO NRC ON DECEMBER 14, 1978.

COMBUSTION ENGINEERING, INC.
NUCLEAR POWER SYSTEMS
POWER SYSTEMS GROUP
WINDSOR, CONNECTICUT

RECEIVED
DEC 26 1978
EDM/GO

LEGAL NOTICE

This report was prepared as an account of work sponsored by Combustion Engineering, Inc. Neither Combustion Engineering nor any person acting on its behalf:

a. Makes any warranty or representation, express or implied including the warranties of fitness for a particular purpose or merchantability, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

b. Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, appartus, method or process disclosed in this report.

I. INTRODUCTION

II. TECHNICAL PRESENTATION

A. DESIGN DESCRIPTION

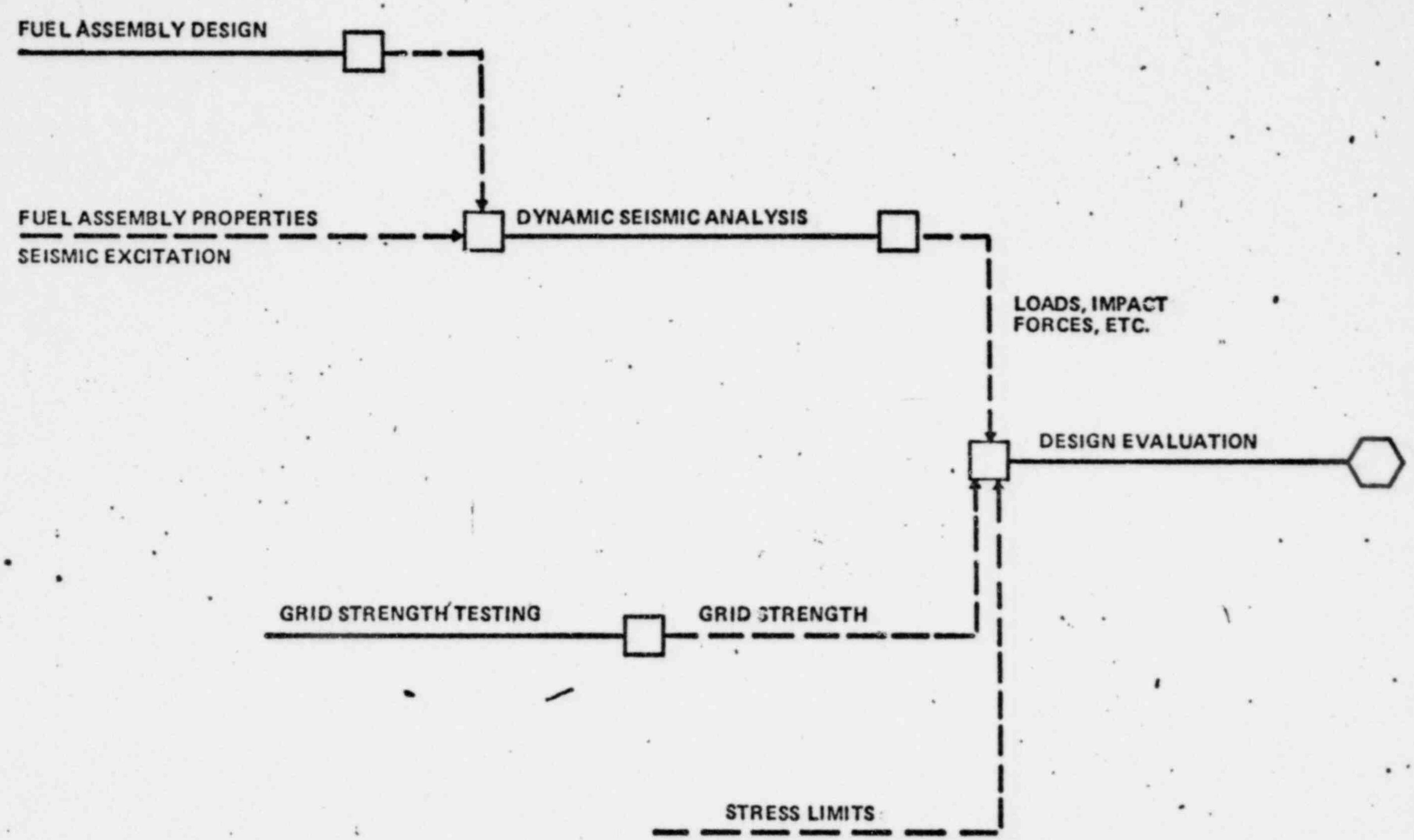
B. ANALYSIS

C. TEST

D. DESIGN EVALUATION

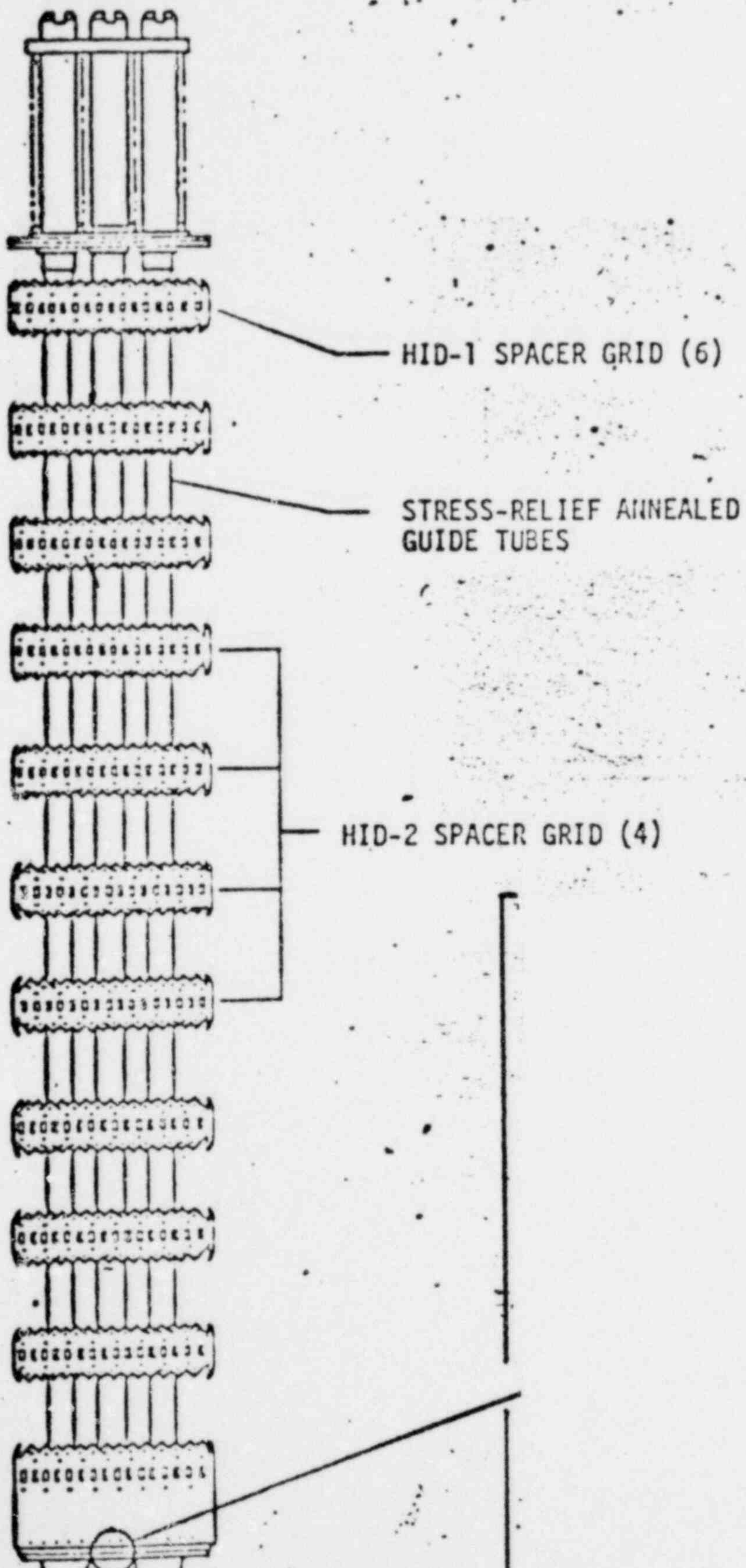
III. DISCUSSION

FUEL SEISMIC DESIGN PROCESS

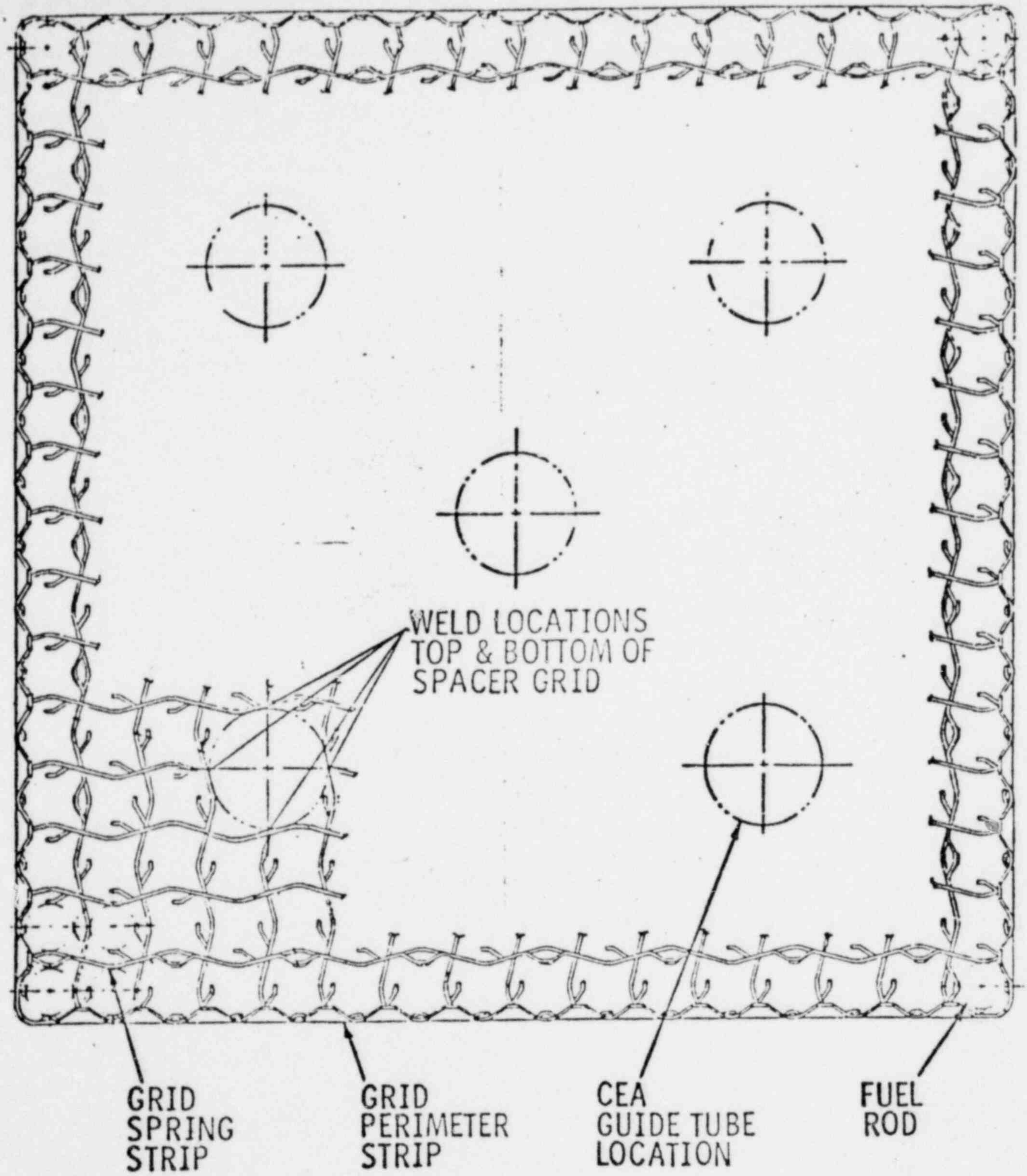


SONGS-II FUEL ASSEMBLY

SEISMIC DESIGN FEATURES



3,5



SAN ONOFRE
NUCLEAR GENERATING STATION
Units 2 & 3

FUEL SPACER GRID

10079-11D-494

CESHOCK

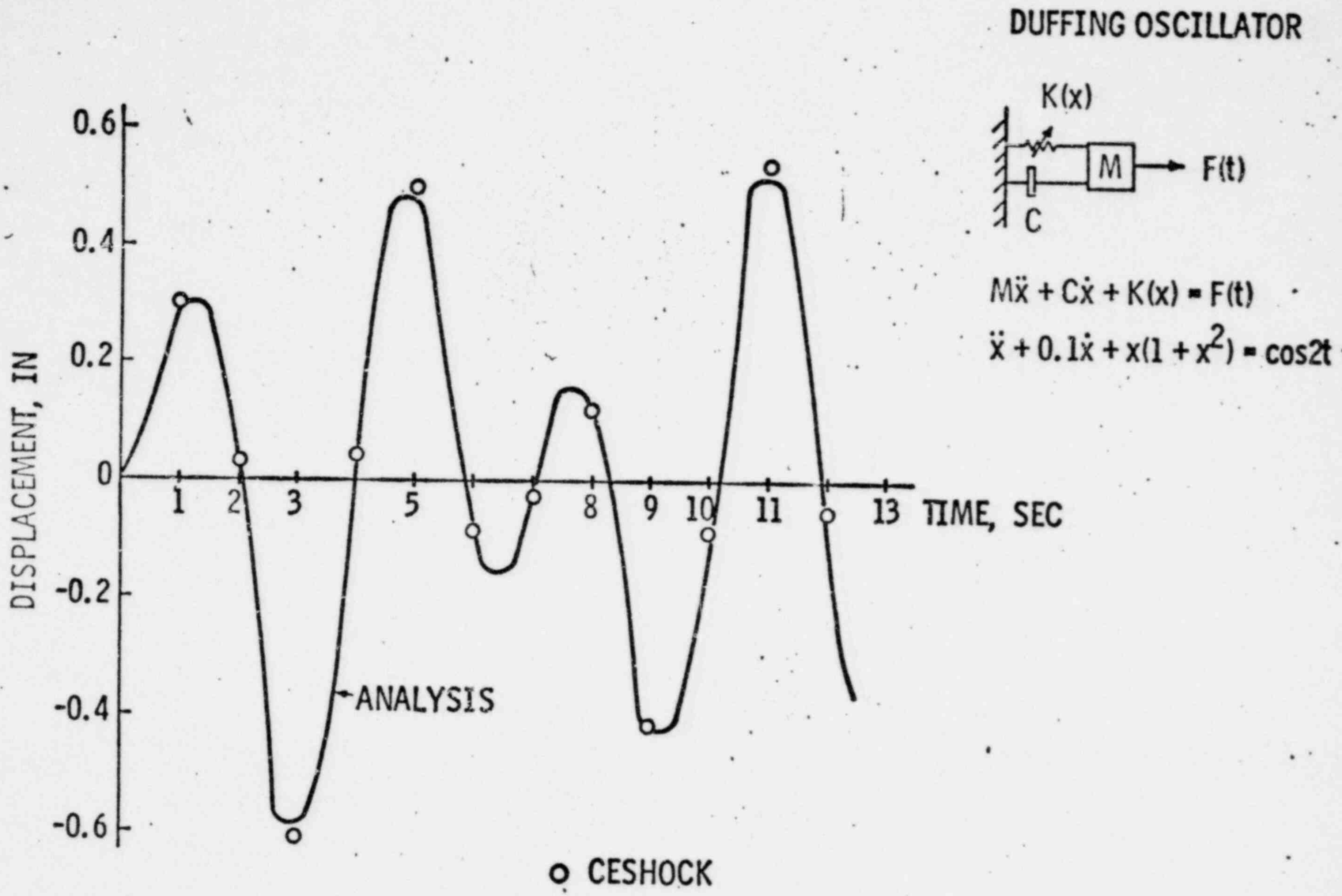
- DYNAMIC RESPONSE OF MULTI-SPRING/MASS SYSTEMS
- AXIAL/LATERAL MODEL CAPABILITIES
- PRELOADS, TENSION-AND COMPRESSION-ONLY SPRINGS, AND NONLINEAR SPRINGS
- GAPS, IMPACT, COEFFICIENT OF RESTITUTION
- α - β DAMPING
- HYDRODYNAMIC MASS MATRIX
- ARBITRARY TIME DEPENDENT EXTERNAL LOADS
- NUMERICAL INTEGRATION TECHNIQUES: RUNGE-KUTTA-GILL AND NEWMARK
- OUTPUT: DISPLACEMENT, VELOCITY, ACCELERATION, FORCE, SHEAR, IMPACT LOAD AND MOMENT TIME HISTORIES

SUMMARY OF THE METHODS EMPLOYED TO VERIFY THE CESHOCK CODE

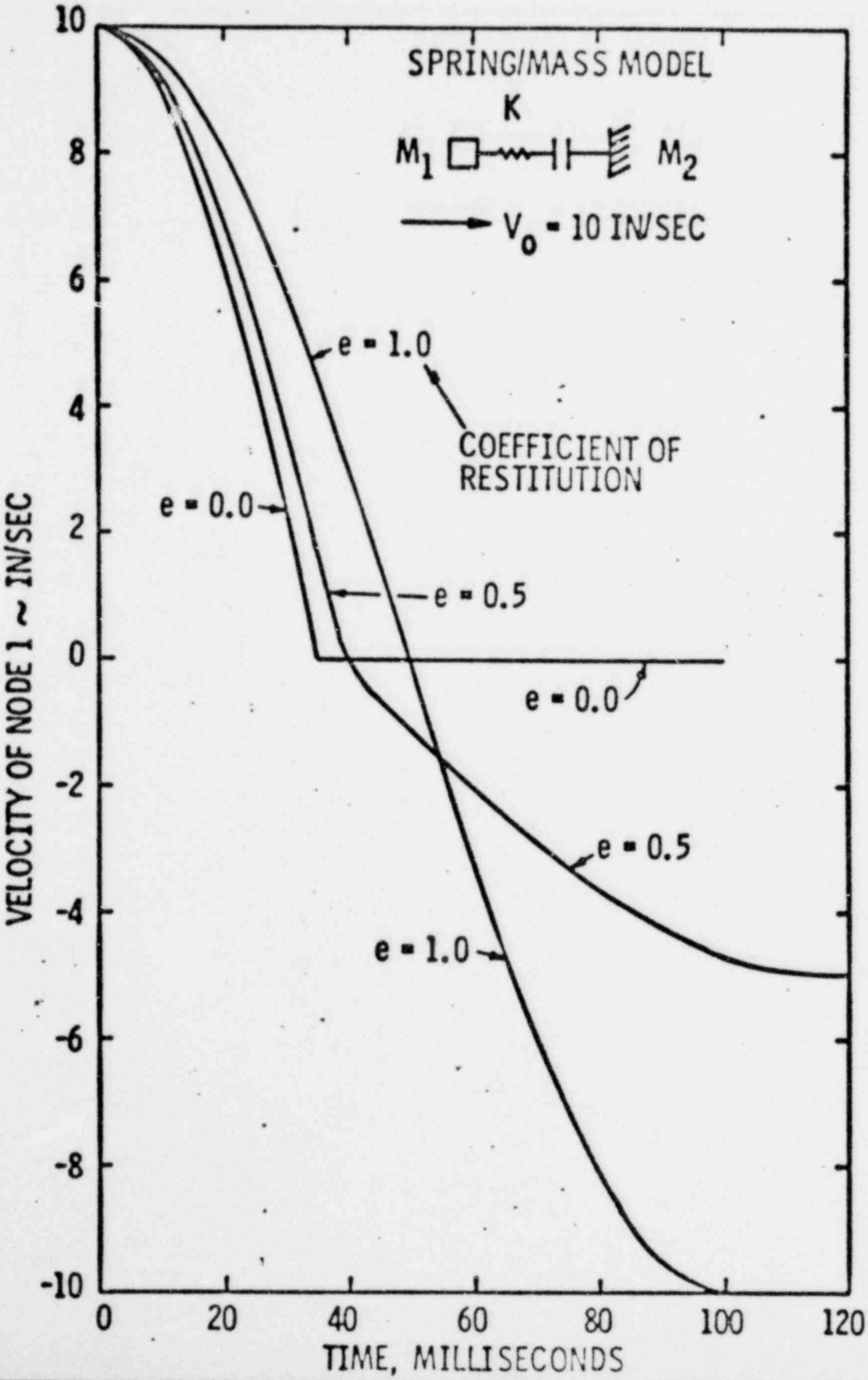
TYPE OF CESHOCK PROBLEM	METHOD OF VERIFICATION
I. NONLINEAR, DAMPED PULSE EXCITED SYSTEM A. DEGREE OF NONLINEARITY VARIED (DUFFING OSCILLATOR) B. TYPE OF PULSE VARIED	PUBLISHED CLASSICAL SOLUTION
II. MULTI-DEGREE OF FREEDOM BASE EXCITED LATERAL SYSTEM WITH FRICTION, GAPS, AND DAMPING A. WITHOUT HYDRODYNAMIC MASS B. WITH HYDRODYNAMIC MASS	INDEPENDENT COMPUTER CODE
III. FRICTION ELEMENT WITH STATIC AND DYNAMIC COEFFICIENTS OF FRICTION A. COEFFICIENT OF FRICTION VELOCITY NON-DEPENDENT B. COEFFICIENT OF FRICTION VELOCITY DEPENDENT	ANALYTICAL SOLUTION
IV. IMPACT ELEMENT WITH COEFFICIENT OF RESTITUTION	ANALYTICAL SOLUTION
V. HYSTERESIS ELEMENT: TWO DOF SYSTEM WITH SPRING AND GAP ELEMENTS	INDEPENDENT COMPUTER CODE

NONLINEAR, DAMPED PULSE EXCITED SYSTEM

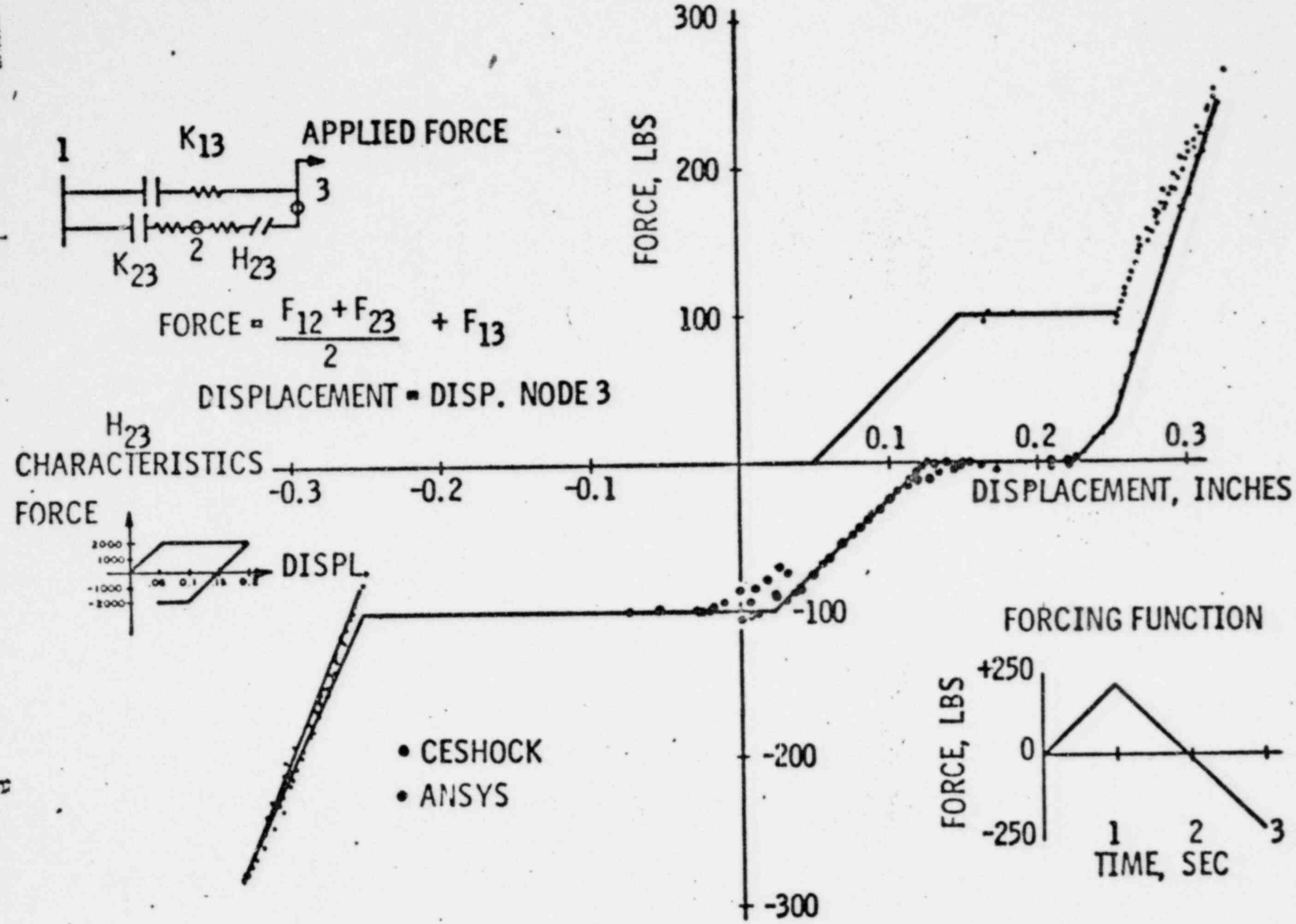
I



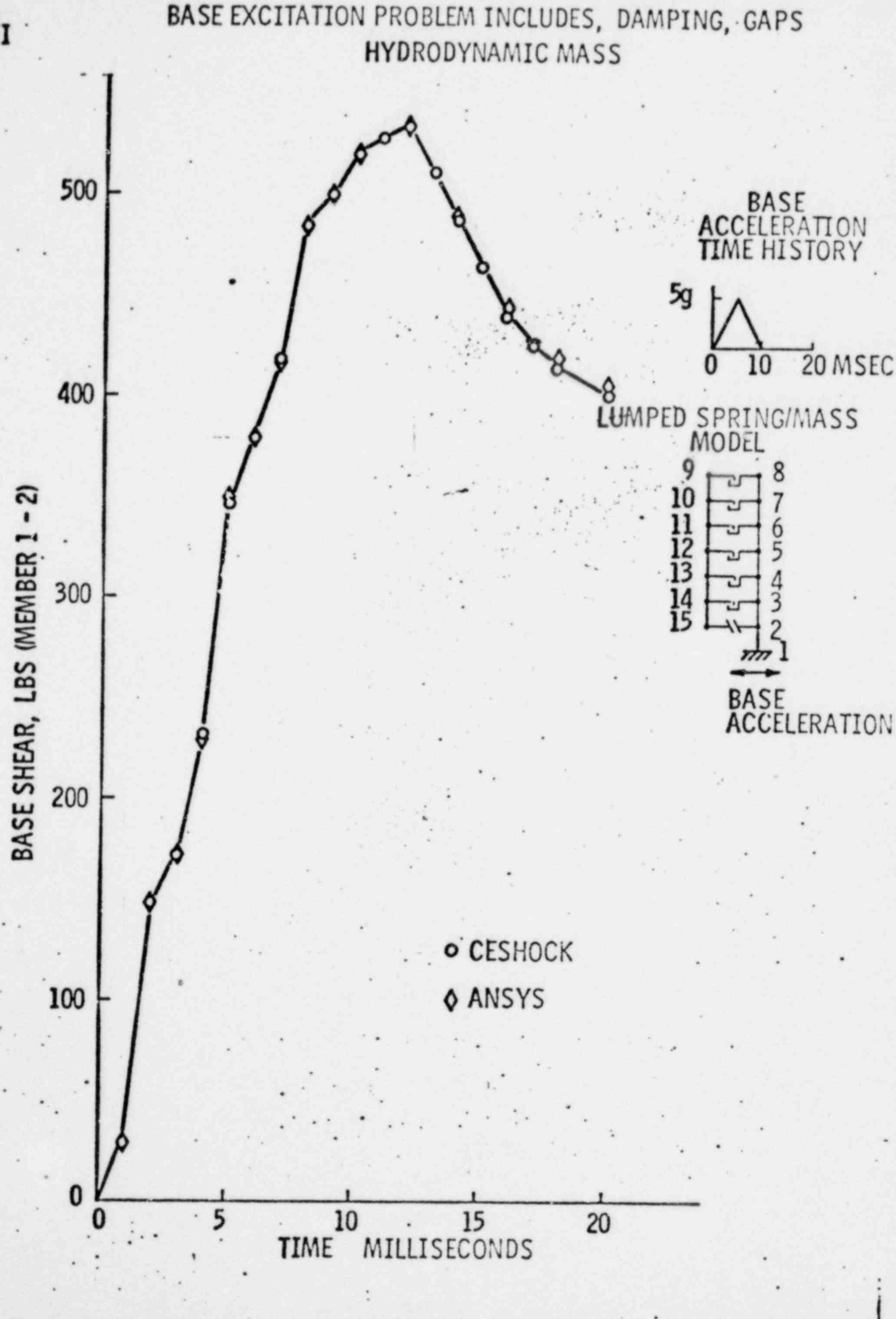
IMPACT ELEMENT WITH COEFFICIENT OF RESTITUTION



TWO DEGREE OF FREEDOM HYSTERESIS PROBLEM WITH GAPS



II

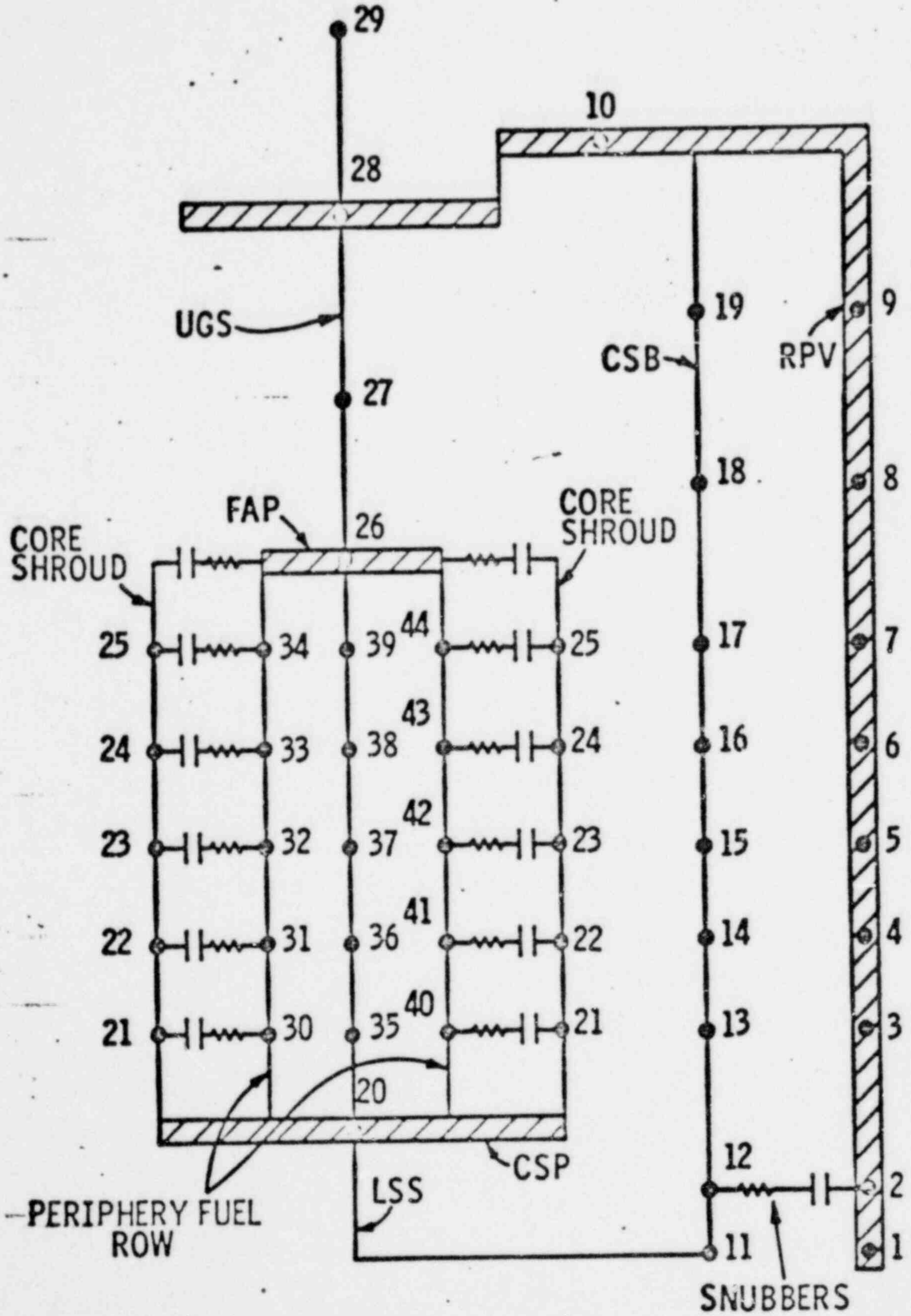


BASE EXCITATION PROBLEM INCLUDES, DAMPING, GAPS
HYDRODYNAMIC MASS
BASE SHEAR, LBS (MEMBER 1 - 2)
0
100
200
300
400
500
0
5
10
15
20
TIME MILLISECONDS
BASE
ACCELERATION
TIME HISTORY
5g
0
10
20 MSEC
LUMPED SPRING/MASS
MODEL
9
8
10
7
11
6
12
5
13
4
14
3
15
2
1
BASE
ACCELERATION
o CESHOCK
◊ ANSYS

FUEL TESTING

- STATIC LOAD - DEFLECTION
- FORCED VIBRATION
- BUNDLE IMPACT
  HORIZONTAL
  VERTICAL
- SPACER GRID IMPACT
  PENDULUM
  DROP
  PLUCK

SCE - CORE INTERNALS MODEL



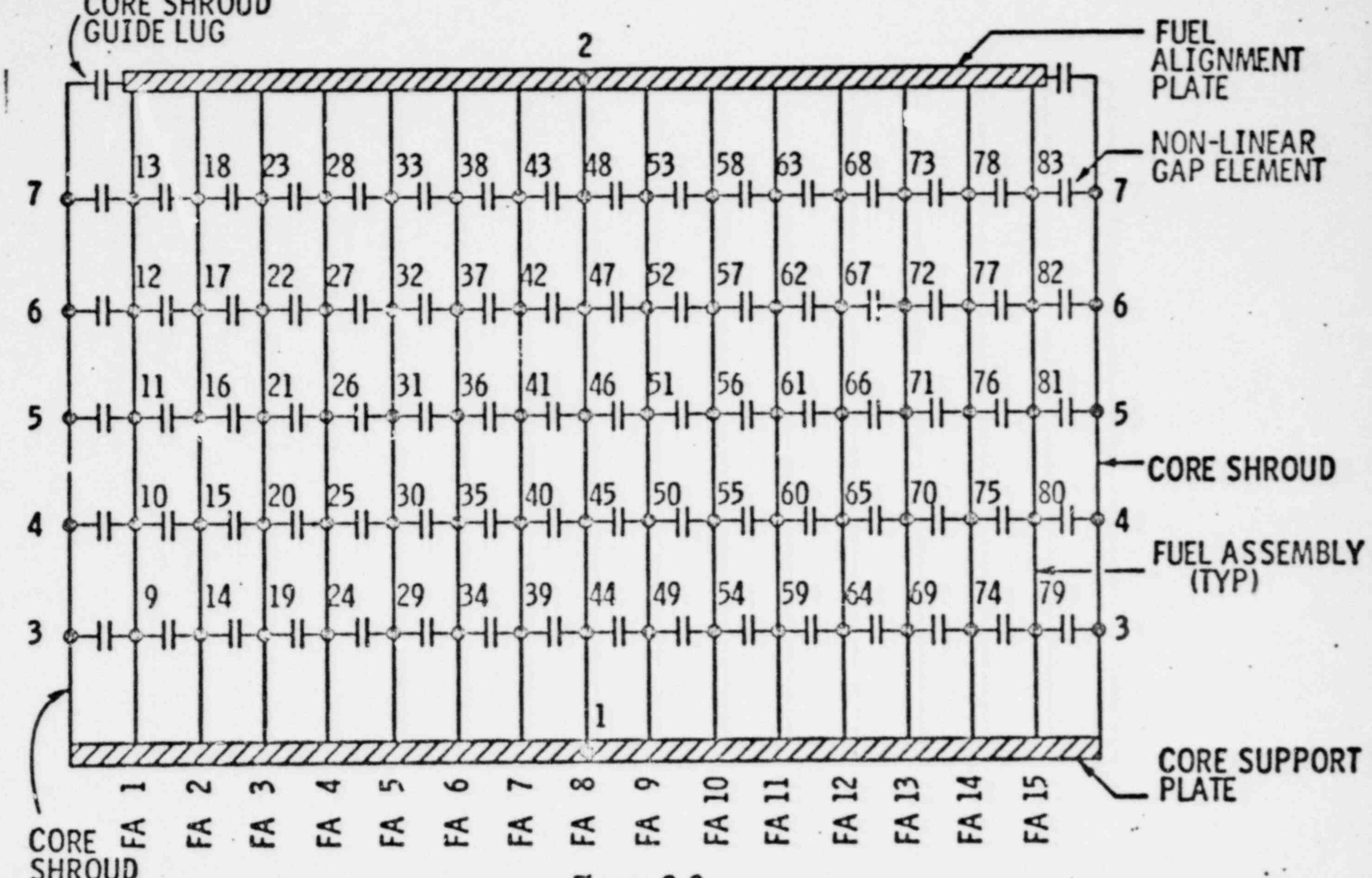
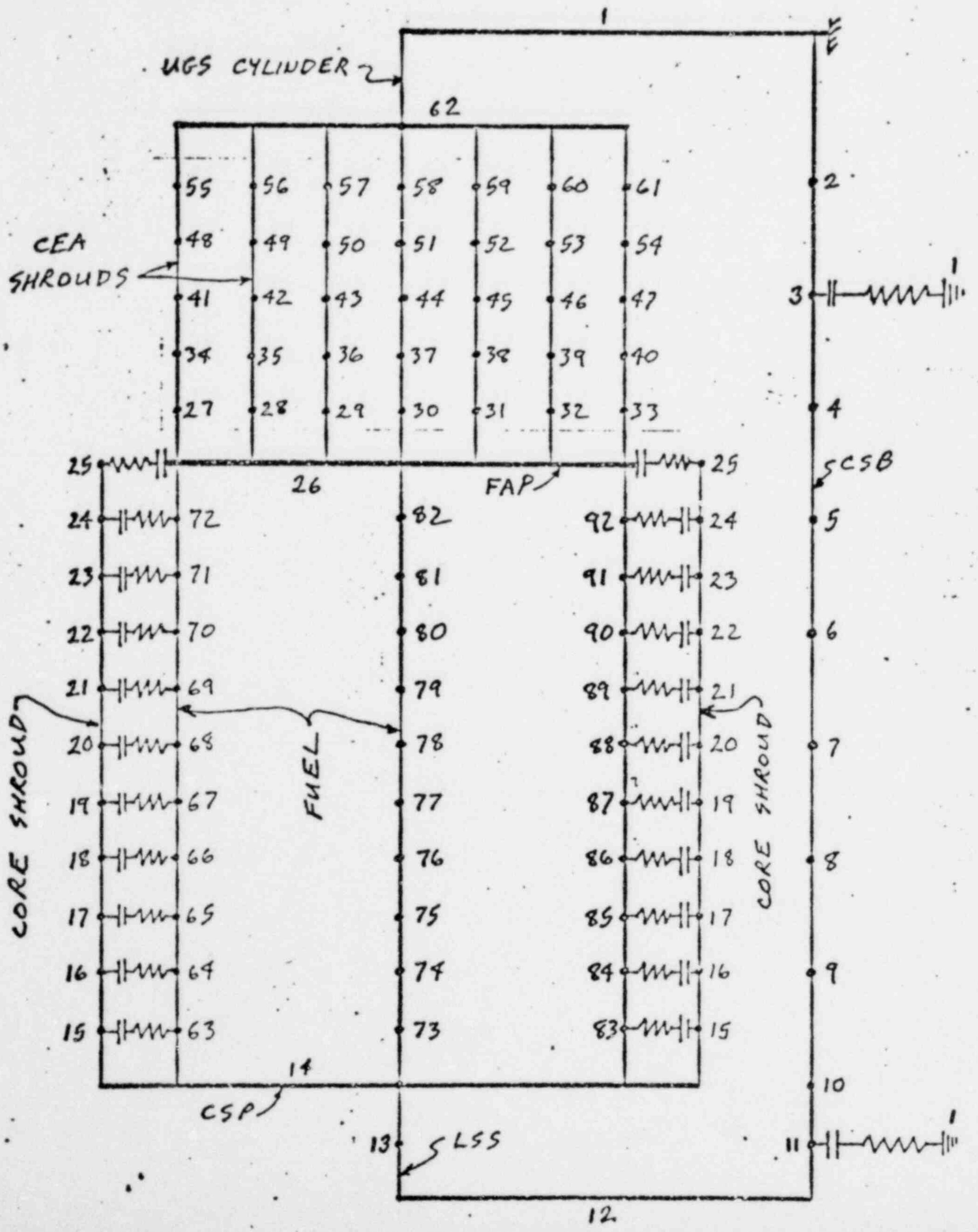


Figure 3-3

DETAILED HORIZONTAL CORE SEISMIC MODEL

SCE HORIZONTAL COUPLED CORE/INTERNALS LOCA MODEL



S.C.E. DETAILED CORE SEISMIC MODEL RESULTS

ONE ROW OF 17 FUEL ASSEMBLIES

3,4,5

S.C.E. DETAILED CORE SEISMIC MODEL RESULTS

ONE ROW OF 17 FUEL ASSEMBLIES

S.C.E. DETAILED CORE MODEL LOCA RESULTS

ONE ROW OF 17 FUEL ASSEMBLIES

3,4,5

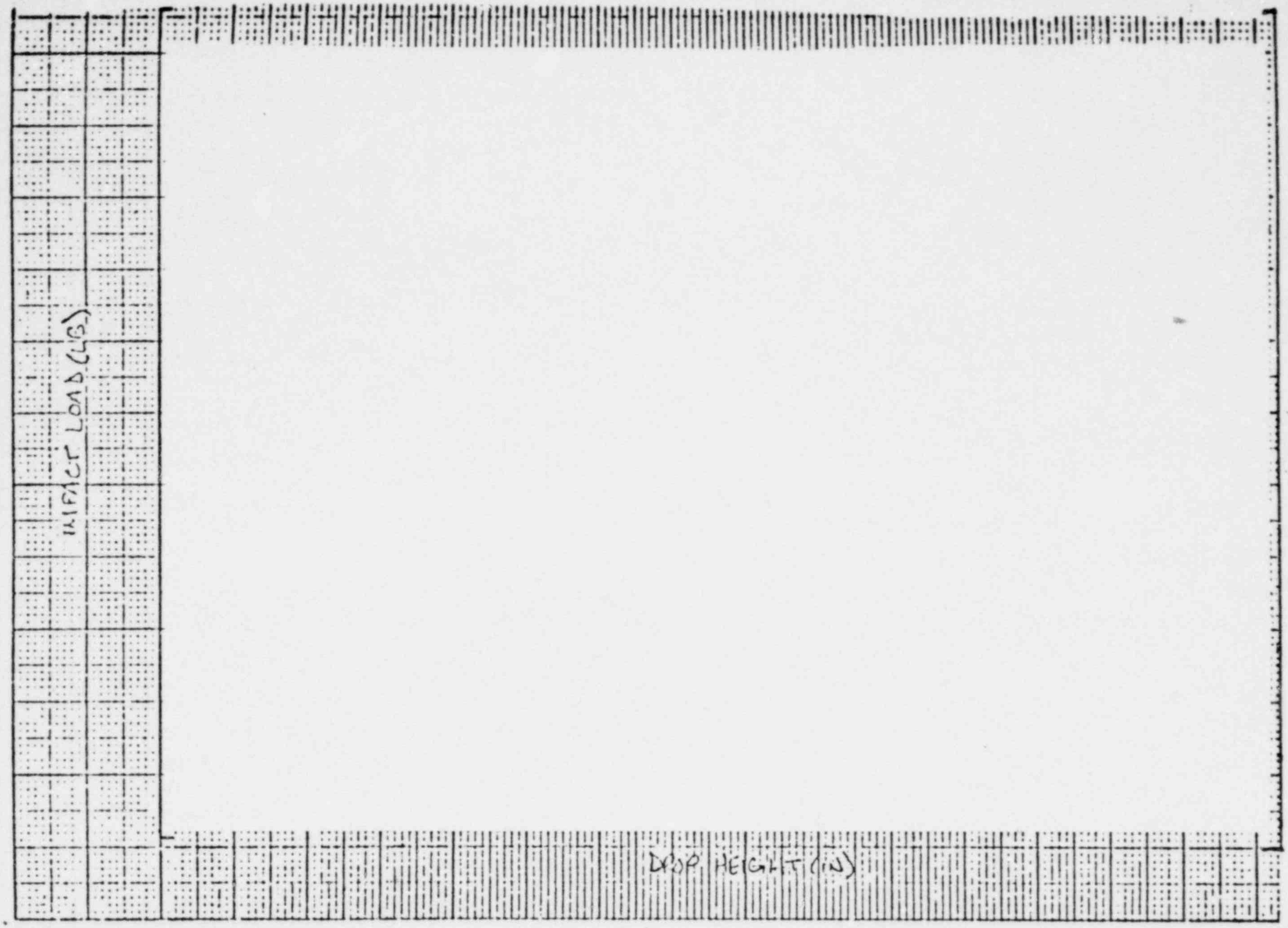
S.C.E. DETAILED CORE MODEL LOCA RESULTS

ONE ROW OF 17 FUEL ASSEMBLIES

3,4,5

2,3

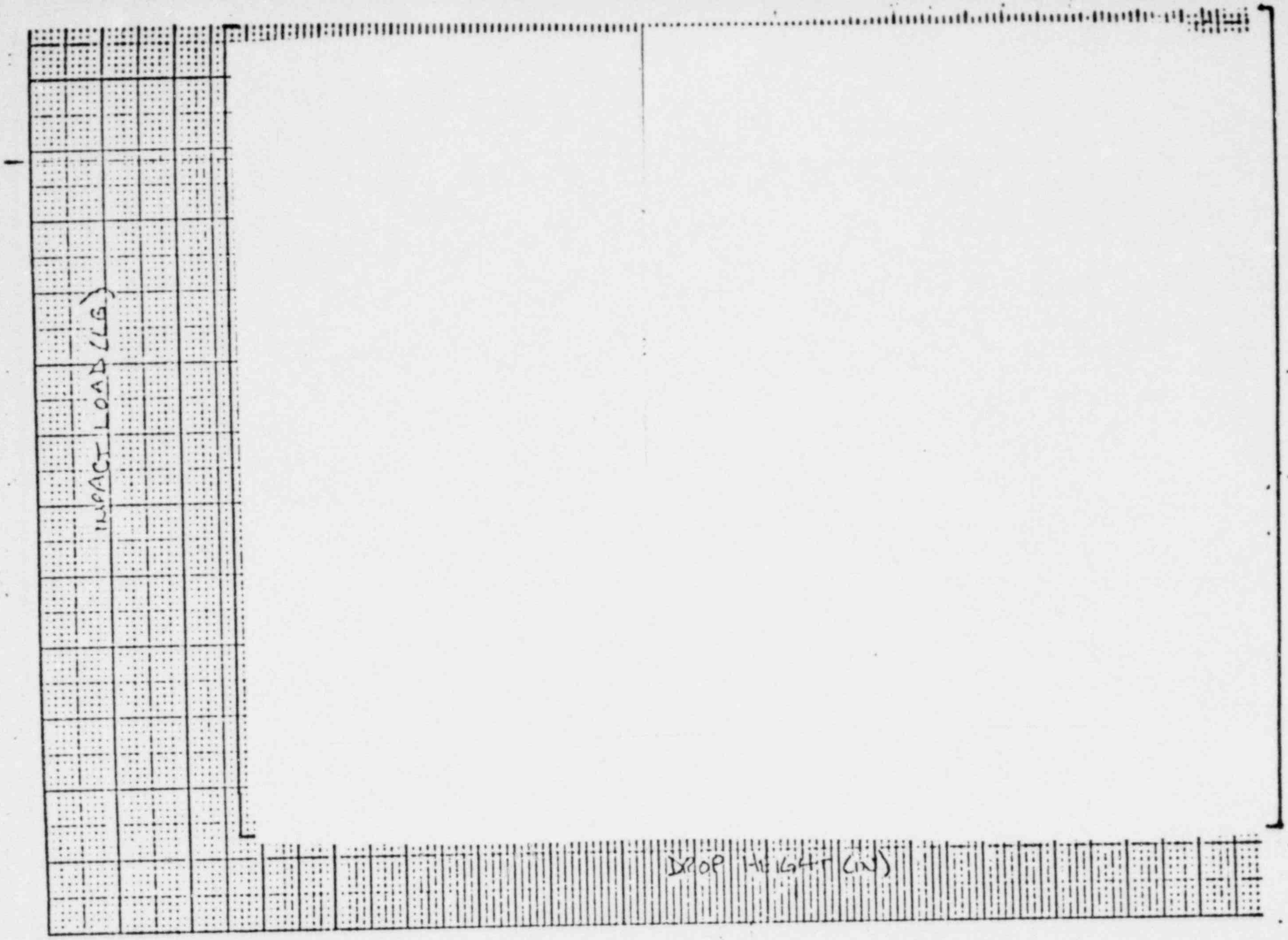
COMPARISON OF TYPICAL LOAD DEFLECTION
CHARACTERISTICS



4,5

PROPRIETARY INFORMATION

HID-2 ONE SIDED IMPACT



4,5

PROPRIETARY INFORMATION

HID-1 ONE SIDED IMPACT

SSE

GUIDE TUBE STRESS CALCULATION

STRUCTURAL ANALYSIS

INPUT

1. HORIZONTAL SSE DEFLECTED SHAPE
2. VERTICAL SSE LOADS
3. NORMAL OPERATING LOADS

→ FUEL ASSEMBLY STRESS ANALYSIS → SSE STRESS INTENSITIES

OUTLET BREAK

GUIDE TUBE STRESS CALCULATION

STRUCTURAL ANALYSIS

INPUT

1. LOCA OUTLET BREAK DEFLECTED SHAPES
2. LOCA OUTLET BREAK VERTICAL LOADS
3. NORMAL OPERATING LOADS

→ FUEL ASSEMBLY STRESS ANALYSIS → LOCA OUTLET BREAK STRESS INTENSITIES

COMBINED SSE/LOCA

GUIDE TUBE STRESS CALCULATION

FUEL ASSEMBLY

STRESS ANALYSIS

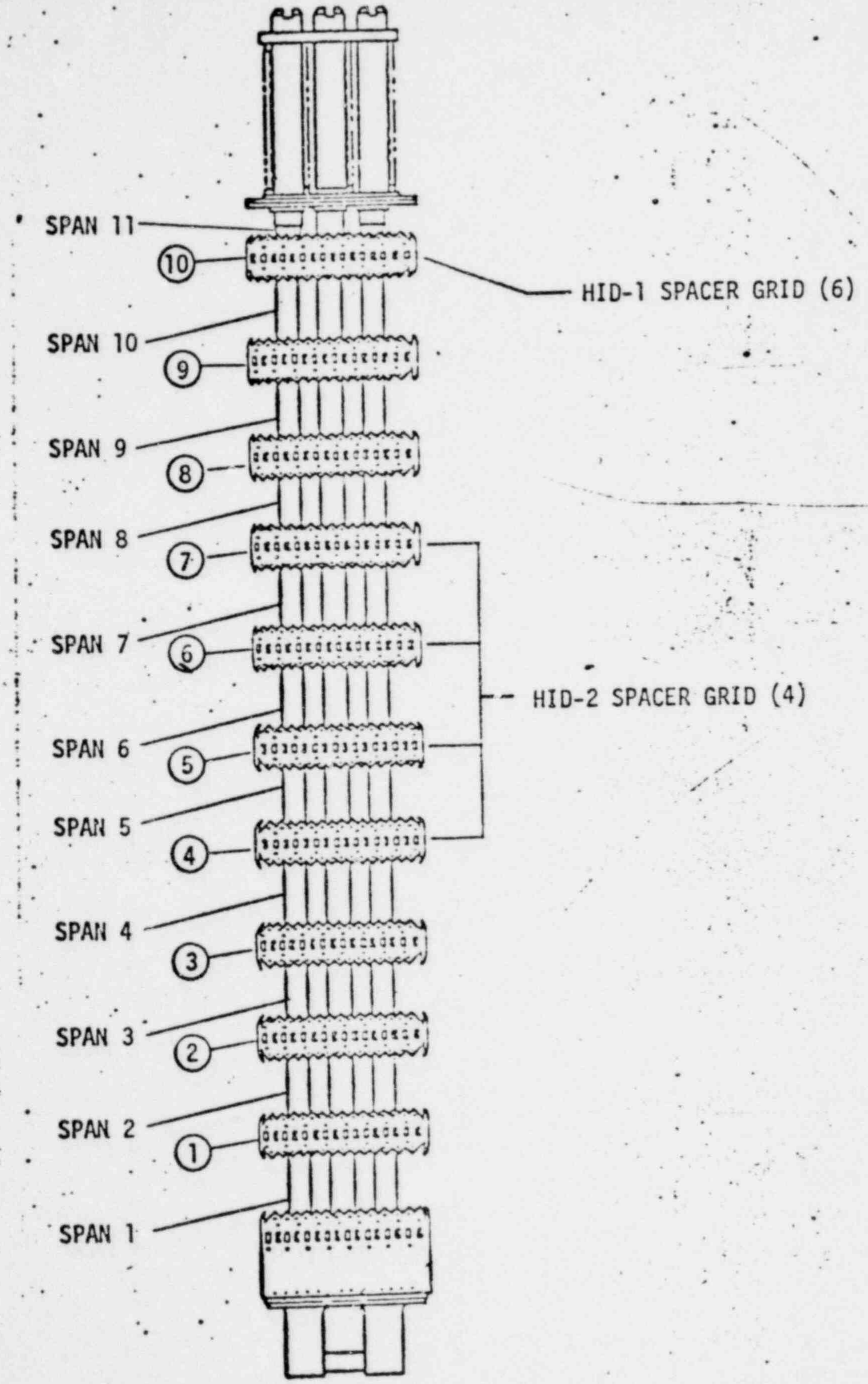
1. LOCA INLET BREAK STRESS INTENSITIES
2. SSE STRESS INTENSITIES
3. LOCA OUTLET BREAK STRESS INTENSITIES

→ SRSS AT COMMON ASSEMBLY LOCATIONS → COMBINED SSE/LOCA GUIDE TUBE STRESS INTENSITIES

Faulted Condition Criteria Summary

Component	Statement of Criteria	Numerical Limit
1. End Fitting Castings	$P_m \leq 2.4\ S_m$ $P_b + P_m \leq F_s \times 2.4\ S_m$	
2. Upper End Fitting Posts	$P_m \leq 2.4\ S_m$ $P_b + P_m \leq F_s \times 2.4\ S_m$	
3. Upper End Fitting Springs	Calculated Shear Stress Not to Exceed Minimum Yield Stress in Shear	
4. Guide Tubes	$P_m \leq .7\ S_u$ $P_b + P_m \leq F_s \times .7\ S_u$ $F_s = 1.39$	
5. Spacer Grids	Impact Load Less Than Tested Grid Strength at Temperature	
6. Fuel Rods	$P_m \leq S_y$ $P_b + P_m \leq F_s \times S_y$ $F_s = 1.36$	

3,4,5


SPAN 11
10
HID-1 SPACER GRID (6)
SPAN 10
9
SPAN 9
8
SPAN 8
7
SPAN 7
6
HID-2 SPACER GRID (4)
SPAN 6
5
SPAN 5
4
SPAN 4
3
SPAN 3
2
SPAN 2
1
SPAN 1

GUIDE TUBE STRESS (PSI)

DBE

	CALCULATED	ALLOWABLE @ 650°F
P_m	[	] 3,4,5
$P_m + P_b$		

LOCA

	CALCULATED	ALLOWABLE @ 650°F
P_m	[	] 3,4,5
$P_m + P_b$		

COMBINED DBE AND LOCA

	CALCULATED	ALLOWABLE @ 650°F
P_m	[	] 3,4,5
$P_m + P_b$		

SPACER GRID IMPACT LOADS (LBS)

DBE

HID-1		HID-2	
CALCULATED	ALLOWABLE @ $600^{\circ}F$	CALCULATED	ALLOWABLE @ $600^{\circ}F$

3,4,5

LOCA

HID-1		HID-2	
CALCULATED	ALLOWABLE @ $600^{\circ}F$	CALCULATED	ALLOWABLE @ $600^{\circ}F$

3,4,5