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MECHANICAL DESIGN AND TESTING OF DEVELOPMENT FUEL FOR CONSUMERS POWER BIG ROCK POINT REACTOR

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GEAP-3851
AEC Research and
Development Report

April, 1962

MECHANICAL DESIGN AND TESTING OF DEVELOPMENT FUEL FOR CONSUMERS POWER BIG ROCK POINT REACTOR

by

W. D. Fowler

U. S. Atomic Energy Commission
Contract No. AT(04-3)-361

ATOMIC POWER EQUIPMENT DEPARTMENT

GENERAL ELECTRIC

SAN JOSE, CALIFORNIA

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SECTION I

INTRODUCTION

The development and irradiation testing of low cost fuel fabrication processes and mechanical assembly designs are presently being pursued under the AEC-sponsored High Power Density Program. Under the program, the irradiation of prototype fuel assemblies holding promise of having reduced fuel fabrication costs, long fuel life, and high power density will first be conducted in the VBWR. Subsequently, irradiation of full-size assemblies will be conducted in the Consumers Big Rock reactor.

The development of fuel fabrication processes and fuel assembly designs having good cost reduction potential have been reported.[1-4] Irradiation in the VBWR of nine fuel assemblies containing these low cost features is in progress.[5] With the fabrication development program essentially complete, and the irradiation in VBWR well under way, there remains the design of fuel with low cost features for irradiation testing in the Consumers Big Rock reactor. The purpose of this report is to present a fuel assembly design having potential for reduced fuel fabrication costs to be irradiated in the Big Rock reactor at a power density of 45 kw/liter (average) and an exposure of 10,000 MWD/T (average).

SECTION II

SUMMARY

A fuel assembly design for the development fuel to be irradiation-tested in the Consumers Big Rock reactor under conditions of 45 kw/liter and 10,000 MWD/T has been completed. The design includes novel features that represent a 25 per cent reduction in fabrication costs. The fuel assembly design consists of an 11 x 11 array of fuel rods, free floating in a fuel assembly structure (see Figure 3-1). Design data for the fuel assembly are:

Cladding material	304 stainless steel
Cladding thickness (inches)	0.010
Fuel rods per assembly	
0.425 in. OD	109
0.320 in. OD	12
Fuel	UO_2
Enrichment (% U-235)	2.7% ± 0.050
UO_2 weight per assembly (pounds)	383-395
Average heat flux at 45 kw/l (Btu/hr-ft^2)	126,000
Water/fuel ratio	2.4
Hydraulic diameter (inches)	0.58

The development fuel offers the following advantages over the first core fuel design.

1. The individual fuel rods are free floating (not fixed at either end of the assembly), and therefore easily insertable or removable.

2. Spacers are of a single layer design not a part of or attached to the assembled fuel rods.

3. The design permits the use of fuel rods having variations in rod length of about 3/4 inch. This makes the design amenable to the use of rods fabricated by powder compaction techniques where the final lengths vary slightly.

4. The design permits the use of any type of end plug on the fuel rod without regard to attachment or location provisions to tie plates.

5. A simplified structure design that represents a 25 per cent cost reduction.

A dummy development fuel assembly was fabricated and successfully subjected to mechanical and flow tests. Three VBWR prototype assemblies containing features of the development fuel assembly design are presently undergoing irradiation testing. The tests are proceeding satisfactorily after 3000 MWD/T, as of May 1, 1962.

Eight development fuel assemblies of the design described are scheduled for delivery to the Big Rock reactor by December, 1962. Fuel rods for four assemblies will be fabricated by the swaged pellet

process. The swaged powder process will be used to fabricate fuel rods for the remaining four assemblies.

SECTION III

BIG ROCK DEVELOPMENT FUEL ASSEMBLY DESIGN DETAILS

The design of the developmental fuel for the Consumers Big Rock reactor must necessarily be within the parameters set by the physics, hydraulics, and heat transfer considerations established for the reactor first core. Within these boundary conditions, a set of criteria were defined for the developmental fuel.

3.1 Development Fuel Design and Performance Criteria

1. Low cost mechanical assembly structure to hold and space the fuel rods.
2. Individual fuel rods to be easily insertable and removable.
3. Relaxation of stringent tolerances on fuel rod length.
4. Elimination of threaded type end plug to reduce cost.
5. Utilization of cladding purchased to commercial tolerances and specifications.
6. Use of rod type, stainless steel clad, UO_2 fuel.
7. Attainment of 45 kw/liter (average) power density and 10,000 MWD/T (average) burnup.

3.2 Development Fuel Design Description

The final fuel design that evolved from the criteria listed above and from development and testing work is illustrated in Figure 3-1. Design drawings for the development fuel are shown in Appendix C.

Functionally, the component parts of the fuel assembly are shown in Figure 3-2, and break down into five areas:

Part	Function
Spacer	1. To laterally position the fuel rods with respect to each other, the corner angles, and the channel in which the bundle will be placed.
	2. To add stiffness to the corner angles and tie them together.
Corner Angles	1. To transmit tensile loads from the support to the weldment-retainer which forms the handle for the bundle.
	2. To axially position the spacers.
	3. To provide protection for the fuel rods during insertion and removal from channels by being the outermost part of the fuel bundle.
	4. To assist in controlling corner rod flux peaking.

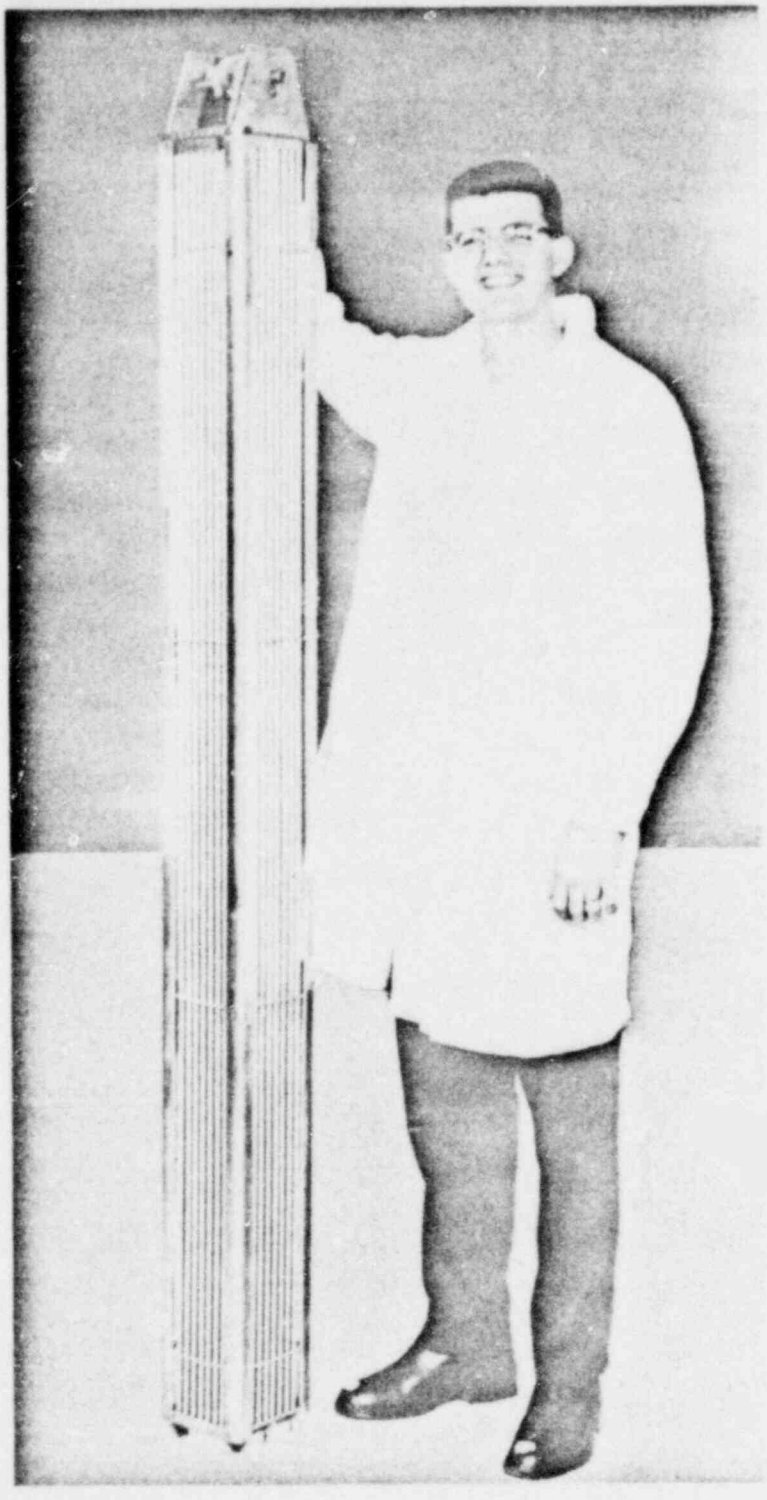

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FIGURE 3-1
BIG ROCK DEVELOPMENT FUEL ASSEMBLY

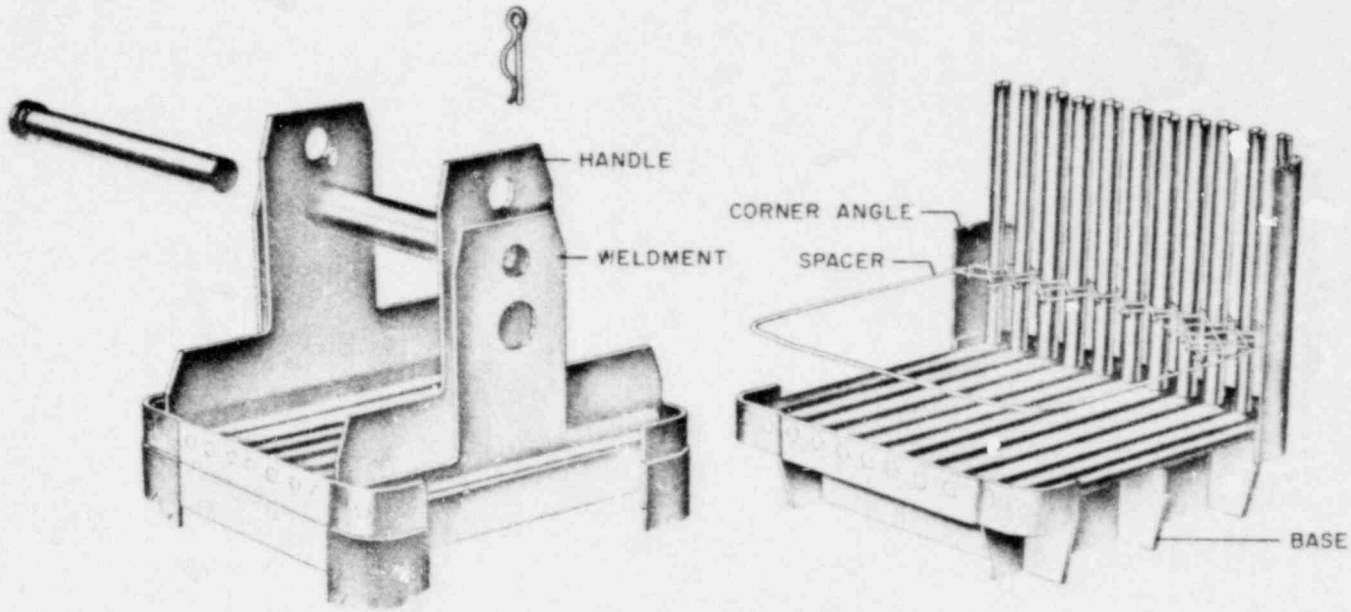

FIGURE 3-2
MECHANICAL ARRANGEMENT OF COMPONENT PARTS

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Part	Function
Support	1. To support the weight of all fuel rods and transmit this force to the corner angles.
	2. To prevent individual fuel rods from dropping out of the bundle.
Weldment	1. To provide a handle for the fuel bundle without obstructing fuel rod removal.
	2. To transmit the weight of the fuel rods from the corner angles to the lifting device.
	3. To position and capture the retainer.
Retainer	1. To prevent withdrawal of fuel rods.
	2. To add stiffness to the weldment.

3.3 Fuel Testing

The fuel assembly design shown in Figure 3-1 has been subjected to mechanical and flow testing. Specific tests, which include handling, tensile, wear, and drop tests, are discussed in detail in Appendix A. The results of these tests were satisfactory, and confirmed the final design of the Big Rock developmental fuel.

In-reactor testing of VBWR prototypes of the Big Rock development fuel design is presently in progress. The design of the VBWR prototype

Big Rock development fuel is shown in Figure 3-3. Three fuel assemblies are currently in the VBWR, with three more similar assemblies scheduled for insertion by mid-1962. The leading assembly has attained a burnup of about 3000 MWD/T, and operated at a power density of 97 kw/liter, as of May 1, 1962.

3.4 Development Fuel Design Data

Design data for the Big Rock development fuel are presented in Table 3-1. In selecting 0.010-inch thick 304 stainless steel as the fuel element cladding, it was necessary to make a slight departure from the "free standing"* criterion normally used in fuel design. The use of thin cladding necessarily dictates that the UO_2 fuel column assists in preventing the cladding from wrinkling or collapsing due to reactor pressure. Attendant with the use of thin cladding is the requirement that the clad have sufficient strength at the end of fuel irradiation life to resist deformation from internal pressure due to fission gas. Table 3-2 presents data that show the stress due to internal pressure in 10-mil clad fuel rods of the development rods to be within acceptable levels after 10,000 MWD/T burnup.

Detailed design calculations supporting Table 3-2 are presented in Appendix B, along with clad stress nomographs that show the effect exposure, fission gas release, gas collection volume, and heat flux exert on the clad stress at zero reactor pressure. Two types of fuel are presented in Table 3-2, in that the first loading of development fuel in the

* The "free-standing" criterion is based on the tubular cladding material not collapsing as a result of 125 per cent or rated reactor pressure when the tube is assumed to be empty.

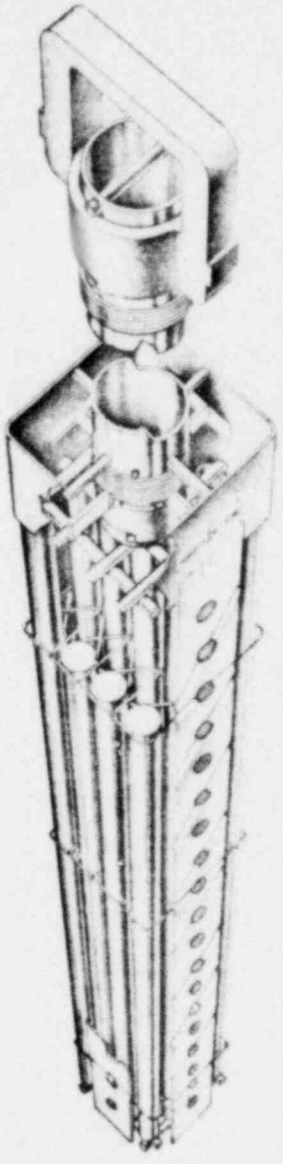

FIGURE 3-3
VBWR PROTOTYPE OF BIG ROCK
DEVELOPMENTAL ASSEMBLY

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TABLE 3-1

DESIGN DATA FOR
THE BIG ROCK DEVELOPMENT FUEL ASSEMBLY

Water/fuel ratio	2.4
Cladding material	304 St. Steel
Cladding thickness (inches)	0.010
Fuel rods per bundle	121
0.425" OD	109
0.320" OD	12
Fuel	UO_2
Enrichment (% U-235)	2.7 ± 0.050
Heat transfer area per bundle (ft^2)	76.6
Active fuel length (inches)	70.0
Core volume per bundle (liters)	63
UO_2 weight per bundle (pounds)	383 - 395
Kilograms of U per bundle	153 - 158
Kilograms of U-235 per bundle	4.14 - 4.26
Average heat flux at 45 kw/l (Btu/hr-ft^2)	126,000
UO_2 cross-sectional area/bundle ($in.^2$)	14.9
Moderator area per bundle ($in.^2$)	35.8
Hydraulic diameter (inches)	0.58
Clad area/UO_2 area	0.105

Big Rock reactor will contain both swaged pellet and swaged powder fuel.

Maximum UO_2 temperature has not been used as a primary criterion in this design. It was included in the design as a secondary factor since the UO_2 temperature does affect the mean fission gas temperature in the powder fuel rods, and the gas temperature, in turn, affects the clad stress criteria stated above.

TABLE 3-2

CLAD STRESS AT THE END OF FUEL LIFE (10,000 MWD/T) FOR PELLET AND COMPACTED POWDER TYPE FUEL

Type of UO_2	Pellets		Compacted Powder	
Rod diameter (inches)	0.320	0.425	0.320	0.425
Mean fission gas temperature (°R)	700	700	800	800
Internal pressure (psi)	1550	1550	850	865
Pressure stress in clad (psi)	24,000	32,300	13,000	18,000
Minimum Y.S. of clad @ 300 °F	34,400	46,000	18,900	25,800
Safety margin $\left[\frac{Y.S.}{\sigma}\right] - 1$	43%	43%	43%	43%

3.5 Advantages of the Design

1. The design permits the use of fuel rods having variations in rod length of approximately 3/4 inch. This feature makes the design acceptable for fuel rods fabricated from centerless-ground fuel pellets, swaged-over pellets, vibratory-compacted

UO_2 powder, swaged powder, or Calrod rolled powder. None of these processes is expected to yield fuel rods having more than a 3/4-inch length variation.

2. The removal and replacement of individual fuel rods is accomplished with relative ease. This is an important advantage for the Big Rock development fuel where frequent gamma-scans will be performed on individual fuel rods to determine the actual power profile within the fuel bundle. Also, it has the advantage of permitting the reloading of the assembly structure with fresh fuel, if this is desired. In addition, it would be possible to replace some fuel rods in each bundle with poison to hold down the reactivity in a new core until equilibrium is reached. Having reached the equilibrium condition, the poison rods could be removed and replaced with normal fuel bearing rods.

3. Any type of end plug may be used on the fuel rod without regard to attachment or location provisions to tie plates as long as the end closure diameter is not larger than the clad OD. For the design presented here, inexpensive cold-drawn hemispherical end plugs are used.

4. Low fuel assembly structure costs are possible as a result of eliminating castings and the need for the fuel rods to be a structural part of the assembly. Comparison of fabrication

costs shows that the development fuel assembly design represents a cost saving potential of 25 per cent over the first core fuel design.

SECTION IV

CONCLUSIONS

Based on the data presented in Section III, the Big Rock development fuel design shown in Figure 3-1 fulfills the program objectives for a fuel assembly holding promise of having reduced fuel fabrication costs, long fuel life, and capability of operating at high power density.

SECTION V

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APPENDIX A

TESTING

Various mechanical tests were performed, both on the fuel bundle components and on a full-size mockup, in order to simulate the mechanical operations to which the bundle will be subjected in actual service. The scope of these tests were such that the final design has been confirmed by way of testing in addition to analysis where it was reasonable, and by irradiation under conditions that simulated the Big Rock design when analysis was not feasible or where the cost of a detailed analysis exceeded the experiment cost.

A.1 Fuel Rod Vibration Testing

The single- and two-phase flow induced vibration that occurs in the fuel rods has been investigated by E. P. Quinn* at the Atomic Power Equipment Department, San Jose. Quinn's experiments indicate a mid-span amplitude for either swaged pellet or swaged powder fuel rods that is less than 0.001 inch.

It had been assumed at the outset of the design that the vibration amplitude would be held to less than 0.005 inch by adding more spacers if it was necessary. Since the 0.001 inch is much less than the 0.005 inch expected, the four-spacer design is adequate to hold the vibration amplitude well within reasonable limits.

---

* Report now in preparation.

APPENDIX A

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---

* Report now in preparation.

A.2 Fuel Assembly Tensile Testing

A small prototype bundle was destructively tested to determine the force required to cause permanent deformation of the structure. The structure after the test is shown in Figure A-1.

It was interesting to note that permanent deformation occurred in three different places, at loads from 3000 to 3150 lb. Since the normal tensile load to be transmitted by the structure is 393 lb, the safety factor of 7.5 is considered more than adequate.

It should be noted that the final design does not have holes in the corner angles as shown in Figure A-1. The permanent deformation that occurred at a tensile load of 3000 lb was in the thin section presented between the edge of the angle and the holes in the angle. Since the only purpose of the holes in the angles was to present an opening where the corner fuel rods could be visually inspected without disassembly, it was decided that the inspection criterion would be omitted and the holes could be eliminated to further strengthen the structure and reduce the cost of the angles.

A.3 Fuel Rod Fretting Test

There was some concern that the lower end plug would wear or fret through the edge weld that connects the end plug to the cladding, as a result of relative motion between the fuel rod lower end and the support rod. To determine whether or not this was a problem, a test was performed in the CL-1 loop to simulate the conditions that might be encountered in pile. A schematic diagram of a specimen and holder is shown in Figure A-2.

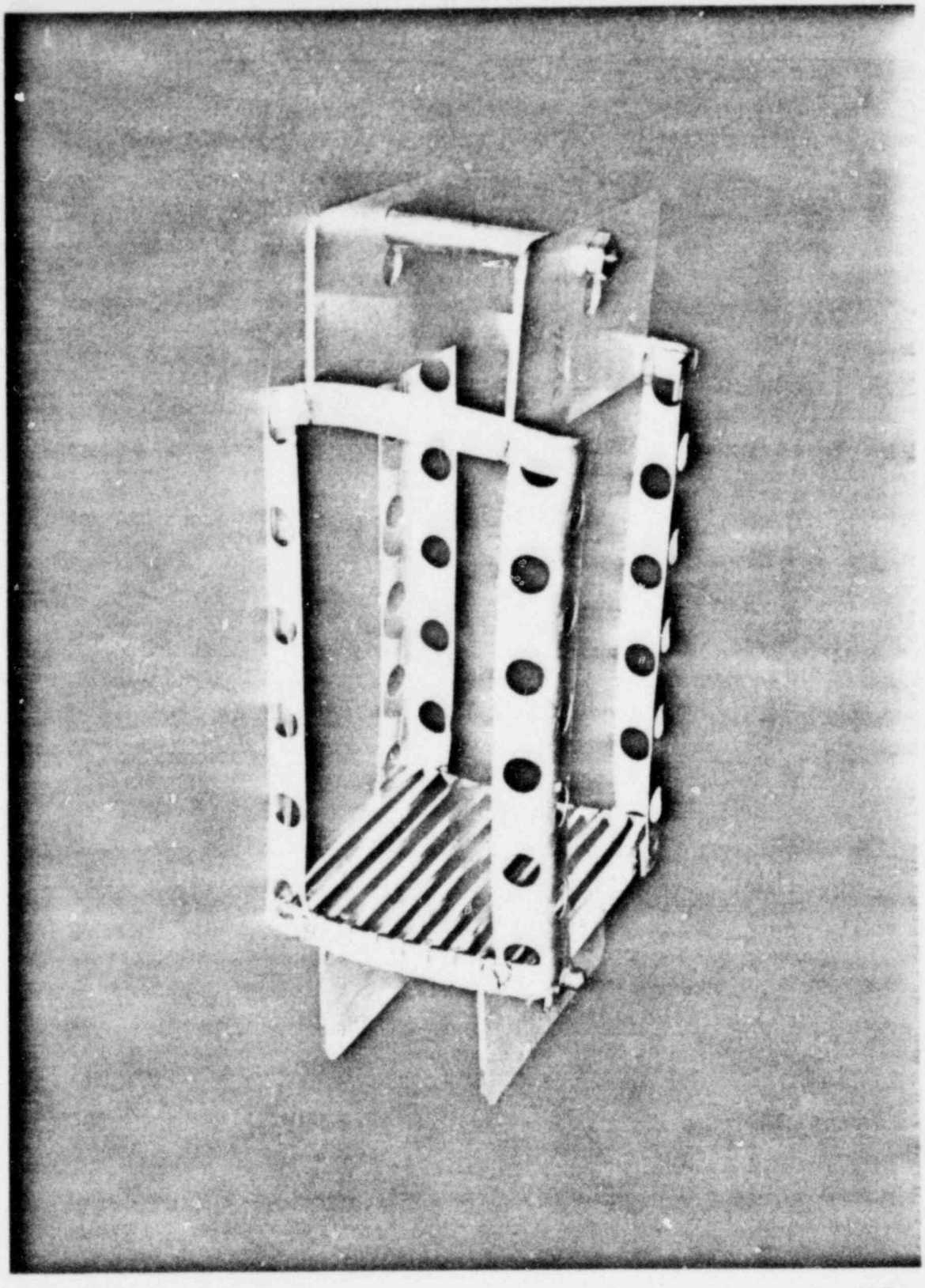

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FIGURE A-1 TENSILE TESTING, STRUCTURE AFTER BEING DESTRUCTIVELY TESTED

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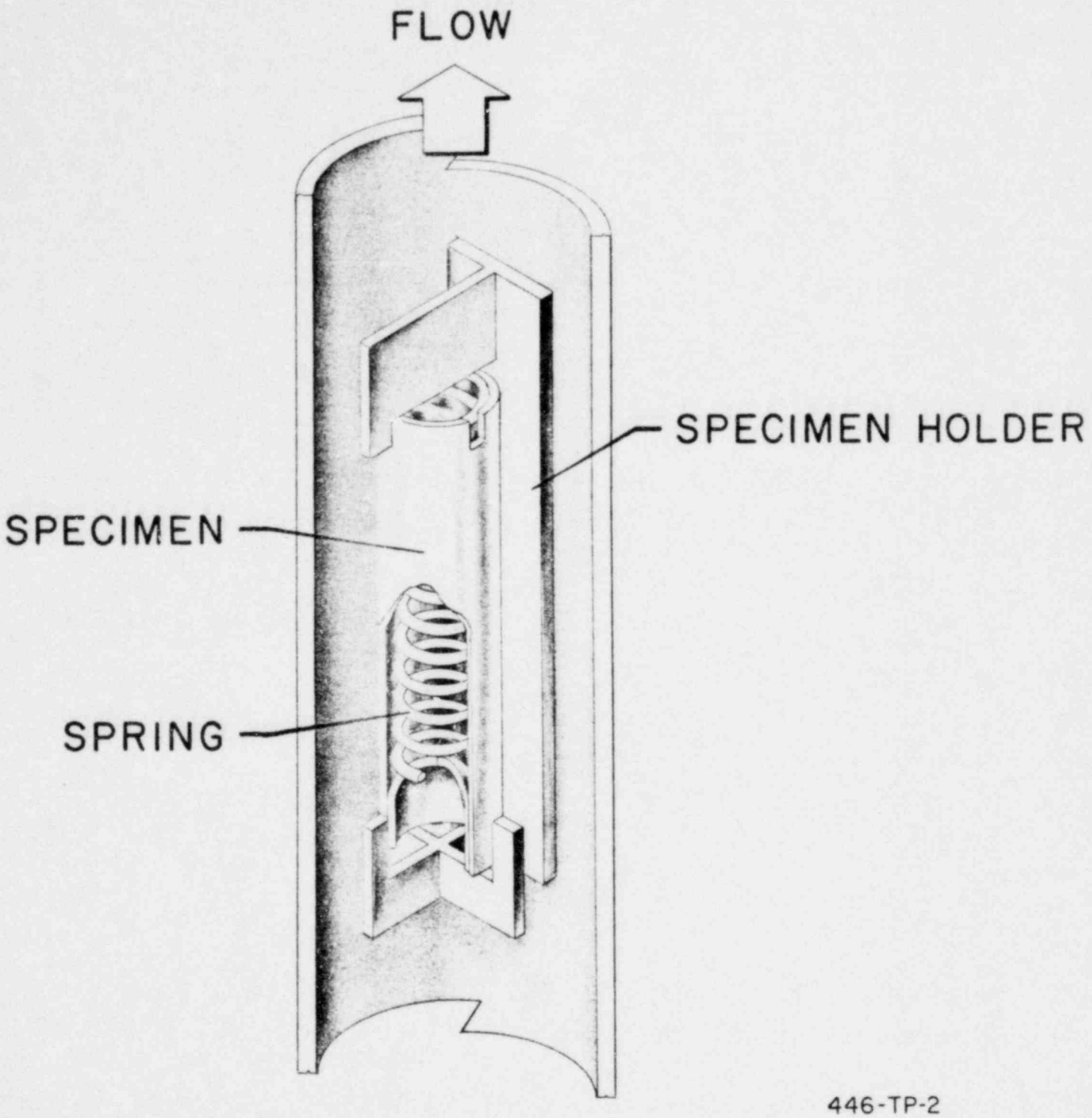

FIGURE A-2

SPECIMEN AND HOLDER

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The inconel spring was guided by the clad, and constrained on the ends by the top of the specimen holder and the hemispherical end plug. Using this scheme, the spring-free length was varied to provide each specimen with a different force (1-7 lb) between the edge weld and the X-bars at the lower end of the specimen holder.

Test conditions in the CL-1 loop during Run No. 46 were as follows:

Length of time at test conditions	993 hours
Water chemistry	
Chloride	<0.1 ppm
pH (at 60 F)	7 ± 0.5
Reactivity (at 60 F)	1.6×10^6 ohm-cm
Oxygen (time-weighed average)	0.14 ppm
Oxygen Range	0.09 - 0.16 ppm
Temperature	546 F
Pressure	1000 psig
Water velocity in specimen section	5.6 ft/sec

Six specimens were tested, and the macroscopic results are shown in Figure A-3, where the specimen numbers are identified by the spring force they experienced.

Metallographic sections were taken through each sample, and the results are shown in Figures A-4a, A-4b, A-4c, A-4d, A-4e, A-4f. It is concluded from these results that no serious problem should exist in regard to fretting or wear of the weld when the fuel rod is supported in this manner.

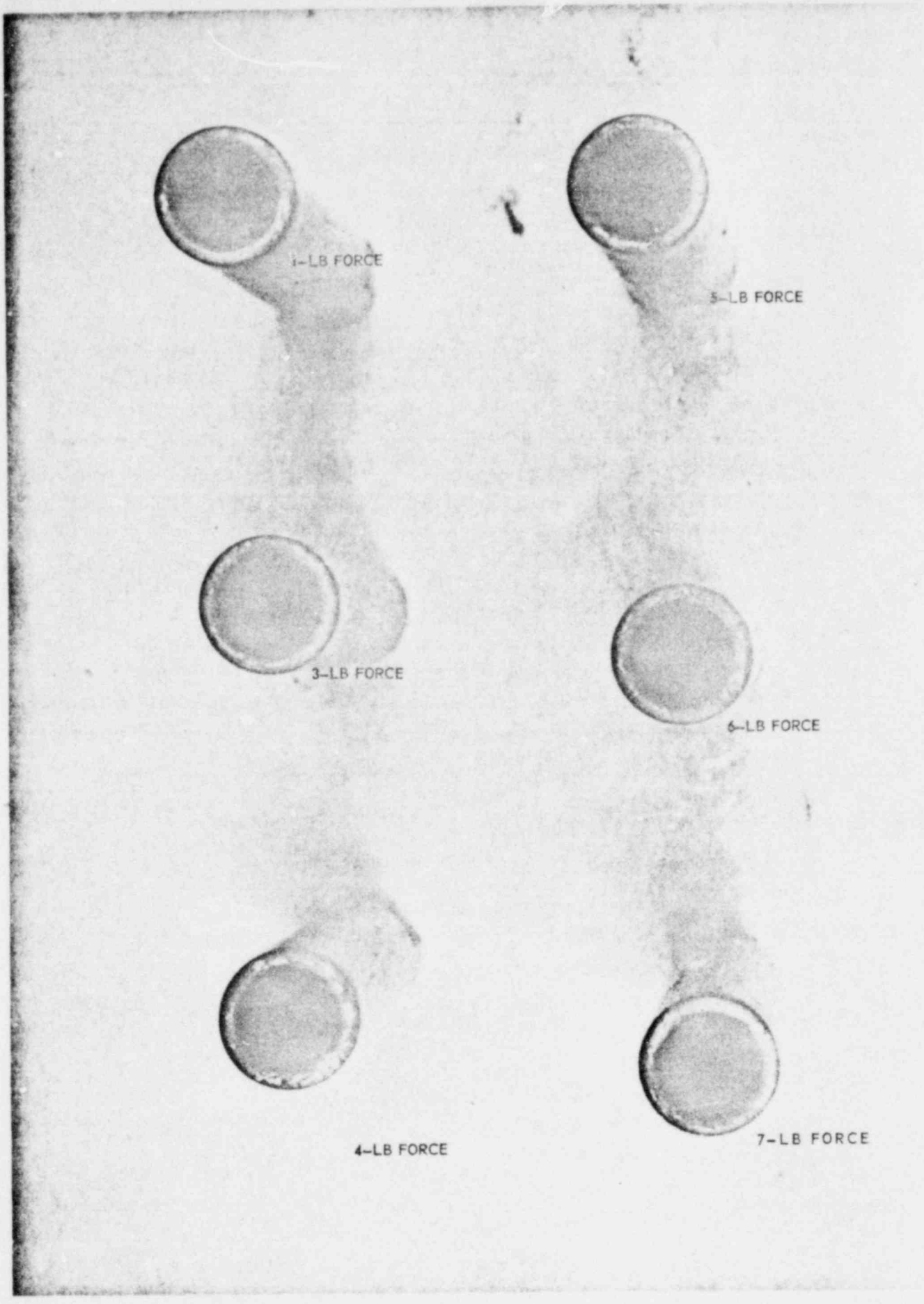

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FIGURE A-3 MACROSCOPIC RESULTS OF SIX SPECIMENS

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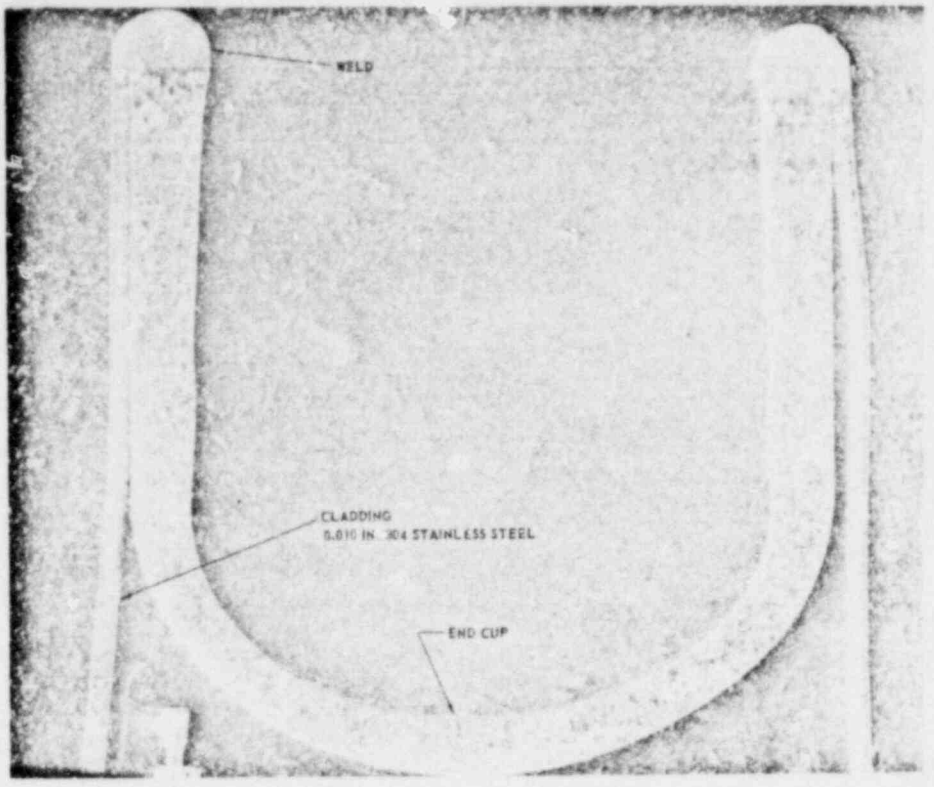

FIGURE A-4A METALLOGRAPHIC SECTION 1-LB FORCE 10% OX.

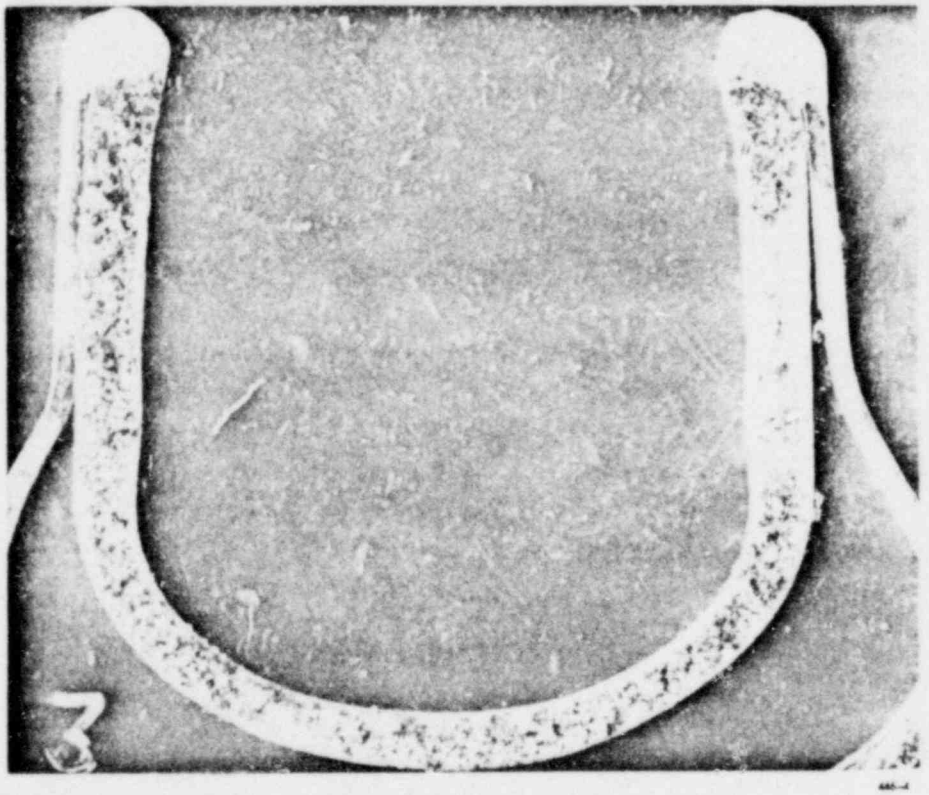

FIGURE A-4B METALLOGRAPHIC SECTION 3-LB FORCE 10% OX.-10X MAG.

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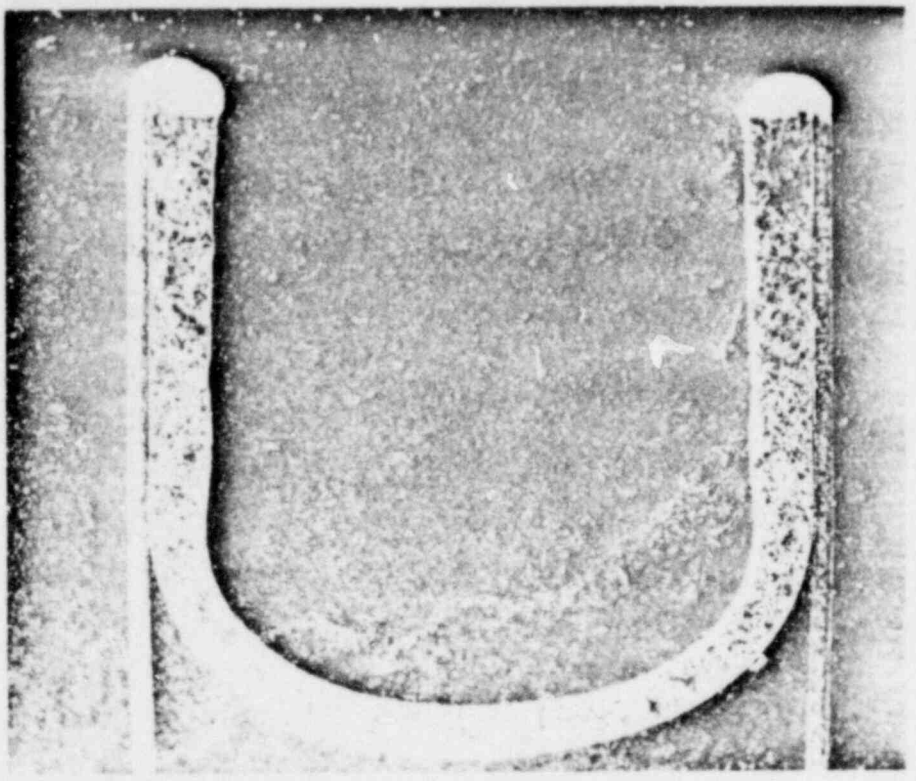

FIGURE A-4C METALLOGRAPHIC SECTION 4-LB FORCE 10% OX.-10X MAG.

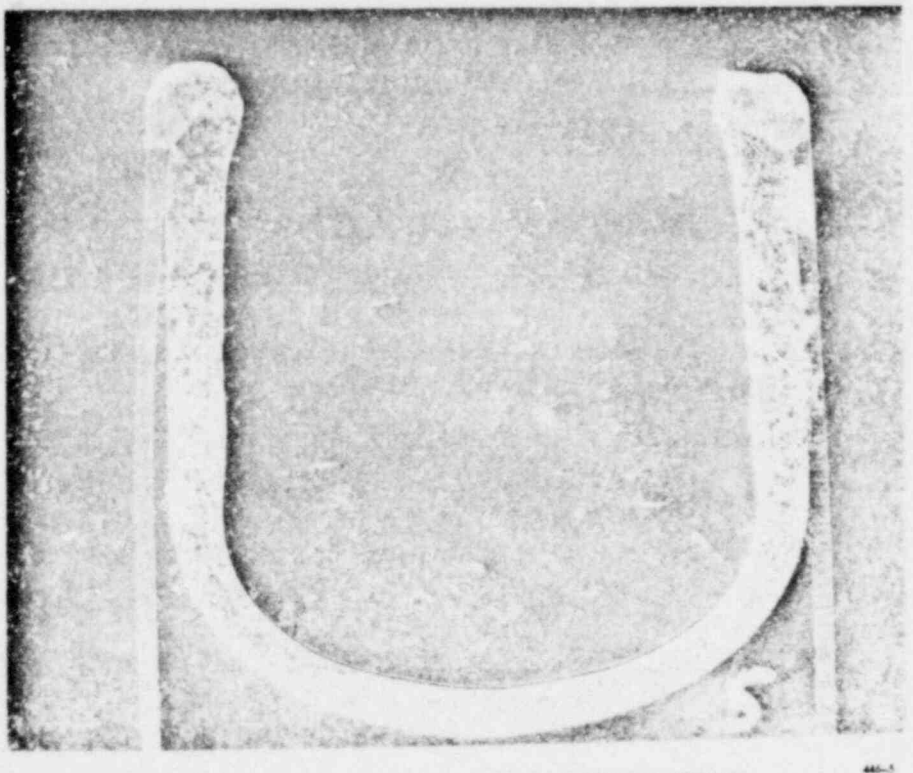

FIGURE A-4D METALLOGRAPHIC SECTION 5-LB FORCE 10% OX.-10X MAG.

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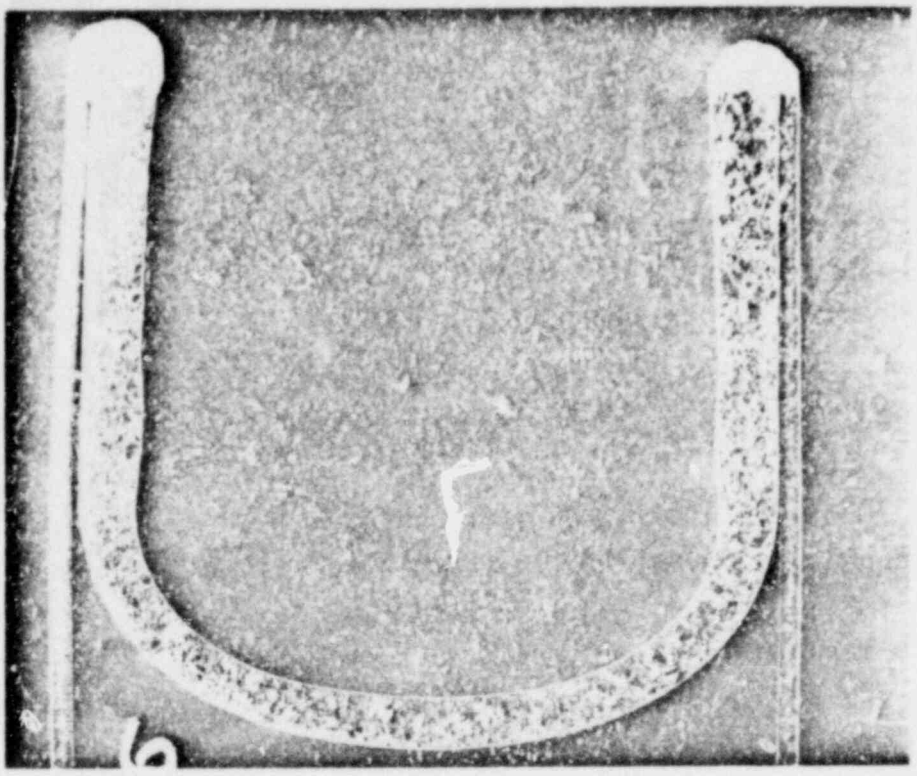

FIGURE A-4E METALLOGRAPHIC SECTION 6-LB FORCE 10% OX.-10X MAG.

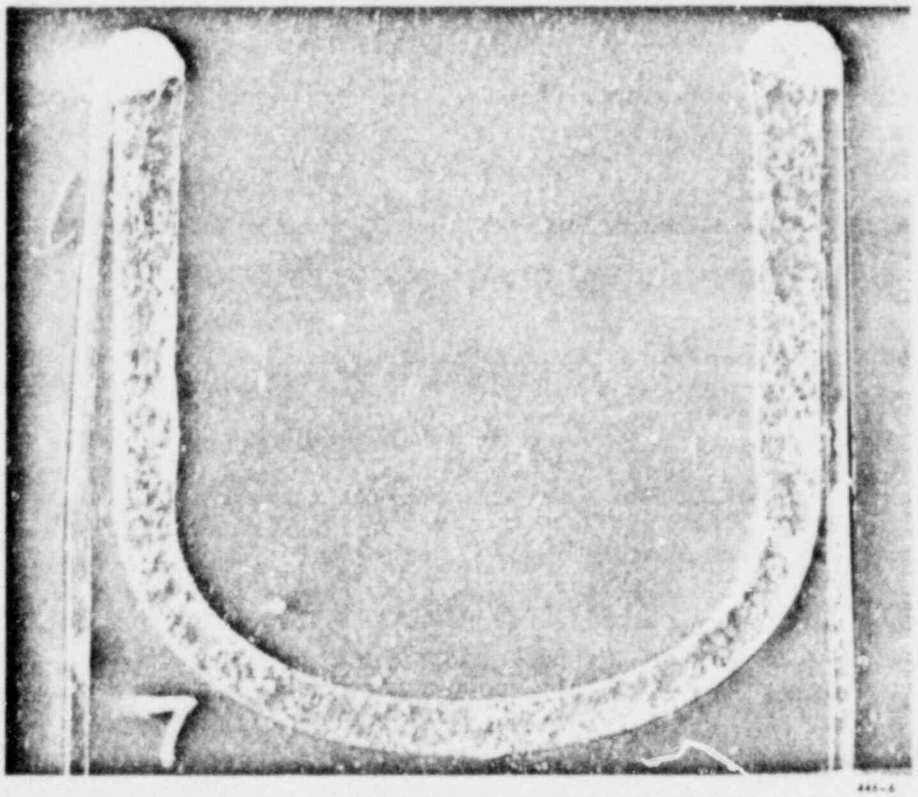

FIGURE A-4F METALLOGRAPHIC SECTION 7-LB FORCE 10% OX.-10X MAG.

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Six High Power Density special fuel bundles will use this support method in the VBWR to further evaluate this condition.

A.4 Spacer Tests

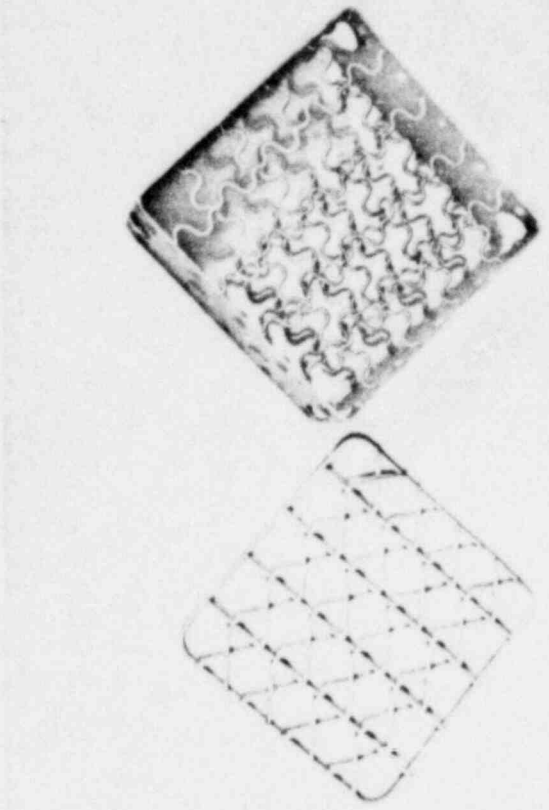
Two types of spacers are presently being tested in the VBWR, as shown in Figure A-5. Irradiation of fuel with each type of spacer is approximately 5000 MWD/T. Both types are functioning satisfactorily, with neither spacer apparently superior to the other. As a result of this test, the single layer spacer configuration, shown in the lower photo in Figure A-5, has been selected as the one to be used for the Big Rock development fuel because it is the least expensive of the two types.

The spacers tested in the VBWR have from 0- to 0.005-inch clearance between the fuel rods and spacer openings, and within this range, no adverse effects have been visually noticeable on the cladding.

A.5 Handling Tests

Handling tests were performed on a full-size Big Rock development fuel bundle containing fuel rods loaded with lead shot to simulate the actual fuel bundle weight. The bundle was repeatedly loaded off-center into a regulation size Big Rock fuel channel. The misalignment between the fuel bundle center line and the channel center line was as much as 3 inches. Even in the extreme case, no difficulty was encountered with the fuel bundle entering the channel.

Following these tests, the bundle was dropped in air from a height of 18 inches, to simulate the deformation to be expected from a free fall through water where its terminal velocity would be approximately



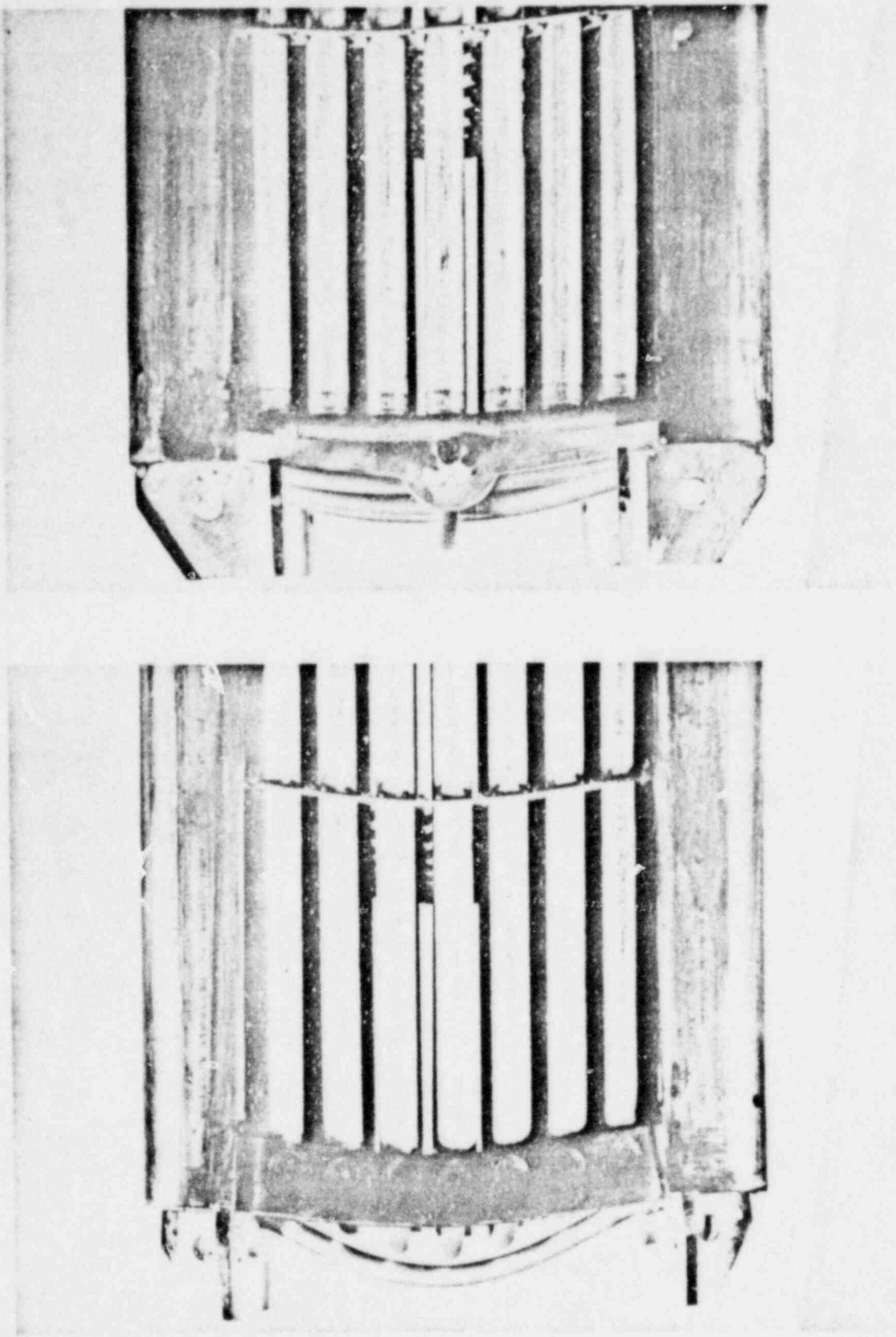
446-2

FIGURE A-5 SPACERS BEING PRESENTLY TESTED IN THE VBWR

10 ft/sec. The bundle was dropped squarely onto a reinforced concrete floor. The extent of damage to the bundle was limited to deformation, but not fracture, of the lower support (see Figure A-6).

As a result of this test, the lower support was strengthened to increase the bundle's resistance to impact deformation, particularly in the center of the fuel bundle. The details of this change are shown in Appendix C, Drawing No. 985C212 - Base.

It should also be noted that even though there was permanent deformation in the fuel bundle structure as a result of this test, there was no deformation at any place other than the base, and the fuel rods could still be removed.



446-11

FIGURE A-6 FUEL BUNDLE DEFORMATION CAUSED BY IMPACT (SIDE VIEWS)

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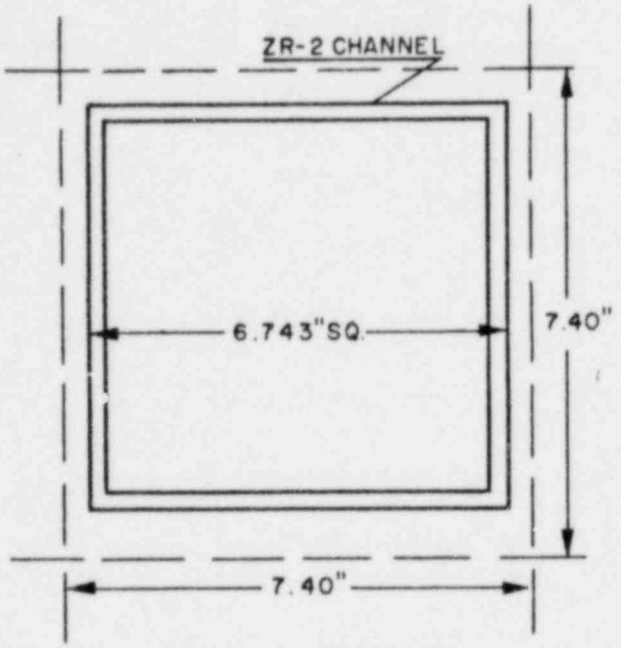
APPENDIX B

ANALYSIS

B.1 Water/Fuel Ratio



TYPICAL LATTICE 446-TP-2

Data: 109 fuel rods 0.425 in. OD x 0.010 in. wall

12 fuel rods 0.320 in. OD x 0.010 in. wall

Channel thickness is 0.100 in. thick

Water area contained in a typical lattice is = Lattice area-channel area-fuel rod area

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$$\text{Water Area} = (7.40)^2 - 4(6.643)\ (0.10) - \frac{\pi}{4}\left[109(0.425)^2 + 12(0.320)^2\right]$$
$$= 54.76 - 2.66 - 16.50 = 35.60\ \text{in}^2$$

Fuel Area — Assuming 100 per cent dense fuel and zero diametral gap between fuel and clad ID, fuel area in a typical lattice is

$$= \frac{\pi}{4}\left[109(0.405)^2 + 12(0.300)^2\right] = 14.90\ \text{in.}$$

Water/Fuel Ratio

$$\frac{\text{Water area}}{\text{Fuel area}} = \frac{35.60\ \text{in}^2}{14.90\ \text{in}^2} = 2.40$$

B.2 Stainless Steel/Fuel Ratio

Stainless steel area = cladding area + corner angle area

$$\text{Cladding area} = \frac{\pi}{4}\left[109(0.425^2 - 0.405^2) + 12(0.320^2 - 0.300^2)\right]$$
$$= 1.56$$

$$\text{Corner angle area} = (4)\ (2.02\ \text{in.})\ (0.031\ \text{in.}) = 0.25\ \text{in}^2$$

$$\text{Stainless steel/fuel ratio} = \frac{1.81}{14.90} = 0.121$$

B.3 Fuel Temperature as a Function of Heat Flux

The temperatures of the fuel were determined by use of the diffusion equation and difference equation techniques. The diffusion equation is

$$\nabla^2 T = -\frac{Q}{k(T)}$$

where

T = Temperature within the fuel

Q = Volumetric heating rate, used as constant across fuel section

$k(T)$ = Full thermal conductivity, data from J. L. Bates, Nucleonics, Vol.19, No. 6, p.83, 1961.

Difference equation techniques were used to determine the temperatures of each of a series of thin cylindrical shells. Twenty shells represented the fuel section. The maximum temperature was directly available, and the volumetric average temperature was obtained by numerical integration of the temperatures of the individual shells. The assumptions used were:

1. Boiling heat transfer coefficient is h = 10,000 Btu/hr-ft^2, and is constant.

2. Thermal contact resistance between the UO_2 and the cladding ID is R = 1000 Btu/hr-ft^2, and is constant.

The UO_2 temperature as a function of heat flux is plotted in Figure B-1.

Having generated these data, it was then necessary to determine the volumetric mean temperature of UO_2 within the fuel rods to know at what average temperature the gases contained within a fuel rod exist. This information is shown in Figure B-2. It was obtained by dividing the maximum heat flux by 1.5 (the peak/average axial heat flux) to determine the average heat flux in the rod. At this average heat flux, the

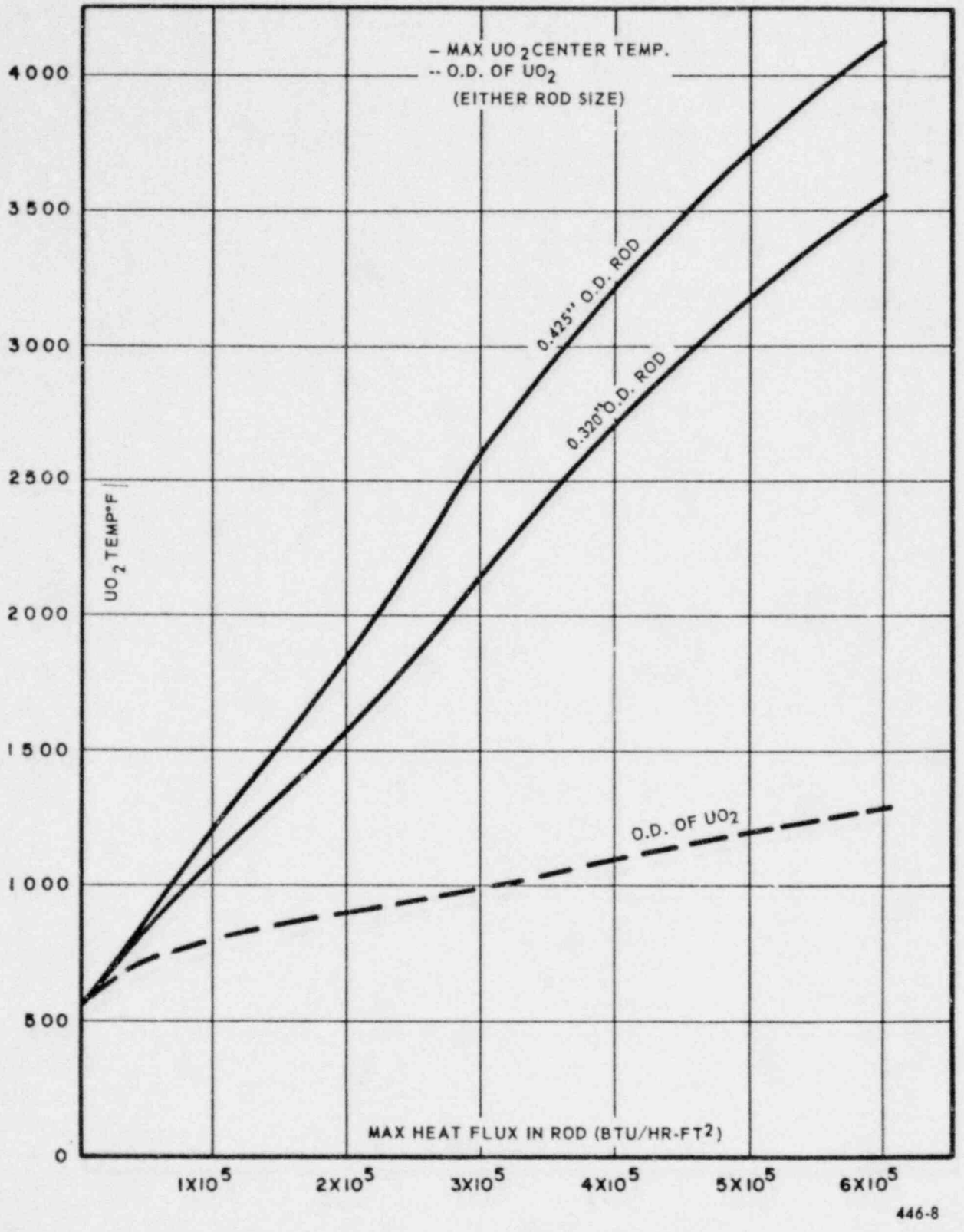

FIGURE B-1 UO_2 TEMPERATURE

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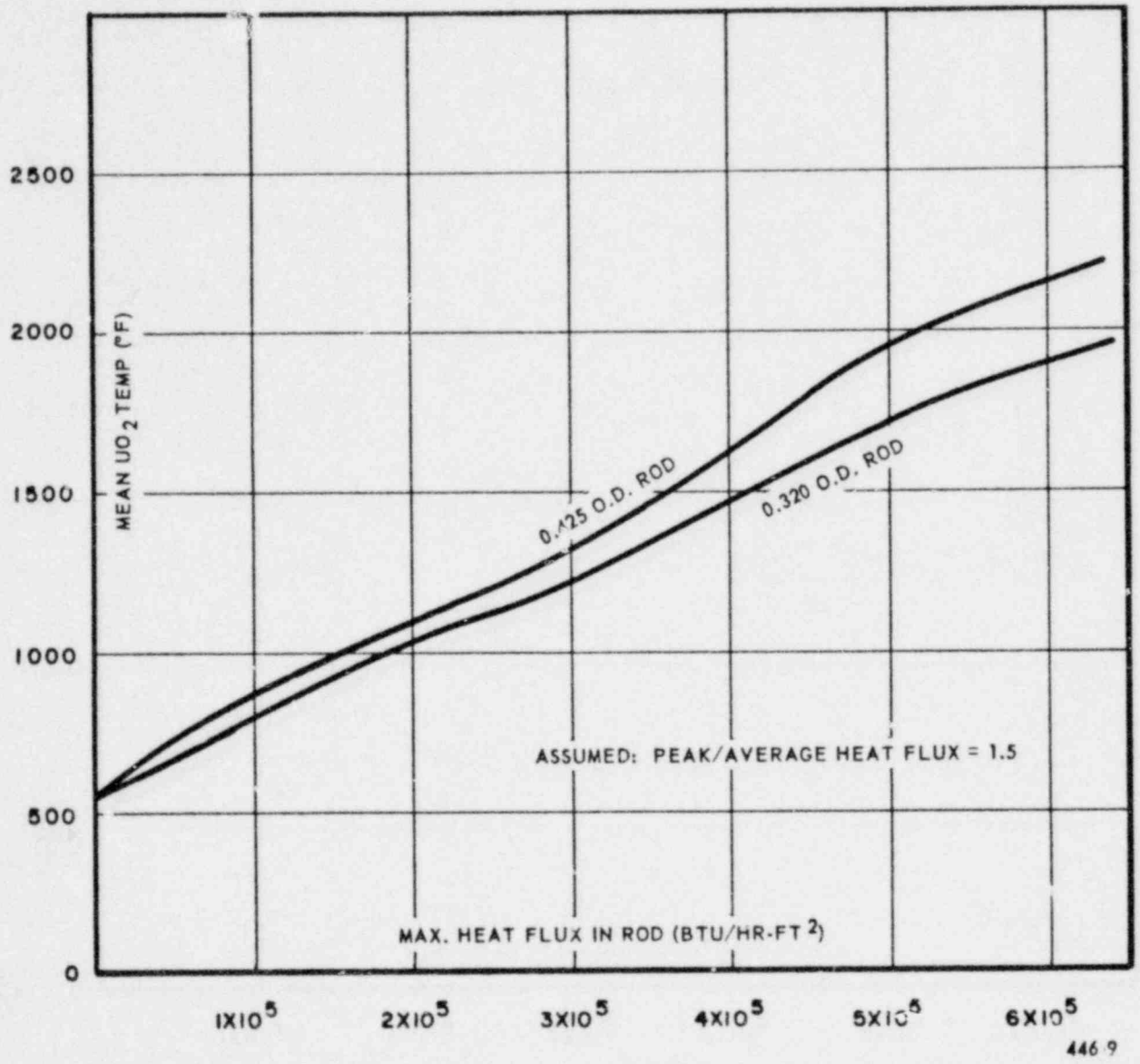

FIGURE B-2 VOLUMETRIC MEAN TEMP OF UO_2 WITHIN A FUEL ROD

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volumetric mean UO_2 temperature was calculated again, using the method and assumptions stated above.

B.4 Heat Transfer Area Per Bundle

Data: 109 rods, 0.425 inch OD

12 rods, 0.320 inch OD

70 in. active fuel length

$$\frac{\pi \left[.425 \times 109 + .320 \times 12\right] 70}{144} = 76.6 \text{ ft}^2$$

B.5 Average Heat Flux at 45 kw/l Power Density

Lattice area x core height x C = liters

$$(7.4 \text{ in.})^2 \times 70 \text{ in.} \times \frac{0.0164 \text{ liters}}{\text{in.}^3} = 63 \text{ liters}$$

$$63 \frac{\text{liters}}{\text{bundle}} \times 45 \frac{\text{kw}}{\text{liter}} = 2840 \frac{\text{kw}}{\text{bundle}}$$

$$\left(2840 \frac{\text{kw}}{\text{bundle}}\right)\left(0.948 \frac{\text{Btu}}{\text{sec-kw}}\right)\left(3600 \frac{\text{Sec}}{\text{hr}}\right)\left(\frac{\text{bundle}}{76.6 \text{ ft}^2}\right)$$

126,000 Btu/hr-ft^2 average

B.6 Hydraulic Diameter Within The Fuel Channel

$$D_H = \frac{4A}{P}$$

A = flow area

P = wetted perimeter

A = channel inside area - fuel rod area (inches)

$$= 6.543^2 - \frac{\pi}{4}\left[109(.425)^2 + 12(.320)^2\right]$$

$$= 42.9 - 16.4 = 26.5 \text{ in}^2$$

$$P = \text{channel wall perimeter} + \text{fuel perimeter}$$
$$= (6.543)\ (4) + \pi\left[109(.425) + 12(.320)\right]$$
$$= 26.1 + 157 = 183.1 \text{ in.}$$
$$D_H = \frac{(4)\ (26.5)}{183.1} = 0.58 \text{ in.}$$

B.7 Fission Gas Release, Containment, and Clad Stress

In the case of either powder- or pellet-type fuel rods, it will be assumed that 100 per cent of the fission gas generated will be released from the UO_2, and must be contained within the fuel rod. In the case of powder-filled rods, the fission gas is assumed to exist at the temperature shown in Figure B-2. It is further assumed that the gas is contained witnin the 8 per cent void volume within the fuel rod (i.e., the powder occupies 92 per cent of the volume within the rod; therefore the remaining 8 per cent is void and can be occupied by gas).

For the fuel rods containing UO_2 sintered pellets (at 95 per cent of theoretical density) a plenum space has been provided in the fuel rod to collect the fission gases that are released. Since these fuel rods are non-segmented, it is a simple matter to position this plenum either above or below the active core. In this case, the plenum was placed above the core (i.e., the upper end of the fuel rods) because of space limitations within the fuel channel at the lower end.

A sample calculation for a 0.425-inch OD powder-filled rod and a 0.425-inch OD pellet-filled rod is presented in Sections B.7.1 and B.7.2 to show how the data for the following items were generated:

1. Fission gas collection volume,

2. Total fission gas generated in each fuel rod,

3. The fission gas temperature in each fuel rod,

4. The internal pressure and pressure stress in each rod,

5. The thermal stress in each rod, and

6. The combined thermal and pressure stress within each fuel rod.

Based on the detailed calculated data, clad stress nomographs were prepared to illustrate the effect of exposure, fission gas release, gas collection volume, and heat flux exerted on the clad stress at zero reactor pressure. These nomographs are shown in Figures B-3 through B-6. The effect of reactor pressure on the clad stresses of swaged pellet and swaged powder fuel at the end of life is shown in Figures B-7 and B-8.

B.7.1 Powder-Filled Rods (0.425 OD)

1. Gas Collection Volume (V $in.^3$)

$$V = (1.00 - \rho) \frac{\pi}{4} D^2 H$$

P = fraction of theoretical density of the UO_2

D = fuel OD in inches

H = 70 inch active fuel

$$V = (1.00 - .92) \frac{\pi}{4} (.405)^2 \, 70 = 0.720 \text{ in.}^3$$

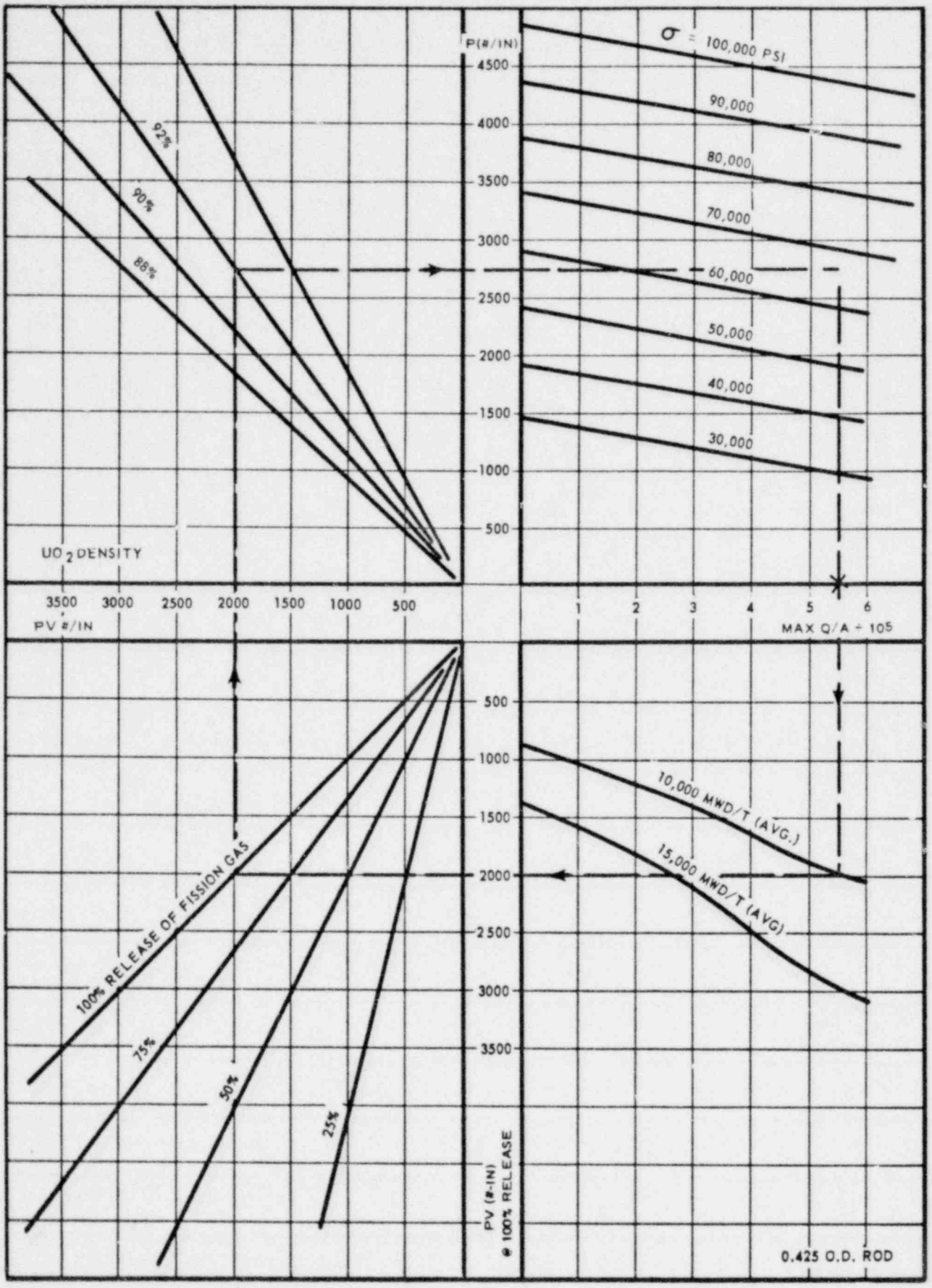

FIGURE B-3 CLAD STRESS NOMOGRAPH - 0.425 O.D. - POWDER FUEL ROD

POOR ORIGINAL

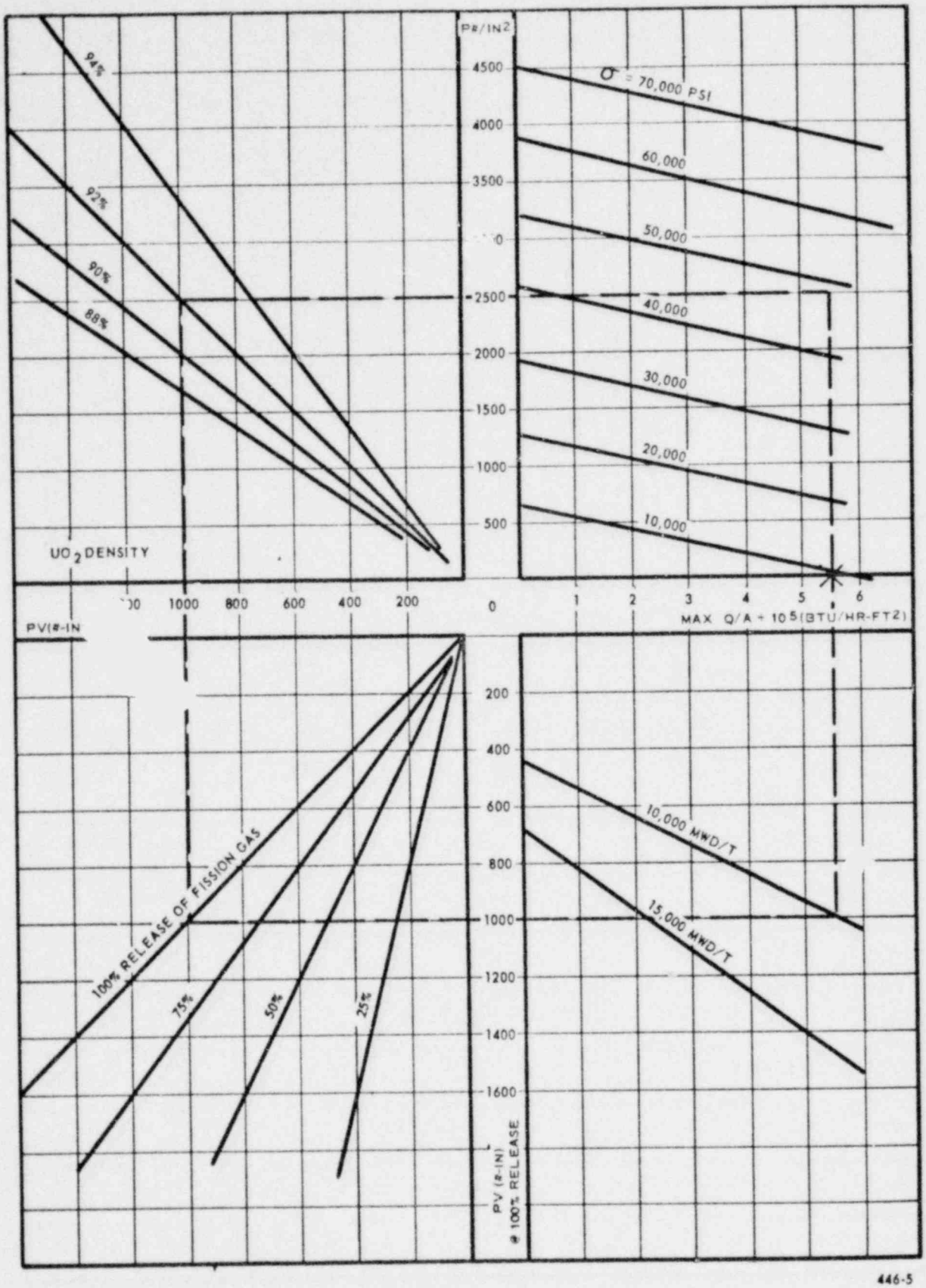

FIGURE B-4 CLAD STRESS NOMOGRAPH 0.320 O.D. - POWDER FUEL ROD

POOR ORIGINAL

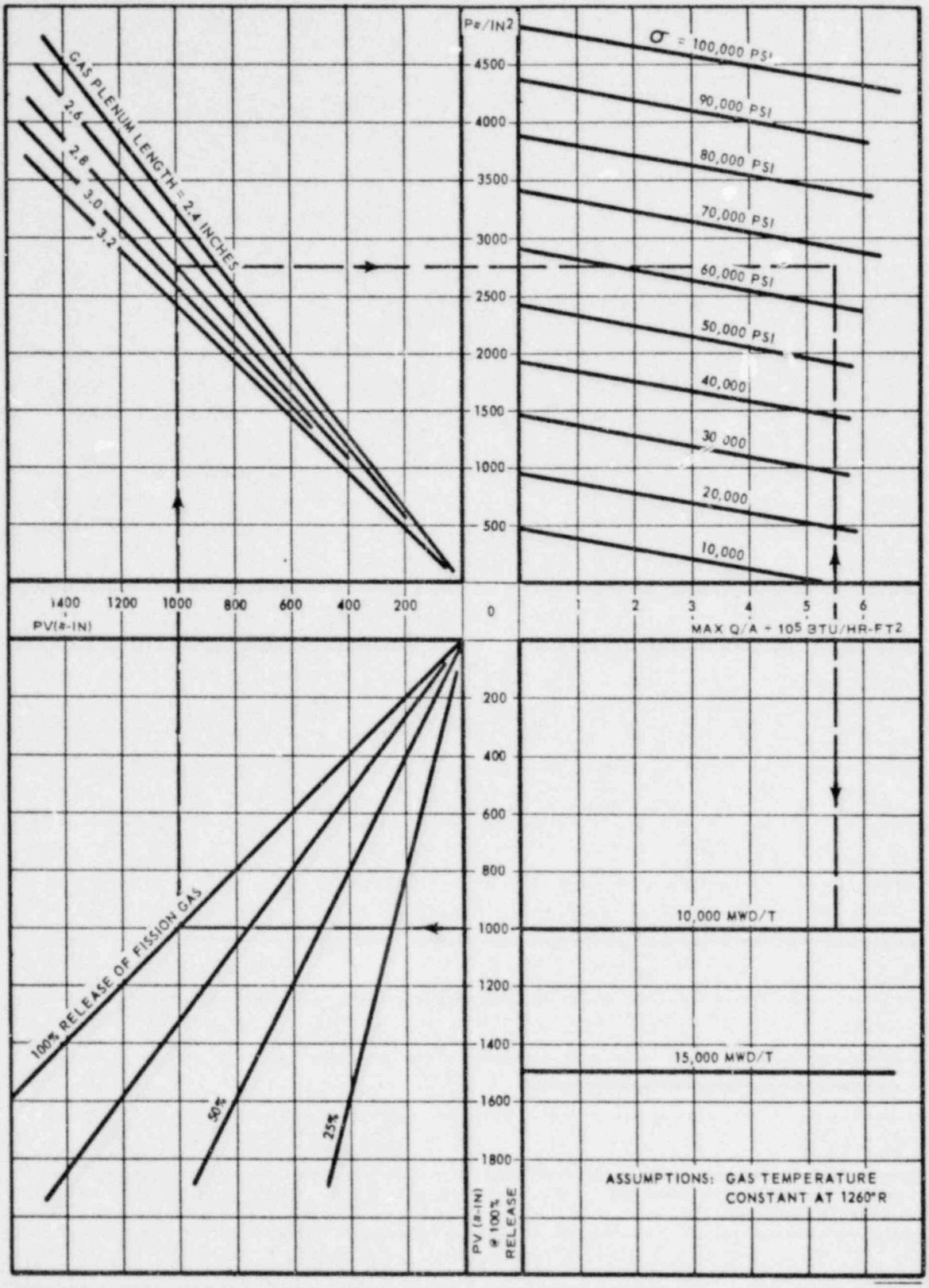

FIGURE B-5 CLAD STRESS NOMOGRAPH 0.425 O.D. PELLET FUEL RODS

POOR ORIGINAL

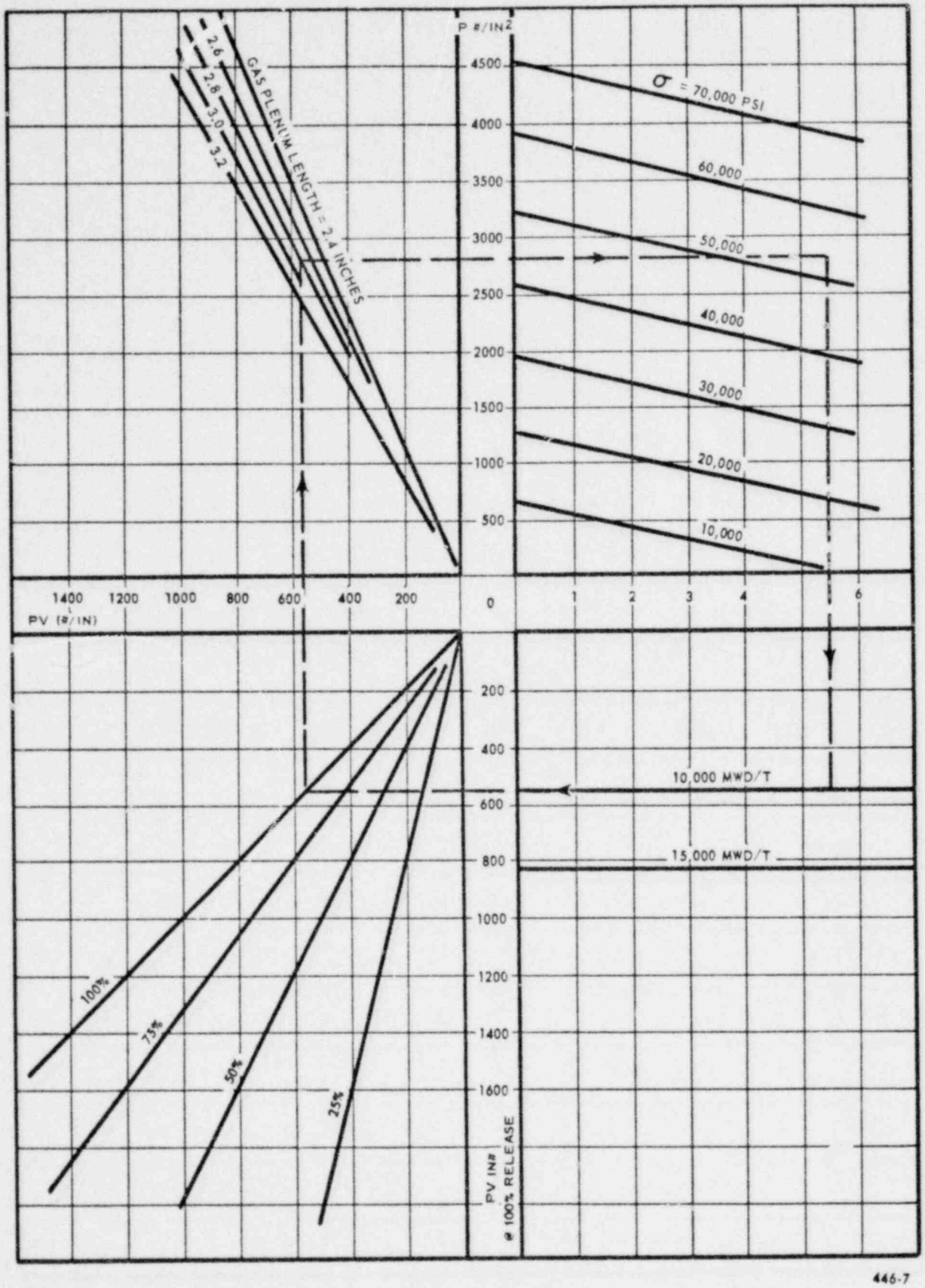

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FIGURE B-6 CLAD STRESS NOMOGRAPH 0.360 OD PELLET FUEL ROD

POOR ORIGINAL

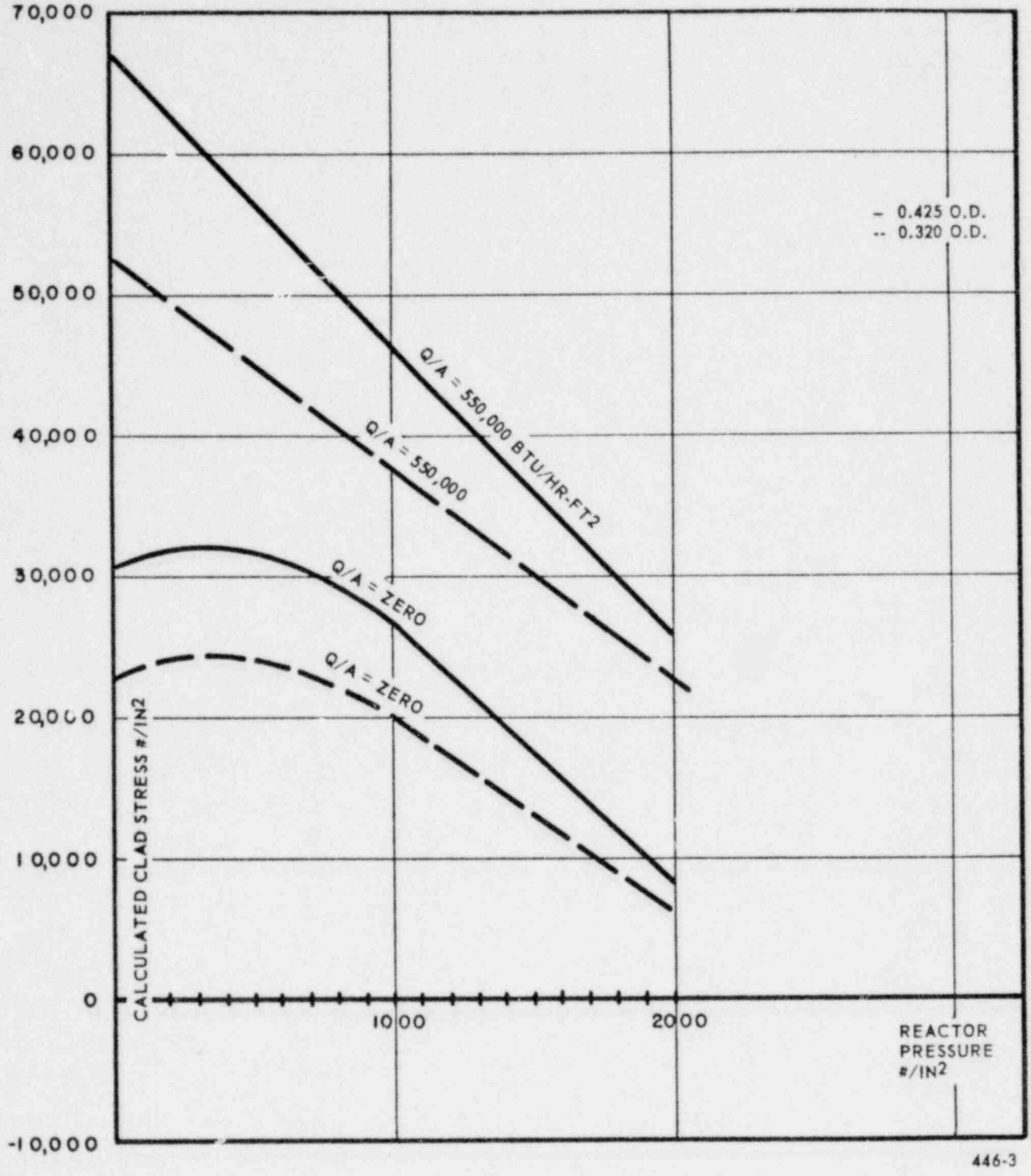


FIGURE B-7 END OF LIFE CLAD STRESS FOR PELLET RODS

POOR ORIGINAL

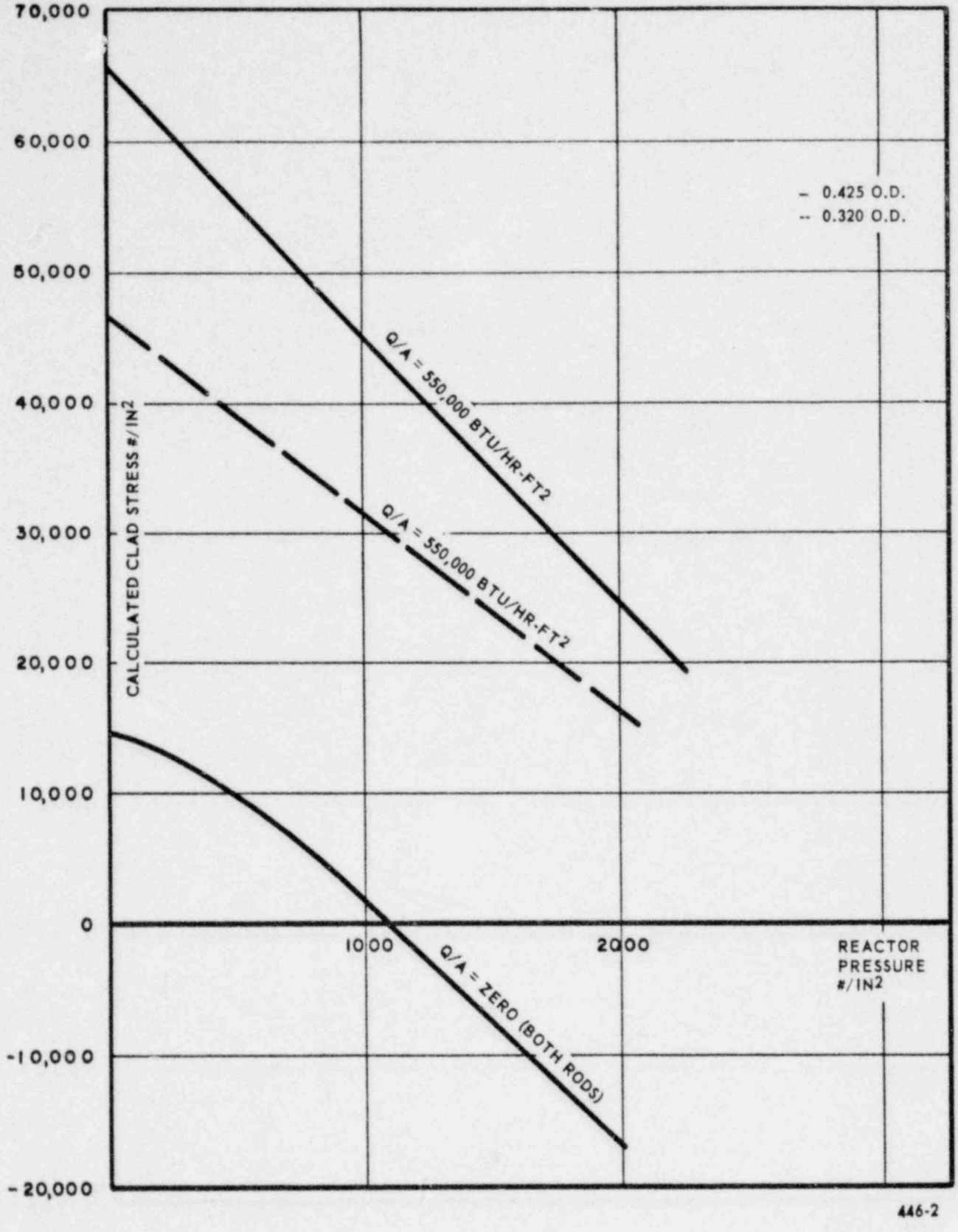


FIGURE B-8 END OF LIFE CLAD STRESS FOR POWDER RODS

POOR ORIGINAL

2. Total Fission Gas Generated in Each Rod

Personal communications with C. N. Spalaris have indicated that 1.31×10^{-3} gm-mols of Kr + Xe are formed per megawatt day (MWD) of exposure. Using this data and assuming all of the gas generated is released from the UO_2, the total mols of Kr + Xe can be calculated as shown below.

Tons of U per rod:

$$\left[\frac{238 \text{ lb.U}}{270 \text{ lb.UO}_2}\right]\left[\frac{\pi}{4}\ (0.405)^2\ 70 \text{ in.}^3\right]\quad (0.92)\left[\frac{0.396 \text{ lb.}}{\text{in.}^3}\right]\frac{\text{Ton}}{2000 \text{ lb.}}$$

$= 1.45 \times 10^{-3}$ tons of U/rod

Since the design exposure is 10,000 MWD/T, the total Kr + Xe is

1.31×10^{-3} gm-mols/MWD x 1.45×10^{-3} T x 10^4 MWD/T

$= 1.90 \times 10^{-2}$ gm-mols of Kr + Xe/rod

3. Fission Gas Temperature in Each Rod

For the powder-filled fuel rods, the mean fission gas temperature may be obtained directly from Figure B-2, knowing the maximum heat flux on the rod surface.

4. The Internal Pressure in Each Fuel Rod

The internal pressure in the fuel rod is based on a maximum heat flux of 550,000 Btu/hr-ft^2. Entering (as shown in Figure B-2) at 550,000 Btu, the mean temperature of the UO_2 (fission gas also) is 2050 F (2510 R). Then, from

$PV = n RT$

$V = 0.720 \text{ in.}^3$

$n = 1.90 \times 10^{-2}$ gm-mols

$R = 40.6 \frac{\text{in.} - \text{lb.}}{\text{gm-mol } ^\circ R}$

$T = 2510 R$

the internal pressure due to Kr + Xe is calculated to be

2690 lb/in.^2

Assuming zero reactor pressure at this condition, the maximum tensile stress in the clad would be defined by

$$\sigma = \frac{Pr}{t}$$

σ = tensile stress in the clad (lb/in.^2)

P = internal pressure (lb/in.^2)

r = mean clad radius (in.)

t = clad thickness (in.)

or

$$= \frac{(2690)\ (0.208)}{0.010} = 56{,}000 \text{ lb/in.}^2$$

5. Thermal stress in the cladding.

The thermal stress is calculated using the Timoshenko* equation for thin-walled cylinders.

$$\sigma_t = \frac{E\alpha\Delta t}{2(1-\mu)}$$

where E = Young's Modulus ($30 \times 10^6 \text{ lb/in.}^2$)

* Timoshenko, S., Strength of Materials, Part II, 3rd Edition, D. Van Nostrand Co., 1956.

α = coefficient of expansion (10^{-5} in./in.)

Δt = temperature drop across the clad wall (°F)

μ = Poisson's Ratio (0.3)

and since

$$\Delta t = \frac{(Q/A)(X)}{k}$$

where Q/A = Btu/hr-ft^2 550,000

X = wall thickness $\frac{0.010}{12}$ ft

k = thermal conductivity 10 Btu/hr-ft^2

we can substitute for Δt

$$\sigma t = \frac{E\alpha(Q/A)(X)}{2k(1-\mu)}$$

$$= \frac{30 \times 10^6 \times 10^{-5} \times 5.5 \times 10^5 \times 0.010}{2 \times 10 \times (1 - 0.3)(12)}$$

$$= 9,820 \text{ lb/in.}^2$$

This will be tension on the clad OD and compression on the ID.

6. The combined thermal and pressure stress in the clad at an exposure of 10,000 MWD/T, zero reactor pressure, and a heat flux of 550,000 Btu/hr-ft^2 is

$$\sigma \text{ total} = \sigma \text{ thermal} + \sigma \text{ pressure}$$

$$= 9,820 + 56,000$$

$$= 65,820 \text{ lb/in.}^2$$

B.7.2 Pellet-Filled Rods (0.425 OD)

1. Gas Collection Volume

The gas collection volume (plenum) for these rods was derived from matching, as closely as possible, the clad stress (at 10,000 MWD/T, a heat flux of 550,000 Btu/hr-ft^2, and zero reactor pressure) of the powder-filled fuel rods. This trial-and error matching process yielded a plenum volume for the 0.425 OD fuel rods of 0.362 in.^{3}.

2. The total fission gas generated is calculated in the same manner used for the powder rods, except the UO_2 density is 95 per cent. On this basis, each rod contains 1.50×10^{-3} tons of U, and 1.96×10^{-2} gm-mols of Xe + Kr are generated and released.

3. The fission gas is assumed to be contained within the plenum, and is assumed to exist at a temperature of 800 F (a conservative estimate that is greater than the mean surface temperature of the plenum walls).

4. The Internal Pressure in Each Fuel Rod

The pressure is calculated using the same method presented for the powder rods, namely:

$$P = \frac{n\,RT}{V}$$

where $n = 1.96 \times 10^{-2}$ gm-mols

$R = 40.6$ in.-lb/gm-mol-°R

$T = 1260$ °R

$V = 0.362$ in.^{3}

then,

$$P = \frac{1.96 \times 10^{-2} \times 40.6 \times 1260}{0.362}$$

$$= 2850 \text{ lb/in.}^2$$

Assuming zero reactor pressure, the tensile stress in the clad due to Kr + Xe pressure at the end of life is

$$\sigma = \frac{Pr}{t} \quad \frac{(2850)(0.208)}{0.010}$$

$$= 59,400 \text{ lb/in.}^2$$

5. The thermal stress in the cladding will be the same for either powder- or pellet-type fuel rods having the same clad thickness and operating at the same heat flux. Therefore, the thermal stress will be 9,820 lb/in.^{2} as calculated for the powder rods.

6. The combined thermal and pressure stress in the clad at an exposure of 10,000 MWD/T, zero reactor pressure, and a heat flux of 550,000 Btu/hr-ft^2 is

$$\sigma_{\text{total}} = \sigma_{\text{thermal}} + \sigma_{\text{pressure}}$$

$$= 9,820 + 59,400$$

$$= 69,220 \text{ lb/in.}^2$$

The analysis method presented above was also used to calculate the conditions in the 0.320-diameter fuel rods.

Table B-1 tabulates data relating to fission gas for the two sizes of pellet of power fuel rods calculated as discussed above. Table B-2

TABLE B-1

DESIGN DATA RELATING TO FISSION GAS
FOR PELLET AND COMPACTED POWDER TYPE FUEL ROD

Type of UO_2	Pellets		Compacted Powder	
Rod diameter (inches)	0.320	0.425	0.320	0.425
UO_2 density (% of T.D.)	95	95	92	92
Tons of U per rod ($\times 10^{-3}$)	0.82	1.50	.79	1.45
Pounds (or kg) of UO_2	1.86 (0.845)	3.40 (1.55)	1.80 (0.82)	3.30 (1.50)
Location of fission gas collection space	Plenum (out of core)		Within UO_2	
Fission gas volume ($in.^3$)	0.198	0.362	0.396	0.720
Total fission gas generated (moles of Kr ± Xe at 10,000 MWD/T)	0.0108	0.0196	0.0104	0.0190
Assumed % release of fission gas	100	100	100	100

TABLE B-2

FUEL ROD CLAD STRESS AT THE END OF LIFE,
ASSUMING A SUDDEN LOSS OF REACTOR PRESSURE

Type of UO_2	Pellets		Compacted Powder	
Rod diameter (inches)	0.320	0.425	0.320	0.425
Maximum UO_2 temperature (°F)	3375	3950	3375	3950
Mean UO_2 temperature (°F)	1800	2050	1800	2050
Mean fission gas temperature (°R)	1260	1260	2260	2510
Internal pressure (psi)	2800	2770	2410	2690
Pressure stress in clad (psi)	42,500	56,900	36,700	56,000
Thermal stress in clad (psi)	9820	9820	9820	9820
Tensile stress in clad OD (psi)	52,320	66,720	46,520	65,820
Minimum U.T.S. of clad @ 650°F	65,500	83,500	58,300	82,000
Safety margin $\left[\frac{\text{U T.S.}}{\sigma}\right] - 1$	25%	25%	25%	25%

NOTES:

(1) Q/A Max. = 550,000 Btu/hr-ft^2

(2) Peak/axial heat flux = 1.5

tabulates individual fuel rod clad stress for the condition of sudden loss of reactor pressure at the end of fuel life. The significant fact from Table B-2 is that, with a sudden loss in reactor pressure, the clad has sufficient strength to prevent rupture of the fuel rod from internal pressure due to fission gas.

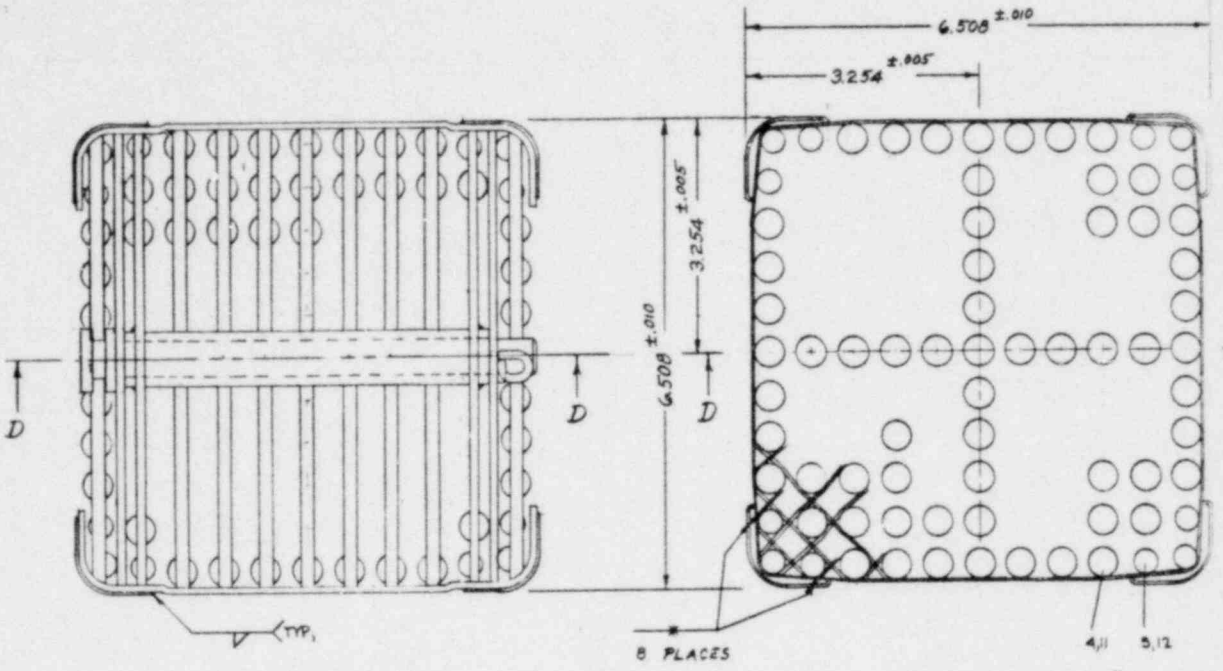
APPENDIX C

DRAWINGS

The following is a list of the drawings that comprise the Big Rock Development Fuel.

124F725		Fuel Bundle
	141F898	Spacer
	985C211	Handle
	985C212	Base
	985C213	Weldment
	985C214	Bracket
	985C215	Angle
	114B5456	Retainer Bolt
	114B5457	Hairpin
	114B5833	Rod
	114B5834	Foot
	114B5835	Plate
	114B5850	Fuel Rod
	117B1233	Plate
	114B1450	Fuel Rod
	124F725	Assembly Fuel Bundle
	149A4071	End Plug
	149A4958	Pellet

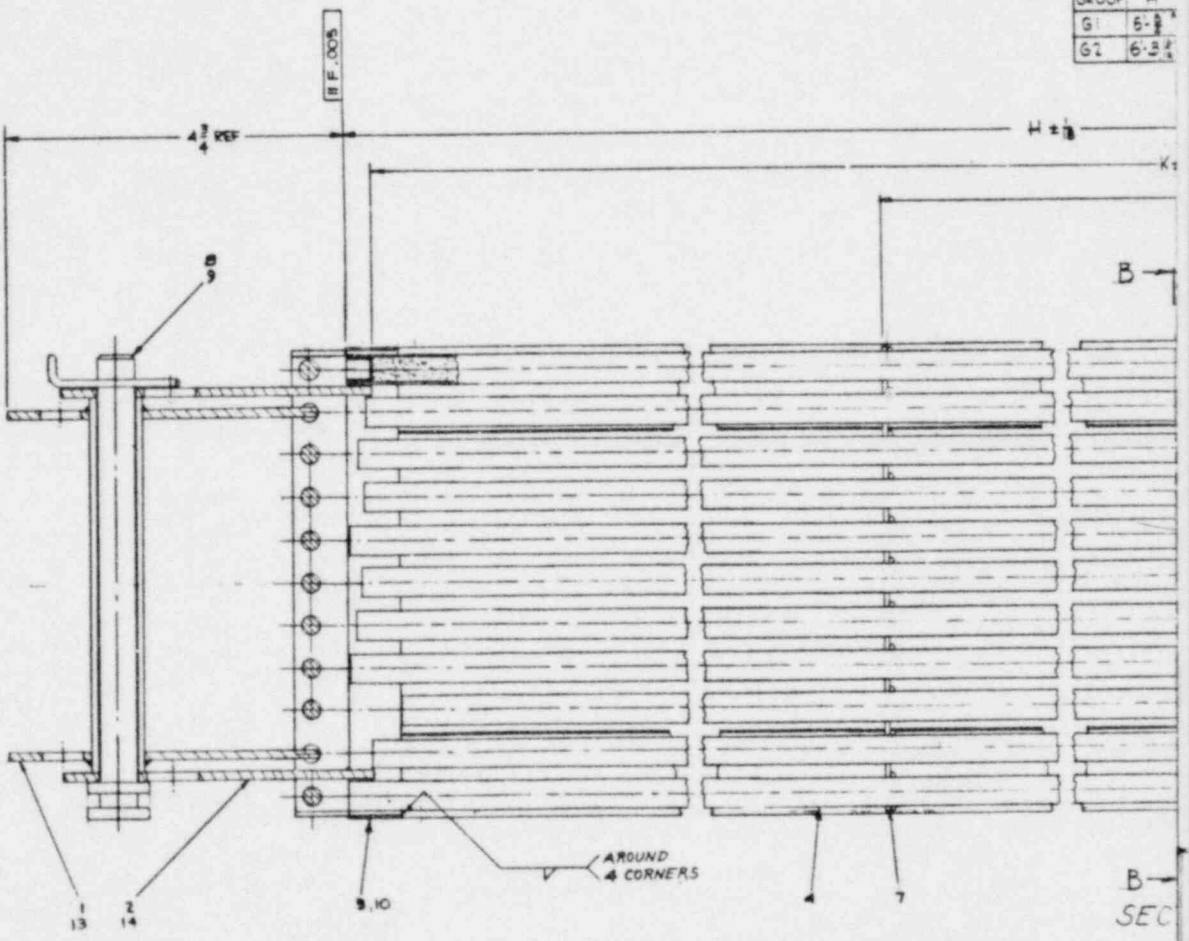
12AF125



TOP VIEW

SECTION BB

GROUP	H
G1	5-3/8
G2	6-3/8



POOR ORIGINAL

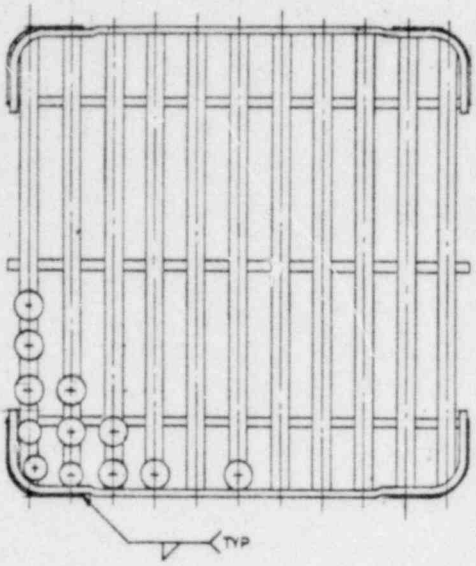
GENERAL ELECTRIC

124F725

APPLIED PRACTICES	SURFACES				
14SA5481	✓	± 1/4	±	±	124F725

TITLE ASSEMBLY
FUEL BUNDLE
FIRST MADE FOR CONSUMERS POWER DEV.
FCF ON

P.L. ISSUED

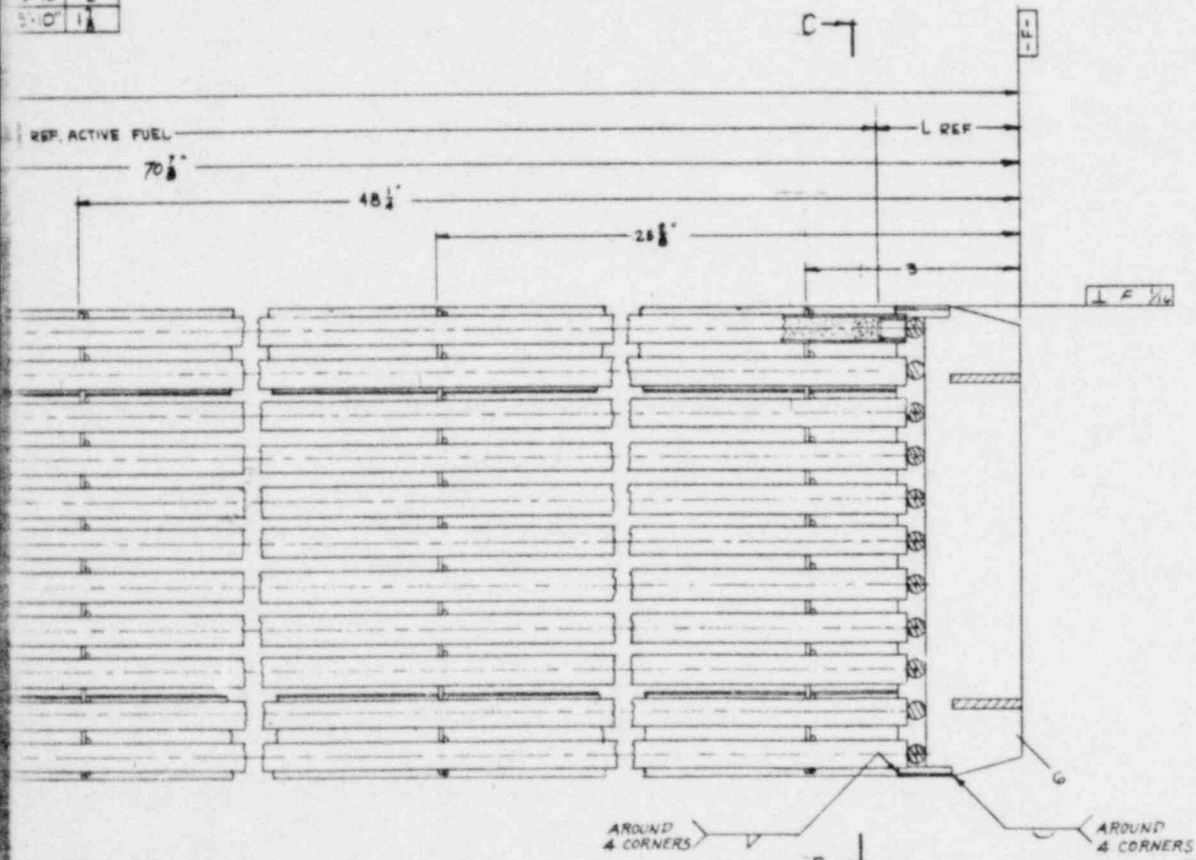


SECTION "C-C"

NOTES:

1. BOW OR TWIST OF BUNDLE MUST NOT EXCEED .060 WHEN BUNDLE IS IN VERTICAL POSITION WITH ALL WEIGHT SUPPORTED BY BASE P6
2. MATCH MARKS ON SPACERS TO ALL BE ON ONE SIDE OF BUNDLE & ON TOP SIDE OF SPACER.

K	L
5'-10"	2
5'-10"	1 1/8

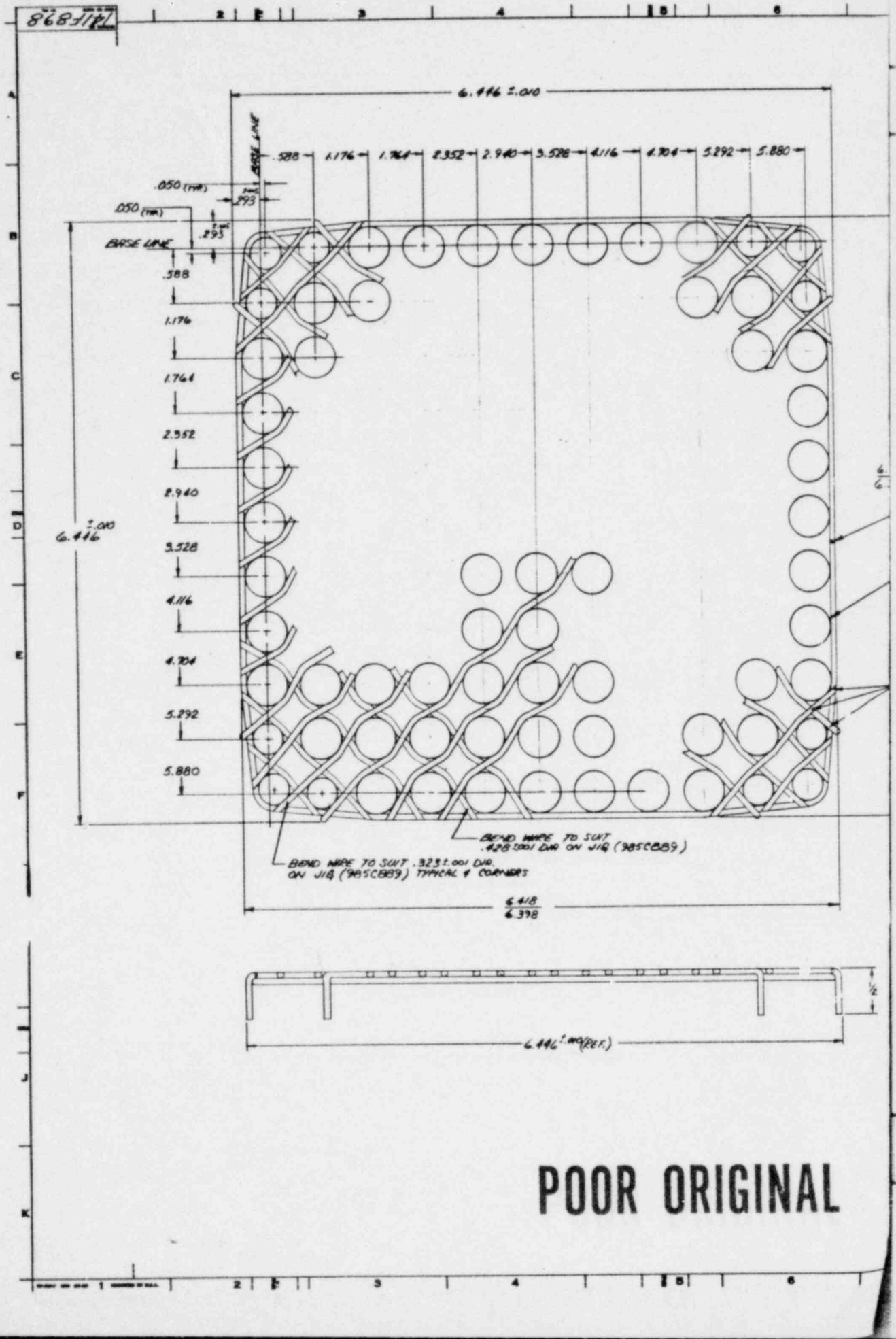


ION DD

POOR ORIGINAL

APED
SAN JOSE

124F725



POOR ORIGINAL

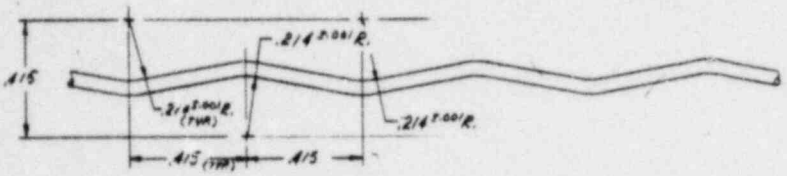
GENERAL ELECTRIC

141F898

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING					
APPLIED PRACTICES	SURFACES	TOLERANCE IN DECIMALS			
145A5481	✓	± 1/64	±.005	±	141F898

TITLE: SPACER

FIRST MADE FOR: FCF ON 124F725



REFERENCE ONLY

WIRE TO BE .050 ± .002 DIA. 300 SERIES STN. STL. (ANNEALED). WIRE MAY BE HAND FORMED IN JIG (985C889) PREFORMING IS NOT NECESSARY.

MATCH MARK JIG & SPACER

CIRCLES SHOW LOCATION OF BUTTONS ON JIG (985C889)

AT ALL INTERSECTIONS

NOTES:

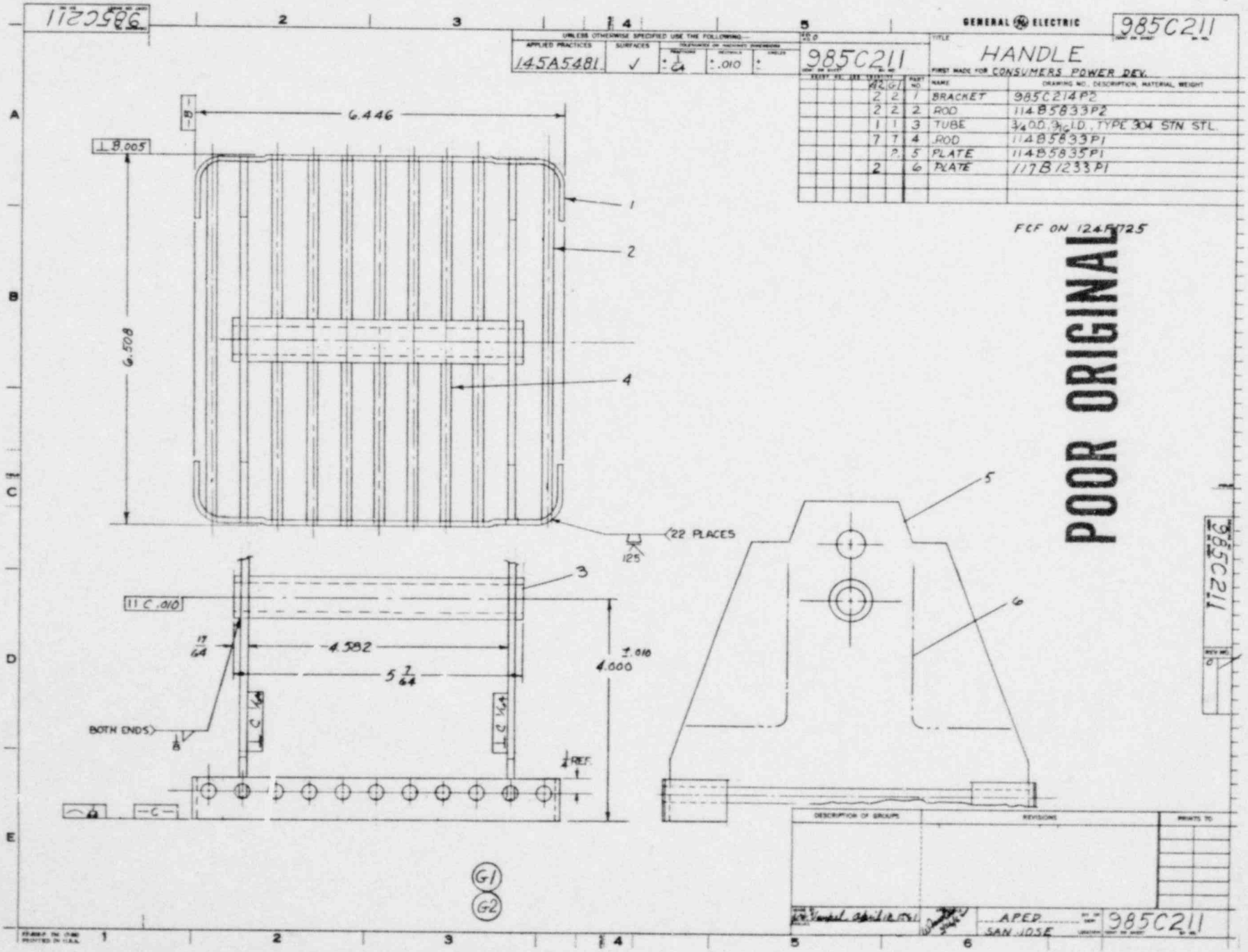
1. ALL WELDS TO BE MADE PER MFG. INSTRUCTION E-9 FOR .050 ± .002 DIA WIRE
2. ANY WELD FLASH EXTENDING FROM INTERSECTION OF WIRES TO WITHIN .020" OF BUTTONS ON JIG TO BE REMOVED BY VAPOR BLAST OR WIRE BRUSH.

POOR ORIGINAL

REVISIONS | PRINTS TO

R.P.E.D. SAN JOSE

141F898


985C211
GENERAL ELECTRIC
985C211
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING
APPLIED PRACTICES
SURFACES
145A5481
√
±.010
985C211
TITLE
HANDLE
FIRST MADE FOR CONSUMERS POWER DEV.
NAME
DRAWING NO., DESCRIPTION, MATERIAL, WEIGHT
2 2 1 BRACKET 985C214P2
2 2 2 ROD 114B5833P2
1 1 3 TUBE 3/4 O.D., 9/16 I.D., TYPE 304 STN STL.
7 7 4 ROD 114B5833P1
2 5 PLATE 114B5835P1
2 6 PLATE 117B1233P1
FCF ON 124F1725
POOR ORIGINAL
6.446
8.005
6.508
22 PLACES
125
4.582
5 7/64
4.000
±.010
17/64
BOTH ENDS
1/4 REF.
DESCRIPTION OF GROUPS
REVISIONS
PRINTS TO
APED
SAN JOSE
985C211
G1
G2

POOR ORIGINAL

GENERAL ELECTRIC

985C212

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —

APPLIED PRACTICES	SURFACES	TOLERANCES ON DECIMALS DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
145A5481	✓	±	± .015	±

985C212

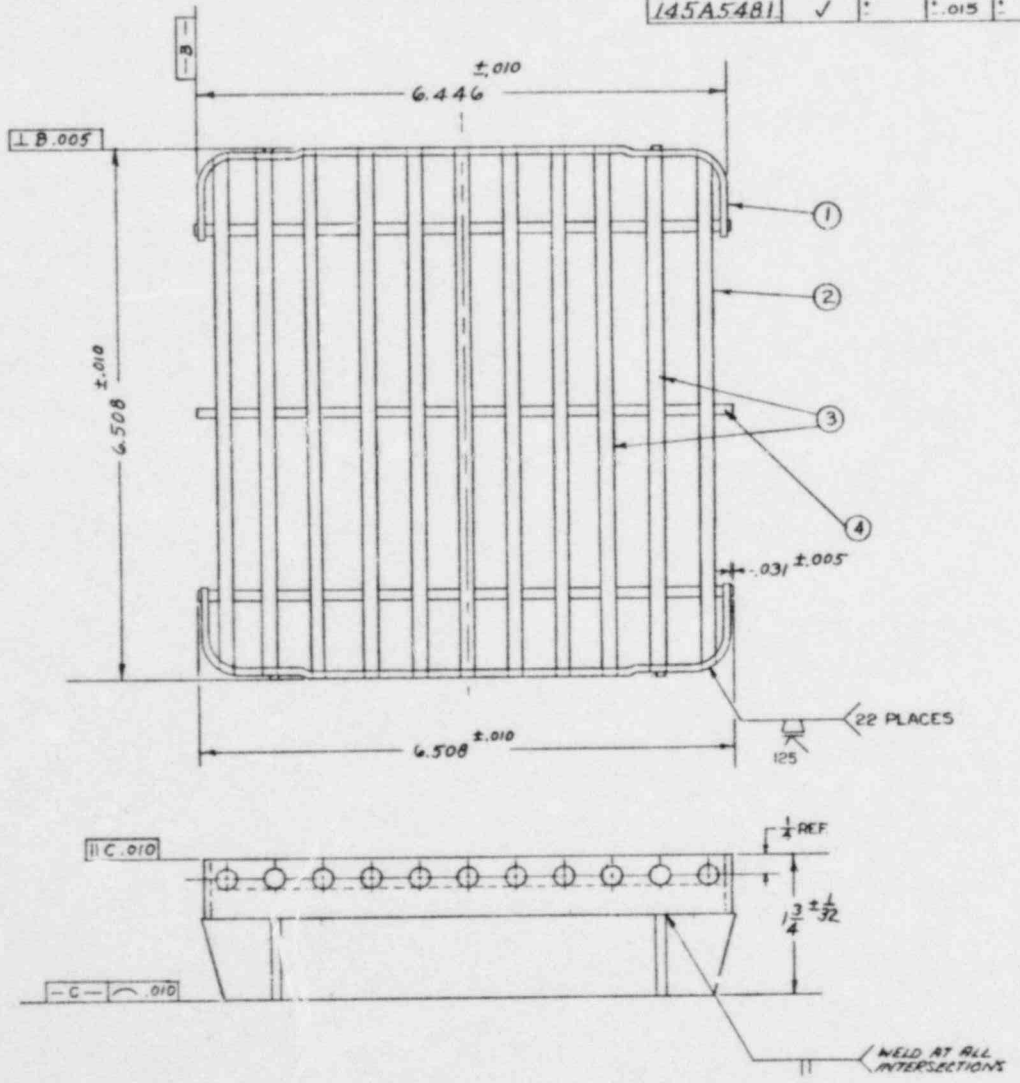
TITLE

BASE

FIRST MADE FOR CONSUMERS POWER DEV.

GI	PART NO.	NAME	DRAWING NO., DESCRIPTION, MATERIAL, WEIGHT
2	1	BRACKET	985C214P2
2	2	ROD	114B5833P2
9	3	ROD	114B5833P1
1	4	FOOT	114B5834G1

FCF ON 124F725



G1

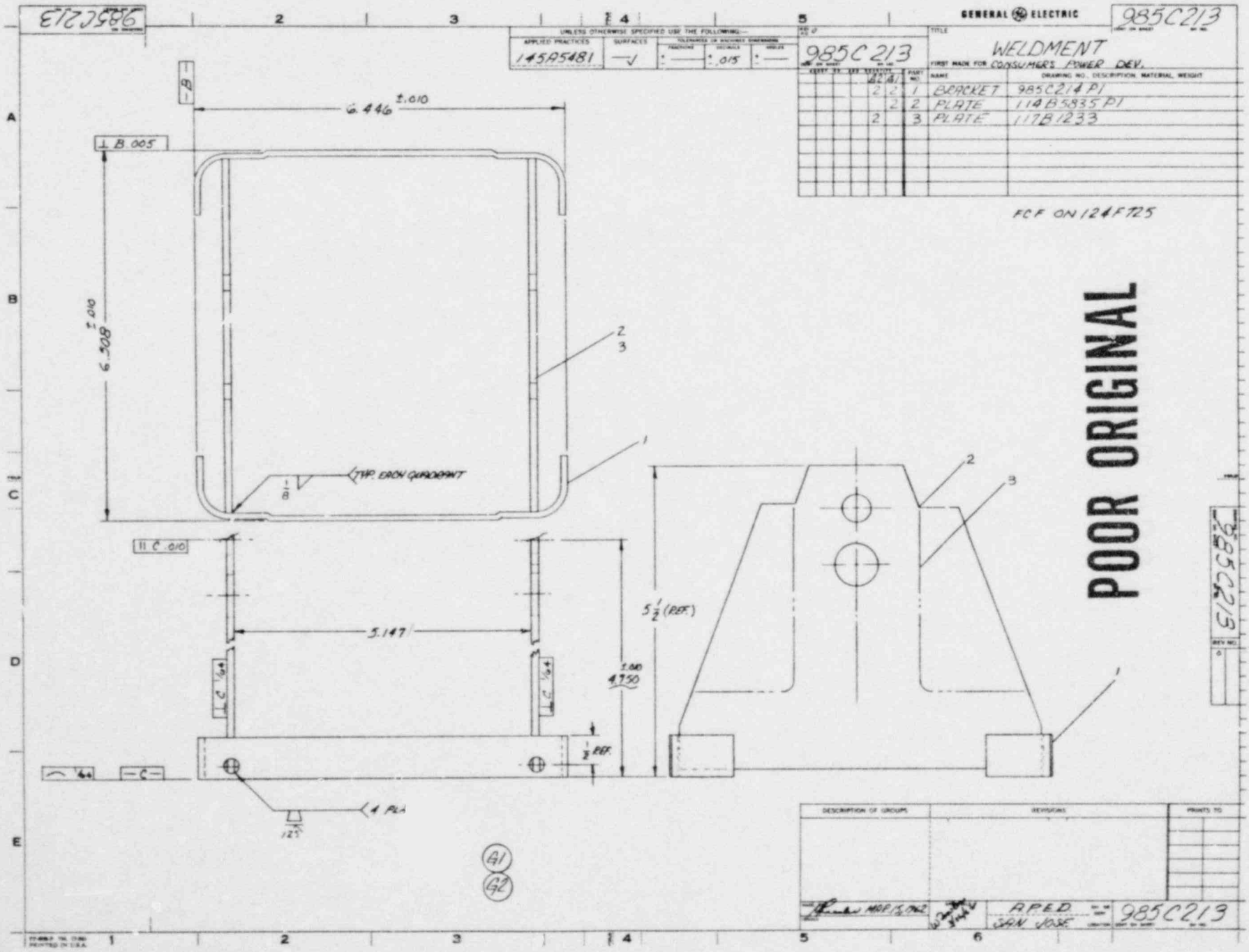
985C212

REV NO. 0

DESCRIPTION OF GROUPS	REVISIONS	PRINTS TO

APED SAN JOSE

985C212


985C213
GENERAL ELECTRIC
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:—
APPLIED PRACTICES
145A5481
SURFACES
TOLERANCES ON MACHINED DIMENSIONS
FRACTIONS
DECIMALS
ANGLES
±.015
985C213
TITLE
WELDMENT
FIRST MADE FOR CONSUMER'S POWER DEV.
NAME
DRAWING NO., DESCRIPTION, MATERIAL, WEIGHT
2 2 1 BRACKET 985C214 P1
2 2 PLATE 114B5835 P1
2 3 PLATE 117B1233
FCF ON 124F725
POOR ORIGINAL
6.446 ±.010
⊥ B .005
6.508 ±.010
TYP. EACH QUADRANT
1/8
5.147
5 1/2 (REF.)
4.750 ±.010
1/2 REF.
4 PLA
.125
G1
G2
DESCRIPTION OF GROUPS
REVISIONS
PRINTS TO
MAR 15 1962
A.P.E.D.
SAN JOSE
985C213

GENERAL ELECTRIC

985C214

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —

APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS		
		FRACTIONS	DECIMALS	ANGLES
145A5481	250 √	± 1/64	± .—	± —°

TITLE

BRACKET

FIRST MADE FOR CONSUMERS POWER REV.

FOR 985C211
985C212
985C213

POOR ORIGINAL

.093 STOCK

1.168 ±.005

$\frac{1}{2}$ $^{+\frac{1}{64}}_{-0}$ R

$\frac{3}{32}$ R

.031 $^{+.063}_{-.000}$

$\frac{3}{32}$ R

$2\frac{1}{16}$ $\pm\frac{9}{32}$

$4\frac{1}{8}$ $\pm\frac{9}{16}$

6.446 ±.010

3.223 ±.005

$\frac{3}{4}$ STOCK

2.636 ±.005

5.272 ±.010

$\frac{17}{64}$ DIA - 2 HOLES

1/2

(1) MAT'L: STN STL TYPE 304

$\frac{17}{64}$ DIA, 11 HOLES

.588 TYP — 1.176 TYP — 1.764 TYP — 2.352 TYP — 2.940 TYP

1/4

(2) MAT'L: STN STL TYPE 304
PT. 2 SAME AS PT. 1 EXCEPT AS SHOWN

REVISIONS	PRINTS TO

APED SAN JOSE

985C214

REV NO. 0

POOR ORIGINAL

GENERAL ELECTRIC

985C215

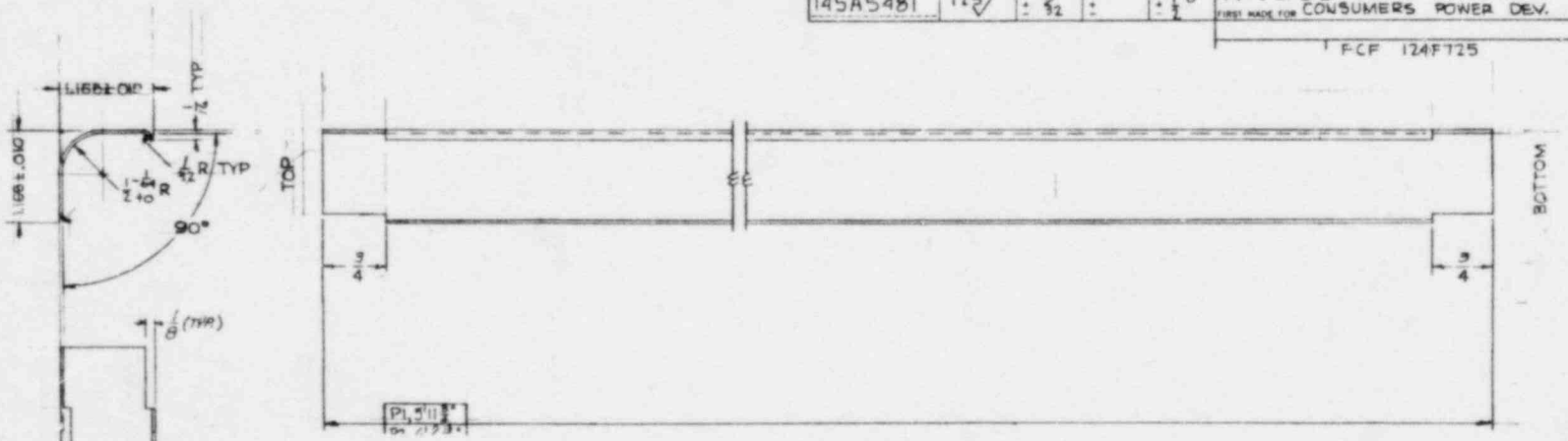
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —

APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS		
		FRACTIONS	DECIMALS	ANGLES
145A5481	125	± 1/32	±	± 1°

TITLE: ANGLE

FIRST MADE FOR CONSUMERS POWER DEV.

FCF 124F725



(1) .031 THK, SEN SEL TY 304A

(2) OVERALL LGH CHG.
OTHERNISE SAME AS P1

985C215
REV NO. 0

REVISIONS

PRINTS TO

PRELIMS BOX 61

A P E D — 985C215
SAN JOSE

114B5456

GENERAL ELECTRIC

114B5456

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:

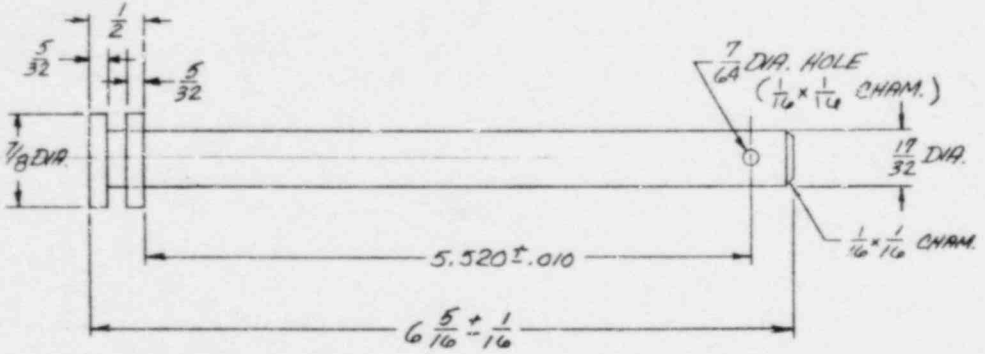
APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
145A5481	125 √	± 1/64	± —	± —

REV NO 114B5456

TITLE RETAINER BOLT

FIRST MADE FOR CONSUMERS POWER DEV.

FCF ON 124F725



(1) MAT'L: TY304 STN. STL.
REMOVE ALL SHARP EDGES & CORNERS.

POOR ORIGINAL

REVISIONS

PRINTS TO

MAR. 21, 1966

APED
SAN JOSE

114B5456

PRINTED IN U.S.A.

GENERAL ELECTRIC

114B5457

CONT ON SHEET SH NO.

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:—

APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
145A5481	250	± 1/64	±.010	± 2°

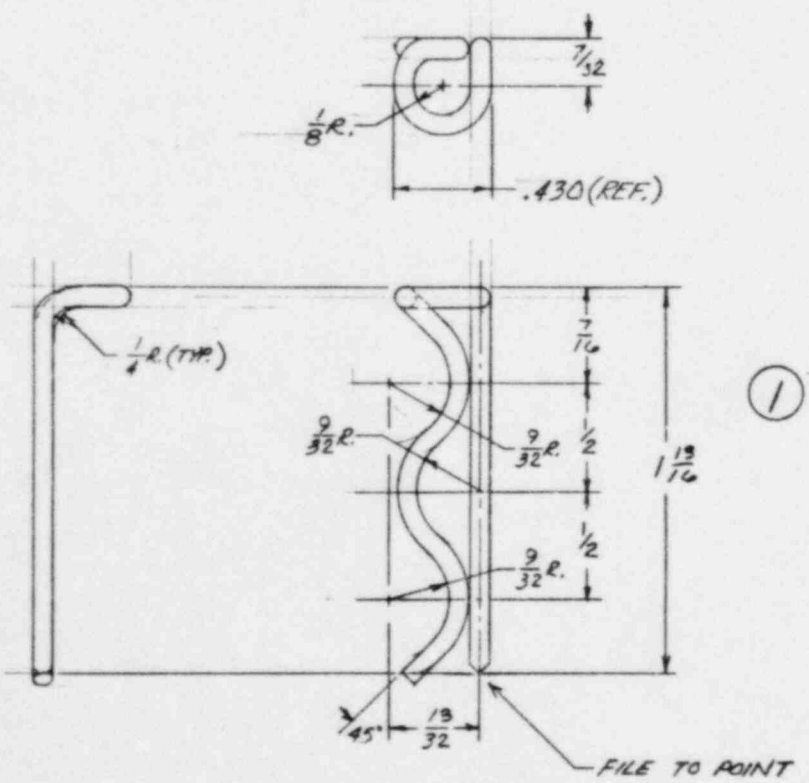
REV NO. 114B5457

CONT ON SHEET SH NO.

TITLE HAIRPIN

FIRST MADE FOR CONSUMERS POWER DEV.

FCF ON 124F725



(1) .090 DIA. WIRE
TY 304 STN. STL.

POOR ORIGINAL

REVISIONS

PRINTS TO

MADE MAR. 21, 1962

APPROVALS

A.P.E.D.

SAN JOSE

114B5457

CONT ON SHEET SH NO.

FF-606-P (5-61) PRINTED IN U.S.A.

GENERAL ELECTRIC

114B5833

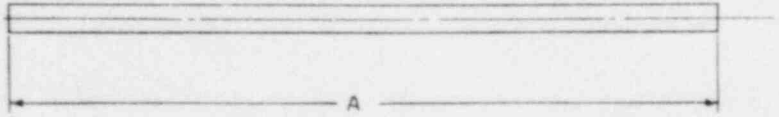
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:					REV. NO. 0
APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES	114B5833
145A5481	250	± ——	± .015	± ——	

TITLE: ROD

FIRST MADE FOR CONSUMERS PWR. DEV.

FCF 985C212
985C211

POOR ORIGINAL



PT. NO.	A	MATL.
1	6.457	1/4 DIA. ROD STK., TP 304 STN. STL.
2	6.385	STN. STL.

REVISIONS | PRINTS TO

M Pellon MAY 25 1961

APED SAN JOSE

114B5833

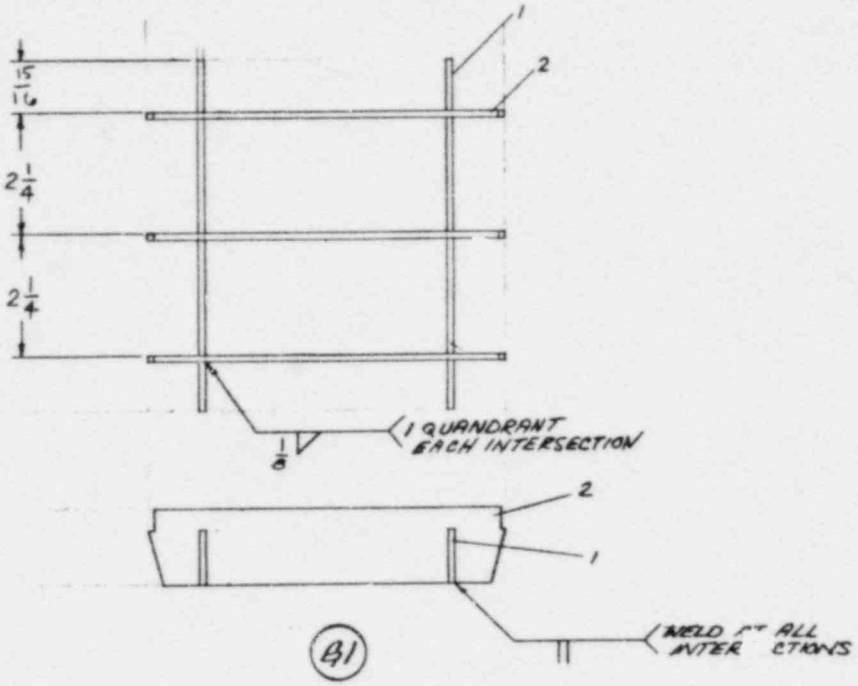
FF-636-P (2-60) PRINTED IN U. S. A.

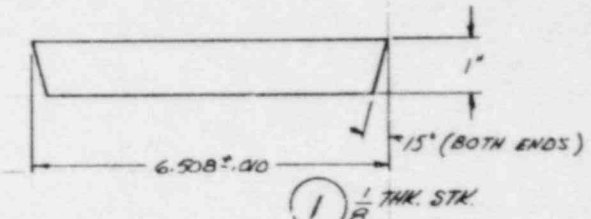
GENERAL ELECTRIC

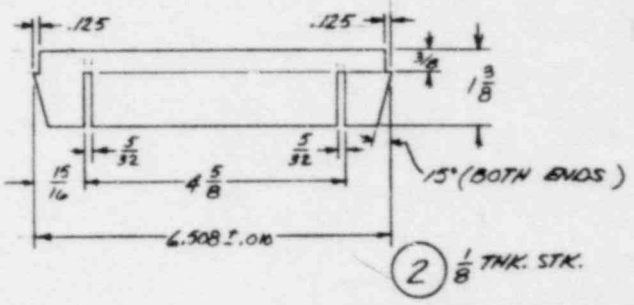
114B5834

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:—					REV NO.	TITLE
APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES		FOOT
145A5481	250	± 1/64	±.005	± 1°	114B5834	FIRST MADE FOR

QUANTITY	PART NO.	NAME	DESCRIPTION
4			
2	1	PLATE	TY 304 STN STL.
3	2	PLATE	TY 304 STN STL.







POOR ORIGINAL

REVISIONS	PRINTS TO

MAR. 12 1968 — A.P.E.D. SAN JOSE — 114B5834

FF-606-P (5-61) PRINTED IN U.S.A.

POOR ORIGINAL

GENERAL ELECTRIC

114B5835

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:—

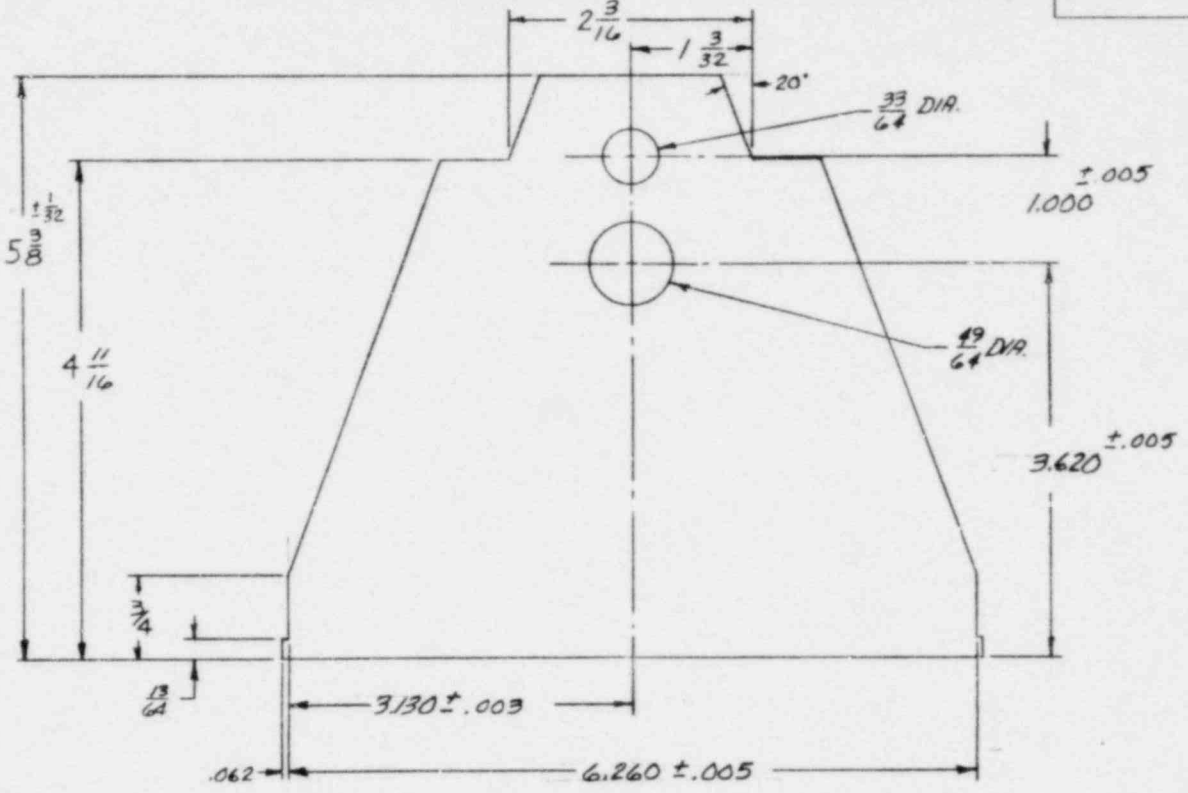
APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
145A5481	250	± 1/64	± .015	± 1°

REV NO. 114B5835

TITLE PLATE

FIRST MADE FOR CONSUMERS POWER DEV.

FCF ON 985C211
985C213



(1) 1/8 THK. STK.
TY 304 STN. STL.
REMOVE ALL SHARP EDGES & CORNERS.

REVISIONS

PRINTS TO

MAR. 19, 1962

APED
SAN JOSE

114B5835

FF-806-P (6-61) PRINTED IN U.S.A.

114B5850

GENERAL ELECTRIC

114B5850

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:—

APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
	✓	±	±	±

REV. NO. 0

114B5850

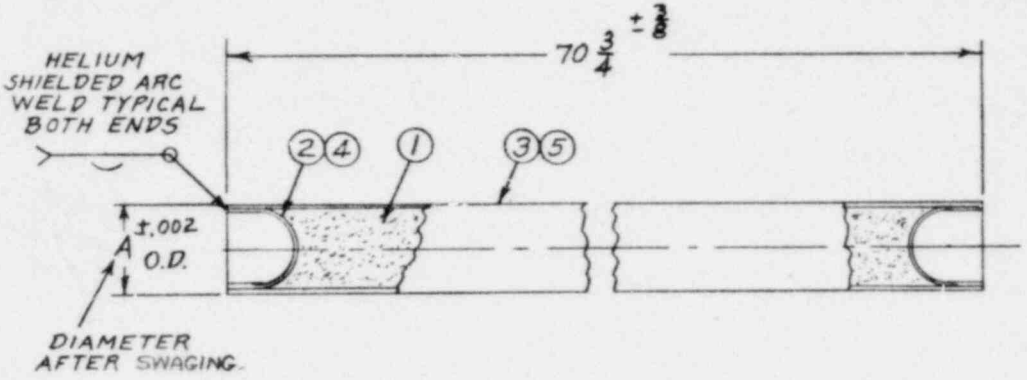
TITLE ASSEMBLY

FUEL ROD

FIRST MADE FOR CONSUMERS POWER DEV.

G2	G1	PT. NO.	NAME	DESCRIPTION
AR	AR	1	POWDER	SEE NOTE 1.
	2	2	END PLUG	149A4071
	1	3	TUBE	ASTM A269 TYPE 304 STN. STL.
2		4	END PLUG	149A4071.
1		5	TUBE	.375 O.D. X .010 WALL STOCK SIZE
				STN STL ASTM A269 TYPE 304

FCF ON 124F725



NOTE 1. POWDER-ARC FUSED UO_2 ENRICHMENT LATER PER PROCESS SPEC. LATER

G. NO.	A.
1	.425
2	.320

REVISIONS

PRINTS TO

MADE BY [signature] April 26 1961

APPROVED [signature] 3/26/62

APED

SAN JOSE

114B5850

FF-606-P (5-60) PRINTED IN U. S. A.

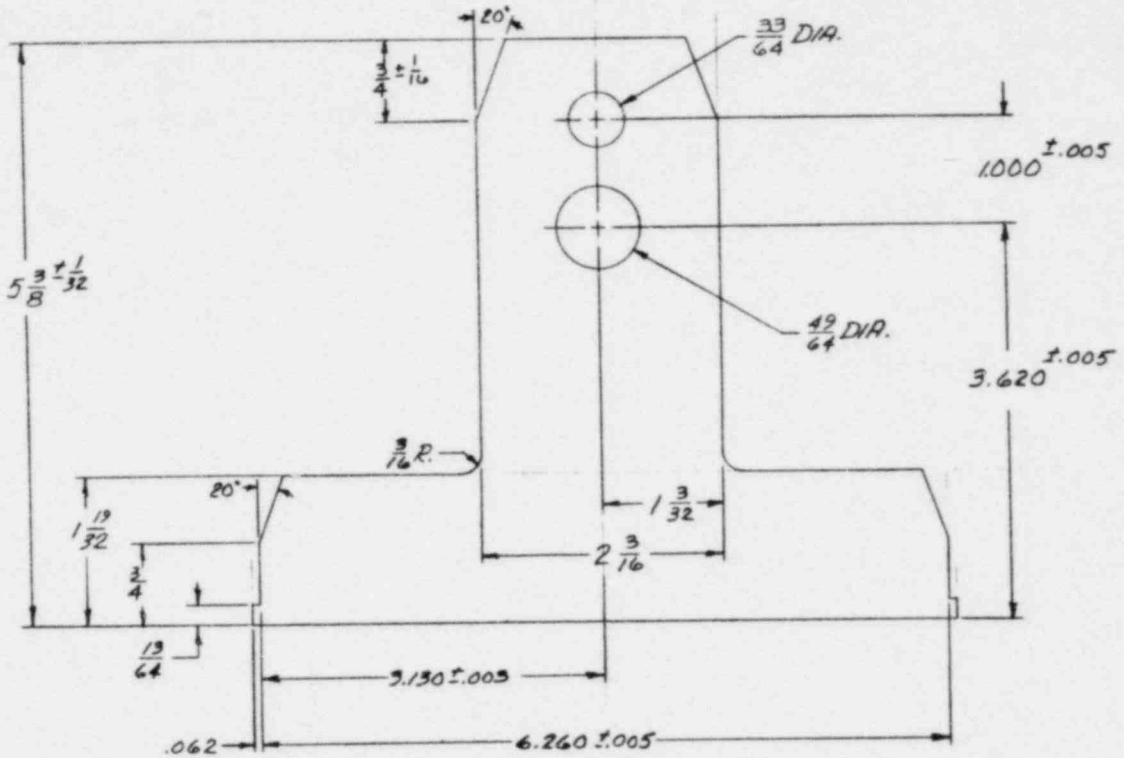
POOR ORIGINAL

GENERAL ELECTRIC

117B1233

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:—					REV NO.	TITLE
APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES	117B1233	PLATE
145A5481	250	± 1/64	± .015	± 1°		FIRST MADE FOR CONSUMERS POWER DEV.

FCF ON 985C211
985C213



(1) 1/8 THK. STK.
TY 304 STN. STL.
REMOVE ALL SHARP EDGES & CORNERS.

POOR ORIGINAL

REVISIONS	PRINTS TO

MAR. 16, 1962 | 3/26/62 | APED SAN JOSE | 117B1233

FF-606-P (6-61) PRINTED IN U.S.A.

POOR ORIGINAL

GENERAL ELECTRIC

117B1450

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:—				
APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
145A5481	✓	±	±	±

REV NO. 0

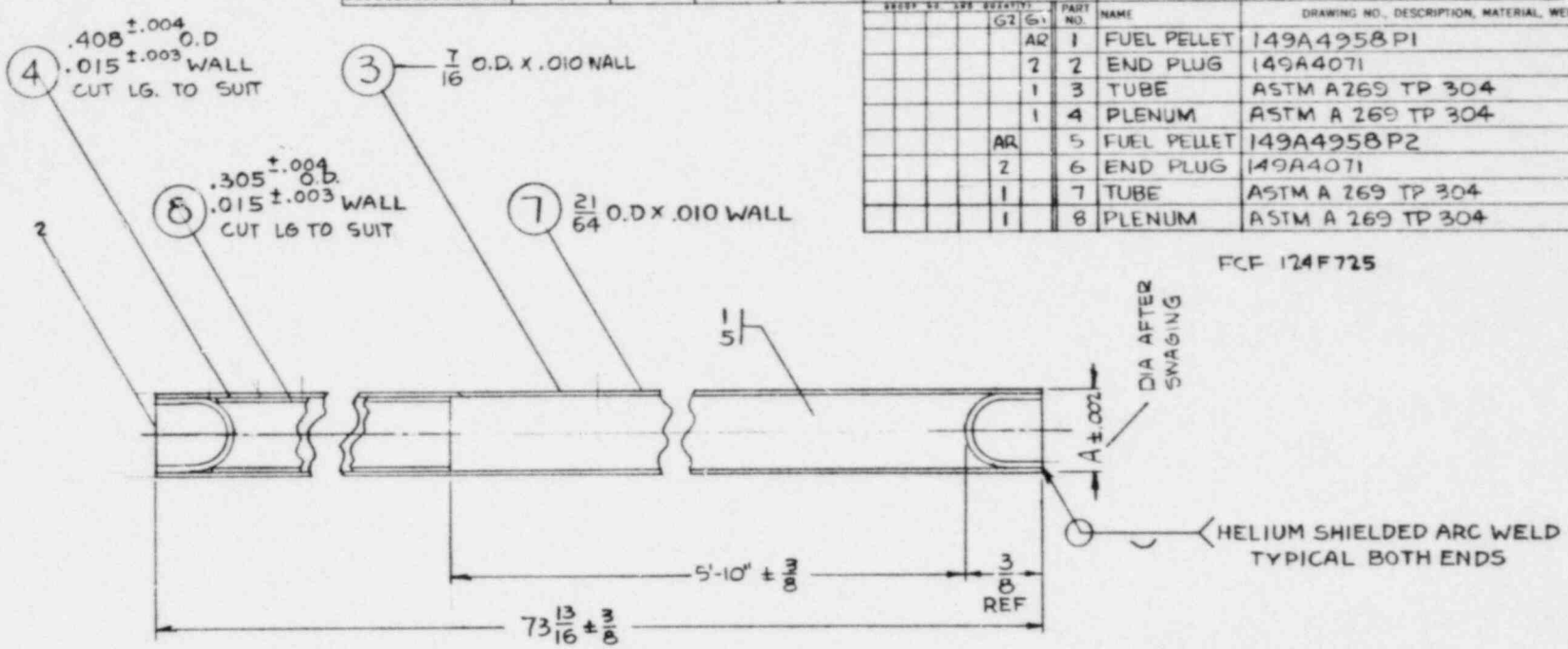
117B1450

TITLE: FUEL ROD

FIRST MADE FOR CONSUMERS POWER DEV.

GROUP NO. AND QUANTITY G2	G1	PART NO.	NAME	DRAWING NO., DESCRIPTION, MATERIAL, WEIGHT
	AR	1	FUEL PELLET	149A4958P1
	2	2	END PLUG	149A4071
	1	3	TUBE	ASTM A269 TP 304
	1	4	PLENUM	ASTM A 269 TP 304
AR		5	FUEL PELLET	149A4958P2
2		6	END PLUG	149A4071
1		7	TUBE	ASTM A 269 TP 304
1		8	PLENUM	ASTM A 269 TP 304

FCF 124F725



G.NO	A DIA
1	.425 ±.002
2	.320 ±.002

DESCRIPTION OF GROUPS	REVISIONS	PRINTS TO

MADE BY: B. WILLIAMS 13 OCT 61

APPROVED: 3/24/62

A P E D — DIV OR DEPT

SAN JOSE — LOCATION

117B1450

FF-808-F (10-58) PRINTED IN U.S.A.

GENERAL ELECTRIC

PARTS LIST FOR 124F725 CONT ON SHEET SH NO.

REV NO.

PARTS LIST FOR 124F725 CONT ON SHEET SH NO.

TITLE ASSEMBLY

FUEL BUNDLE

FIRST MADE FOR CONSUMERS POWER DEV.

GROUP NO AND QUANTITY G2	GROUP NO AND QUANTITY G1	PART NO.	NAME	DRAWING NO., DESCRIPTION, MATERIAL, WEIGHT
	1	1	HANDLE	985C211G1
	1	2	WELDMENT	985C213G1
	4	3	ANGLE	985C215P1
	109	4	FUEL ROD	114B5850G1
	12	5	FUEL ROD	114B5850G2
1	1	6	BASE	985C212G1
4	4	7	SPACER	141F898G1
1	1	8	RETAINER BOLT	114B5456P1
1	1	9	HAIRPIN	114B5457P1
4		10	ANGLE	985C215P1
109		11	FUEL ROD	117B1450G1
12		12	FUEL ROD	117B1450G2
1		13	HANDLE	985C211G2
1		14	WELDMENT	985C213G2

DESCRIPTION OF GROUPS

G1 - POWDER
G2 - PELLETS

REVISIONS

POOR ORIGINAL

PRINTS TO

MADE BY J.W. Vaupel ISSUED April 26 1961

APPROVED W Fowler 3/26/62

APED DIV. OR DEPT.

SAN JOSE LOCATION

PARTS LIST FOR 124F725 CONT ON SHEET SH NO.

GENERAL ELECTRIC

149A4071

CONT ON SHEET — SH NO. 1

REV NO. ~~4~~ ~~1~~ ~~2~~ ~~3~~ 4

149A4071

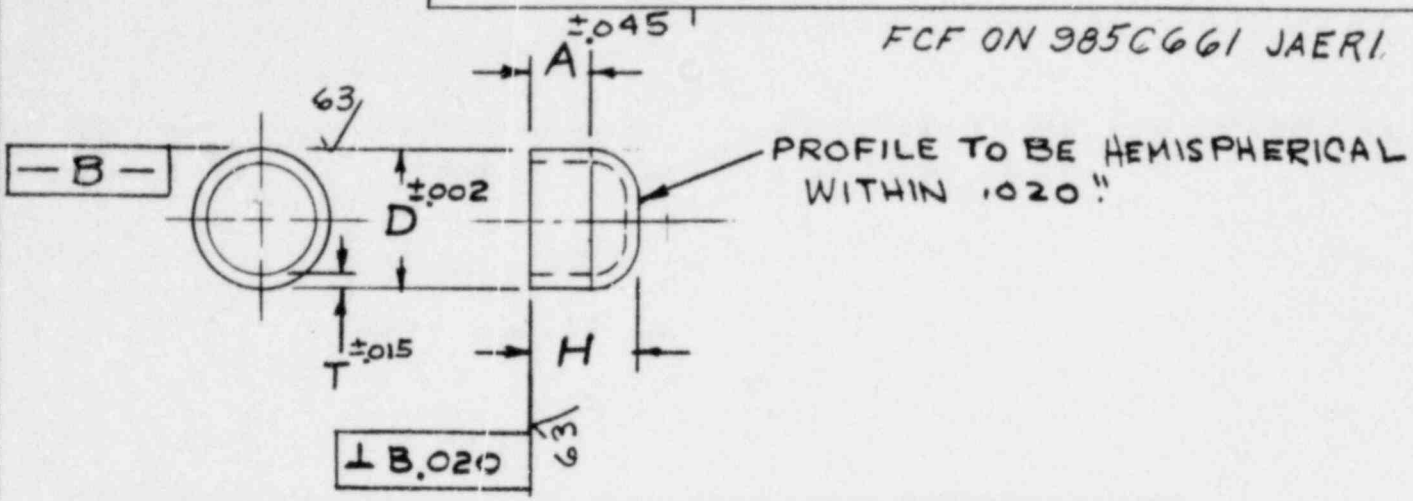
CONT ON SHEET — SH NO. 1

TITLE

END PLUG

FIRST MADE FOR HPD TASK 1B

FCF ON 985C661 JAER1



PNo	"D"	"H"	"A"	"T"	MATERIAL
1	.353	.160/.375	.145	.035	STN. STL. TYPE 304
2	.305	.160/.375	.145	.035	STN STL. TYPE 304
3	.472	.160/.426	.145	.035	STN STL. TYPE 304
4	.482	.160/.375	.145	.035	STN. STL TYPE 304
5	.382	.160/.426	.145	.035	STN STL TYPE 304
6	.420	.160/.426	.145	.035	STN. STL. TYPE 304
7	.583	.230/.270	.200	.030	ZIRCALLOY 2
8	.642		.300	.030	ZIRCALLOY 2

UNLESS OTHERWISE SPECIFIED USE	APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS		
			FRACTIONS	DECIMALS	ANGLES
	145A5481	125 ✓	± —	± —	± —

REVISIONS

						PRINTS TO
4	[signature]		1	Sept. 7 '61 W. Butler	WBK.	
CHG'D. PROFILE NOTE & ADDED 63 finish TO END			ADD P6.			
			2	Sept. 14 '61 [signature]	WBK.	
			ADDED PTS 7 & 8			
			3	Oct. 13 '61 J. M. Vaupel	10/12/61 4.E.4.	
			ADDED FCF ON 985C661 AND .230-.270 "H" P7			

POOR ORIGINAL

MADE BY W. Butler Nov 22, 1960

ISSUED A. E. Graham Apr. 24 '61

APPROVALS W. [signature] 11/22/60

APED

SAN JOSE CALIF.

DIV OR DEPT.

LOCATION

149A4071

CONT ON SHEET — SH NO. 1

FF-803-P 25M (1-57)

GENERAL ELECTRIC

149A4958
CONT ON SHEET SH NO.

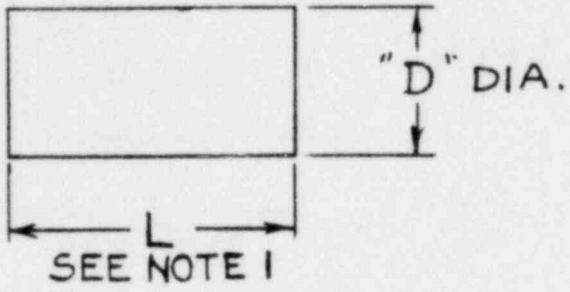
REV NO. 0

149A4958
CONT ON SHEET SH NO.

TITLE

PELLET

FIRST MADE FOR CONSUMERS POWER DEV.



MAT'L - URANIUM DIOXIDE (UO_2)
2.7% U-235
PROCESS SPEC. (LATER)

PART	"D" ±.003
1	.405
2	.300

NOTE 1. $L/D > 1.5$ AND MFG. OPTION

UNLESS OTHERWISE SPECIFIED USE	APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS		
			FRACTIONS	DECIMALS	ANGLES
		✓	±	±	±

REVISIONS

PRINTS TO

POOR ORIGINAL

MADE BY G.E. Graham FEB. 16, 1962
ISSUED

APPROVED W Fowler 3/16/62

APED DIV OR DEPT.
SAN JOSE LOCATION

149A4958
CONT ON SHEET SH NO.

FF-803-P 25M (1-57)