SAN ONOFRE UNITS 2 AND 3

DOCKETS 50-361 AND 50-362

CEN-140(S)-NP

DATA TRANSMITTAL FOR SCE FUEL AUDIT ANALYSIS

OCTOBER 10, 1980

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STATIC & DYNAMIC FUEL ASSEMBLY TEST DATA

ORM EG&G-2374
Rev. 6-77)

VENDOR DATA REQUEST FORM

TEST DATA				
TYPE		AXIAL	LATERAL	DESIRED FORM
FORCE-DEFLECTION (STATIC)		FIGURE 4	FIGURE 3	PLOTS
MODE SHAPES	1st 5 LATERAL		FIGURE 1	AMPLITUDE AT GRIDS PLOTS
FREQUENCIES	1st 5 LATERAL		TABLE 1	TABLE
DROP TEST FORCE-TIME	+ DROP HEIGHT	FIGURES 5,6		PLOTS
INTERNAL ROD TO GRID IMPACT STIFFNESS			TABLE 3	TABLE
EXTERNAL GRID IMPACT STIFFNESS			TABLE 3	TABLE
BEAM-COLUMN RESULTS		TABLE 6 FIGURES 8,9		DISCUSSION TABLE OR PLOTS
				DISCUSSION TABLE OR PLOTS
GRID-ROD FRICTION		TABLE 4		TABLE
GRID CRUSH STRENGTH (IMPACT)			TABLE 5	TABLE

DISCUSSION OF LATERAL DIRECTION TEST DATA

In the information that follows, spacer grid elevations are always given with respect to the bottom of the lower end fitting. Most of the tests were run in air at room temperature (70°F). Some information is provided in water at room temperature.

For the forced vibration test program the fuel assembly was supported in special fixturing which simulated reactor end support conditions. The fuel assembly was preloaded in the axial direction by compressing the holddown springs 3/8 inch. Sinusoidal excitation was applied from a hydraulic shaker by a rod link to the simulated core support plate which was resting on rollers. The simulated fuel alignment plate remained fixed during the test program. For the water environment tests, a cylinder with a 30 inch I.D. was installed over the fuel assembly. The water level was held above the simulated fuel alignment plate during the in-water test program. The lateral displacement of the assembly was monitored at every spacer grid.

In Table 1, the first five fuel assembly natural frequencies and associated critical damping ratios are listed. These values were taken from a forced vibration test. The assembly was in a simulated "end of life" condition during this test series. The values are for the largest double amplitude input used in each mode.

Fuel assembly mode shape data are given in Table 2. Plots of this data are provided in Figure 1 (a) - (e). This data provides an envelope of the peak response of the fuel assembly at each resonant frequency and not a true mode shape. The envelope of peak response is the maximum response of each grid without regard to the phase between the response and the input. The divergence from a true mode shape is particularly evident near the lower end fitting where the input excitation is applied. However, these data are the best available. Refer to the static lateral deflection shape discussed below for guidance in approximating the true first mode shape. Mode shapes are not used directly in our modelling effort and therefore we have never attempted to determine exact mode shapes.

The static lateral displacement shape of a fuel assembly with a load applied to the central grid is given in Figure 2. This figure is based on many sets of displacement shape data with central grid displacements of 0.4 inches to 1.6 inches.

The lateral load-deflection characteristics of a fuel assembly are shown in Figure 3. The lateral load was applied to the central grid (grid #6) and the deflection of that grid was monitored.

TABLE 1. FUEL ASSEMBLY FREQUENCY AND DAMPING TEST DATA

ALL MID-1 GRID 16X16 FUEL ASSEMBLY
TR-ESE-304 : TESTS 3-22

A) AIR ENVIRONMENT IN ROOM TEMPERATURE

MODE	NATURAL FREQUENCY (HZ)	DAMPING RATIO (%)	DA INPUT DISPL. (IN)	RESPONSE AMPLITUDE (IN)
1				
2				
3				
4				
5				

B) WATER ENVIRONMENT IN ROOM TEMPERATURE

MODE	NATURAL FREQUENCY (HZ)	DAMPING RATIO (%)	DA INPUT DISPL. (IN)	RESPONSE AMPLITUDE (IN)
1				
2				
3				
4				
5				

NOTES:

(1): DA=DOUBLE AMPLITUDE
(2): NA=NOT AVAILABLE
(3): FREQUENCY AND DAMPING DATA TAKEN FROM THE LARGEST DA INPUT TEST PERFORMED FOR EACH MODE. THESE DATA FALL IN THE LARGE AMPLITUDE ASYMPOTIC REGIONS OF THE FREQUENCY AND DAMPING CURVES.

TABLE 2. SUMMARY OF ENVELOPES OF RESPONSE OF TESTED FUEL ASSEMBLIES

FUEL BUNDLE MODE SHAPE TEST DATA (1)

MODES SHAPES IN AIR AT ROOM TEMPERATURE
16X16 (ARKANSAS) FUEL BUNDLE
TR-ESE-110 ; TEST SERIES NO 1 ; 3/16 DA INPUT DISPLACEMENT

ELEVATIONS ARE GIVEN WITH RESPECT TO THE BOTTOM SURFACE OF THE LOWER END FITTING (TOP OF SIMULATED CORE SUPPORT PLATE). THE DISTANCE BETWEEN THE TOP OF THE SIMULATED CORE SUPPORT PLATE AND THE BOTTOM OF THE SIMULATED FUEL ALIGNMENT PLATE IS 175.053 INCHES.

GRID NO	ELEVATION (IN),(2)	MODE 1 (IN)	MODE 2 (IN)	MODE 3 (IN)	MODE 4 (IN)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

Notes: (1) 4 mode shapes were obtained during this test series

FUEL BUNDLE MODE SHAPE TEST DATA

IN AIR AT ROOM TEMPERATURE
ALL MID-1 GRID 16X16 FUEL ASSEMBLY
TR-ESE-304 ; 1/8" DA INPUT DISPLACEMENT

GRID NO	ELEVATION (IN)	MODE 5
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

FIGURE 1a

FUEL MODE SHAPE TEST DATA

IN AIR AT ROOM TEMPERATURE ; TR-ESE-110

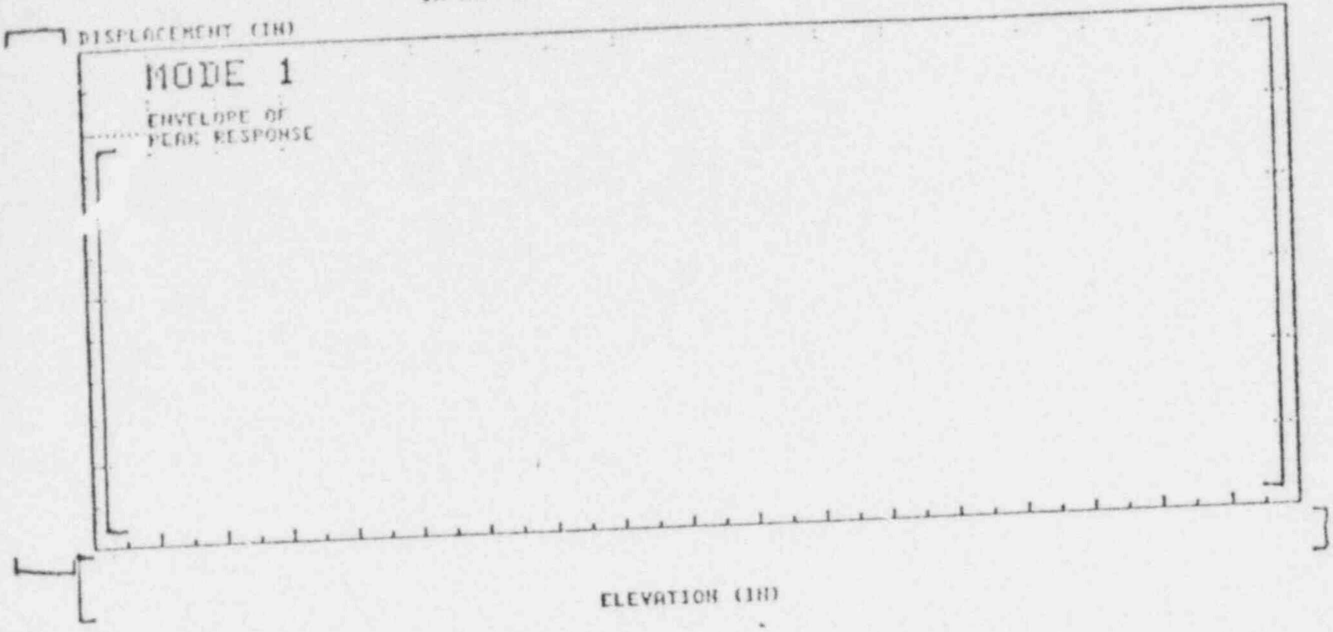


FIGURE 1b

FUEL MODE SHAPE TEST DATA

IN AIR AT ROOM TEMPERATURE ; TR-ESE-110

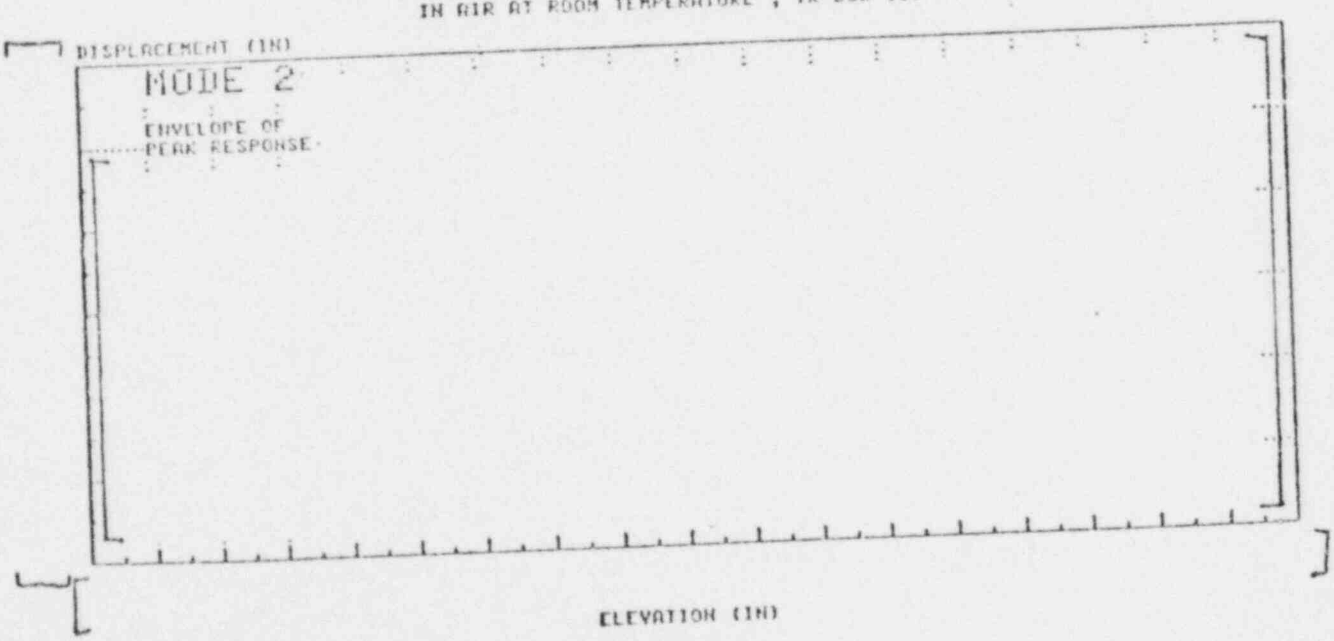


FIGURE 1c

FUEL MODE SHAPE TEST DATA

IN AIR AT ROOM TEMPERATURE ; TR-ESE-110

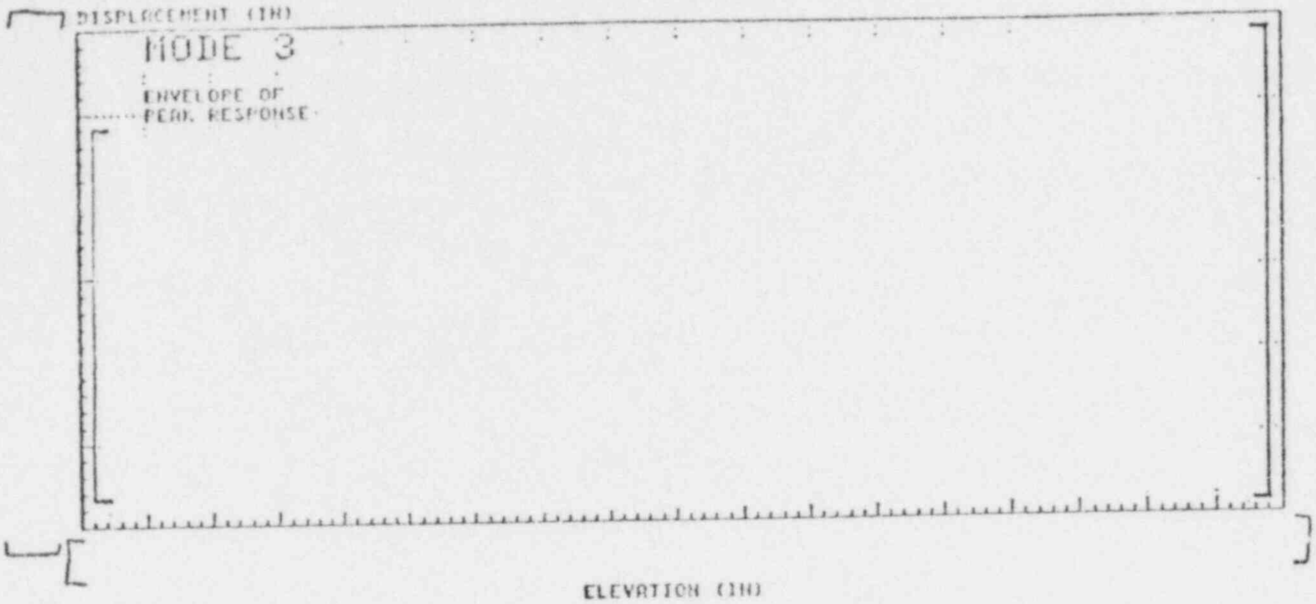


FIGURE 1d

FUEL MODE SHAPE TEST DATA

IN AIR AT ROOM TEMPERATURE ; TR-ESE-110

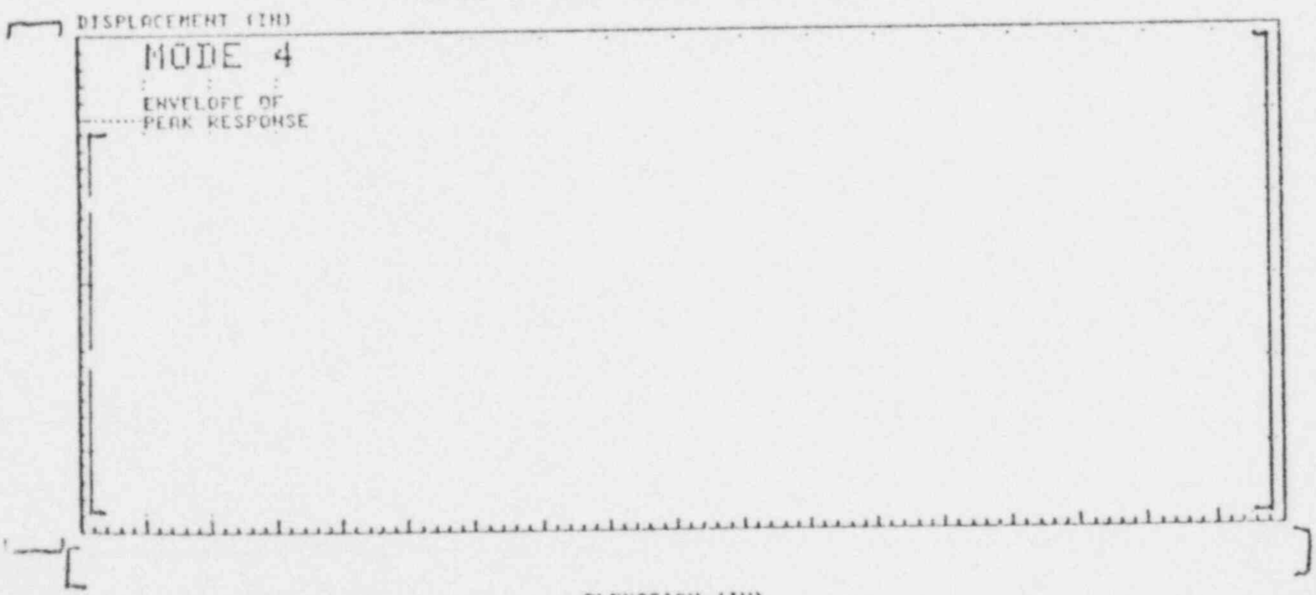


FIGURE 1e

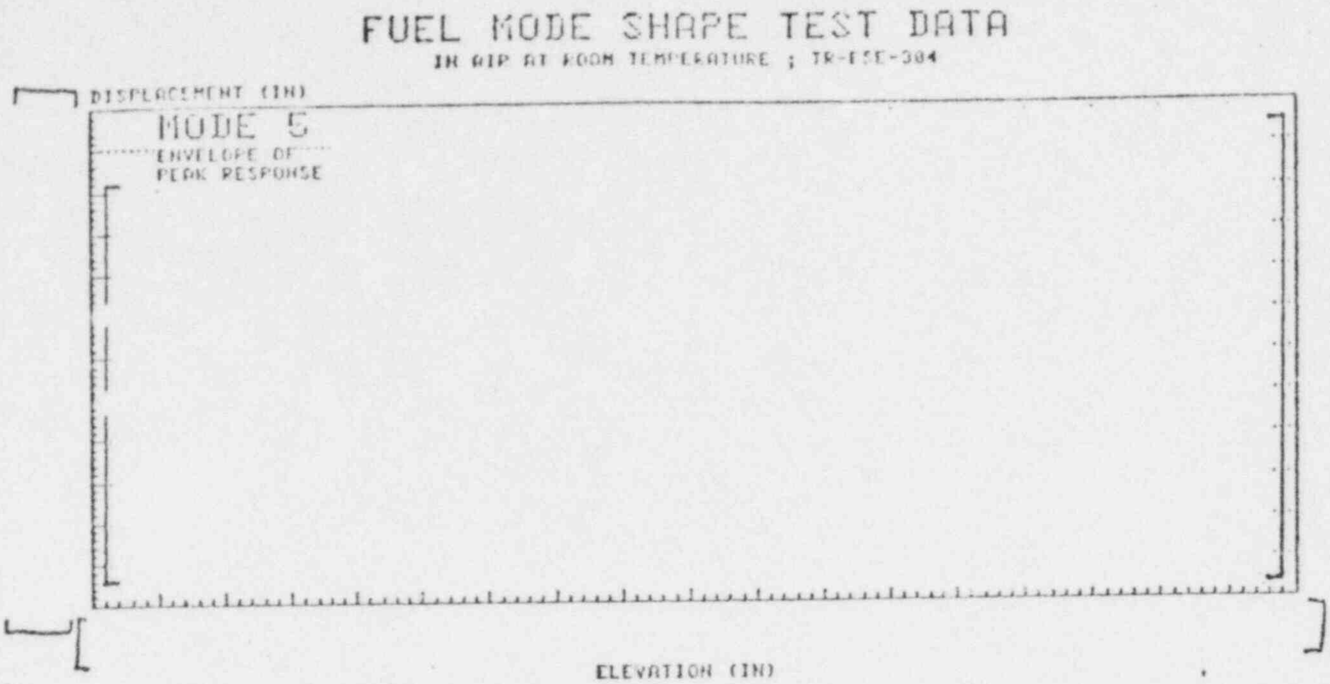
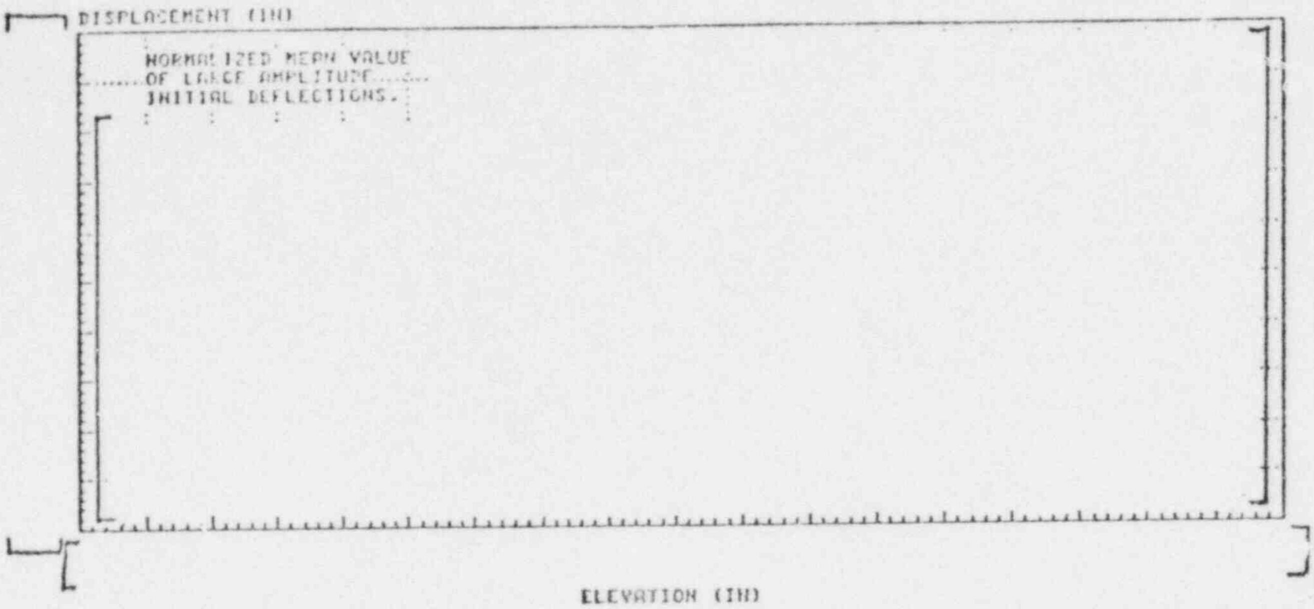

FUEL MODE SHAPE TEST DATA
IN AIR AT ROOM TEMPERATURE ; TR-ESE-304
DISPLACEMENT (IN)
MODE 5
ENVELOPE OF
PEAK RESPONSE
ELEVATION (IN)

FIGURE 2

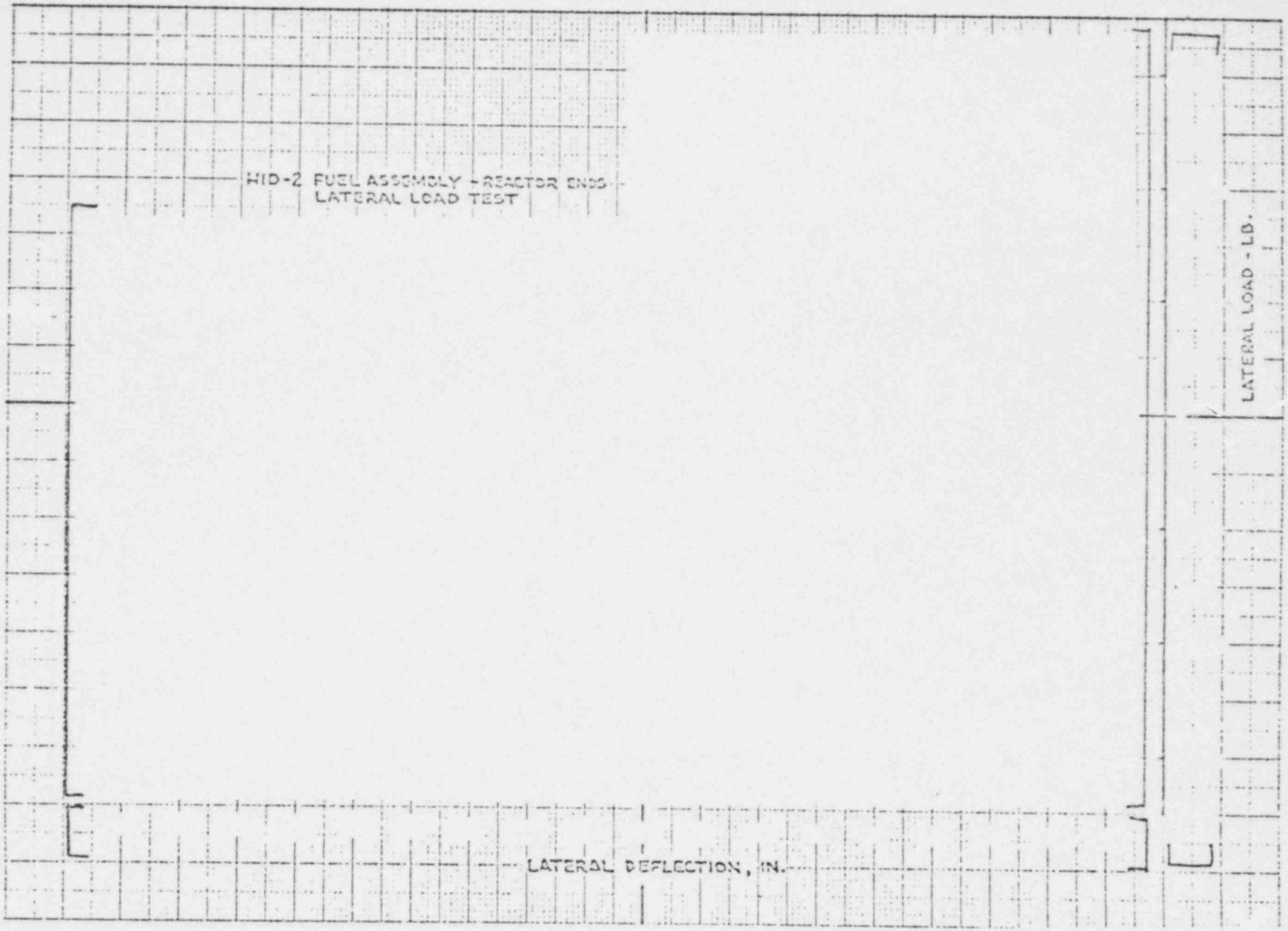
SCE FUEL STATIC DISPLACEMENT SHAPE

IN AIR AT ROOM TEMPERATURE ; TR-ESE-353



S C E F U E L B U N D L E S T A T I C S H A P E
NORMALIZED MEAN VALUE FROM LARGE AMPLITUDE TEST DATA
TR-ESE-353 ; 0.4 - 1.6 IN. INITIAL DEFLECTION

GRID NO.	ELEVATION (IN)	DEFLECTION (IN)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		



HID-2 Fuel Assembly Lateral Test Hysteresis

FIGURE 3

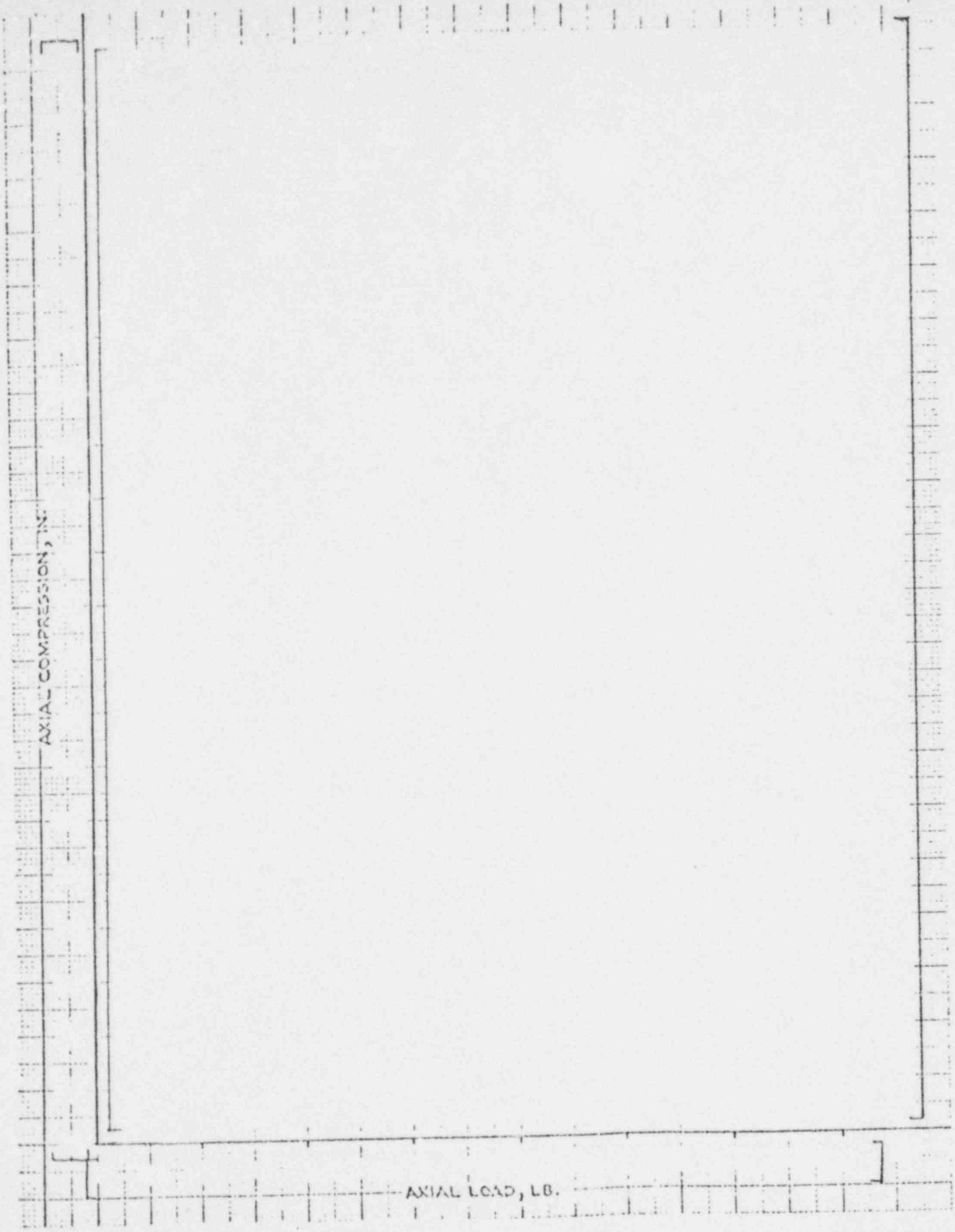
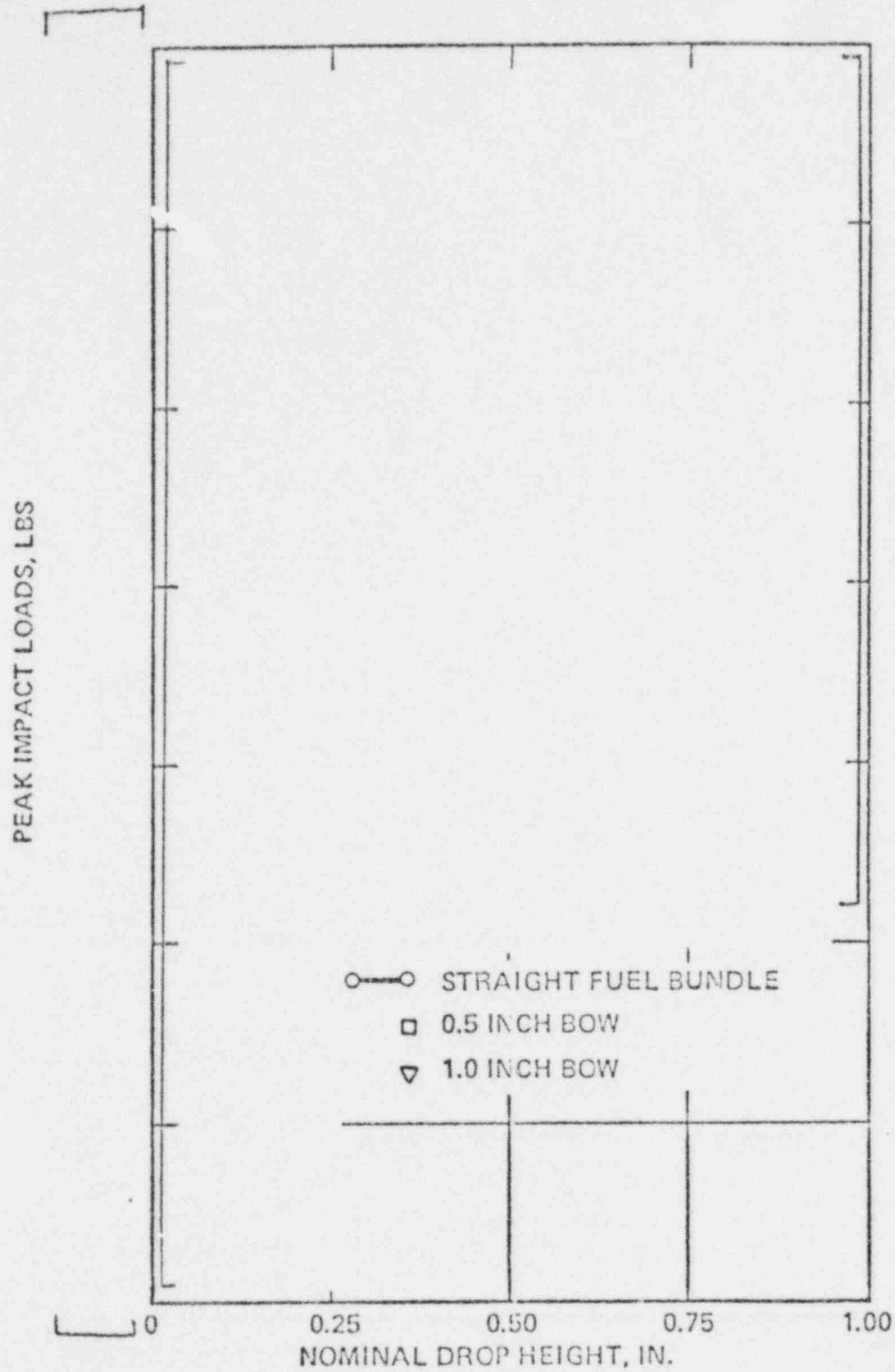


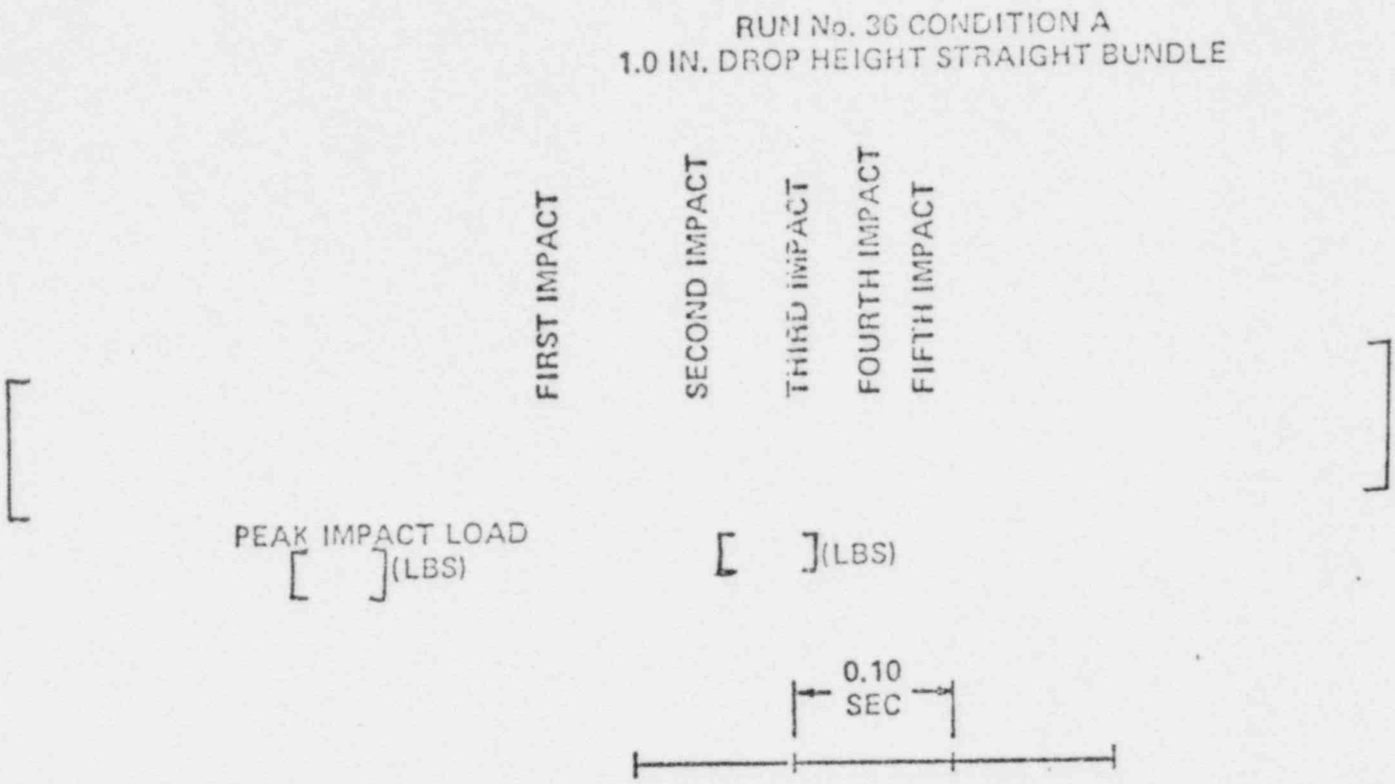
FIGURE 4 : HID-2 Fuel Assembly Axial Load versus Axial Compression

FIGURE 5



MAXIMUM IMPACT LOAD vs DROP HEIGHT
TEST CONDITION B
WITH HOLDDOWN SPRINGS

FIGURE 6



IMPACT LOAD TIME HISTORY CHARACTERISTICS
1 INCH DROP HEIGHT
STRAIGHT FUEL BUNDLE
CONDITION A

TABLE 3

GRID IMPACT STIFFNESSES (HOT)

1.

	One-Sided (Internal Rod to Grid Impact Stiffness) (#/in)	Thru (External Grid Impact Stiffness) (#/in)
HID-2	[	[
HID-1	]	]

2. Coefficient of Restitution = [ ] (in place of impact damping)

3. Uniform Beam Models of Fuel (HOT)

EI = [ ] in^2-lb

K_{upper} = [ ] in/lb/rad

K_{lower} = [ ] in/lb/rad

K_{upper} = Torsional Spring Representing Upper End Fitting

K_{lower} = Torsional Spring Representing Lower End Fitting

TABLE 4

GRID-ROD FRICTION

BOL (HOT)	Force Per Rod Per Grid (All Grids Same)	[
EOL (HOT)	Force Per Rod at Top Zircaloy Grid	
	Force Per Rod at Lower Inconel Grid	
	Remaining Grids	]

ASSUME STATIC FRICTION FORCE EQUALS DYNAMIC FRICTION FORCE

TABLE 5

Spacer Grid Crush Strength

(to be supplied following completion of production testing)

BEAM COLUMN RESULTS

The following data gives the results of a test program designed to determine the dynamic response characteristics of a bowed 16 x 16 fuel assembly (see Fig.7) subjected to axial impact loadings. The experiments were performed in air with simulated reactor end conditions. The fuel assembly was incrementally deflected and raised, then released, and allowed to strike a rigid impact base. For each drop cycle the impact load, the displacement, the velocity and acceleration characteristics at the lower end fitting location were to be monitored as a function of time. In addition, time history traces of the lateral deflection behavior at three spacer grid locations were developed. A tabular summary of the lateral amplitude excursions as measured from the LVDT traces is presented in Table 6.

Figure 8 summarizes the effect of axial impact on lateral deflection. Drop height versus the percentage increase of lateral deflection from the fuel assemblies initial bow are presented for a 1.0" bow (at midspan). Tnree spacer grid elevations are considered. Fuel assembly hysteresis and friction effects tend to mask the effects of axial loads on lateral deformation for initial bows of less than[ ]

Further test data corroboration of the minimal effect of axial loads on the lateral deformation of a fuel assembly is shown in Figure 9. Figure 9 indicates a less than[ ]increase in lateral deformation due to a[ ]lb. axial load statically applied to an initially deformed (0.5") 16 x 16 fuel assembly.

TABLE 6

Bow	Spacer Grid No.	Drop Height 0.25"	0.5"	0.75"
		Lateral Amplitude Excursions (in.)		
0.5"	3			
1.0"				
0.5"	6			
1.0"				
0.5"	9			
1.0"				

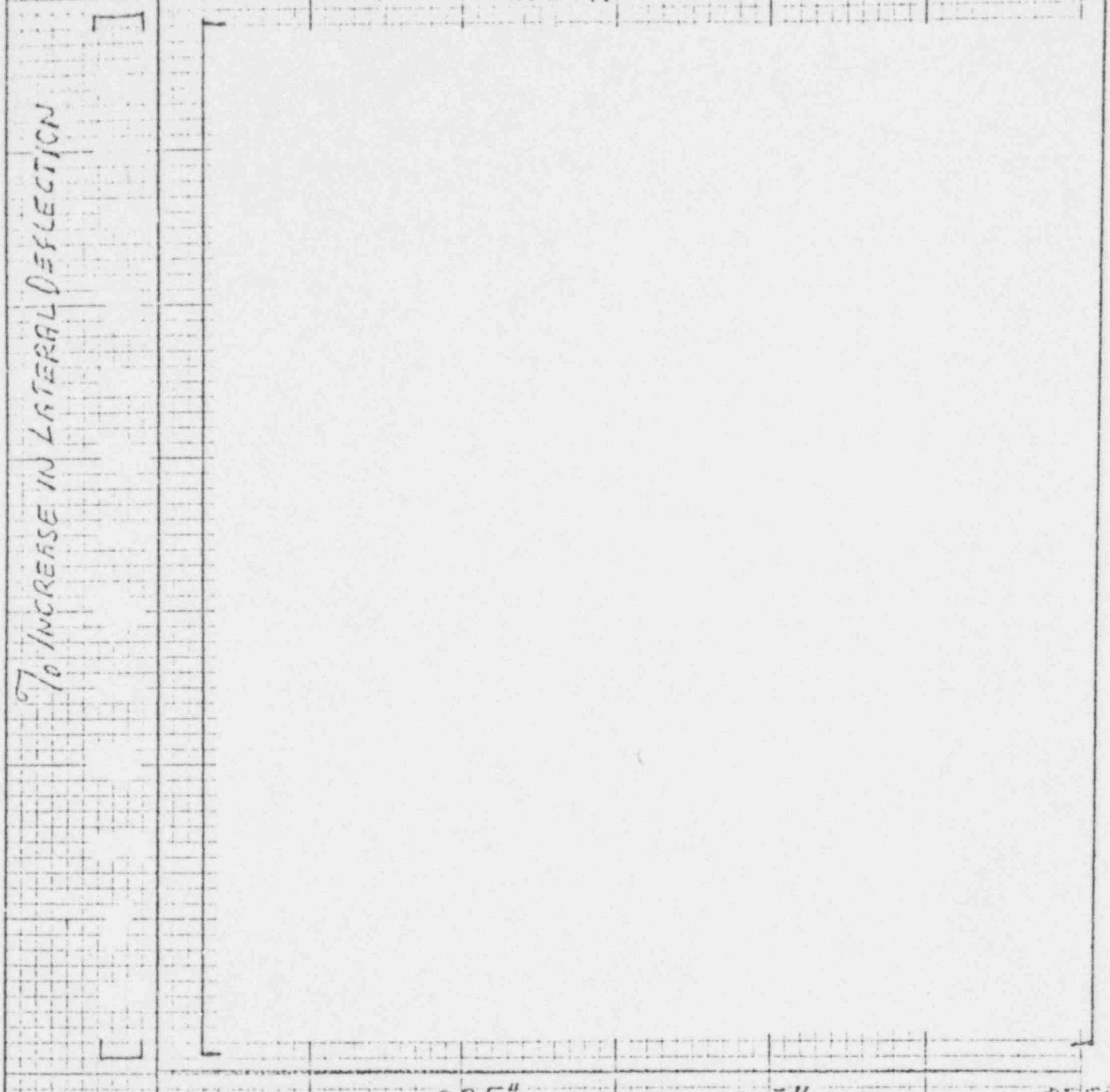
Figure 7

TEST SETUP 16 x 16 FUEL ASSEMBLY DROP TESTS

FIG. 8

DROP HEIGHT VS. % INCREASE IN LATERAL DEFLECTION

1" INITIAL BOW



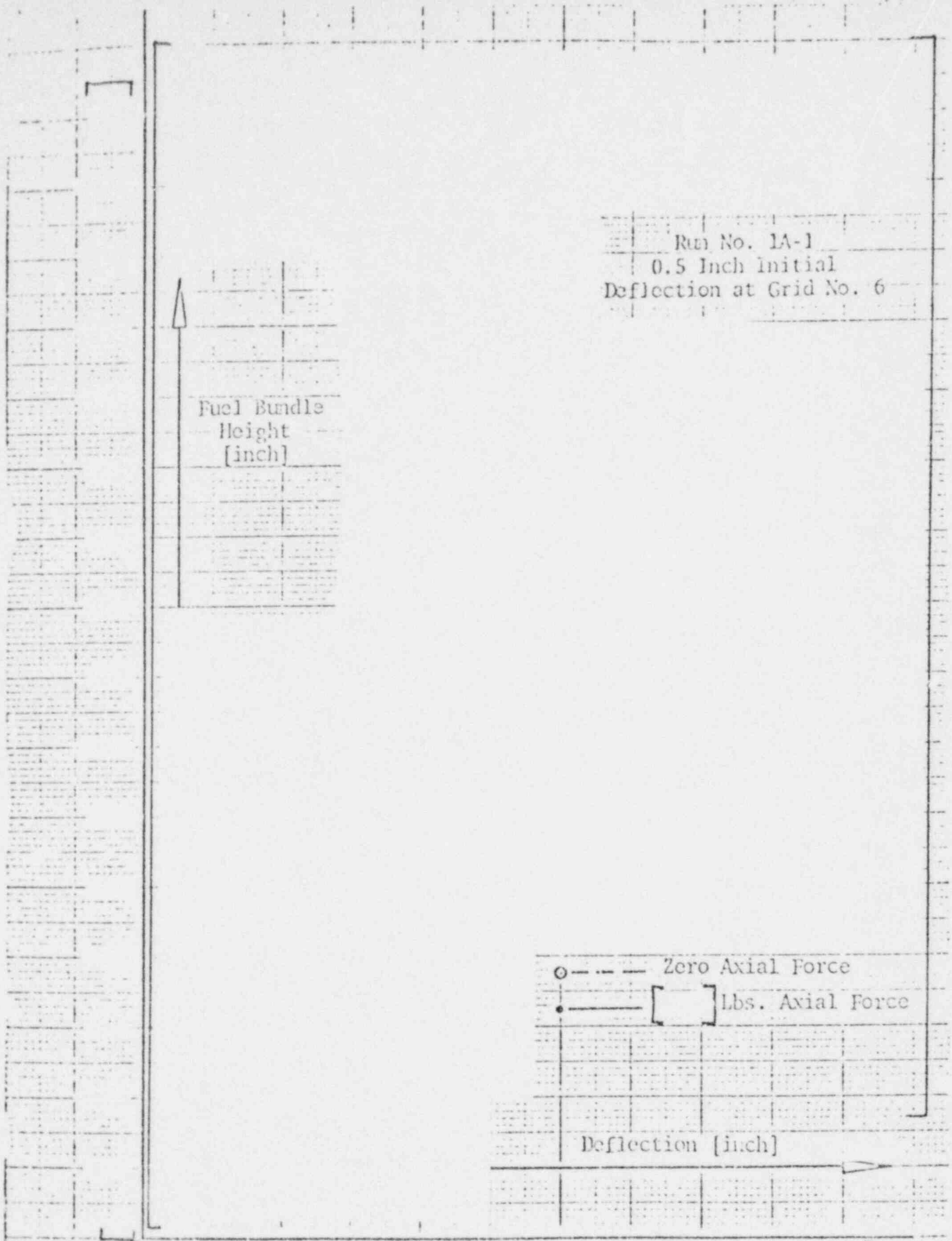


Figure 9

Fuel Bundle Deflection at Zero and at [ ] Lbs.
Axial Force for 0.5 Inch Lateral Displacement

FUEL ASSEMBLY MATERIAL DESCRIPTION

San Onofre Unit 2 - Vendor Data Request Form
Material Description

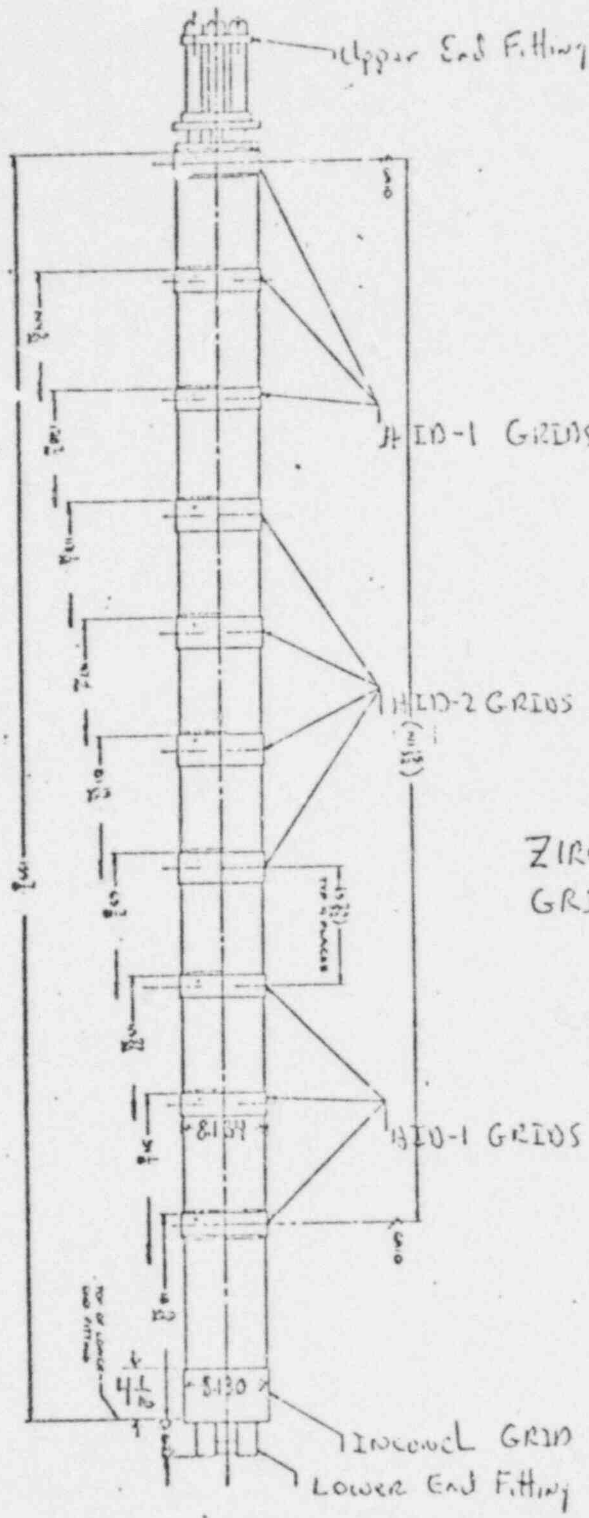
Component	Weight (lbs)	Center of Gravity (inches)	Type of Material	Stiffness and/or Preload
Fuel Rod	[ ]	Not Requested	• Clad & End Caps, Zr-4 • Plenum Spring, 302 SS • Spacers: Al_2O_3 • Fuel: Enriched UO_2	Not Requested
Spacer Grid	• HID-1: [ ] • HID-2: [ ] • Inconel w/o Skirt: [ ] • Inconel w Skirt: [ ]	Not Requested	• HID-1: Zr-4 • HID-2: Zr-4 • Inconel: Inconel 625	Not Requested
Top End Box, i.e , Upper End Fitting Assembly	[ ]	Not Requested	• Posts: 304 SS • Holddown Plate & Flow Plate: 304 SS Casting Type CF-8 • Holddown Springs: Inconel X-750	Not Requested
Bottom End Box, i.e., Lower End Fitting Assembly	[ ]	Not Requested	304 SS Casting Type CF-8	Not Requested
Fuel	[ ] per Rod [ ] per bundle	Not Requested	UO_2	Not Requested
Fuel Assembly, i.e., Fuel Bundle Assembly	[ ]	[ ]	• End Fittings: 304 SS • Guide Tube: Zr-4	Not Requested
Holddown Spring (5 Holddown Springs per Bundle)	[ ] per spring	Not Requested	Inconel X-750	• Stiffness per Spring: Cold [ ] lb/in Hot [ ] lb/in • Preload BOL Hot= [ ] lbs per spring

Miscellaneous Information

Requested at September 9, 1980 Meeting

1. Spacer grid axial spacing, outside dimensions, and assembly to assembly gap - Figure 10
2. Guide tube/upper end fitting connection - Figure 11
3. Guide tube/lower end fitting connection - Figure 12
4. Guide tube/spacer grid connection - Figure 13
5. Fuel rod/spacer grid interface - Figure 14
6. Upper end fitting/fuel alignment plate interface - Figure 15
7. Lower grid/lower end fitting connection - Figure 16
8. Guide tube details - Figure 17
9. Fuel rod details - Figure 18

FIGURE 10
Spacer Grid Information



ZIRC GRID to ZIRC
GRID GAP HOT 0.075"

FIGURE 11

Guide Tube/Upper End Fitting Connection

FIGURE 12

Guide Tube/Lower End Fitting Connection

[ ]

FIGURE 13

Guide Tube/Spacer Grid Connection

FIGURE 14

Fuel Rod/Spacer Grid Interface

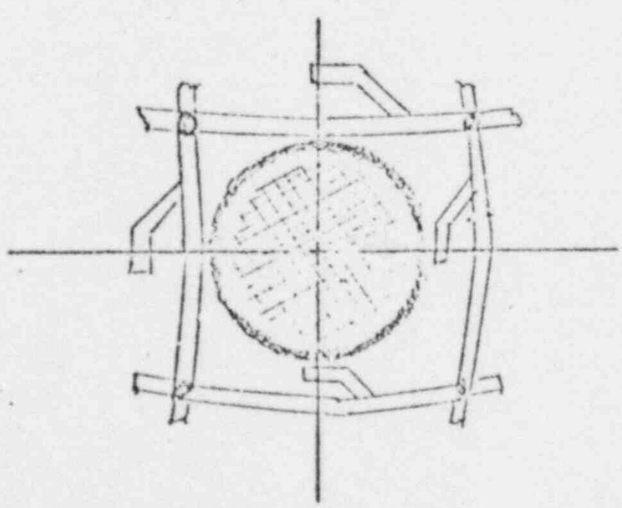


FIGURE 15

Upper End Fitting/Fuel Alignment Plate Interface

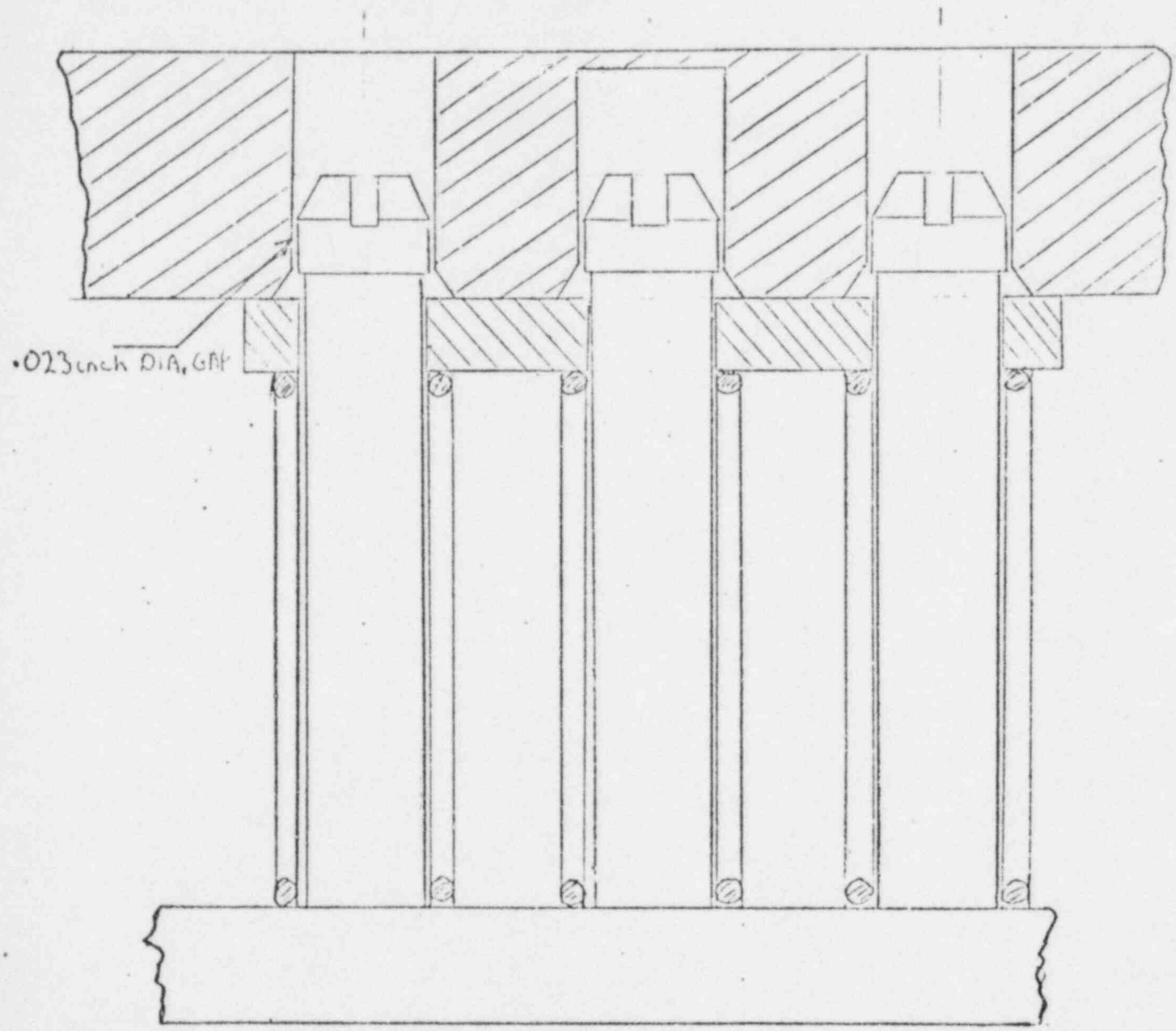


FIGURE 16

Lower Grid/Lower End Fitting Interface

FIGURE 17

Guide Tube Details

[ ]

Center Guide Tube

Outer Guide Tube

FIGURE 18

Fuel Rod Details