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AEC RESEARCH AND DEVELOPMENT REPORT

JULY 1971

SEFOR FUEL ROD FABRICATION 1970-1971

MASTER

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W. K. EGGERT

U.S. ATOMIC ENERGY COMMISSION
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ABSTRACT

Nuclear Fuel Services, Inc., Erwin, Tennessee fabricated fuel rods for the SEFOR Site during 1970 and early 1971. A description of the fabrication effort, quality assurance activities, and problem areas are summarized in this report.

SECTION I

SUMMARY AND INTRODUCTIONI.1 SUMMARY

Fuel rods for the SEFOR were fabricated at Nuclear Fuel Services, Inc., (NFS) Erwin, Tennessee under Revision 4 to the GE Purchase Order No. 205-58226NG. During the fabrication campaign that took place in 1970-1971, NFS produced 104 fuel rods, repaired 19 fuel rods, and shipped 20.6 kg of loose fuel pellets.

This report summarizes the fabrication effort at NFS and the quality assurance activities carried out by General Electric personnel to monitor the fabrication effort.

I.2 INTRODUCTION

The Southwest Experimental Fast Oxide Reactor (SEFOR) is a 20 MW fast spectrum reactor fueled with mixed $\text{PuO}_2\text{-UO}_2$ and cooled with sodium. SEFOR has characteristics similar to large, soft spectrum, fast breeder reactors fueled with mixed $\text{PuO}_2\text{-UO}_2$ for economic electrical power generation. SEFOR is being used to obtain physics and engineering data at fuel compositions, temperatures, and crystalline states characteristic of power reactor operating conditions. The reactor is particularly designed for the systematic determination of the Doppler coefficient of reactivity at temperatures up to the vicinity of fuel melting.

The SEFOR project consists of two major parts: the design and construction of the reactor and a related research and development program. Funds for the design and construction of the facility were provided by the

Southwest Atomic Energy Associates (a group of seventeen investor-owned utility companies located in the South and Southwest part of the United States), together with the Karlsruhe Laboratory of the Federal Republic of Germany, Euratom, and the General Electric Company.

The United States Atomic Energy Commission is supporting the research and development program. The R and D Program consists of two phases:

Phase I - Pre-Operational Research and Development

Phase II- Post Construction Research and Development

This report describes work performed under Task 9, Fuel Fabrication, in Phase I of the Research and Development Program.

The fuel rods for SEFOR are described in Reference 1 and a schematic drawing of the rod is shown in Figure 1. The fuel rods were fabricated by Nuclear Fuel Services, Inc. (NFS) Erwin, Tennessee under GE Purchase Order No. 205-58226 NG. The first fabrication campaign consisting of approximately 750 fuel rods was carried out in 1967-1968, and is reported in Reference 2. A second fabrication campaign, involving approximately 100 fuel rods, under Revision 4 to the GE purchase order No. 205-58226 NG was carried out in 1970-1971.

The number and title of the specifications issued by GE to define the fuel rods and the Quality Control Plans that were used during the fabrication are given below:

<u>GE SPECIFICATION NUMBER</u>	<u>TITLE</u>
22A1546 Rev. 3	Plutonium Nitrate for SEFOR Core I Fuel Pellets
22A1547 Rev. 3	Uranium Nitrate for SEFOR Core I Fuel Pellets
22A1545 Rev. 4	$\text{PuO}_2\text{-UO}_2$ Fuel Pellets for SEFOR Core I
22A1583 Rev. 2	UO_2 Insulator Pellets for SEFOR Core I
22A1548 Rev. 4	Fuel Rods for SEFOR Core I
FP-136 Rev. 6	Quality Control Plan for SEFOR Core I Fuel Pellets
FP-138 Rev. 3	Quality Control Plan for SEFOR Core I Fuel Rods

112C2053

ITEM NO.		ITEM NO.		FIRST MADE FOR		SEFOR 210		TASK 9.0	
G3 G2 G1		PART NO.		NAME		DRAWING NO.		DESCRIPTION, MATERIAL, WEIGHT	
	1	1	1	1	TOPEND PLUG	129 B	2357 PI		
	1	1	1	2	SPACER	159 A	2752 PI		
	1	1	1	3	BOTTOM END PLUG	129 B	2359 PI		
	1	1	1	4	TUBE	159 A	2747 PI		
				5					
	1	1	1	6	SPRING	159 A	2752 PI		
	1	1	1	7	SPRING	167 A	1564 PI		
AR	AR			8	FUEL PELLET	159 A	2736 PI		
2	2	2		9	REFLECTOR	59 A	2751 PI		
4	4	4		10	INSULATOR	159 A	2750 PI		
	1			11	TOPEND PLUG	29 B	2353 P2		
	AR			12	FUEL PELLETT	159 A	2736 P2		
X	X	X		3	6246 603-107600 603 MAT 1/2 IN	35C	4906 FIS		
	X	X		14	603 MAT 1/2 IN 603 MAT 1/2 IN	35C	4906 FIS		
X	X	X		15	DRAWING LIST	194X	795

1. FOR FUEL ROD SPEC, SEE 22A1549.

2. ASSEMBLY TO BE STRAIGHT WITHIN .005/FT.

3. OUTSIDE DIAMETER OF WELDS SHALL BE .980 MAX.

4. WELDS SHALL BE FULL PENETRATION.

5. WELD P2 USING ELECTRON BEAM WELD.

6. ONE FUEL PELLETT LENGTH MAY BE 3/8 MIN. TO 3/4 MAX. AS NECESSARY TO MEET COLUMN DIM'S.

7.

8. ENGRAVE SERIAL NUMBER .010 DEEP X 5/16 HIGH. LINE WIDTH 3/64. CENTER NUMBER ABOUT .125 SLOT & AS SHOWN.

SERIALIZE G1 RODS USING NUMBERS BETWEEN 101	£	924
SERIALIZE G2 RODS USING NUMBERS BETWEEN A01	£	A19.
SERIALIZE G3 RODS USING NUMBERS BETWEEN 000	£	100 AND BETWEEN 930 £ 999.

GROUP NR	DIM 4
1	49 ⁵ / ₈
2	49 ¹ / ₂
3	49 ⁵ / ₈

[illegible]

FIGURE 1 - SEFOR FUEL ROD

Revision 4 to GE Purchase Order No. 205-58226 NG stipulated that NFS supply the following items:

- 102 fuel rods
- 20.5 kg of loose fuel pellets
- Repair 22 fuel rods fabricated during the 1967-1968 campaign that were found to leak helium during the receiving inspection at the SEFOR site.

This report describes the fabrication effort and the related quality assurance activities during the second fuel rod fabrication campaign (1970-1971) at NFS.

SECTION 2

NFS PROCESS DESCRIPTION AND QUALITY PLAN

Nuclear Fuel Services' process for fabricating SEFOR fuel rods and the related quality control procedures are given in the following NFS documents:

<u>NFS NUMBER</u>	<u>TITLE</u>
256-B-101 Rev. 8	NFS Fuel Pellet Fabrication Process Manual
NFS-M-10 Rev. 5	Quality Control Procedure for the Fabrication of SEFOR Core I Fuel Pellets
NFS-M-11 Rev. 7	Fabrication and Quality Control Procedure for SEFOR Core I Fuel Rods

These documents were reviewed and approved by General Electric prior to the start of the second fabrication campaign. Figure 2 summarizes the NFS process and indicates the quality control release points called out in the Quality Control Procedures (NFS-M-10 and 11) and the runsheet numbers (data records) that are generated at each station.

2.1 PROCESS DESCRIPTION

2.1.1 Fuel Pellets

The process for producing the mixed oxide for the fuel pellets was accomplished by co-precipitation from a master mix of plutonium-uranyl nitrate. The precipitate was reduced to oxide and blended. The powder was pressed into pellets, sintered, and centerless ground to finish outside diameter. As a provision of Revision 4 to the GE purchase order no redissolved scrap was recycled in the fuel pellet process. After the fuel pellets were vacuum outgassed, they were assembled into fuel stacks for loading into fuel rod tubes.

FIGURE 2
 NFS
 PROCESS DIAGRAM
 BEFORE FUEL RODS

- Q.C. Points (NFS-M-10)
 △ Runsheet Number (NFS-M-10)
 □ Runsheet Number (NFS-M-11)
 ○ Q.C. Points (NFS-M-11)
 ○ Mandatory N.P.S. QC
 ○ Release Points

2.1.2 Fabrication of Inert Parts and Fuel Rod Assembly

Purchased materials (tubing and bar stock) were fabricated into fuel rod individual parts under purchase orders from NFS to outside vendors. The hold down springs for the fuel stacks was purchased by NFS as a finished item. The fuel rod tube and center spacer were assembled at Buehler Corp., Indianapolis, Indiana using the electron-beam welding process.

At final assembly, the fuel rod stacks were loaded into the upper and lower section of the fuel tube - center spacer subassembly and end plugs were welded on each end in a weld box containing a helium atmosphere. The bottom end plug was slotted prior to cleaning and passivating the fuel rod.

2.2 QUALITY PLAN

2.2.1 Fuel Pellets

The NFS Quality Control Procedure (NFS-M-10) required in-process analysis and measurement of product quality and releases by the Quality Control Department signifying satisfactory results were obtained. Mandatory release points were established for release to production of the:

- plutonium nitrate
- uranyl nitrate
- master-mix solution
- mixed oxide powder for pelletizing
- fuel stacks for fuel rod loading

A preproduction phase was stipulated in the GE purchase order Revision 4 that required GE approval of the fuel pellet process and product. In order to satisfy this requirement, NFS was required to submit ten fuel pellets to GE for approval prior to starting production operations.

When production started, runsheets generated at specified process steps and a minimum of three fuel pellets per pellet batch were submitted to GE for review and verification analysis.

2.2.2 Inert Parts and Assembly

The NFS Quality Control Procedure (NFS-M-11) required the release of all incoming materials prior to the use of that material for fabrication of individual parts. After parts were fabricated a receiving inspection was performed and the parts were released by the Quality Control Department for use in fuel rod assembly.

The weld processes for making the center spacer weld (electron-beam) and the end plug welds (gas tungsten arc weld) were required to be qualified prior to start of production. NFS was required to submit ten weld samples of the end plug weld and the center spacer weld to GE for approval prior to starting production operations.

Inspection of each assembled fuel rod included:

- Dimensions and surface
- Helium leak check
- X-ray of end plug welds
- Gamma scan

Final release for shipment of the fuel rods was given by the Quality Control Department. Certification of compliance with the GE specifications was also required.

SECTION 3

QUALITY ACTIVITIES BY GENERAL ELECTRIC

The quality plan for the SEFOR fuel rod procurement covered by purchase order 205-58226 NG was contained in FP-136 Rev. 6 and FP-138 Rev. 3. These plans were in effect for the second fabrication campaign as described in Revision 4 to the purchase order.

In addition to the quality plans, a Quality Assurance Audit Plan (given in Appendix A) was formulated to provide a guide for the systematic audit of NFS processes quality control activities during the production of fuel rods.

The key to the implementation of the audit plan was the GE resident QC Engineer established at the NFS plant during fuel rod production. The GE QC Engineer provided an audit of NFS quality control inspections and in-process evaluation and records. This audit information along with the pre-production verifications and fuel pellet batch sampling and verification provided assurance that the fuel rods complied with the fuel rod specifications.

A system of quality assurance files was developed by the GE Resident Engineer to document his audit activities during fuel rod production. A listing of these files is given in Table I. Information contained in the quality assurance files is summarized in this report under the appropriate subject heading.

TABLE 1 - LIST OF QUALITY ASSURANCE FILES DEVELOPED BY GE
RESIDENT ENGINEER

TITLE

Master Mix
NFS Run Sheets 4 & 5
Fuel Pellet Fabrication
O/U + Pu Ratio and Volatiles
Tubes
End Plug
Springs
Reflectors
Insulator Pellets
Fuel Rod Assembly
NFS Run Sheets 18 and 26
Gamma Scan
Repair Rods
NFS Run Sheet 20
Quarantined Material Record
Shipments

These files are maintained by the BRDO Quality Assurance Subsection.

SECTION 4

PRODUCTION OF FUEL RODS4.1 Pre-production Activities4.1.1 Chemical Analysis Checks Between GE and NFS Laboratories

A round robin chemical analysis program was initiated to assure that reasonable agreement could be obtained between the GE and NFS analytical laboratories when master-mix solution samples and fuel pellet samples were analyzed for the attributes listed in the specifications. The NFS and GE laboratories concurrently analyzed samples of a synthetic master-mix solution prepared by NFS and samples of fuel pellets from the first fabrication campaign. The results of these analyses are shown in Table II and indicated good agreement between the two laboratories.

4.1.2 Weld Qualificationa. End Plug Weld

In order to qualify the end plug weld, NFS was required to make 10 consecutive welds with the equipment that was used during production. The 10 qualification welds must be acceptable to qualify the weld technique and parameters.

NFS submitted end plug weld samples that consisted of half sections of ten welds. The welds were made on the production equipment at NFS using the parameters given below:

- Welding Method - Gas tungsten arc weld (GTA).

TABLE II

SEFOR FUEL ROD PRODUCTION GE-NFS ROUND-ROBIN CHEMICAL ANALYSIS RESULTS

Sample		General Electric		Results		Nuclear Fuel Services	
1. Synthetic Master Mix							
a.	Grams/Pu gram solution	0.02476	0.02490	Avg 0.02484	0.02473	Avg 0.02473	
		0.02491	0.02479		0.02475		
		0.02487	0.02478		0.02475		
		0.02497	0.02473				
b.	Grams U/gram solution	0.08842	0.08838	Avg 0.08837	0.08749	Avg 0.08768	
		0.08878	0.08839		0.08776		
		0.08796	0.08827				
2. (Pu-U)O ₂ Fuel Pellets							
a.	O/M Ratio	1.9914			1.990		
		1.9902					
b.	Pu Total Pu + U	0.2676	0.2669	Avg 0.2677	0.2704	0.2700 } Avg 0.2700	
		0.2673	0.2683		0.2699		
					0.2700		
c.	Moisture, ppm	< 1, 3					
d.	Total gas microliters/gram	66.3	69.1	(1350°C)	72		
			69.4	(1650°C)			
e.	Impurities, ppm						
	H	-			5.8		
	B	<1	<1		<0.2		
	N				16		
	Cl	11			<5		
	F	19			<5		
	Al	50	50		846		
	Ag	<0.1	<0.1		0.8		
	Ca	<25	<25		7		
	Cd	<2	<2		<0.2		
	Co	14	14		20		
	C	161	141		146		
	Cu	30	30		22		
	Fe	200	150		144		
	Mg	4	4		12		
	Mn	10	10		8		
	Mo	<10	<10		5		
	Na	<15	<15		110		
	Ni	<24	<24		41		
	Pb	<50	<50		2		
	Si	12	8		57		
	Sn	<1	<1		<2		
	Ti	-	-		<250		
	V	<3	<3		<5		
	Zn	<10	<10		27		
	Li	<10	<10				
	Be	<0.3	<0.5			Total Metallic Impurities	
	Co	<1	<1			1559 ppm	
	P	<50	<50				

- Atmosphere - Helium
- Welding Current - 26 ± 2 amps (automatically controlled for each weld)
- Voltage - 14 ± 2
- Electrode - 0.040" diameter - Tungsten - 2% ThO_2
- Arc Gap - 0.025"
- Chill Distance - $1/8 \pm 1/32$
- Surface Speed - 0.278 in/sec
- Weld Time - $10.75 \pm .25$ sec.

The ten weld samples submitted to GE were evaluated by visual examination, x-ray and metallographic methods. Typical metallographic cross sections of the end plug weld are shown in Figure 3 and 4. The results of the weld sample evaluation were satisfactory and the end plug weld was released for production.

b. Center Spacer Weld

The center spacer was designed to be electron-beam (EB) welded into the fuel tube using a single weld. During the pre-production qualification of this weld during the first fabrication campaign the single EB weld was replaced by two EB welds because of (1) lack of complete fusion of the spacer end and (2) cracks in the weld which appeared when the spacer end was not completely fused. The two EB welds resulted in a total weld thickness at the tube-spacer interface of 0.040 inches, but some small cracks (0.004 inches long or less) were observed in the welds at the tube-spacer interface. The observed small cracks were accepted on the basis that tube wall defects up to 0.004 inches were allowable.

During the pre-production welding for the second fabrication campaign by Buehler Corp., Indianapolis, Ind.

316
TUBING

304L
END PLUG

Neg No 70 Px 0606

40X

WELD CROSS SECTION 3A

304L
END PLUG

316
TUBING

Neg No 70 Px 0607

40X

WELD CROSS SECTION 3B

304L
END PLUG

316
TUBING

Neg No 70 Px 0608

40X

WELD CROSS SECTION 3C

FIGURE 3 PHOTOMICROGRAPHS OF END PLUG WELD SAMPLE NO 3
ETCHANT: 60% HNO_3 ELECTROLYTIC

304L
END PLUG

316
TUBING

Neg No 70 Px 0617

40X

CROSS SECTION OF WELD 7A

316
TUBING

304L
END PLUG

Neg No 70 Px 0618

40X

CROSS SECTION OF WELD 7B

304L
END PLUG

316
TUBING

Neg No 70 Px 0619

40X

CROSS SECTION OF WELD 7C

FIGURE 4 PHOTOMICROGRAPHS OF END PLUG WELD SAMPLE NO 7
ETCHANT: 60% HNO_3 ELECTROLYTIC

the first and second qualification tests were made with double welds. Examination of these welds showed cracks in the welds at the tube spacer interface greater than 0.004" long. The cracks appeared to be caused by a stress present at the tube-spacer interface when the weld solidified. Clearance between the tube inside diameter and the spacer outside diameter contributed to this condition. In addition, the chemical composition of the tube and spacer material (316 and 304 stainless steel respectively) indicated only a small amount of ferrite would be present in the weld (Table III) contributing to weld cracking by hot shortness of the weld metal.

The cracking in the weld was eliminated by making one weld at the spacer end that completely consumed the spacer end. The width of the weld was controlled so that a total weld thickness of 0.036 inches minimum was maintained.

Buehler Corporation produced ten tube-center spacer subassemblies using a single EB weld using the weld equipment and parameters given below:

- Welding equipment - Hamilton Standard 6 KW electron beam welder (Model W-2-56-36-36)
- Filament current - 1.8 amps
- Beam current - 15 ma
- Voltage - 100 KV
- Weld speed - 100 inches/min

The qualification welds were examined visually and by metallographic examination. Visual examination showed the end of the spacer was consumed and that the weld was smooth and oxide free. Metallographic examination was done

TABLE III

CENTER SPACE EB WELD

Estimated Ferrite Content

Center Spacer Material
304L

Heat 27275

C	Mn	Si	P	S	Cr	Ni	Mo	Cu
.023	1.41	.43	.013	.012	18.37	10.23	.14	.09

Tubing
316

Heat 03697

C	Mn	Si	P	S	Cr	Ni	Mo	Cu
.014	1.75	.45	.011	.012	16.32	13.44	2.32	-

$$\text{Ni Equiv.} = \% \text{Ni} + 30 \times \% \text{C} + .5 \times \% \text{Mn}$$

$$\text{Spacer} = 10.23 + 30(.025) + .5(1.41)$$

$$\text{Ni Eq.} = 10.23 + 0.69 + 0.70$$

$$= \underline{11.62}$$

$$\text{Tubing} = 13.44 + 30(.014) + .5(1.75)$$

$$\text{Ni eq.} = 13.44 + 0.42 + 0.87$$

$$= \underline{14.73}$$

$$\text{Cr Equiv.} = \% \text{Cr} + \% \text{Mo} + 1.5 \times \% \text{Si} + 0.5 \times \% \text{Cb}$$

$$\text{Spacer} = 18.37 + 1.41 + 1.5(.43)$$

$$\text{Cr Eq.} = 18.37 + 1.41 + .645$$

$$= \underline{20.425}$$

$$\text{Tubing} = 16.32 + 1.75 + 1.5(.45)$$

$$\text{Cr.Eq.} = 16.32 + 1.75 + .655$$

$$= \underline{18.725}$$

From Schaeffler Diagram

<u>SPACER</u>	~8% Ferrite	} Weld ~2% Ferrite
<u>TUBING</u>	No Ferrite	

on five of the welds at Buehler Corp. (with a GE representative present) and at GE. Three cross sections were cut from the weld, prepared for metallographic examination and evaluated. No cracks were found in the welds as illustrated by the photomicrographs shown in Figure 5. Measurements of the weld thickness at the tube-spacer interface were made using a metallograph and a filar eye piece. The weld thickness measurements are summarized in Table IV.

Based on the results of these qualification tests the center spacer weld was released for production.

4.1.3. Fuel Pellets

Ten pre-production pellets from NFS fuel pellet Batch 701A were submitted to GE for evaluation and approval. The fuel pellets were evaluated for the attributes called out in the GE Specification and the results of the pellet evaluation is shown in Table V. The results of the NFS evaluation of this pellet batch is also shown in Table V. Production of fuel pellets was approved based on the satisfactory results of the pellet evaluation.

4.2 Repair of Fuel Rods

Twenty-two fuel rods assembled in the first fabrication campaign were returned to NFS for repair. During the receiving inspection of these fuel rods, a mass spectrometer helium leak check indicated leaks in the rods. From past experience, when leaks occurred in a fuel rod it was usually due to porosity in the wall of the end plugs.

Inspection of the returned fuel rods at NFS indicated two of the fuel rods were mechanically damaged and the rods could not be repaired by replacing the end plugs.

70PX0661

25X

WELD NO. 9181

70PX0663

25X

WELD NO. 9182

70PX0665

25X

WELD NO. 9183

70PX0667

25X

WELD NO. 9184

70PX0670

25X

WELD NO. 9185

FIGURE 5 - TYPICAL CROSS SECTIONS OF OUTER SPACER ELECTRON-BEAM WELDS QUALIFICATION TESTS

TABLE IV

DIMENSIONS OF SEFOR CENTER SPACER QUALIFICATION WELDS

Weld No.	Width of Weld at Tube-Spacer Interface inches	Gap Between Tube & Spacer inches	Undercutting Of OD of weld inches	Cross-Section Angular Position
9181				
Cross Section #1	.046	.0013	None	0°
Cross Section #2	.055	.0007	None	180°
Cross Section #3	.040	None	None	45° or 315°
9182				
Cross Section #1	.050	.0002	None	225°
Cross Section #2	.046	.0017	None	45°
Cross Section #3	.041	None	None	0° or 270°
9183				
Cross Section #1	.046	.0005	None	90°
Cross Section #2	.047	.005	.002	270°
Cross Section #3	.036	.0015	None	45° or 315°
9184				
Cross Section #1	.052	.0006	None	135°
Cross Section #2	.038	.0003	.002	315°
Cross Section #3	.039	.0015	None	90°
9185				
Cross Section #1	.059	.0025	None	180°
Cross Section #2	.038	.0008	None	0°
Cross Section #3	.047	.0015	None	135° or 225°

Based on these measurements, the following composite of weld thickness around the circumference is obtained.

Note: Numbers in

are in one of the 2 positions shown, but records do not definitely show which position. 0° is chosen at end of weld tail-off.

TABLE V

PREPRODUCTION PELLET ANALYSIS
GE Specification 22A1545 Rev. 4

Specification Requirement	G.E. RESULTS									
	Pellet No.									
	1	2	3	4	5	6	7	8	9	10
Diameter										
0.874" to 0.876"	0.8757	0.8756	0.8754	0.8756	0.8757	0.8749	0.8753	0.8754	0.8755	0.8755
Length 5/8"±3/32"										
0.531" to 0.719"	0.6507	0.6434	0.6548	0.6565	0.6653	0.6653	0.6623	0.6680	0.6560	0.6556
Dish Depth										
0.012" to 0.018"	0.0121	0.0124	0.0129	0.0125	0.0118	0.0132	0.0124	0.0122	0.0131	0.0127
I.D. Marking (V)	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Surface Appearance										
Photograph	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Comp. with Crack Std.	ok	ok	ok	ok	ok	ok	ok	ok	ok	ok
Density 9.99 to 10.40 g/cc	10.31	10.31	10.35	10.36	10.30	10.33	10.42	10.32	10.32	10.32
Total Gas <50 µL/g	50.7	27.1	20.2	19.2	34.1	21.1	14.8	48.1	25.5	28.5
Moisture 30 ppm Max	<1	1	<1	2	<1	<1	<1	<1	<1	<1
O/M 1.97 to 1.99	1.9815	1.9790	1.9807	-	-	-	-	-	-	-
Pu239+241 Pu+U 18.7±0.3%	18.75	18.72	18.95	-	-	-	-	-	-	-
Pu Total										
% Pu of net weight*†	18.00	17.97	18.19	-	-	-	-	-	-	-
U Total										
% U of net weight†	69.76	69.80	69.56	-	-	-	-	-	-	-
U235										
0.204%±0.01 of Total U	0.21	0.21	0.21							
Homogeneity										
First Sample % Pu	18.13	18.21	18.19	The Pu concentration in a 0.1 gram SAMPLE taken at any region of the pellet shall not deviate more than 1% from the average Pu concentration in the pellet.						
Second Sample % Pu	18.14	18.25	18.18							

Impurities		1	2	3
	PPM Max			
H	5	3.85	2.07	1.48
B	10	<1	<1	<1
N	200	<200	<200	<200
C	250	25	22	27
C1	25	<2	3	<2
F	25	2	2	1

TABLE V (Continued)

G.E. RESULTS					
Specification Requirement	Pellet No.				
	1	2	3		
<u>All Other Elements</u>					
<u>2500</u>					
Ag	<0.1	<0.1	<0.1		
Al	<4	<4	<4		
B	<1	<1	<1		
Be	<0.5	<0.5	<0.5		
Ca	<25	<25	<25		
Cd	<2	<2	<2		
Co	<1	<1	<1		
Cr	24	24	24		
Cu	11	16	20		
Fe	200	220	220		
Mg	4	4	4		
Mn	4	4	4		
Mo	<10	<10	<10		
Ni	40	40	40		
Pb	<1	<1	<1		
Si	<6	<6	<6		
Sn	<1	<1	<1		
V	<3	<3	<3		
Zn	<10	<10	<10		
P	<50	<50	<50		
Li	<10	<10	<10		
Na	<15	<15	<15		
<u>Characteristics</u>		<u>NFS Results</u>			
<u>Density</u>					
Whole Pellet	10.23, 10.38, 10.28 g/cc				
Within Pellet	<u>Whole</u>	<u>Center</u>			
	10.23	10.17			
	10.38	10.35			
	10.28	10.13			
	10.37	10.17			
	10.38	10.28			
	10.32	10.14			
Single Phase of Mixed Oxide	Acceptable				
O/M Ratio	1.987	1.984 before outgassing			
	1.980	1.976 after outgassing			
<u>Pu total</u>				<u>Center</u>	<u>Edge</u>
<u>Pu+U</u> Ratio	0.2050	0.2051	0.2051	0.2050	0.2052

TABLE V (Continued)

<u>Characteristics</u>	<u>NFS Results</u>	
Homogeneity	Acceptable	
Volatiles	0.033 cc/gram	
Landwidth	<u>Letter Side</u>	<u>Blank Side</u>
	0.043; 0.044"	0.039; 0.041"
	0.043; 0.039"	0.039; 0.044"
	0.041; 0.043"	0.037; 0.041"
Impurities (ppm)		
H - 2.6	Cr - 150	Sn - 3
B - <0.25	Cu - 11	Ti - <250
N -	Fe - 215	V - <5
C - 53	Mg - 23	Zn - 35
Cl - 6	Mn - 8	
F - <5	Mo - 6	
Al - 73	Na - 10	
Ag - 0.5	Ni - 100	
Ca - 30	Pb - <5	
Cd - 0.2	Si - 45	

*Check Analysis-Round-Robin Sample

Rerun of Round-Robin Sample for Pu = 23.33% of net weight.

Original Analysis of Round-Robin

Sample; Pu = 23.43% of net weight

†NBL also performed Pu and U analyses on samples from these three pre-production pellets, their results are

	<u>Pellet No.</u>		
	<u>1</u>	<u>2</u>	<u>3</u>
% Pu of net weight	18.14	18.18	18.16
	18.14	18.16	18.15
% U of net weight	69.98	69.96	70.02
	70.00	69.94	70.01
	69.98	70.02	

The remaining 20 fuel rods were repaired by cutting off and rewelding end plugs that were suspected of leaking. This operation did not disturb the fuel stacks in the fuel rod. One fuel rod was rejected because the end plug weld post sample showed wall thinning at the weld. Table VI lists the serial number of the fuel rods returned for repair, the work accomplished on each rod and its disposition.

4.3 New Fuel Rods

4.3.1 Fuel Pellet Production

a. Master Mix Solution (256-B-110)

The master-mix solution was compounded from five lots of plutonium nitrate supplied by Atlantic Richfield Co. (ARCO) Richland, Washington and one lot of uranyl nitrate supplied by NFS. The analyses of the plutonium nitrate lots and the uranyl nitrate lot are shown in Table VII & VIII. After the master mix was completed it was sampled and analyzed for plutonium and uranium content by NFS. A sample of the master mix was sent to GE for a check analysis. The results of these analyses are given in Table IX below.

Table IX

Analysis of SEFOR Master Mix Solution 256-B-110

<u>Attribute</u>	<u>NFS Analysis</u>	<u>GE Analysis</u>
Grams Pu/gram solution	0.03597 ⁽¹⁾	0.03591 ⁽²⁾
Grams U/gram solution	0.13796 ⁽¹⁾	0.13865 ⁽¹⁾
$\frac{\text{Pu}}{\text{Pu+U}}$ ratio	0.2068 ⁽³⁾	0.2057 ⁽³⁾

(1) Average of six readings

(2) Average of seven readings

(3) Based on the weights (NFS) and assays (ARCO & NBL) of Pu and U solutions used in the master-mix make up the $\frac{\text{Pu}}{\text{Pu+U}}$ ratio is 0.2046 (see Appendix B)

TABLE VIFUEL RODS RETURNED TO NFS FOR REPAIR

<u>SERIAL NUMBER</u>	<u>REPAIR</u>	<u>DISPOSITION</u>
A-13	Top and borrom end plug replaced	Returned to SEFOR site
A-14	Not possible-bowed greater than .2 inches	Returned to SEFOR site unrepaired
473	Top and bottom end plug replaced	Returned to SEFOR site
483	Rejected because of weld thinning	↓
497	Top and bottom end plug replaced	Returned to SEFOR site
499	Top end plug replaced	↓
509	Top end plug replaced	↓
518	Top and bottom end plug replaced	↓
525	Top and bottom end plug replaced	↓
537	Top and bottom end plug replaced	Returned to SEFOR site
549	Top end plug replaced	Returned to SEFOR site
552	Top end plug replaced	↓
557	Top end plug replaced	↓
559	Top end plug replaced	↓
563	Top end plug replaced	↓
564	Top end plug replaced	↓
569	Top and bottom end plug replaced	Returned to SEFOR site
592	Top and bottom end plug replaced	↓
597	Not possible-bowed greater than .25 inch. Both end plugs damaged	Returned to SEFOR site unrepaired
679	Top end plug replaced	↓
710	Top and bottom end plug replaced	Returned to SEFOR site
717	Top end plug replaced	↓

TABLE VII

PLUTONIUM NITRATECHEMICAL ANALYSIS

Element	Specified GE 22A1546 Rev. 3	Specified NFS-M-10 Rev. 5	Lot 227-30-6-1		Lot 227-30-6-2		Lot 227-30-6-6		Lot 227-30-6-7		Lot 227-30-7-1	
			NFS	ARCHO	NFS	ARCHO	NFS	ARCHO	NFS	ARCHO	NFS	ARCHO
Pu	180-270g/l	180/270g/l	241.68		242.92							
Pu-240	8-9%	8-9%		8.478		8.190		8.554		8.549		8.663
H ion	Report	3-6M		4.64		4.54	4.575	5.06	5.025	4.95	5.925	5.06
Impurities*												
Al	1000	1000	<20	<1	<20	5	23	12	24	24	<20	35
B	20	20	<.25	<1	<.25	<1	<.25	<1	<.25	5	<.25	2
C	300	300	-	75	-	70	-	405 500 (1)	-	560 525 (1)	-	730 670 (1)
Cr	100	100	41	29	45	61	30	160 58 (1)	35	170 68 (1)	35	185 66 (1)
Ca	50	50	20	4	24	38	13	68 <10 (1)	14	67 <10 (1)	11	78 <10 (1)
Cd	500	500	<.3	<1	<.3	<1	<.3	<1	<.3	<1	<.3	<1
Fe	1000	1000	347	250	257	266	270	296	250	345	268	375
Mg	200	200	34	<1	51	<1	27	12	21	<1	11	<1
Na	1000	1000	18	46	18	5	18	<1	22	<1	18	<1
Ni	100	100	100	<1	79	<1	77	82 60 (1)	101	94 65 (1)	102	98 45 (1)
U	2000	2000	17	<10	65	73	145	370	183	250	200	264
Cl	25	25	18	<20	16	<20	29	<20	34	<20	17	<20
F	130	130	8	<10	2	<10	6	<10	2	<10	6	<10
V	200	200	4	1	4	5	4	<1	4	<1	4	<1

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*Maximum parts per million parts plutonium
(1) Data correction TWX July 24, 1970 from AEC

TABLE VII (Continued)

Element	Specified GE 22A1546 Rev. 3	Specified NFS-M-10 Rev. 5	Lot 227-30-6-1		Lot 227-30-6-2		Lot 227-30-6-6		Lot 227-30-6-7		Lot 227-30-7-1	
			NFS	ARCHO	NFS	ARCHO	NFS	ARCHO	NFS	ARCHO	NFS	ARCHO
SO ₄	2000	2000	21	<1000	17	<1000	23	<1000	24	<1000	23	<1000
Cu	-	-	<2	1	<2	2	<2	2	<2	4	<2	3
Zn	-	-	<50	<1	<50	8	<50	<1	<50	<1	<50	<1
Si	-	-	150	33	<20	25	<20	<10	<20	29	<20	20
Ti	-	-	60	2	59	8	66	<1	64	2	66	2
Total of Cu,Zn,Si, Ti	800	800	<262	<37	<131	43	<138	<14	<136	<36	<138	<26
Ag	-	-	24	<1	<10	<1	<10	<1	<10	<1	<10	<1
Mn	-	-	26	1	19	8	19	12	20	8	19	8
Mo	-	-	<10	1	39	10	39	<1	56	11	39	10
Pb	-	-	<5	<1	<5	<1	<5	<1	<5	<1	<5	<1
Sn	-	-	67	10	32	2	32	<1	23	<1	32	2
Total of Ag,Mn,Mo, Pb,Sn	200	200	<132	<14	<105	<22	<105	<16	<114	<22	<105	<22
Total Impurities Except U	3000	3000										

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TABLE VII (Continued)

Impurities Not Specified But Reported By ARCHO	227-30-6-1	227-30-6-2	Lot Number 227-30-6-6	227-30-6-7	227-30-7-1
Ga	2	13	<1	3	<1
K	6	14	3	4	6
Li	<1	<1	<1	<1	<1
Nb	<35	62	<35	<35	<35
P	13	131	<20	<20	<20
Ta	<35	47	<35	<35	<35
Zr	61	106	<50	<50	<50
TMI ⁽²⁾	574	937	1173 993 ⁽¹⁾	1169 1001 ⁽¹⁾	1241 1003 ⁽¹⁾

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(1) Data correction: TWX July 24, 1970 from AEC.

(2) TMI - The sum of those elements analyzed spectrochemically including the lower detection limit plus uranium which was analyzed fluorometrically.

TABLE VII (Continued)

PLUTONIUM NITRATE
Pu CONCENTRATION DATA SHEET

Lot Number	Pu Concentration grams Pu/gram Soln.			Isotopic Analysis %					
	NFS Analysis	ARCHG Analysis	NBL Analysis	239	241	239+ 241	238	240	242
227-30-6-1	Individual .1593								
	.1587 .1590								
	.1590			90.382	1.038	91.420	.042	8.478	.060
	Average 0.1590	0.1581*	0.1612						
227-30-6-2	Individual .1593								
	.1588 .1596			90.868	0.868	91.736	.030	8.190	.044
	Average 0.1592	0.1597*	0.1617						
227-30-6-6	Individual 0.1432								
	.1441			90.244	1.100	91.344	.035	8.554	.067
	Average 0.1439	0.1470	0.1476*						
227-30-6-7	Individual 0.1477								
	.1428 .1482			90.255	1.098	91.353	.033	8.549	.065
	.1477 .1432								
	Average 0.1478	0.1480	0.1478*						
227-30-7-1	Individual 0.1446			90.107	1.128	91.235	.034	8.663	.068
	Average 0.1446	0.1477	0.1475*						

*These numbers used in Master Mix Calculations

TABLE VIII

URANYL NITRATE
CHEMICAL ANALYSIS

<u>Composition</u>	<u>Specified</u> <u>GE 22A1547 Rev.3</u>	<u>Specified</u> <u>NFS-M-10 Rev. 5</u>	<u>NFS Analysis</u> <u>Lot No. 256B10</u>	<u>Remarks</u>
H ion	-	.75 - 1.25 M	.86	
U-235	.204 ± .01% ⁽¹⁾	.204 ± .01%	.213	
Total U	>100g/liter	>100g/liter		
Verification of Total U	Per QC Plan FP-136	Verification made at NBL	.1866g U/g Soln. NFS Analysis .1866g U/g soln. .1864g U/g soln.	
Impurities*				
Ag	500	500	<.1	
Al	500	500	<10	
B	5	5	<.20	
C	150	150	<50	
Ca	25	25	<20	
Cd	20	20	<.10	
Cl	25	25	7	
Cr	500	500	7	
Cu	500	500	2	
F	130	130	39	
Fe	500	500	34	
Mg	25	25	8	
Na	500	500	25	
Ni	500	500	22	
Pb	500	500	<1	
Si	100	100	78	
Sn	500	500	<1	
V	500	500	<2.5	
Zn	500	500	<25	
Total Impurities	2000*		Th <100	

*Maximum parts per million parts uranium

(1) GE specification modified by GE letter of Jan. 8, 1970 Behlen to Pedersen

Appendix B summarizes the master mix make up from a solution weight standpoint and the calculated values for plutonium and uranium concentration in the master-mix solution.

b. Plutonium Nitrate Impurities

When the plutonium nitrate was received at NFS, the carbon content of three out of the five lots was above specification as shown in Table VII.

The three lots were accepted on the basis that dilution would occur when the plutonium nitrate was blended in the master mix. GE also increased the allowable carbon impurity in the fuel pellet to 300ppm from 250ppm originally specified. The chemical analysis of the fuel pellet batches was monitored to check on the final carbon impurity content. For all fuel pellet batches, the carbon impurity was reported to be less than 100ppm in the finished pellets as shown below

<u>Batch No.</u>	<u>ppm Carbon</u>	
	<u>NFS Analysis</u>	<u>GE Analysis</u>
701A	53	25
802	79	34
803	43	24
804	71	17
805	43	27
806	74	7

c. Pellet Batches

The mixed oxide powder from co-precipitation of the master-mix solution and reducing process was blended and cross blended to assure uniformity of the powder. The powder was divided into sequential batches with a batch consisting of a maximum of 125 Kg of mixed

oxide powder. Six batches were produced for the second fabrication campaign; 701A, the pre-production batch and 802 thru 806, the production batches. Sample selection, analysis, and release of the fuel pellets was based on this batch designation.

NFS was required to take samples, analyze, and certify each batch of fuel pellets. In addition, a minimum of three fuel pellets from each batch were shipped to GE for verification analysis. The pellet batch certifications supplied by NFS and the results of the verification analysis by GE is given in Appendix C.

d. Oxygen to Metal Ratio of Fuel Pellets

The oxygen to metal ratio (O/M) of the fuel pellet batches was determined from a sample pellet selected from the batch after it was processed through the vacuum outgassing furnace. The samples for GE verification analysis were also taken after the outgassing step. Table X shows a list of the outgas furnace runs, the batch numbers involved and the O/M results from NFS and GE laboratories. Each outgas furnace run holds approximately one-third of a pellet batch. From this information, it was determined that part of Batch 803 and all of Batch 804 and 805 should be reworked to lower the O/M.

A pellet sample from Batch 805 prior to outgassing was checked for O/M by NFS and GE laboratories. The O/M was 1.994 and 1.996 respectively indicating the O/M was above specification after sintering and that the outgas furnace run was not causing the problem.

TABLE X

OXYGEN TO METAL RATIO OF FUEL PELLET BATCHES

OUTGAS FURNACE RUN NUMBER	FUEL PELLET BATCH	NFS REPORTED O/M RATIO	GE O/M RATIO ANALYSIS	REMARKS
1	802	1.981 1.980	No sample	-
2	-	-	-	Rerun as Run #5
3	-	-	-	Rerun as Run #4
4	701A& 802	-	701A 1.985 1.984 ⁽¹⁾	One sample pellet from Batch 802 to GE
5	802	-	(1)	Two sample pellets to GE
6	-	-	-	Rerun as Run #8
7	803	-	(2)	Two sample pellets to GE
8	803	-	(2)	One sample pellet to GE
9	803 804	804-1.999 2.033 803-2.001	-	All pellets resintered " "
10	804	1.985 1.984	-	All pellets resintered
11	804 805	1.999 1.999	-	All pellets resintered
12	805	2.005 2.008	-	"
13	805	1.997 1.998	-	"

(1) Three samples were taken from Batch 802 pellets outgassed in these runs: O/M results 1.973, 1.979 and 1.977. The average O/M was within specification so pellets were acceptable.

(2) Three samples were taken from Batch 803 pellets outgassed in these runs; O/M results 1.981, 1.991 and 1.986. The average O/M was within specification so pellets were acceptable.

The problem was traced to a deficiency in the sintering furnace atmosphere. It was determined that the volume of the nitrogen sweep gas at the exit end of the sintering furnace was inadvertently increased sometime during the sintering of Batch 803. The nitrogen back-diffused into the furnace atmosphere (normally 6-8% H_2 in argon) decreasing the H_2 concentration in the furnace atmosphere. The change in the H_2 concentration resulted in the shift of the O/M ratio.

In order to rework the pellets from Batch 803, 804 and 805 that were out of specification it was necessary to re-sinter the pellets at a temperature and time that would reduce the O/M ratio but not result in shrinkage since the pellets were ground to finish size. A series of test sinterings were made by NFS to determine the temperature-time necessary to adjust the fuel pellet O/M without changing the dimensions of the pellets. Table XI shows the test program and the O/M results. From this information, a temperature of 2700°F and a 5 hr. cycle time was selected as the sintering conditions for rework of the fuel batches involved.

As provided in the NFS procedures (NFS-M-10), the sampling frequency was increased for O/M measurements during the rework process. One sample of each batch was taken after resintering and two samples were taken after each outgassing furnace run. These results are reported for the batches affected in Appendix C. Batch 806 was sintered after the O/M problem was resolved.

TABLE XI

NFS TESTS TO DETERMINE RESINTERING CYCLE FOR FUEL PELLETS

TEST NO.	BATCH NO.	TEST CONDITION		RESULTING O/M RATIO
		SINTERING TEMP °F	CYCLE TIME ⁽¹⁾	
1	804	2800	1 1/2	1.997
2	804	2800	3	1.997 1.998
3	804	2800	4 1/2	1.998
4	804	2900	3	1.998
5	-	2825	1 1/2	Sample lost
6	803	2700	12 hour hold ⁽²⁾	1.998 1.998
7	804	2700	12 hour hold	1.990-1.988
8	804	2700	36 hour hold	1.992
9A	803	2700	3	1.987
9B	804	2700	3	1.981
9C	805	2700	3	1.987 1.987 1.989
10A	803	2700	5	1.983 1.986
10B	804	2700	5	1.986 1.984
10C	805	2700	5	1.982 1.982

(1) Time elapsed between movement of one boat through the furnace. Hot zone of furnace is three boat lengths.

(2) Hold--time held in the hot zone of furnace.

4.3.2 Inert Parts

a. Tubing

Tube lengths for the fuel rods (Type 316SS .890" ID x .041" wall x 45 5/8" long) were purchased from Tube Methods Inc., Bridgeport, Pa. Two heats of material were used (26081 & 03697). The non-destructive testing of the tube lengths for wall defects and thickness was done by Orbit Industries, Cleveland, Ohio under subcontract to NFS as part of the receiving inspection. Additional verification of Orbit Industries results was done by Conam Inspection Inc., Columbus, Ohio. A yield of approximately 60% was realized on the tube lengths after non-destructive testing. The main causes for rejection were out of tolerance dimensions for the inside diameter and wall thickness. Tube lengths that were acceptable were shipped to Buehler Corp. for welding of the center spacer. The identification of the tubing by heat number was maintained throughout the processing and a serial number was assigned to each tube-spacer assembly when it was accepted by NFS' receiving inspection. Table XII summarizes the receiving inspection data on the tube lengths.

b. End Plugs and Center Spacer

The end plugs and center spacer were machined from 304SS bar stock. A summary of the chemical analysis and mechanical properties of the bar stock is given in Table XIII.

During the first fabrication campaign (Reference 2), it was found that helium leaking through the end plugs could be caused by inclusions in the bar stock. For the second fabrication campaign, vacuum melted material was recommended as starting material for the end plugs but it could not be obtained in the small quantities required. Therefore,

TABLE XII

SUMMARY --RECEIVING INSPECTION OF 316 SS TUBE LENGTHS

CHEMICAL COMPOSITION WT. PERCENT

<u>HEAT NO.</u>	<u>C</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Si</u>	<u>Cr</u>	<u>Ni</u>	<u>Mo</u>
26081	.046	1.14	.024	.027	.42	17.34	13.79	2.20
03697	.013	1.79	.010	.026	.48	16.87	13.57	2.18

MECHANICAL PROPERTIES

<u>HEAT NO.</u>	<u>ULTIMATE STRENGTH PSI</u>	<u>YIELD STRENGTH .2% OFFSET PSI</u>	<u>ELONGATION IN 2" %</u>	<u>HARDNESS R_B</u>
26081	85,500	41,200	60	73
03697	82,500	45,200	59	74

Grain Size - ASTM 6 for Heat 26081 and 03697

NON-DESTRUCTIVE TESTING

<u>TOTAL TUBES SHIPPED FROM TUBE METHODS INC.</u>	<u>INSIDE DIAMETER MEASURED BY AIR GAGE</u>			<u>WALL DEFECTS BY ULTRASONIC</u>			<u>WALL THICKNESS BY ULTRASONIC</u>		
	<u>TESTED</u>	<u>REJECTED</u>	<u>ACCEPTED</u>	<u>T.</u>	<u>R.</u>	<u>A</u>	<u>T.</u>	<u>R.</u>	<u>A</u>
330	292	90	202	292	13	289	292	96	196

TABLE XIII

SUMMARY - RECEIVING INSPECTION OF 304 SS BAR STOCK (ASTM-A276)CHEMICAL ANALYSIS

<u>HEAT NO.</u>	<u>WEIGHT PERCENT</u>						
	<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>P</u>	<u>S</u>	<u>Cr</u>	<u>Ni</u>
27275	.023	1.41	.43	.013	.012	18.37	10.23
E110613	.022	1.66	.74	.035	.024	18.26	9.68
812750	.023	1.15	.33	.021	.020	18.40	9.61

MECHANICAL PROPERTIES

<u>HEAT NO.</u>	<u>ULTIMATE TENSILE STRENGTH PSI</u>	<u>YIELD STRENGTH .2% OFFSET PSI</u>	<u>ELONGATION IN 2" %</u>	<u>REDUCTION OF AREA %</u>	<u>HARDNESS BHN</u>
27275 ⁽¹⁾	77,100	35,500	63.0	80.0	143
E110613 ⁽²⁾	76,400	29,800	69.5	79.0	149
812750 ⁽¹⁾	83,800	50,000	51.5	72.7	170

MANUFACTURER

(1) Carpenter Steel Co (Thermo well Quality)

(2) Crucible Steel Co.

ultrasonic inspection of bar stock for end plugs was performed to identify lengths of bar stock that contained excessive inclusions. Approximately 176 ft. of one inch diameter bar stock was ultrasonically inspected at GE San Jose Plant from three heats of material as shown below:

<u>Heat No.</u>	<u>Total Length, Ft.</u>
27275	74
E110613	80
812750	22

One 11 ft. length from Heat 27275 was rejected for inclusions; the balance of the bar stock passed the ultrasonic test. The length of bar stock which was rejected for ultrasonic defect indications was also examined metallurgically. Three samples were cut from the bar as shown in Figure 6. These samples were taken from two areas where defects were indicated. Longitudinal and transverse sections from each location were mounted and prepared for metallographic examination. Representative photomicrographs were taken at each location illustrating the inclusions found and they are shown in Figures 1 through 9. A transverse sample at each location was etched and the grain size measured. Photomicrographs illustrating the grain size are shown in Figure 10.

The inclusions found at each area examined were rated by ASTM E-5 Method A. The results are listed below:

Area 4 (See Figure 1) B-2 Heavy Series

Area 5 (See Figure 8) B-3 Heavy Series

No defect indications (See Figure 9) B-3 Thin Series

The inclusions in the bar stock line up in the longitudinal

FIGURE 6 LOCATION OF SAMPLES FOR METALLOGRAPHY
SEFOR END PLUG BAR STOCK 304ss 1/16" DIA.

FIGURE 7 Photomicrographs Showing Typical Inclusion Found at Area 4

FIGURE 8 Photomicrographs Showing Typical Inclusion Found at Area 5

FIGURE 9 Photomicrographs of Typical Inclusions
Found Between Area #4 & #5
No Ultrasonic Indications

Figure 10 Microstructure of 304 Bar Stock SEFOR End Plugs Heat 27275

direction or direction of rolling. If these inclusions were continuous and aligned across the thin wall area of an end plug a leak path could result. The metallographic examination showed that inclusions could be present even though the ultrasonic test indicated no defects. For this reason, it is apparent that the ultrasonic testing of bar stock prior to end plug fabrication cannot guarantee that there will be no leaks through the end plugs.

For material traceability, the top end plugs and center spacers were machined from bar stock from Heat 27275 and the bottom end plugs were machined from bar stock from Heat E110613 and 812750.

c. Nickel Reflectors & Springs

The reflectors for each fuel rod were machined from nickel bar .875" in diameter and the hold down springs were purchased from an outside vendor as a finished part.

d. Finished Parts

(1) Chemical Analysis

Toward the end of this fabrication campaign the GE resident engineer selected at random a sample of each finished inert part that makes up a fuel rod. If more than one heat of material was used to fabricate a part a sample from each heat was obtained. These samples were analyzed for chemical composition to verify the composition of materials used for the fuel rods. The results of these analyses are given in Table XIV.

(2) Weight of Individual Parts

As required in the GE specification, the individual weight of the fuel rod components is given in Table XV.

TABLE XIV

VERIFICATION OF THE CHEMICAL ANALYSIS OF INERT PARTS

<u>Fuel Rod Tubing</u>		Weight percent							
		C	Mn	P	S	Si	Cr	Ni	Mo
Specified:	316SS;ASTM A269	.08 Max	2.00 Max	.045 Max	.030 Max	1.0 Max	16.0 18.0	10.0 14.0	2.0 3.0
Heat No. 26081									
Cert.	Analysis from NFS	.046	1.14	.024	.027	.42	17.34	13.79	2.20
Verification	Analysis	.053	1.20	.023	.023	.45	17.51	14.0	2.27
Heat No. 03697									
Cert.	Analysis from NFS	.013	1.79	.010	.026	.48	16.87	13.57	2.18
Verification	Analysis	.014	1.82	.014	.021	.50	16.94	14.16	2.29
<u>Top End Plugs & Spacers</u>		C	Mn	P	S	Si	Cr	Ni	
Specified:	304SS,ASTM A 276	.08 Max	2.00 Max	.045 Max	.030 Max	1.0 Max	18.0 20.0	8.0 12.0	
Heat 27275									
Cert.	Analysis from NFS	.023	1.41	.013	.012	.43	18.37	10.23	
Verification	Analysis	.017	1.39	.012	.014	.48	18.23	10.08	
<u>Bottom End Plugs</u>		C	Mn	P	S	Si	Cr	Ni	
Specified:	304SS; ASTM A 276	.08 Max	2.00 Max	.045 Max	.030 Max	1.0 Max	18.0 20.0	8.0 12.0	
Heat E110613									
Cert.	Analysis from NFS	.022	1.66	.035	.024	.74	18.26	9.68	
Verification	Analysis	.030	1.65	.030	.017	.79	18.37	9.55	
Heat 812750									
Cert.	Analysis from NFS	.023	1.15	.021	.020	.33	18.40	9.61	
Verification	Analysis	.021	1.20	.018	.022	.35	18.12	9.25	
<u>Reflectors</u>		C	Mn	Fe	S	Si	Cu	Ni	
Specified:	Nickel;ASTM B160	.15 Max	.35 Max	.40 Max	.010 Max	.35 Max	.25 Max	99.0	Min.
Heat N4214A									
Cert.	Analysis from NFS	.08	.24	.11	.005	.04	.01	99.49	
Verification	Analysis	.079	.24	.13	.004	<.02	.01	99.7	

TABLE XIV (Continued)

Springs

	C	Mn	S	Si	Cr	Ni	Cu	Fe	Co	Al	Ti	Cb/Ta
Specified: Inconel 750	.08	1.0	.01	.5	14.0	70.0	.5	5.0	-	.4	2.25	.70
ASTM A461	Max	Max	Max	Max	17.0	Min	Max	7.0	-	1.0	2.75	1.20

Heat 9467X

Cert. Analysis from												
NFS	.05	.10	.007	.22	15.53	72.85	.03	7.14	.14	.80	2.37	.88
Verification Analysis	.07	.54	.005	.40	14.80	73.3	.04	6.87	.08	.66	2.25	.82

Heat 8305J2

Cert. Analysis from												
NFS	.05	.09	.007	.20	15.65	72.85	.04	6.80	.04	.73	2.65	.91
Verification Analysis	.064	.10	.005	.23	15.58	73.2	.05	6.68	.05	.71	2.25	.85

TABLE XV

WEIGHT OF INDIVIDUAL INERT PARTS

<u>COMPONENT</u>	<u>SAMPLE SIZE</u>	<u>WEIGHED TO THE NEAREST GRAM</u>	<u>AVERAGE WEIGHT GRAMS</u>	<u>RANGE GRAMS</u>
Tube with Spacer	50	1	726.0	722-734
Top end Plug	20	0.5	69.1	68.5-69.5
Bottom end plug (before slotting)	20	0.5	29.0	29.0-29.0
Bottom Spring	20	0.5	9.6	9.5-10.0
Top Spring	20	.01	6.13	5.97-6.25
Reflector	20	.01	346.10	345.76-346.36
Insulator Pellet	20	.01	36.48	35.51-37.34

Total average weight of non-fuel components (bottom end plug not slotted)
is 1678.12 grams

4.3.3 UO₂ Insulator Pellets

The UO₂ insulator pellets that are placed at each end of the fuel stack were produced during the first fuel rod fabrication campaign (1967-1968). The pellets were stored at NFS in polyethylene bags inside 5 gallon metal containers until they were ready for use in the second fabrication campaign. Prior to their use, the UO₂ insulator pellet batches were sampled and analyzed by NFS to assure the pellets met the requirements of GE Specification 22A1583 Rev. 3 "UO₂ Insulator Pellets for SEFOR Core 1". In addition pellet samples were sent to GE for verification analysis and approval.

The results of the NFS and GE analysis of the UO₂ insulator pellets is given in Appendix D. Based on these results the pellets were approved for use.

4.3.4 Assembly & Inspection

A total of 104 fuel rods were assembled during the second fabrication campaign. Table XVI gives the serial numbers of the fuel rods produced and pertinent data for each rod.

As required in the GE Specification for the fuel rods, a dummy fuel rod was fabricated with the production fuel rods. The dummy fuel rod that serves as an archive sample was similar in all respects to production fuel rods except depleted UO₂ pellets were substituted for the fuel stacks.

The fuel rods were assembled in two steps. The top and bottom fuel pellet stacks were assembled and loaded into each end of the fuel rod tube with the spring and reflector. As far as possible pellets from only one fuel pellet batch were loaded into each rod. The assembly was then transferred to the helium atmosphere weld chamber where the top and bottom end plug were welded on. The weld chamber held a maximum of 10 fuel rods. Each group of fuel rods welded at the same time up to 10 rods was designated a weld lot. For each weld lot a pre and post weld sample was made for metallographic examination

TABLE XVI

SEFOR FUEL RODS - SECOND FABRICATION CAMPAIGN 1970-1971

Fuel Rod Number	Inert Parts ⁽¹⁾		Batch No.	Fuel Pellets		Pu239+241 Wt. grams	Weld Lot No.	Total Wt. Grams
	Tube (316SS) Heat No.	Bottom End Plug (304SS) Heat No.		Fuel Weight g	Pu Weight			
001	26081	812750	802	3368.37	608.33	555.78	6; 11	5046.0
002	26081	E110613	802	3359.57	606.74	554.33	6	5040.0
003	26081	812750	802	3357.55	606.37	554.00	6; 11	5037.0
004	26081	E110613	802	3357.07	606.29	553.92	6	5035.0
005	26081	E110613	802	3362.35	607.24	554.79	5	5041.0
006	26081	812750	802	3355.27	605.96	553.62	6; 11	5036.0
007	26081	E110613	802	3358.93	606.62	554.22	6	5033.0
008	26081	812750	802	3351.15	605.22	552.94	5; 12	5030.0
009	26081	812750	802	3366.17	607.93	555.42	6; 11	5045.0
010	26081	812750	802	3366.25	607.93	555.43	5; 11	5047.0
011	26081	812750	802	3354.43	605.81	553.48	6; 11	5031.0
012	26081	812750	802	3363.75	607.49	555.02	5; 11	5044.0
013	26081	812750	802	3353.83	605.70	553.38	6; 11	5033.0
014	26081	E110613	802	3353.25	605.60	553.29	5	5033.0
015	03697	812750	802	3355.30	605.97	553.62	7; 11	5031.0
016	03697	812750	701A	3365.07	607.73	555.24	6; 12	5038.0
017	26081	E110613	802	3341.35	603.45	551.32	5	5024.0
018	26081	E110613	Top 701A Bot 802	3360.27	606.86	554.44	7	5043.0
019	26081	E110613	802	3353.17	605.58	553.27	7	5039.0
020	26081	E110613	802	3344.47	604.01	551.84	7	5028.0
021	26081	E110613	802	3342.27	603.61	551.47	7	5019.0
022	26081	E110613	802	3332.47	601.84	549.86	7	5010.0
023	26081	E110613	802	3342.35	603.63	551.49	5	5028.0
024	26081	E110613	802	3339.17	603.05	550.96	7	5019.0
025	26081	812750	802	3339.27	603.07	550.98	7	5021.0
026	03697	E110613	802	3344.07	603.94	551.77	7	5025.0
027	03697	812750	802	3347.87	604.63	552.40	7; 12	5023.0

(1) All center spacers from HT.27275 (304SS)
 All Nickel Reflectors from HT. N4214A (Ni)
 All bottom springs from HT. 9467X (Inconel 750)

A sc attached to Bottom Springs from HT 135780F (304SS)

All Top Springs from HT 8305J2 (Inconel 750)
 All Top End Plugs from HT 27275 (304SS)

TABLE XVI (Continued)

Fuel Rod Number	Inert Parts ⁽¹⁾		Batch No.	Fuel Pellets		Pu239+241 Wt. grams	Weld Lot No.	Total Wt. Grams
	Tube(316SS) Heat No.	Bottom End Plug(304SS) Heat No.		Fuel Weight g	Pu Weight			
028	03697	E110613	802	3335.67	602.42	550.38	8	5009.0
029	03697	E110613	802	3344.67	604.05	551.87	8	5021.0
030	03697	E110613	Top 803 Bot 802	3338.67	602.96	550.88	8	5015.0
031	03697	812750	803	3355.67	606.03	553.69	8; 13	5030.0
032	03697	E110613	803	3342.77	603.70	551.56	8	5018.0
033	03697	E110613	803	3349.47	604.91	552.66	8	5029.0
034	03697	E110613	803	3376.27	609.75	557.08	8	5050.0
035	03697	E110613	803	3371.27	608.85	556.26	8	5049.0
037	03697	812750	803	3373.27	609.21	556.59	8; 12	5051.0
038	03697	812750	803	3372.27	609.03	556.42	8; 12	5048.0
040	03697	E110613	803	3369.97	608.62	556.05	9	5046.0
041	03697	E110613	803	3377.67	610.01	557.32	9	5054.0
042	03697	812750	803	3380.57	610.53	557.79	9; 12	5057.0
044	03697	812750	804	3345.90	604.27	552.07	21	5025.0
045	03697	E110613	803	3374.77	609.48	556.84	9	5055.0
046	03697	E110613	803	3384.97	611.33	558.52	9	5063.0
047	03697	E110613	803	3386.87	611.67	558.83	9	5067.0
048	03697	812750	803	3382.07	610.80	558.04	9; 13	5061.0
050	03697	E110613	803	3382.97	610.96	558.19	9	5060.0
051	03697	E110613	803	3391.57	612.52	559.61	9	5067.0
052	03697	812750	803	3387.47	611.78	558.93	10	5067.0
053	03697	812750	803	3383.47	611.05	558.27	10	5061.0
054	03697	812750	803	3374.87	609.50	556.85	10	5055.0
055	03697	812750	803	3379.37	610.31	557.60	10	5054.0
056	03697	812750	Top 804 Bot 803	3371.57	608.91	556.31	10; 15	5050.0
061	03697	812750	805	3376.47	609.79	557.12	19; 20	5056.0
067	03697	812750	804	3360.07	606.83	554.41	19	5038.0

(1) See footnote page 4-40

TABLE XVI (Continued)

Fuel Rod Number	Inert Parts (1)		Batch No.	Fuel Pellets		Pu239+241 Wt. grams	Weld Lot No.	Total Wt. Grams
	Tube(316SS) Heat No.	Bottom End Plug (304SS) Heat No.		Fuel Weight g	Pu Weight			
068	03697	812750	805	3368.17	608.29	555.75	19	5044.0
069	03697	812750	803	3358.90	606.62	554.22	14	5040.0
072	03697	812750	804	3360.17	606.85	554.43	14	5036.0
073	03697	812750	804	3357.57	606.38	554.00	14	5041.0
074	03697	812750	804	3363.47	607.44	554.97	14	5049.0
075	03697	812750	804	3363.37	607.97	555.45	14	5053.0
076	03697	812750	804	3364.07	607.55	555.07	14	5045.0
077	03697	812750	803	3371.07	608.82	556.23	14	5051.0
078	03697	812750	803	3375.07	609.54	556.89	14	5055.0
079	26081	812750	803	3371.27	608.85	556.26	14	5048.0
080	26081	812750	803	3361.17	607.03	554.59	15	5043.0
081	26081	812750	804	3367.77	608.22	555.68	15	5047.0
082	26081	812750	804	3367.97	608.26	555.72	15	5050.0
083	26081	812750	804	3372.07	609.00	556.39	15	5055.0
084	26081	812750	804	3370.27	608.67	556.09	15	5055.0
085	26081	812750	804	3374.67	609.47	556.82	15	5055.0
086	26081	812750	804	3362.57	607.28	554.82	15	5041.0
087	26081	812750	805	3363.57	607.46	554.99	15	5043.0
088	26081	812750	805	3377.57	609.99	557.30	15	5056.0
089	26081	812750	805	3364.57	607.64	555.15	16	5047.0
093	26081	812750	805	3363.57	607.46	554.99	16	5043.0
095	26081	812750	805	3378.57	610.17	557.46	16	5059.0
096	26081	812750	805	3366.17	607.93	555.42	16; 19	5045.0
097	26081	812750	805	3368.57	608.36	555.81	16	5051.0
098	26081	812750	805	3369.67	608.56	556.00	16	5054.0
099	26081	812750	805	3366.17	607.93	555.42	16	5049.0
100	26081	812750	805	3365.47	607.80	555.30	16	5049.0
930	26081	812750	805	3373.07	609.18	556.56	16	5044.0
931	26081	812750	805	3369.97	608.62	556.05	16	5057.0
933	26081	812750	805	3378.37	610.13	557.43	17	5061.0
934	20681	812750	805	3373.27	609.21	556.59	17	5055.0

(1) See footnote page 4-40

TABLE XVI (Continued)

Fuel Rod Number	Inert Parts (1)		Batch No.	Fuel Pellets		Pu239+241 Wt. grams	Weld Lot No.	Total Wt. Grams
	Tube(316SS)	Bottom End Plug (304SS)		Fuel Weight g	Pu Weight			
	Heat No.	Heat No.						
935	20681	812750	805	3371.57	608.91	556.31	17	5055.0
936	20681	812750	805	3368.37	608.33	555.78	17	5054.0
937	20681	812750	805	3383.50	611.06	558.28	17	5066.0
938	20681	812750	805	3368.17	608.29	555.75	17	5054.0
939	20681	812750	805	3368.57	608.36	555.81	17	5049.0
940	20681	812750	805	3371.84	608.95	556.35	17	5051.0
941	20681	812750	805	3382.37	610.86	558.09	17	5059.0
942	20681	812750	805	3370.37	608.69	556.11	17	5051.0
943	20681	812750	805	3371.17	608.94	556.34	18	5053.0
944	20681	812750	805	3369.97	608.62	556.05	18	5053.0
945	20681	812750	805	3374.27	609.39	556.75	18	5056.0
946	20681	812750	804	3359.07	606.65	554.25	18	5038.0
947	20681	812750	804	3361.77	607.14	554.69	18; 19	5046.0
948	20681	812750	804	3359.67	606.76	554.35	18	5042.0
949	20681	812750	804	3361.97	607.17	554.73	18	5038.0
950	20681	812750	804	3361.17	607.03	554.59	18	5038.0
951	20681	812750	804	3360.67	606.94	554.51	18	5041.0
953	20681	812750	804	3361.87	607.15	554.71	19	5045.0
954	20681	812750	804	3357.67	606.40	554.02	19	5037.0

(1) See footnote page 4-40

and evaluation of that weld lot. After welding the fuel rods were processed thru the remaining process and inspection steps under the weld lot designation.

The fuel rods were checked for contamination at the weld, decontaminated if necessary, and helium leak checked. If a fuel rod was found to leak, usually the leaks occurred at the end plugs, the fuel rod was assigned to another weld lot for the removal and replacement of the leaking end plug.

During the testing of the first weld lots of fuel rods many indications of leaks (17 out of 47 fuel rods) were revealed at the bottom end plugs. These end plugs had been machined from bar stock from Heat E110613 and had been leak checked, thermal cycled and re-leak checked prior to their use. Additional bottom end plugs were machined from another heat of bar stock (812750) and these were used to replace the end plugs that had been welded and found to leak and all bottom end plug from then on. The occurrence of leaking end plugs at this stage indicated the in-process inspection steps of ultrasonic inspection of the bar and leak checking of the individual end plugs were not adequate to overcome the end plug leak problem.

Inspection of the fuel rods included a gamma scan of each fuel rod to check the plutonium content of each rod. The gamma scan was an additional inspection step incorporated in the second fabrication campaign as a requirement of Revision 4 to the Purchase Order. The gamma scan procedure was based on the selection of a fuel rod as a "standard rod" and the gamma scan equipment was calibrated using this rod. The fuel pellet batch (701A) that was used in the standard rod was analyzed by three laboratories for plutonium content; (1) NFS (2) GE and (3) New Brunswick Laboratory of the AEC. A description of the gamma scan equipment, calibration and

results is given in Appendix E. All fuel rods produced passed the gamma scan acceptance criteria successfully.

All end plug welds were x-rayed by NFS in two positions using correction blocks. In addition one x-ray was taken of the center plenum area. These x-rays were reviewed by the GE resident engineer and were used to evaluate the thickness of the weld, porosity of the weld, and the position of the internal components of the fuel rod.

The fuel rods were passivated in HNO_3 prior to the final inspection and release by the NFS Quality Control Department.

4.3.5. Shipment of Fuel Rods & Pellets

The 104 fuel rods, 19 repaired rods, and one dummy UO_2 filled rod were shipped to the SEFOR site and the loose fuel pellets were shipped to GE Vallecitos Nuclear Center in March 1971. The NFS certification for the fuel rods and the package and shipping list for the fuel rods and loose fuel pellets are shown in Appendix F.

Since three of the 22 fuel rods could not be reworked successfully and parts were available for two new rods, two new fuel rods were furnished. Revision 4 to the purchase order stipulated that as many new fuel rods as parts were available would be fabricated to make up for fuel rods that could not be repaired.

4.3.6. Receiving Inspection

a. X-ray of End Plug Welds

As the first part of the receiving inspection of the new and repaired fuel rods, the end plug welds were x-rayed by X-ray Engineering Co., San Mateo, California. This inspection was done at the NFS plant prior to shipment of the fuel rods to SEFOR site. The

results of the evaluation of these x-rays is given in Appendix G.

b. SEFOR Site Inspection

The balance of the receiving inspection of the fuel rods was performed at the SEFOR Site. This inspection included:

- Dimensions
- Weight
- Visual
- Helium Leak Check at room temperature and 800°F

The results of the inspection are given in Appendix G.

c. Loose Fuel Pellets

The receiving inspection of the loose fuel pellets was accomplished at the GE Vallecitos Nuclear Center. The results of the inspection are given in Appendix G.

4.3.7. Disposition of Loose Fuel Pellets and Fuel Rods

a. Loose Fuel Pellets

The loose fuel pellets supplied by NFS were satisfactory and will be stored at the GE Vallecitos Nuclear Center for use in instrumented fuel rods that are planned to be fabricated.

b. Fuel Rods

As shown in the information in Appendix G some discrepancies were found during the receiving inspection of the fuel rods. Two tests (He leak check at 800°F and elliptical radiographs of the end plug welds) were included that were more stringent than those agreed upon in the GE-NFS contract, and therefore were not part of the acceptance criteria.

As shown in Table XVII, seven fuel rods were returned to NFS for repair because of He leak rates greater than specified. Four fuel rods were returned for

TABLE XVII SUMMARY OF FUEL ROD DISPOSITIONAcceptable Fuel Rods 81 Total (not including dummy rod)

Serial Nos.

001	012	031	048	076	093	938	949	679
002	014	032	050	078	095	939	940	717
003	016	033	051	080	096	940	951	
005	018	035	052	081	098	941	953	
006	019	138	061	082	930	942	954	
007	021	040	067	083	931	943	(Dummy)	
008	024	041	068	084	934	945	509	
009	028	042	069	085	935	946	549	
010	029	044	072	086	936	947	559	
011	030	045	075	087	937	948	564	

He Leak Rate at Room Temperature Greater Than 1×10^{-8} cc/sec - 7 total

Serial Nos.

004	026	569	413
022	537	710	

Mechanical Discrepancies - 4 total

Serial Nos.

552 Bottom slot not correctly aligned with top hole

473

497

525

Top plenum short -- apparent fuel stack shift

He Leak Rate at 800°F greater than 1×10^{-8} cc/sec - 24 total

Serial Nos.

015	037	055	079	518
020	046	056	089	
023	047	073	097	557
025	053	074	099	563
027	054	077	499	592

Indicated Defects from Special Radiographic Inspection of End Plug Welds - 7 total

Serial Nos.

013	034	100	944
017	088	933	

misalignment between the bottom slot and top hole and displacement of the upper fuel stack.

Fuel rods that were indicated to be defective by the elevated temperature He leak check and special radiographs were retained at the SEFOR Site for further investigation.

Thermal cycling and leak check of each individual end plug was performed to identify defective end plugs prior to their use. The thermal cycling was done in a hydrogen atmosphere furnace with a heat cycle of 800°F for 1 hour and furnace cool. No visible oxidation of the end plug surfaces resulted from this thermal cycle.

A total of 344 top and bottom end plugs were thermal cycled and helium leak checked; of these, two were rejected because they failed the helium leak check.

During the leak testing of the finished fuel rods it was determined that a high proportion of bottom end plugs were leaking (even after individual end plug leak check). These end plugs had been machined from bar stock from Heat E110613. When the bottom end plugs from Heat E110613 were found to leak, all bottom end plugs that had not been used from this heat were quarantined and bottom end plugs were machined from another heat of bar stock (Heat 812750). When these bottom end plugs were used the helium leak test was passed successfully. No problems were experienced with the top end plugs machined from bar stock from Heat 27275.

The receiving inspection records for the end plug bar stock (see Table XI) showed that the two heats that produced the most satisfactory end plugs were produced

by Carpenter Steel Co. as "Thermowell Quality".

Thermowell quality is a supplier's designation that indicates the material is subject to special attention at the mill but no unique characteristics are guaranteed.

The evaluation methods for determining inclusions in bar stock are apparently not sensitive enough to detect defects that could cause leaks through the end plugs. Given the present design of the SEFOR end plug and method of manufacture (machine from bar stock) better quality bar stock such as vacuum melted must be specified to reduce the possibility of leak paths through the end plugs.

REFERENCES

1. R. A. Meyer, et al., "Design of SEFOR Core I", GEAP-13598, June 1970.
2. M. L. Johnson, et al., "SEFOR Fuel Rod Fabrication 1967-68", GEAP-13760, January 1972.

APPENDIX A

Q.A. AUDIT PLAN - SEFOR FUEL ROD PRODUCTION

QUALITY ASSURANCE AUDIT PLAN
SEFOR FUEL ROD PRODUCTION

Section

1.0, 2.0

Rev.

No.

Page 1 of

Supersedes

No.

Date

9/15/70

Effective Date

9/16/70

Prepared By:

W. K. Eggert/T. O. Bryan

Approved By:

Hugh J. Stock

1.0 Scope

This Quality Assurance audit plan provides systemized Quality Control audit actions necessary to provide adequate confidence that: (1) the Nuclear Fuel Services QC organization has completed all required QC activities, and through comparison, (2) the fuel rods have complied with pre-determined standards, and (3) documentation of all GE QC audit activities will be accomplished.

1.1 Limitations

The resident General Electric QC engineer will have as his prime duties the audit of the NFS QC Program and will not perform inspection duties, but shall audit inspections as they are performed.

2.0 Applicable Documents

2.1 GE Purchase Order 205-58226, Rev. 4, to NFS, dated 6-18-70.

2.2 GE Specifications

2.2.1 GE Specification 22A1547 - Rev. 3, "Uranyl Nitrate for SEFOR Core I Fuel Pellets"

2.2.2 GE Specification 22A1456 - Rev. 3, "Plutonium Nitrate for SEFOR Core I Fuel Pellets"

2.2.3 GE Specification 22A1583 - Rev. 2, "UO₂ Insulator Pellets for SEFOR Core I"

2.2.4 GE Specification 22A1545 - Rev. 4, "PuO₂-UO₂ Fuel Pellets for SEFOR Core I".

2.2.5 GE Specification 22A1548 - Rev. 4, "Fuel Rods for SEFOR Core I".

2.2.6 GE Specification FP-136 - Rev. 6, "Quality Control Plan for SEFOR Core I Fuel Pellets"

2.2.7 GE Specification FP-138 - Rev. 3, "Quality Control Plan for SEFOR Core I Fuel Rods"

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SEFOR FUEL ROD PRODUCTION

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2.3 GE Drawings

<u>Part</u>	<u>Drawing</u>	<u>Revision</u>
2.3.1 Fuel Rod	112C2053-G1	10
2.3.2 Spring	159A2753	4
2.3.3 Tube	159A2747	9
2.3.4 Spacer	159A2754	6
2.3.5 Top End Plug	129B2357	6
2.3.6 Bottom End Plug	129B2359	8
2.3.7 Spring Assembly	167A1564	2
2.3.8 Fuel Pellet	159A2736	2
2.3.9 Insulator	159A2750	1
2.3.10 Reflector	159A2751	7
2.3.11 Spring	159A2752	5
2.3.12 Pellet Defect Tolerance	135B9630	0
2.3.13 Pellet Defect Tolerance	135B9631	0

2.4 NFS Documents

- 2.4.1 NFS-M-10 - Quality Control Procedure for the Fabrication of SEFOR Core I Fuel Pellets, Rev. 5, March 26, 1970.
- 2.4.2 NFS-M-11 - Fabrication and Quality Control Procedures for SEFOR Core I Fuel Rods, Rev. 7, April 1, 1970.
- 2.4.3 NFS No. 256-B-101 - Fuel Pellet Fabrication Process Manual, Rev. 8, March 26, 1970.

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3.0 General Manufacturing Plan

NFS will manufacture fuel rods as required by Section 2.1 at the Erwin, Tennessee, manufacturing plant. NFS will perform the preparation of the U-Pu Master-Mix, manufacture the ceramic powder, fabricate the fuel pellets, assemble the fuel rods, and perform specified tests, and will use suppliers for materials and tests as follows:

Prepare $UO_2(NO_3)_2$

NFS

Prepare Pu $NO_3 - HNO_3$

ARHCO, Richland, Washington

Prepare Master Mix

NFS

Make Powder

NFS

Fabricate Pellets

NFS

Analyze Nuclear Materials

NFS

GE, Vallecitos

ARHCO, Richland, Washington

AVCO

NBL, New Brunswick, N. J.

Manufacture Tubes

Tube Methods, Bridgeport, Pa.

Test Tubes (NDT)

Orbit, Cleveland, Ohio

Conam, Columbus, Ohio

Supply SS Bar Stock

Tull, Atlanta, Ga.

Carpenter, Reading, Pa.

Test SS Bar Stock

GE, San Jose

Supply Ni Bar Stock

Tull, Atlanta, Ga.

Fabricate Springs

Associated, Bristol, Conn.

Machine Plugs, spacers and reflectors

Accurate, Johnson City, Tenn.

Assemble and Electron Beam weld tube/spacer

Buehler, Indianapolis, Indiana

Analyses of chemical, physical and
mechanical properties of metal components
(in addition to supplier's analyses).

NFS

Coleman, Philadelphia, Pa.

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9/16/70

Prepared By:

Approved By:

W. K. Eggert/T. O. Bryan

Hugh J. Stock

Assemble and seal weld fuel rods

NFS

Test fuel rods

NFS

GE, SEFOR Site

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4.0 Audit Activities

Audit activities have been planned to provide assurance that the delivered fuel rods will be suitable for service in SEFOR and meet all specified requirements. The activities will include observations, review of data records, and verifications.

Observations include:

- (1) NFS's receiving inspections.
- (2) Orbit's & GE's NDT's.
- (3) Production operations (NFS and suppliers)
- (4) Inspection operations (NFS and suppliers)
- (5) NFS's QC activities.
- (6) Sampling for verification evaluations (NFS)
- (7) GE's receiving inspection.

Reviews include:

- (1) Supplier's reports
- (2) Production records
- (3) Inspection records
- (4) QC records
- (5) Verification test reports
- (6) GE's receiving inspection reports

Verifications include:

- (1) Master Mix analysis
- (2) Pellet analysis
- (3) Welding qualifications
- (4) Fuel Rod Identification

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(5) Fuel Rod He leak test

(6) Fuel Rod envelope dimensions

A detailed list of the processes/materials to be audited includes:

<u>Item</u>	<u>Observation</u>	<u>Data Review</u>	<u>Sample Verification</u>
UO ₂ (NO ₃) ₂	X	X	
PuNO ₃ -HNO ₃	X	X	
Master Mix	X	X	X
Precipitate	X	X	
Filtrate	X	X	
Blending	X	X	
Pellets	X	X	X
UO ₂ Insulator Pellets	X	X	
Metal Components	X	X	
Stack & Load	X	X	
Welding	X	X	X
Identification	X	X	X
He Leak Test	X	X	X
Gamma Scan	X	X	
Overall Dimensions	X	X	X
Pack & Ship	X	X	
Recycle Materials	X	X	
Quarantined Materials	X	X	

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In addition to observations, reviewing records and verification analyses; records delivered to GE by NFS and records generated by the GE audit activities will be assembled. This file will provide evidence supporting the level of quality built into SEFOR fuel rods.

The General Electric representative shall transmit weekly reports, as directed by GE-BRDO management, summarizing his activities at NFS and at subcontractors' plants. These reports will contain:

- NFS production activities
- NFS QC/QA activities
- GE resident QC activities
- Administrative

It shall be the responsibility of the GE resident QC engineer to promptly report by documented discrepancy report to responsible GE and NFS management any adverse conditions that may affect the quality or performance of SEFOR fuel rods, and to provide continuing surveillance and reporting of these conditions until corrective action has been established.

SUNNYVALE, CALIFORNIA

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	Prepared By: W. K. Eggert/T. O. Bryan	Approved By: Hugh J. Stock	

5.0 Audit Records**5.1 Receiving Inspection Audit**

Receiving inspections performed by NFS will be audited in accordance with the plan as shown in Figure 1. Results of this audit will be recorded on the form illustrated by Figure 2. This form will be completed for each fuel rod and will provide a record for materials traceability. Materials traceability records will be completed to the extent provided for in the documents listed under Section 2.0. In addition to recording data for materials traceability, the materials supplier's test reports and NFS's receiving inspection reports will be examined to assure that all materials meet the requirements of the applicable specifications, are identified, are accepted and released by NFS QC and any NFS Discrepant Material Reports and Corrective Action Memos have been cleared.

These Receiving Inspection Audits include all items listed in Figure 2.

5.2 Fuel Rod Process Audit

Audit of Fuel Rod fabrication will encompass the sequences shown in Figure 3. Results of this audit will be recorded on the forms shown in Figures 4 and 5. Figure 4 will be used to record the QC actions for fabrication of each batch of pellets. Figure 5 will be used to record the QC actions for assembly of each fuel rod. Data will be recorded on Figures 4 and 5 to provide fabrication traceability to the extent provided for by the documents listed under Section 2. Also, the processing and QC records will be analyzed to assure that all fabrication work meets the requirements of the applicable specifications, all materials are identified, all materials are checked and released by NFS's QC at the required QC Points and all/if any NFS Discrepant Materials Reports and Corrective Action Memos have been cleared.

These Fuel Rod Process Audits include all of those items which are listed in Figures 4 and 5.

SUNNYVALE, CALIFORNIA

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5.3 Fuel Rod Release for Shipment

Prior to shipping, a formal release for shipment will be supplied to NFS by GE-BRDO. The form shown in Figure 6 will be used for this purpose and, in addition, this same form will be used to provide certification by the GE Resident QC Engineer that all required QC activities and data recording, as listed on the form, have been completed.

5.4 Receiving Inspection

Receiving inspections of the Fuel Rods will be performed by GE at the SEFOR Site. Figure 7 depicts the items that will be reviewed and inspected. Completed forms shown in Figure 8 will provide the receiving inspection record.

RECEIVING INSPECTION AUDIT - NFS

FIGURE 1

Project: SEFOR Fuel Rods

Audit Element: Receiving Inspection and Materials

Audit Item: Fuel Rod No.

QUALITY ASSURANCE AUDIT DATA SHEET

[illegible]

FUEL ROD FABRICATION AUDIT - NFS

FIGURE 3

QUALITY ASSURANCE AUDIT DATA SHEET

OPERATION	NFS RUN SHEET NUMBER	ACCEPTED BY NFS	CORRECTIVE ACTION	REMARKS
UNH Prep	1A			
	1B			
QC Point 1	26			
PuNO ₃	2A			
	2B			
QC Point 2	26			
Master Mix	3A			
	3B			
	3C			
QC Point 3	26			
Ppt. filter, wash, & dry	4			
Reduce	7			
QC Point 7	8			
Parent Blend	9			
Cross Blend	10			
QC Point	26			
Slugging	11			
Green Pellets	12			
Sinter	13			
QC Point 9	12,13			
Grinding	14			
Wash, Dry, Inspect	21			
Batch Evaluation	17			
QC Point 10	26			
QC Point 11				

Notes:

FIGURE 4

Signature

Date

AUDITS

INSPECTIONS

SEFOR SITE AUDIT/INSPECTION

FIGURE 7

Project: SEFOR Fuel Rods

Audit Element: Rec. Insp.

Audit Item: Fuel Rod. No.

QUALITY ASSURANCE AUDIT DATA SHEET

[illegible]

APPENDIX B

SUMMARY OF SEFOR MASTER MIX (256-B-110) MAKE UP

APPENDIX BSUMMARY OF SEFOR MASTER MIX (256-B-110) MAKE-UPUranium in Uranyl Nitrate (From NFS Runsheet 3A)

First addition to Master Mix Tank	4144.1 lbs. of solution
Final addition to Master Mix Tank	<u>857.6</u> lbs. of solution
	5001.7 lbs. Total

$$5001.7 \text{ lbs} \times \frac{0.4536 \text{ Kg}}{1 \text{ lb.}} = 2268.46 \text{ Kg of solution added to Master Mix}$$

$$2268.46 \text{ Kg solution at } .1864 \frac{\text{gram U}}{\text{gram solution}} = 422.84 \text{ Kg Uranium in solution}$$

Plutonium in Plutonium Nitrate (From NFS Runsheets 3B)Plutonium nitrate Solution

<u>ARCHO Lot Number</u>	<u>Weight of Solution, grams</u>
227-30-6-1	142,349.8
227-30-6-2	125,062.5
227-30-6-6	149,633.5
227-30-6-7	151,650.5
227-30-7-1	<u>147,663.1</u>

Total 716,359.4 grams solution added to Master Mix

Total Plutonium* and Pu239 + 241* in solution

<u>Lot No.</u>	<u>Total Plutonium, grams</u>	<u>Pu 239 +241, grams</u>
227-30-6-1	22,505.5	20,574.53
227-30-6-2	19,972.48	18,321.95
227-30-6-6	22,085.90	20,174.14
227-30-6-7	22,413.94	20,475.81
227-30-7-1	<u>21,780.31</u>	<u>19,871.27</u>
	108,758.13	99,417.70

* See Table VII for conversion factors

Grams Pu/gram master mix solution

$$\frac{108,758.13}{716,359.4 + 2,268,460} = \frac{108,758.13}{2,984,819.4} = .0364 \text{ g Pu/g, solution}$$

Appendix B continued

Grams U/gram master mix solution

$$\frac{422,841}{2,984,819.4} = .1416 \text{ g. U/g. solution}$$

$$\frac{\text{Pu}}{\text{Pu} + \text{U}} \text{ ratio} = \frac{108,758.13 \text{ g Pu}}{108,758.13 \text{ g Pu} + 422,840 \text{ g U}} = \frac{108,758.13}{531,599.13} = 0.2046$$

$$\frac{\text{Pu}_{239} + 241}{\text{Pu} + \text{U}} \text{ ratio} = \frac{99,417.7}{531,599.13} = .1870$$

BEF/mr

APPENDIX C

NFS FUEL PELLET BATCH CERTIFICATIONS
and
GE VERIFICATION ANALYSIS OF FUEL PELLET BATCHES

CERTIFICATE OF ANALYSIS

CERTIFICATE OF ANALYSISMaterial UO₂-PuO₂ PelletsDate December 29, 1970Customer General Electric CompanyP.O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NGSales Order No. 256-A

ELEMENT	Blend 256-B-110-701A			ANALYSIS, ppm		
	Specification: 22A1545					
10(c)	Density within Pellets					
	Surface	Center	Average			
	10.23	10.17	10.20	Acceptable within + 2%		
	10.38	10.35	10.36	Acceptable within + 2%		
	10.28	10.13	10.20	Acceptable within + 2%		
	10.37	10.17	10.27	Acceptable within + 2%		
	10.38	10.28	10.33	Acceptable within + 2%		
	10.32	10.14	10.23	Acceptable within + 2%		
10(d)	Pellets shall be single phase mixed oxide with not more than 5 percent of material appearing as a second phase outside of solution.					
	Sample					
	1. Acceptable					
	2. Acceptable					
	3. Acceptable					
10(f)	The atom ratio of oxygen to heavy metal (uranium plus plutonium) shall be 1.97 - 1.99.					
		Center		Outer Diameter		
		1.977		1.973		
10(g)	Verification of Pu/Pu + U Ratio					
		20.50%				
		20.51%				
		20.51%				

Certified By: Clayton Brown

QUALITY CONTROL DEPARTMENT

C-3

Erwin, Tennessee

CERTIFICATE OF ANALYSISMaterial UO₂-PuO₂ PelletsDate December 29, 1970Customer General Electric CompanyP.O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NGSales Order No. 256-A

ELEMENT	Blend 256-B-110 (701A)		ANALYSIS, ppm	
	Specification:	22A1545		
10(h)	Impurities			
	Impurity	Maximum Individual Impurity Limit (ppm)	Found	
	H	5	2.6	
	B	10	<0.25	
	N	200	8	
	C	250	53	
	Cl	25	6	
	F	25	<5	
		All Others	2500	
	Al		73	
	Ag		0.50	
	Ca		30	
	Cd		0.20	
	Cr		150	
	Cu		11	
	Fe		215	
	Mg		23	
	Mn		8	
	Mo		6	
	Na		10	
	Ni		100	
	Pb		<5	
	Si		45	
	Sn		3	
	Ti		<250	
	V		<5	
	Zn		35	
		Total	<970	

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Date December 29, 1970

P.O. Box 254

Date Shipped.

San Jose, California

Bill of Lading No.

Purchase Order No. 205-58226-NG

Sales Order No. _____ 256-A

Certified By:

QUALITY CONTROL DEPARTMENT

Erwin, Tennessee

CERTIFICATE OF ANALYSIS

Material UO₂-PuO₂ Pellets

Date December 29, 1970

Customer General Electric Company

P.O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

ELEMENT	Blend 256-B-110-802	ANALYSIS, ppm	
	Specification: 22A1545		
10(a)	<u>Perpendicularity</u>		
	Number Run	Number Rejected	Allowable Rejects
	125	0	14
	<u>End Flatness</u>		
	Number Run	Number Rejected	Allowable Rejects
	125	0	14
10(b)	Pellet density shall be 9.993 to 10.401 grams per cubic centimeter, based on dimensions and weight. Density of the pellets from surface to center shall not vary more than ± 2 percent from the average density of the pellet.		
	<u>Geometric Density</u>		
	Number Run	Number Rejected	Allowable Rejects
	125	0	7
	<u>Immersion Density</u>		
	10.46 g/cc		
	10.27		
	10.41		

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Erwin, Tennessee

Material UO₂-PuO₂ Pellets

Date December 29, 1970

Customer General Electric Company

P.O. Box 254

Date Shipped.

San Jose, California

Bill of Lading No..

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

Certified By:

Clayton Brown
QUALITY CONTROL DE

QUALITY CONTROL DEPARTMENT

C-7

CERTIFICATE OF ANALYSISMaterial UO₂-PuO₂ PelletsDate December 29, 1970Customer General Electric CompanyP.O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NGSales Order No. 256-A

ELEMENT	Blend 256-B-110-802		ANALYSIS, ppm		
	Specification:	22A1545			
10(h)	Impurities				
			Maximum Individual		
	Impurity		Impurity Limit (ppm)	Found	
	H		5	2.6	
	B		10	<0.20	
	N		200	8	
	C		250	79	
	Cl		25	6	
	F		25	8	
	All Others 2500				
	Al			29	
	Ag			0.4	
	Ca			8	
	Cd			0.20	
	Cr			70	
	Cu			<2	
	Fe			260	
	Mg			13	
	Mn			<2	
	Mo			3	
	Na			10	
	Ni			35	
	Pb			<2	
	Si			25	
	Ti			<250	
	V			<5	
	Zn			25	
			Total	<742	

 Certified By: Clayton Brown
 QUALITY CONTROL DEPARTMENT

Erwin, Tennessee

CERTIFICATE OF ANALYSIS

Date December 29, 1970

P.O. Box 254 Date Shipped

San Jose, California Bill of Lading No. _____

Purchase Order No. 205-58226-NG Sales Order No. 256-A

Certified By:

QUALITY CONTROL DEPARTMENT

CERTIFICATE OF ANALYSIS

Date February 23, 1971

Date Shipped_____

Bill of Lading No. _____

Sales Order No. 256-A

Certified By:

C-10

GEAP-13745

Material UO₂-PuO₂ Pellets

Date February 23, 1971

Customer General Electric Company

P. O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

Certified By:

QUALITY CONTROL DEPARTMENT

Erwin, Tennessee

CERTIFICATE OF ANALYSISMaterial UO₂-PuO₂ PelletsDate February 23, 1971Customer General Electric CompanyP. O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NGSales Order No. 256-A

ELEMENT	Blend 256-B-110-803		ANALYSIS, ppm		
	Specification:	22A1545			
10(h)	Impurities				
	Impurity		Maximum Individual Impurity Limit (ppm)	Found	
	H		5	2.2	
	B		10	<0.20	
	N		200	11	
	C		250	43	
	Cl		25	9	
	F		25	<5	
	All Others 2500				
	Al			20	
	Ag			0.5	
	Ca			5	
	Cd			0.30	
	Cr			41	
	Cu			2	
	Fe			105	
	Mg			2	
	Mn			<2	
	Mo			3	
	Na			23	
	Ni			23	
	Pb			<2	
	Si			20	
	Sn			<2	
	Ti			<250	
	V			<5	
	Zn			25	
			Total -	<531	

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Erwin, Tennessee

Erwin, Tennessee

CERTIFICATE OF ANALYSISMaterial UO₂-PuO₂ PelletsDate February 23, 1971Customer General Electric CompanyP. O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NGSales Order No. 256-A

ELEMENT	Blend 256-B-110-804		ANALYSIS, ppm			
	Specification: 22A1545					
10(a)	<u>Perpendicularity:</u>					
	Number Run		Number Rejected		Allowable Rejects	
	125		1		14	
	<u>End Flatness:</u>					
	Number Run		Number Rejected		Allowable Rejects	
	125		1		14	
10(b)	Pellet density shall be 9.993 to 10.401 grams per cubic centimeter, based on dimensions and weight. Density of the pellets from surface to center shall not vary more than ± 2 percent from the average density of the pellet.					
	<u>Geometric Density</u>					
	Number Run		Number Rejected		Allowable Rejects	
	125		2		7	
(After Refire)	160		6		7	
(After Refire)	160		0		7	
	<u>Immersion Density</u>					
	10.24 g/cc					
	10.24					
	10.28					

Certified By: Clayton Brown

QUALITY CONTROL DEPARTMENT

C-14

GEAP-13745

Material UO₂-PuO₂ Pellets

Date February 23, 1971

Customer General Electric Company

P. O. Box 254

Date Shipped.

San Jose, California

Bill of Lading No.

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

Certified By:

QUALITY CONTROL DEPARTMENT

C-15

GEAP-13745

Material UO₂-PuO₂ Pellets

Date February 23, 1971

Customer. General Electric Company

P. O. Box 254 _____ Date Shipped _____

San Jose, California Bill of Lading No. _____

Purchase Order No. 205-58226-NG Sales Order No. 256-A

Certified By:

QUALITY CONTROL DEPARTMENT

C-16

Erwin, Tennessee

Material UO₂-PuO₂ Pellets

Date February 23, 1971

Customer General Electric Company

P. O. Box 254

Date Shipped.

San Jose, California

Bill of Lading No.

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

Certified By:

Clayton Brown
QUALITY CONTROL DEPARTMENT

GEAP-13745

Erwin, Tennessee

Material UO₂-PuO₂ Pellets

Date February 23, 1971

Customer General Electric Company

P. O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

Certified By:

QUALITY CONTROL DEPARTMENT

C-18

Erwin, Tennessee

CERTIFICATE OF ANALYSIS

Material: UO₂-PuO₂ Pellets

Date February 23, 1971

Customer General Electric Company

P. O. Box 254 Date Shipped

San Jose, California Bill of Lading No. _____

Purchase Order No. 205-58226-NG Sales Order No. 256-A

ELEMENT	Blend 256-B-110-805	ANALYSIS, ppm			
	Specification: 22A1545				
10(d)	Pellets shall be single phase mixed oxide with not more than 5 percent of material appearing as a second phase outside of solution.				
	Sample				
	1. Acceptable				
	2. Acceptable				
	3. Acceptable				
10(f)	The atom ratio of oxygen to heavy metal (uranium plus plutonium) shall be 1.97 - 1.99.				
		Center		Outer Diameter	
After Refire/Before Outgas:	1.988			1.988	
After Refire/After Outgas:	1.987			1.987	
	1.985				
	1.986				
10(g)	Verification of Pu/ (Pu + U) Ratio				
	20.62%				
	20.56%				
	20.63%				

Certified By:

QUALITY CONTROL DEPARTMENT

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CERTIFICATE OF ANALYSIS

Material UO₂-PuO₂ PelletsDate February 23, 1971Customer General Electric CompanyP. O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NGSales Order No. 256-A

ELEMENT	Blend 256-B-110-805		ANALYSIS, ppm		
	Specification:	22A1545			
10(h)	Impurities				
			Maximum Individual		
	Impurity		Impurity Limit (ppm)	Found	
	H		5	0.9	
	B		10	<0.20	
	N		200	6	
	C		250	43	
	Cl		25	<5	
	F		25	<5	
	All Others 2500				
	Al			60	
	Ag			0.30	
	Ca			6	
	Cd			0.20	
	Cr			14	
	Cu			70	
	Fe			235	
	Mg			2	
	Mn			2	
	Mo			2	
	Na			10	
	Ni			21	
	Pb			2	
	Si			67	
	Sn			<2	
	Ti			<250	
	V			<5	
	Zn			25	
			Total -	<774	

Certified By: _____

Clayton Brown
 QUALITY CONTROL DEPARTMENT

CERTIFICATE OF ANALYSIS

Material UO₂-PuO₂ Pellets

Date February 23, 1971

Customer General Electric Company

P. O. Box 254

Date Shipped.

San Jose, California

Bill of Lading No.

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

ELEMENT	Blend 256-B-110-805		ANALYSIS, ppm			
	Specification:	22A1545				
10(i)	Volatiles					
	Specification:			Found		
				0.007		
	0.05 cc/gram (excluding water)			0.016		
				0.008		
	30 ppm total moisture			< 10		
10(j)	Homogeneity	(Autoradiography)				
	Sample					
	1. Acceptable					
	2. Acceptable					
	3. Acceptable					
	Homogeneity	(Chemical Analysis Pu/(Pu + U)				
	Center	Edge	Average	Acceptable	within + 1%	
	0.2056	0.2055	0.2056			

Certified By:

Clayton Brown
QUALITY CONTROL DEPARTMENT

C-21

Erwin, Tennessee

CERTIFICATE OF ANALYSIS

Date February 23, 1971

P. O. Box 254

Date Shipped.

San Jose, California

Bill of Lading No.

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

ELEMENT	Blend 256-B-110-806	ANALYSIS, ppm			
	Specification: 22A1545				
10(a)	<u>Perpendicularity</u>				
	Number Run	Number Rejected		Allowable Rejects	
	32	0		5	
	<u>End Flatness</u>				
	Number Run	Number Rejected		Allowable Rejects	
	32	0		5	
10(b)	Pellet density shall be 9.993 to 10.401 grams per cubic centimeter, based on dimensions and weight. Density of the pellets from surface to center shall not vary more than ± 2 percent from the average density of the pellet.				
	<u>Geometric Density</u>				
	Number Run	Number Rejected		Allowable Rejects	
	32	1		2	
	<u>Immersion Density</u>				
	10.16 g/cc				
	10.15				
	10.13				

Certified By:

QUALITY CONTROL DEPARTMENT

C-22

Erwin, Tennessee

CERTIFICATE OF ANALYSIS

Material UO₂-PuO₂ Pellets

Date February 23, 1971

Customer General Electric Company

P. O. Box 254

Date Shipped.

San Jose, California

Bill of Lading No.

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

ELEMENT	Blend 256-B-110-806		ANALYSIS, ppm	
	Specification:	22A1545		
10(d)	Pellets shall be single phase mixed oxide with not more than 5 percent of material appearing as a second phase outside of solution.			
	Sample			
	1. Acceptable			
	2. Acceptable			
	3. Acceptable			
10(f)	The atom ratio of oxygen to heavy metal (uranium plus plutonium) shall be 1.97 - 1.99.			
		<u>Center</u>	<u>Outer Diameter</u>	
		1.991	1.991	
Retest		1.990	1.989	
Retest		1.990	1.988	
10(g)	<u>Verification of Pu/(Pu + U) Ratio</u>			
	20.65%			
	20.68%			
	20.66%			

Certified By:

QUALITY CONTROL DEPARTMENT

C-23

NUCLEAR FUEL SERVICES, INC.

Erwin, Tennessee

GEAP-13745

CERTIFICATE OF ANALYSIS

Material UO₂-PuO₂ PelletsDate February 23, 1971Customer General Electric CompanyP. O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NGSales Order No. 256-A

ELEMENT	Blend 256-B-110-806		ANALYSIS, ppm			
	Specification:	22A1545				
10(h)	Impurities		Maximum Individual Impurity Limit (ppm)		Found	
	H		5		1.7	
	B		10		0.20	
	N		200		8	
	C		250		74	
	Cl		25		7	
	F		25		<5	
	All Others 2500					
	Al				35	
	Ag				1	
	Ca				17	
	Cd				.3	
	Cr				30	
	Cu				4	
	Fe				400	
	Mg				<2	
	Mn				<2	
	Mo				2	
	Na				10	
	Ni				18	
	Pb				<2	
	Si				23	
	Sn				<2	
	Ti				<250	
	V				<5	
	Zn				25	
				Total -	<829	

Certified By: _____

 QUALITY CONTROL DEPARTMENT

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GEAP-13745

Material UO₂-PuO₂ Pellets

Date February 23, 1971

Customer General Electric Company

P. O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

Certified By:

QUALITY CONTROL DEPARTMENT

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SEFOR FUEL PELLETSGE VERIFICATION ANALYSISPage 1 of 2

Spec. No. 22A1545 Rev. 4

Batch No. 701A

<u>Specification Requirement</u>			(Archive) <u>Pellet 11</u>	<u>Pellet 12</u>	<u>Pellet 13</u>
Diameter	.874 to .876"		.8756	.8748	.8758
Length	.531 to .719		.6009	.5905	.5906
Dish Depth	.012 to .018		.0165	.0165	.0165
Identification Marking	"V"		✓	✓	✓
Surface Appearance			✓	✓	✓
Density	9.99 to 10.40 g/cc		10.40	10.34	10.38
Total Gas	<50ul/g			18.6	9.5
Moisture	30 ppm Maximum			5	<1
O/M Ratio	1.97 to 1.99			1.985	1.985
Pu-239+241/Pu+U	18.7±.3%		18.75 (Data from Pellet #1 Preproduction Evaluation)		
Pu Total % of Net Weight			18.0		
U Total % of Net Weight			69.76		
U-235	.204±.01% of Total U		.21		
Homogeneity (1)	First Sample % Pu		18.13		
	Second Sample % Pu		18.14		
Second Phase	No more than 5%		✓		
Impurities	H	5 ppm Max.	3.85		
	B	10 ppm Max.	<1		
	N	200 ppm Max.	<200		
	C	300 ppm Max.	25		
	Cl	25 ppm Max.	<2		
	F	25 ppm Max.	2		
All other elements	Ag		<.1		
	Al		<4		
	Be	2500 ppm max.	<.5		
	Ca		<.25		
	Cd		< 2		

(1) The Pu concentration in a 0.1 gram sample taken at any region of the pellet shall not deviate more than 1% from the average Pu concentration in the pellet.

SEFOR FUEL PELLETS
GE VERIFICATION ANALYSIS

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Spec. No. 22A1545 Rev. 4

Batch No. 701A

<u>Specification Requirement</u>	<u>Pellet 11</u>	<u>Pellet 12</u>	<u>Pellet 13</u>
Impurities, continued			
Co	<1		
Cr	24		
Cu	11		
Fe	200		
Mg	4		
Mn	4		
Mo	<10		
Na	<15		
Ni	40		
Pb	<1		
Si	<6		
Sn	<1		
Ti	-		
V	<3		
Zn	<10		
Total	<595.5		
Information, Not required by Specification			
% Pu239	90.39		
% Pu240	8.53		
% Pu241	1.02		
% Pu242	.06		
NBL Check of Total % Pu	18.14		
NBL Check of Total % U	69.98

FIGURE C-1

NFS Batch 701A (B0583) Pellet #11 "As Received" - 6X
(PL Negative Number 61512)

Figure C-2
NTS Batch 701A (B0583) Pellet #12 "As Received" - 6X
(PL Negative Number 61513)

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Figure C-3
NFS Batch 701A (B0583) Pellet #12 "As Received" - 6X
(PL Negative Number 51514)

Figure C-4
NFS Batch 701A (B0533) Pellet #13 "As Received" - 6X
(PL Negative Number 61515)

Figure C-5

NFS Batch 701A (B0583) Pellet #12 Microstructure - 50X
(PL Negative Number 61519)

Figure C-6

NFS Batch 701A (B0563) Pellet #13 Microstructure - 50X
(PL Negative Number 61520)

Figure C-7
NFS Batch 701A (B0583) Pellet #13 Microstructure - 20CX
(PL Negative Number 61521)

Figure C-8

NFS Batch 701A (B0583) Pellet #12 Alpha Autoradiograph
Approximately 14X (PL Negative Number 61524)

Figure C-9
NFS Batch 701A (B0583) Pellet #13 Alpha Autoradiograph -
Approximately 14X (PL Negative Number 61525)

SEFOR FUEL PELLETS
VERIFICATION ANALYSIS

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Spec. No. 22A1545 Rev. 4

Batch No. 802

<u>Specification Requirements</u>			<u>Pellet 1</u>	<u>Pellet 2</u>	<u>Pellet 3</u>
Diameter	.874 to .876"		.8754	.8753	.8749
Length	.531 to .719		.6308	.6322	.6322
Dish Depth	.012 to .018		.012	.015	.0155
Identification Marking	"V"		✓	✓	✓
Surface Appearance			✓	✓	✓
Density	9.99 to 10.40 g/cc		10.32	10.27	10.12
Total Gas	<50 µl/g		12.4	41.2	
Moisture	30 ppm Maximum		<1	<1	
O/M Ratio	1.97 to 1.99		1.973	1.979	1.978
Pu239+241/Pu+U	18.7±.3%		18.93		
Pu Total % of Net Weight			18.09		
U Total % of Net Weight			69.24		
U-235	.204±.01% of Total U		.22		
Homogeneity (1)	First Sample % Pu		18.15		
	Second Sample % Pu		18.13		
Second Phase	No more than 5%		✓		
Impurities	H	5 ppm Max.	1		
	B	10 ppm max.	<1		
	N	200 ppm Max	46		
	C	300 ppm Max.	423*34	Recheck	
	Ci	25 ppm Max.	4		
	F	25 ppm max.	<1		
All other elements	Ag		<.1		
	Al		<4		
2500 ppm Max.	Be		<.5		
	Ca		<25		
	Cd		<2		
	Co		<1		
	Cr		<24		

*Contamination during sampling suspected.

(1) The pu concentration in a 0.1 gram sample taken at any region of the pellet shall not deviate more than 1% from the average Pu concentration in the pellet.

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SEFOR FUEL PELLETS
VERIFICATION ANALYSIS

Page 2 of 2

Spec. No. 22A1545 Rev. 4

Batch No. 802

<u>Specification Requirements</u>	<u>Pellet 1</u>	<u>Pellet 2</u>	<u>Pellet 3</u>
Impurities, Continued			
Cu	8		
Fe	270		
Mg	20		
Mn	4		
Mo	<3		
Na	<15		
Ni	<24		
Pb	<1		
Si	<6		
Sn	<5		
Ti	-		
V	<3		
Zn	<50		
Total	<528		
Information, not required by specification			
% Pu-239	90.35		
% Pu-240	8.57		
% Pu-241	1.02		
% Pu-242	.06		
NBL check of total % Pu	18.08		
NBL check of total % U	69.68

Figure C-10
NFS Batch 002 (B0536) Pellet #1 "As Received" - 6X
(PL Negative Number 61503)

Figure C-II
NFS Batch 802 (B0586) Pellet #2 "As Received" - 6X
(PL Negative Number 61509)

Figure C-12
NFS Batch 802 (B0586) Pellet #3 "As Received" - 6X
(PL Negative Number 61510)

Figure C-13
NFS Batch 802 (B0586) Pellet #3 'As Received' - 6X
(PL Negative Number 61511)

Figure C-14
NFS Batch 802 (B0586) Pellet #1 Microstructure - 50X
(PL Negative Number 61516)

Figure C-15
NFS Batch 802 (B0586) Pellet #1 Microstructure - 50X
(PL Negative Number 61517)

Figure C-16
NFS Batch 802 (B0536) Pellet #2 Microstructure - 50X
(PL Negative Number 61513)

Figure C-17
NFS Batch 802 (B0586) Pellet #1 Alpha Autoradiograph -
Approximately 14X (PL Negative Number 61522)

Figure C-18
NFS Batch 802 (B0586) Pellet #2 Alpha Autoradiograph -
Approximately 14X (PL Negative Number 61523)

SEFOR FUEL PELLETS
GE VERIFICATION ANALYSIS

Page Page 1 of 3

Spec. No. 22A1545 Rev. 4

Batch No. 803

<u>Specification Requirement</u>	<u>Pellet 1</u>	<u>Pellet 2</u>	<u>Pellet 3</u>
Diameter .874 to .876"	.8754	.8758	.8747
Length .531 to .719	.6380	.6417	.6355
Dish Depth .012 to .018	Dish depth of pellet 1, 2 & 3 measured incorrectly See pellet 4 & 5		
Identification Marking "V"	✓	✓	✓
Surface Appearance	✓	✓	✓
Density 9.99 to 10.40 g/cc	10.15	10.12	10.15
Total Gas <50 μ l/g		23.9	27.2
Moisture 30 ppm Maximum		<1	<1
O/M Ratio 1.97 to 1.99	1.981	1.991	1.986
Pu-239+241/Pu+U 18.7 $\pm$.3%			18.77
Pu Total % of net weight			18.09
U total % of net weight			69.63
U-235 .204 $\pm$.01% of Total U			.22
Homogeneity ⁽¹⁾	First Sample % Pu		18.17
	Second Sample % Pu		18.17
Second Phase	No more than 5%		✓
Impurities	H 5 ppm Max.		2
	B 10 ppm Max.		<1
	N 200 ppm Max.		36
	C 300 Ppm Max.		99 ⁽²⁾ 24
			Recheck
	Cl 25 ppm Max		<1
	F 25 ppm Max.		<1
All other	Ag		<.1
Elements	Al		<4
2500 ppm max.	Be		<.5
	Ca		<25
	Cd		<2

(1) The Pu concentration in a 0.1 gram sample taken at any region of the pellet shall not deviate more than 1% from the average Pu concentration in the pellet.

(2) Contamination during sampling suspected.

SEFOR FUEL PELLETS
GE VERIFICATION ANALYSIS

Page 2 of 3

Spec. No. 22A1545 Rev. 4

Batch No. 803

<u>Specification Requirement</u>	<u>Pellet 1</u>	<u>Pellet 2</u>	<u>Pellet 3</u>
Impurities, continued			
Co			<1
Cr			5
Cu			1
Fe			120
Mg			4
Mn			2
Mo			<3
Na			<15
Ni			<24
Pb			<1
Si			<6
Sn			<5
Ti			-
V			<3
Zn			<50
Total			<272
Information, not required by Specification			
% Pu-239			90.36
% Pu-240			8.56
% Pu-241			1.02
% Pu-242			.06
NBL Check of Total % Pu			18.13
NBL Check of Total % U			69.83

SEFOR FUEL PELLETS
GE VERIFICATION ANALYSIS
 Spec. No. 22A1545 Rev. 4
 Batch No. 803

Page 3 of 3

<u>Specification Requirement</u>	<u>Pellet 4</u>	<u>Pellet 5</u>	<u>Pellet</u>
Diameter .874 to .876"	.8743	.8752	
Length .531 to .719	.5925	.5823	
Dish Depth .012 to .018	.013	.013	
Identification Marking "V"	✓	✓	
Surface Appearance	✓	✓	
Density 9.99 to 10.40 g/cc	10.29	10.27	
Total Gas <50 μ l/g			
Moisture 30 ppm Maximum			
O/M Ratio 1.97 to 1.99			
Pu-239+241/Pu+U 18.7 $\pm$.3%			
Pu Total % of Net Weight			
U Total % of Net Weight			
U-235 .204 $\pm$.01% of Total U			
Homogeneity	First Sample % Pu		
	Second Sample % Pu		
Second Phase No more than 5%			
Impurities	H 5 ppm Max		
	B 10 ppm Max.		
	N 200 Ppm Max.		
	C 300 ppm Max.		
	Cl 25 ppm Max.		
	F 25 ppm Max.		
All other	Ag		
Elements	Al		
2500 ppm max.	Be		
	Ca		
	Cd		
	Co		
	Cr		
	Cu		
	Fe

Figure C-19

NFS Batch 803 (B0592) Pellet #1 "As Received"-5X
(PL Negative Number 61614)

Figure C-22

NFS Batch 803 (B0592) Pellet #4 "As Received"-5X
(PL Negative Number 61764)

Figure C-23

NFS Batch 803 (B0592) Pellet #5 "As Received"-5X
(PL Negative Number 61765)

Figure C-24

NFS Batch 803 (B0592) Pellet #3 Microstructure-50X
(PL Negative Number 61739)

Figure C-25

NFS Batch 803 (B0592) Pellet #3 Microstructure-400X
(PL Negative Number 61740)

Figure C-26

NFS Batch 803 (B0592) Pellet #3 Alpha Autoradiograph-Approximately 15X
(PL Negative Number 61741)

SEFOR FUEL PELLETS
GE VERIFICATION ANALYSIS
 Spec. No. 22A1545 Rev. 4

Page 1 of 2

Batch No. 804

<u>Specification Requirement</u>		<u>Pellet 1</u>	<u>Pellet 2</u>	<u>Pellet 3</u>
Diameter .874 to .876"		.8745	.8753	.8751
Length .513 to .719		.6395	.6089	.6455
Dish Depth .012 to .018		.014	.011	.014
Identification Marking "V"		✓	✓	✓
Surface Appearance		✓	✓	✓
Density 9.99 to 10.40 g/cc		10.26	10.24	10.35
Total Gas <50 μ l/g		-	14.4	16.5
Moisture 30 ppm Maximum		-	<1	<1
O/M Ratio 1.97 to 1.99		1.988	1.991	1.984
Pu-239+241/Pu+U 18.7 $\pm$.3%				18.77
Pu Total % of Net Weight				18.15
U Total % of Net Weight				70.14
U-235 .204 $\pm$.01% of Total U				.21
Homogeneity ⁽¹⁾	First Sample % Pu			18.11
	Second Sample % Pu			17.48
Second Phase	No more than 5%			✓
Impurities	H 5 ppm Max.			1.5
	B 10 ppm Max			<1
	N 200 ppm Max			28
	C 300 ppm Max.			17
	Ci 25 ppm max.			<2
	F 25 ppm Max.			<1
All other	Ag			<.1
Elements	Al			4
	Be			<.5
	Ca			<25
	Cd			< 2
	Co			<1

(1) The Pu concentration in a 0.1 gram sample taken at any region of the pellet shall not deviate more than 1% from the average Pu concentration in the pellet.

SEFOR FUEL PELLETS
GE VERIFICATION ANALYSIS

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Spec. No. 22A1545 Rev. 4

Batch No. 804

<u>Specification Requirement</u>	<u>Pellet 1</u>	<u>Pellet 2</u>	<u>Pellet 3</u>
Impurities, continued			
Cr			20
Cu			<1
Fe			250
Mg			4
Mn			3
Mo			<3
Na			<15
Ni			30
Pb			<1
Si			35
Sn			<1
Ti			-
V			<3
Zn			<10
Total			<409
Information, not required by Specification			
% Pu-239			90.39
% Pu-240			8.55
% Pu-241			1.01
% Pu-242			.06
NBL Check of Total % Pu			18.18
NBL Check of Total % U			69.94

Figure C-27

NFS Batch 804 (B0597) Pellet #1 "As Received"-5X
(PL Negative Number 61766)

Figure C-28
NFS Batch 804 (B0597) Pellet #2 "As Received"-5X
(PL Negative Number 61767)

Figure C-29

NFS Batch 804 (B0597) Pellet #3 "As Received"-5X
(PL Negative Number 61768)

Figure C-30

NFS Batch 804 (B0597) Pellet #3 Microstructure-50X
(PL Negative Number 61782)

Figure C-31

NFS Batch 804 (B0597) Pellet #3 Microstructure-200X
(PL Negative Number 61783)

Figure C-32

NFS Batch 304 (B0592) Pellet #3 Alpha Autoradiograph-
Approximately 14X (PL Negative Number 61789)

SEFOR FUEL PELLETS
GE VERIFICATION ANALYSIS

Page 1 of 2

Spec. No. 22A1545 Rev. 4

Batch No. 805

<u>Specification Requirement</u>	<u>Pellet 1</u>	<u>Pellet 2</u>	<u>Pellet 3</u>
Diameter .874 to .876"	.8752	.8755	.8750
Length .531 to .719	.6082	.6276	.6135
Dish Depth .012 to .018	.010	.014	.010
Identification Marking "V"	✓	✓	✓
Surface Appearance	✓	✓	✓
Density 9.99 to 10.40 g/cc	10.27	10.28	10.25
Total Gas <50 μ l/g	-	30.2	9.8
Moisture 30 ppm Maximum	-	<1	<1
O/M Ratio 1.97 to 1.99	1.995	1.984	1.991
Pu239+241/Pu+U 18.7 $\pm$.3%			18.76
Pu Total % of Net Weight			18.17
U Total % of Net Weight			70.32
U-235 .204 $\pm$.01% of Total U			.22
Homogeneity ⁽¹⁾	First sample % Pu		16.90 18.00 ⁽²⁾
	Second Sample % Pu		18.06
Second Phase No more than 5%			✓
Impurities	H 5 ppm Max.		0.5
	B 10 ppm Max		<1
	N 200 PPM Max.		19
	C 300 ppm Max.		27
	Ci 25 ppm Max.		<1
	F 25 ppm max.		<1
All other	Ag		<.1
Elements	Al		15
2500 ppm Max.	Be		<.5
	Ca		< 25
	Cd		<2

(1) The Pu concentration in a 0.1 gram sample taken at any region of the pellet shall not deviate more than 1% from the average Pu concentration in the pellet.

(2) Resampled; sample size increased from 42 to 100 mg.

SEFOR FUEL PELLETS
GE VERIFICATION ANALYSIS

Page 2 of 2

Spec. No. 22A1545 Rev. 4

Batch No. 805

<u>Specification Requirement</u>	<u>Pellet 1</u>	<u>Pellet 2</u>	<u>Pellet 3</u>
Impurities, continued			
Co			<1
Cr			30
Cu			<1
Fe			550
Mg			4
Mn			7
Mo			<3
Na			<15
Ni			30
Pb			<1
Si			100
Sn			<1
Ti			-
V			<3
Zn			<10
Total			<799
Information, not required by Specification			
% Pu-239			90.36
% Pu-240			8.57
% Pu-241			1.01
% Pu-242			.06
NBL Check of Total % Pu			18.18
NBL Check of Total % U			69.95

Figure C-33
NFS Batch 805 (B0591) Pellet #1 "As Received"-5X
(PL Negative Number 61761)

Figure C-34

NFS Batch 805 (B0591) Pellet #2 "As Received"-5X
(PL Negative Number 61762)

Figure C-35
NFS Batch 805 (B0591) Pellet #3 "As Received"-5X
(PL Negative Number 61763)

Figure C-36

NFS Batch 805 (B0591) Pellet #3 Microstructure-50X
(PL Negative Number 61787)

Figure C-37

NFS Batch 805 (B0591) Pellet #3 Microstructure-200X
(PL Negative Number 61788)

Figure C-38

NFS Batch 805 (B0591) Pellet #3 Alpha Autoradiograph-Approximately 14X
(PL Negative Number 61791)

SEFOR FUEL PELLETS
GE VERIFICATION ANALYSIS

Page 1 of 2

Spec. No. 22A1545 Rev. 4

Batch No. 806

<u>Specification Requirement</u>	<u>Pellet 1</u>	<u>Pellet 2</u>	<u>Pellet 3</u>
Diameter .874 to .876"	.8759	.8736	.8758
Length .531 to .719	-	.6086	.6089
Dish Depth .012 to .018	.011	.015	.015
Identification Marking "V"	✓	✓	✓
Surface Appearance	✓	✓	✓
Density 9.99 to 10.40 g/cc	-	10.07	10.06
Total Gas <50 μ l/g		31.4	26.2
Moisture 30 ppm Maximum		<1	<1
O/M Ratio 1.97 to 1.99	1.989	1.988	1.986
Pu-239+241/Pu+U 18.7 $\pm$.3%			18.84
Pu Total % of Net Weight			18.23
U Total % of Net Weight			70.22
U-235 .204 $\pm$.01% of Total U			.21
Homogeneity (1)	First Sample % Pu		17.62
	Second Sample % Pu		17.69
Second Phase No more than 5%			✓
Impurities	H 5 ppm Max.		2.1
	B 10 ppm Max.		<1
	N 200 ppm Max.		34
	C 300 ppm Max.		7
	Ci 25 ppm Max		<2
	F 25 ppm Max		1

(1) The Pu concentration in a 0.1 gram sample taken at any region of the pellet shall not deviate more than 1% from the average Pu concentration in the pellet.

SEFOR FUEL PELLETSGE VERIFICATION ANALYSISPage 2 of 2

Spec. No. 22A1545 Rev. 4

Batch No. 806

<u>Specification Requirement</u>	<u>Pellet 1</u>	<u>Pellet 2</u>	<u>Pellet 3</u>
Impurities, continued			
All other Ag			<.1
Elements Al			4
2500 ppm max. Be			<.5
Ca			<25
Cd			<2
Co			<1
Cr			25
Cu			<1
Fe			250
Mg			4
Mn			4
Mo			<3
Na			<15
Ni			30
Pb			<1
Si			60
Sn			<1
Ti			-
V			<3
Zn			<10
Total			<440
Information, not required by Specification			
% Pu-239			90.39
% Pu-240			8.54
% Pu-241			1.01
% Pu-242			.06
NBL Check of Total % Pu			18.18
NBL check of total % U			69.97

Figure C-39
NFS Batch 806 (B0598) Pellet #1 "As Received"-5X
(PL Negative Number 61769)

Figure C-40

NFS Batch 806 (B0598) Pellet #2 "As Received"-5X
(PL Negative Number 61770)

Figure C-41

NFS Batch 806 (B0598) Pellet #3 "As Received"-5X
(PL Negative Number 61771)

Figure C-42

NFS Batch 806 (B0598) Pellet #3 Microstructure-50X
(PL Negative Number 61784)

Figure C-43

NFS Batch 806 (B0598), Pellet #13 Microstructure-200X
(PL Negative Number 61785)

Figure C-44

NFS Batch 806 (B0598) Pellet #13 Microstructure-400X
(PL Negative Number 61786)

Figure C-45

NFS Batch 806 (B0598) Pellet #3 Alpha Autoradiograph-Approximately 14X
(PL Negative Number 61790)

APPENDIX D

SEFOR FUEL RODS

UO₂ INSULATOR PELLETS

APPENDIX D

NFS EVALUATION

The information for the UO_2 insulator pellets submitted by NFS is included. NFS concluded the pellets were satisfactory for use in SEFOR fuel rods.

GE EVALUATION

The three insulator pellet samples received from NFS were visually inspected. An identification mark ("—") was visible on each pellet and the surface appearance as judged for cracks and chips was satisfactory. A pellet number (1 thru 3) was assigned to each pellet and the evaluation was completed as outlined in Reference B. The requirement of the GE specification and the results of the evaluation are given in Table D-1. The values NFS reported are listed for comparison.

The density of Pellets 1 and 3 was high by .04 g/cc but this is considered acceptable for use in SEFOR fuel rods.

CONCLUSIONS

The UO_2 insulator pellets from NFS Lots 1 and 2 are satisfactory for use in SEFOR fuel rods.

TABLE D-1

SEFOR FUEL RODS
UO₂ INSULATOR PELLET
PRODUCTION SAMPLES

ATTRIBUTE	SPECIFIED GE 22A1583 REV 2	NFS ANALYSIS		NFS OVERCHECK	GE ANALYSIS
		LOT 1	LOT 2		PELLET #3
Density	9.983-10.42 g/cc	Ave. 10.15 Range 9.97 10.32	Ave. 10.27 Range 10.17 10.38		Ave. 10.42 10.46 10.46 10.34
O/M Ratio	2.00 - 2.03	2.029 2.029	2.029 2.034	Lot 1-2.010 Lot 2-2.013	2.00
U-235/U Ratio	.22 ± .01	.228	.228	-	.21
Impurities*					
Al	500	24 20	8 6		<4
B	6	<0.2	<0.2		<1
C	150	<25	<25	Lot 1 59 Lot 2 71	39
Cd	20	<.01	<.01		<2
Ca	25	<20	<20		<25
Cl	25	<10	<10	Lot 1 4 Lot 2 3	3
Cr	500	9 6	5 3		<3
Cu	500	1	1		<.5
F	25	10	10		4
Fe	500	26 23	24 18		<14
Pb	500	<1	<1		<1

TABLE D-1 (Cont.)

SEFOR FUEL RODS
 UO₂ INSULATOR PELLET
PRODUCTION SAMPLES

ATTRIBUTE	SPECIFIED GE 22A1583 REV 2	NFS ANALYSIS		NFS OVERCHECK	GE ANALYSIS
		LOT 1	LOT 2		PELLET #3
Mg	25	9 8	7 6		<2
Ni	500	18 10	26 22		<24
Si	100	95 80	75 65		60
N	200	<10	<10		<200
Na	500	<40	<40		<15
Ag	500	<0.1	<0.1		<.1
Sn	500	<1	<1		<1
V	500	<2.5	<2.5		<3
Zn	500	<25	<25		<10
TOTAL IMPURITIES	<2500				<238.1

*Maximum parts per million parts uranium

SEFOR FUEL RODS
UO₂ INSULATOR PELLET
PRODUCTION SAMPLES

ATTRIBUTE	SPECIFIED GE DRWG 159A2750	NFS INSPECTION			GE EVALUATION	
		Lot	Ave.	Range		
Diameter	.882" to .884"	1	.8832	.8841/.8827	Pellet 1	.8830"
		2	.8828	.8835/.8820	2	.8827"
					3	.8834"
Length	.312" to .438"	1	.3578	.3683/.3508	Pellet 1	.3543"
		2	.3547	.3671/.3424	2	.3497"
					3	.3586"
Dish Depth	.007" to .017"	Lot	Ave.	Range	Pellet 1 Top	.0077"
		1(A)	.012	.010/.015	Bot	.0109"
		(B)	.013	.010/.015	Pellet 2 Top	.0092"
		2(A)	.012	.010/.014	Bot	.0099"
		(B)	.012	.010/.014	Pellet 3 Top	.0101"
					Bot	.0081"
Weight	Not Specified	Not Measured			Pellet 1	36.62 g
					2	35.65 g
					3	37.12 g

NUCLEAR FUEL SERVICES EVALUATION
OF UO_2 INSULATOR PELLETS

Erwin
August 27, 1970

TO: Mr. Urban Bird
FROM: E. E. Crowder
SUBJECT: UO₂ Insulator Pellets for Sales Order 256-A
REFERENCE: General Electric TWX to NFS dated 8/13/70

The following information was compiled for transfer to G-E.

1. Pellet certification and summary of physical attributes for lots 1 and 2.
2. Summary of storage conditions.
3. NFS' evaluation of effects of storage on pellet quality.

The depleted UO₂ insulator pellets are identified as lots 1 and 2 of Sales Order 256-A. These pellets were stored in polyethylene bags inside 5-gallon metal containers. Evaluation of materials for deterioration during storage was performed by NFS and the results are attached.

E. E. Crowder

EEC/jsd

Attachment

Material Insulator Pellets
Customer General Electric Company
175 Curtner Avenue
San Jose, California
Purchase Order No. 205-58226-NG

Sales Order No. 256-A

Certified By: K.D. Hensley
Quality Control Department
K.D. Hensley

Erwin, Tennessee

CERTIFICATE OF ANALYSIS

Material: UO₂ Insulator Pellets

Date September 15, 1970

Customer General Electric Company

P.O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NG

Sales Order No. 256-A

[illegible]

Ermine E Crowder
E. E. Crowder

Certified By: E. E. Crowder

QUALITY CONTROL DEPARTMENT

GEAP-13745

CERTIFICATE OF ANALYSIS

Date August 26, 1970

P. O. Box 254

Date Shipped_____

Bill of Lading No. _____

Sales Order No. 256-A

The above analyses were run by Nuclear Fuel Services to evaluate the effects of storage on UO₂ pellets. Nuclear Fuel Services concludes that there has been no deterioration of quality due to storage.

Certified By:

Eigene E. Crowder
QUALITY CONTROL DEPARTMENT

NUCLEAR FUEL SERVICES, INC.
ERWIN, TENNESSEE

GEAP-13745

MATERIAL UO Pellets (Depleted)
2

DATE December 14, 1966

CUSTOMER General Electric Company

SALES ORDER NUMBER 256-A

P.O. Box 254

San Jose, California

LOT #1

PURCHASE ORDER NUMBER 205-58226-NG

INSULATOR PELLETS

Pellet Number	Length (in.)	Diameter (in.)	Density (g/cc)	Land Width (in.)	Perpendicularity (in.)		Dist. Depth (in.)	
					(A)	(B)	(A)	(B)
1	0.3622	0.8834	10.17	0.105	0.0020	0.0025	0.010	0.011
2	0.3588	0.8841	10.15	0.100	0.0025	0.0030	0.012	0.012
3	0.3595	0.8831	10.16	0.100	0.0015	0.0020	0.012	0.011
4	0.3528	0.8827	10.27	0.100	0.0030	0.0030	0.011	0.011
5	0.3655	0.8839	10.23	0.095	0.0025	0.0015	0.012	0.015
6	0.3611	0.8830	10.21	0.105	0.0015	0.0020	0.012	0.011
7	0.3550	0.8831	10.17	0.095	0.0015	0.0020	0.012	0.011
8	0.3590	0.8831	10.18	0.100	0.0020	0.0020	0.011	0.012
9	0.3577	0.8828	10.22	0.105	0.0025	0.0020	0.013	0.013
10	0.3556	0.8831	10.17	0.110	0.0030	0.0015	0.012	0.012
11	0.3602	0.8823	10.14	0.095	0.0020	0.0025	0.010	0.012
12	0.3514	0.8833	10.23	0.105	0.0020	0.0030	0.012	0.011
13	0.3611	0.8837	10.16	0.100	0.0020	0.0020	0.013	0.011
14	0.3584	0.8827	10.24	0.105	0.0015	0.0020	0.013	0.011
15	0.3587	0.8832	10.17	0.110	0.0015	0.0020	0.013	0.013
16	0.3536	0.8837	10.12	0.110	0.0030	0.0025	0.012	0.012
17	0.3551	0.8836	10.24	0.095	0.0025	0.0020	0.013	0.011
18	0.3509	0.8830	10.02	0.110	0.0025	0.0015	0.012	0.012
19	0.3585	0.8838	10.11	0.095	0.0020	0.0015	0.015	0.011
20	0.3594	0.8829	10.16	0.100	0.0020	0.0030	0.012	0.012
21	0.3600	0.8839	10.22	0.100	0.0015	0.0015	0.014	0.012
22	0.3551	0.8833	10.17	0.095	0.0020	0.0020	0.012	0.014

NUCLEAR FUEL SERVICES, INC.
ERWIN, TENNESSEE

GEAP-13745

MATERIAL UO₂ Pellets (Depleted)

DATE December 14, 1966

CUSTOMER General Electric Company
P.O. Box 254
San Jose, California

SALES ORDER NUMBER 256-A

LOT #1 (Continued)

PURCHASE ORDER NUMBER 205-58226-NG

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INSULATOR PELLETS

Pellet Number	Length (in.)	Diameter (in.)	Density (g/cc)	Land Width (in.)	Perpendicularity (in.)		Disc Depth (in.)	
					(A)	(B)	(C)	(D)
23	0.3525	0.8829	10.23	0.105	0.0025	0.0025	0.011	0.011
24	0.3570	0.8832	10.25	0.100	0.0020	0.0025	0.013	0.014
25	0.3586	0.8834	10.23	0.095	0.0025	0.0020	0.014	0.011
26	0.3555	0.8835	10.24	0.095	0.0025	0.0020	0.013	0.010
27	0.3538	0.8835	10.09	0.100	0.0025	0.0020	0.013	0.014
28	0.3583	0.8831	10.17	0.095	0.0020	0.0020	0.012	0.013
29	0.3551	0.8827	10.15	0.095	0.0015	0.0015	0.013	0.012
30	0.3570	0.8832	10.21	0.100	0.0030	0.0025	0.011	0.013
31	0.3598	0.8836	10.27	0.105	0.0030	0.0025	0.014	0.010
32	0.3605	0.8830	10.28	0.105	0.0030	0.0025	0.012	0.011
33	0.3629	0.8832	10.16	0.095	0.0015	0.0020	0.013	0.012
34	0.3508	0.8835	10.15	0.105	0.0015	0.0020	0.013	0.012
35	0.3586	0.8833	10.12	0.105	0.0020	0.0025	0.014	0.011
36	0.3587	0.8833	9.97	0.095	0.0020	0.0030	0.014	0.014
37	0.3454	0.8834	10.26	0.095	0.0025	0.0030	0.011	0.012
38	0.3566	0.8834	10.27	0.095	0.0025	0.0030	0.014	0.012
39	0.3571	0.8828	10.26	0.100	0.0015	0.0025	0.012	0.013
40	0.3544	0.8823	10.20	0.105	0.0030	0.0015	0.012	0.014
41	0.3540	0.8832	10.09	0.110	0.0030	0.0015	0.011	0.012
2	0.3552	0.8832	10.08	0.095	0.0020	0.0020	0.014	0.012
43	0.3583	0.8832	10.19	0.095	0.0015	0.0015	0.011	0.011
44	0.3558	0.8831	10.18	0.110	0.0020	0.0015	0.014	0.012

GEAP-13745

DATE December 14, 1966

SALES ORDER NUMBER 256-A

PURCHASE ORDER NUMBER 205-58226-NG

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[illegible]

NUCLEAR FUEL SERVICES, INC.
ERWIN, TENNESSEE

GEAP-13745

MATERIAL UO₂ Pellets (Depleted)

DATE December 14, 1966

CUSTOMER General Electric Company
P.O. Box 254
San Jose, California

SALES ORDER NUMBER 256-A

LOT #2

PURCHASE ORDER NUMBER 205-58226-NG

INSULATOR PELLETS

Pellet Number	Length (in.)	Diameter (in.)	Density (g/cc)	Land Width (in.)	Perpendicularity (in.)		Diameter	
					(A)	(B)	(1)	(2)
1	0.3610	0.8830	10.20	0.100	100% Inspection		0.015	0.010
2	0.3615	0.8830	10.24	0.100	"	"	0.010	0.012
3	0.3544	0.8820	10.32	0.100	"	"	0.013	0.012
4	0.3570	0.8830	10.21	0.100	"	"	0.013	0.011
5	0.3524	0.8830	10.21	0.100	"	"	0.010	0.012
6	0.3643	0.8830	10.33	0.100	"	"	0.011	0.012
7	0.3670	0.8635	10.20	0.095	"	"	0.011	0.013
8	0.3591	0.8826	10.29	0.095	"	"	0.012	0.010
9	0.3518	0.8831	10.24	0.095	"	"	0.010	0.013
10	0.3424	0.8832	10.38	0.095	"	"	0.010	0.012
11	0.3605	0.8821	10.28	0.095	"	"	0.014	0.010
12	0.3489	0.8832	10.25	0.095	"	"	0.010	0.014
13	0.3534	0.8822	10.27	0.090	"	"	0.013	0.013
14	0.3506	0.8823	10.17	0.090	"	"	0.012	0.012
15	0.3535	0.8824	10.27	0.100	"	"	0.010	0.012
16	0.3580	0.8827	10.36	0.095	"	"	0.012	0.013
17	0.3569	0.8835	10.21	0.095	"	"	0.011	0.013
18	0.3615	0.8835	10.26	0.100	"	"	0.010	0.011
19	0.3518	0.8823	10.24	0.090	"	"	0.012	0.012
20	0.3536	0.8826	10.20	0.095	"	"	0.011	0.011
21	0.3464	0.8821	10.33	0.095	"	"	0.012	0.013
22	0.3479	0.8825	10.21	0.095	"	"	0.013	0.011

NUCLEAR FUEL SERVICES, INC.
ERWIN, TENNESSEE

GEAP-13745

MATERIAL UO₂ Pellets (Depleted)

DATE December 14, 1966

CUSTOMER General Electric Company
P.O. Box 254
San Jose, California

SALES ORDER NUMBER 256-A

LOT #2 (Continued)

PURCHASE ORDER NUMBER 205-58226-NG

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Pellet Number	Length (in.)	Diameter (in.)	Density (g/cc)	Land Width (in.)	Perpendicularity (in.)		Disc Cover (in.)	
					(A)	(B)	(A)	(B)
23	0.3541	0.8831	10.29	0.100	100% Inspected		0.012	0.012
24	0.3554	0.8828	10.22	0.095	"	"	0.010	0.012
25	0.3554	0.8831	10.33	0.100	"	"	0.013	0.010
26	0.3659	0.8823	10.34	0.095	"	"	0.012	0.012
27	0.3565	0.8830	10.35	0.100	"	"	0.013	0.011
28	0.3528	0.8827	10.34	0.105	"	"	0.013	0.010
29	0.3494	0.8832	10.36	0.100	"	"	0.012	0.012
30	0.3526	0.8835	10.34	0.100	"	"	0.014	0.010
31	0.3550	0.8835	10.20	0.100	"	"	0.012	0.012
32	0.3479	0.8834	10.33	0.100	"	"	0.012	0.012
33	0.3619	0.8822	10.26	0.095	"	"	0.011	0.011
34	0.3554	0.8835	10.34	0.100	"	"	0.010	0.012
35	0.3613	0.8821	10.27	0.100	"	"	0.013	0.013
36	0.3545	0.8830	10.24	0.095	"	"	0.012	0.012
37	0.3538	0.8820	10.21	0.100	"	"	0.012	0.013
38	0.3572	0.8835	10.22	0.095	"	"	0.013	0.013
39	0.3523	0.8835	10.36	0.090	"	"	0.012	0.011
40	0.3478	0.8827	10.33	0.100	"	"	0.013	0.013
41	0.3565	0.8823	10.27	0.100	"	"	0.013	0.012
42	0.3545	0.8825	10.31	0.095	"	"	0.013	0.011
43	0.3494	0.8826	10.21	0.090	"	"	0.013	0.013
44	0.3497	0.8823	10.24	0.095	"	"	0.012	0.013

GEAP-13745

DATE December 14, 1966

SALES ORDER NUMBER 256-A

PURCHASE ORDER NUMBER 205-58226-NG

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APPENDIX E

GAMMA SCANNING OF SEFOR FUEL RODS

APPENDIX E

GAMMA SCAN OF THE FUEL RODS

As a provision of Revision 4 to the GE purchase order, the fuel rods fabricated during the second fabrication campaign were gamma scanned to determine the uniformity of fuel loading. The procedure for accomplishing the gamma scan was part of the NFS Fabrication and Quality Control Procedure NFS-M-11 and it is given below.

A. Procedure

Paragraph 8.4 Determination of Pellet to Pellet Uniformity in SEFOR Fuel Rods by Gamma Spectrometry.

SUMMARY

The total gamma activity of the pellets in each SEFOR rod is measured by comparison with a standard rod of known plutonium content. A strip chart trace of each rod is made which will show fluctuations should any pellets be high or low in plutonium content.

EQUIPMENT

1. Gamma Scintillation Counter. A suitable instrument consists of the following components:
 - A. A lead-shielded sodium iodide (thallium activated) crystal properly shielded with lead bricks so that the crystal sees only a 3mm (.118 inch) slit. The crystal is attached to a suitable multiplier phototube;
 - B. A single channel pulse-height analyzer;
 - C. A count-rate meter;
 - D. A scaler-timer;
 - E. A strip-chart recorder.
2. A controlled speed transport mechanism so designed to push or pull a fuel rod across the detector slit at a rate such that adequate counting statistics are obtained. Rate of rod travel approximately 1.26 inches per minute.

STANDARD FUEL ROD

From one of the initial batches of finished fuel pellets, select at random nine (9) fuel pellets. Transfer three (3) pellets to the NFS laboratory for individual analyses for plutonium content (i.e. weight percent plutonium in pellet); three (3) pellets to an independent laboratory for individual analyses for plutonium content and retain the remaining three (3) pellets for reference. Using only pellets from the analyzed standard batch load one half of a fuel rod in the normal manner except near the center of the loaded half of the rod, load depleted UO₂ pellets equal in length to one plutonium containing pellet. Seal the loaded end of the rod and clearly designate this rod as the standard defective rod.

Select at random one (1) finished fuel rod which has been loaded, using only pellets from the batch selected as the standard batch. This rod shall be designated as the standard acceptable rod. Apply the average weight percent plutonium of the six (6) analyzed pellets to the weight of pellets loaded into the standard rods to establish the plutonium content of the rods. The average of the six (6) analyses will be used only if the individual analyses show no statistical biases or evidence of nonhomogeneity. If nonhomogeneity or statistical bias is indicated, either additional analyses must be performed on other pellets from the selected batch or another batch selected and analyzed.

The following fuel pellet batch analysis, standard defect rod, and standard rod have been established for use as reference points when gamma scanning the SEFOR rods.

FUEL PELLET BATCH

Sample pellets from batch 701A were analyzed for Pu content by NFS and the AEC New Brunswick Lab. The average of these analyses was $18.17\% \pm .07\%$ at three sigma with no statistical bias.

STANDARD DEFECT ROD

The lower portion of rod no. 071 was loaded with pellets from batch 701A.

A UO-2 pellet was placed exactly in the middle of the stack. Rod 071 shall be considered the standard defect rod.

STANDARD ACCEPTABLE ROD

Rod no. 016 was loaded with pellets from batch 701A in both the upper and lower sections. Rod 016 shall be considered the standard acceptable rod.

PROCEDURE

1. Equipment shall be calibrated prior to each batch of rods and prior to start up after any period of equipment shutdown by scanning the standard acceptable rod three (3) times. Equipment settings shall be adjusted so as to integrate the counts in the range of 180 KEV to 452 KEV Peaks for PU-239 & 241. Using the standard defective rod, scan rate and instrument settings shall be adjusted so that significant deflection is shown on the trace at the position along the rod where the depleted UO-2 pellets were placed.

A. Equipment Settings

The integrated count rate gate shall be set at six (6) seconds. The count rate shall be plotted on strip chart paper every six (6) seconds. A minimum of 5 six-second counts shall be made in each pellet in a fuel rod.

B. Standard Acceptable Rod Calibration

The gamma scan equipment shall be set up so that the average six second count for the entire rod shall occur between 827 and 859. The individual six second count shall occur between 738 and 943.

C. Standard Defect Rod Calibration

When the standard defect rod is scanned with the gamma scan equipment calibrated as in paragraph 1.B. above the average six second count in the center of the pellet stack where the UO-2 pellet is located shall be recorded. The minimum six second count for the defect area should be less than 300.

2. Each rod shall be scanned once using the same equipment settings and scan speed as used for the equipment calibrations scans on the standard acceptable rod. Rod scans shall be made after end plug welding.
3. The standard acceptable rod shall be scanned after each tenth rod and at the end of each batch or rods using the same equipment settings and scan times as for the production rods.
4. Background counts shall be taken and corrections made as necessary.
5. All strip chart traces shall be identified as to rod number, date and time of scan and any other information pertinent to correlation of the data to the rods and standard acceptable rod.
6. Any rods which exceed the reject limits for gamma scanning will be marked as gamma scan reject rods and held in quarantine for disposition by NFS.

A. Reject Limits

Strip charts for each fuel rod shall be examined. If the average of five consecutive six-second counts or two of five consecutive six-second counts are outside the limits of.

738 to 948 the fuel rod shall be set aside for rescanning.

The suspect fuel rod shall be rescanned twice. The results of these rescans must be within the limits of 738 to 948 as given above to be acceptable.

If either of the rescans are outside the limits given above the fuel rod shall be marked as gamma scan reject and held in quarantine for disposition by NFS.

(1) These are the + or - 3 sigma limits established by 8 separate determination of the average 6-second count over the standard acceptable rod.

(2) These are the + or - 3 sigma limits established by 8 separate determinations of the standard deviation of the individual 6-second counts over the standard acceptable rod.

B. Data used to Establish the Gamma Scan Acceptance Limits

Data from eight run with the Standard Acceptable Rod were used to establish the gamma scan acceptance limit as shown below:

<u>Run No.</u>	<u>Average 6-Second Count</u>	<u>Standard Deviation</u>
1	837	24.3
2	847	27.9
4	843	27.2
6	839	29.7
7	841	25.3
8	838	27.6
9	848	26.0
17	851	24.7

$$\bar{X} = 843$$

$$s_{\bar{X}} = 5.2$$

The average six-second count for the standard rod should always fall within the limit of $843 \pm [3 \times 5.2] = 827 - 859$.

The maximum standard deviation for a single run was found to be 29.7, run No. 6. Therefore, the individual six-second counts should fall within the range $827 - [3 \times 29.7]$ to $859 + [3 \times 29.7] = 738 - 948$.

C. Gamma Scan Charts

Typical charts produced when the fuel rods were gamma scanned are shown in Figure 1 & 2 to this Appendix. One chart shows a trace of the Standard Acceptable Rod and the other a trace of the Standard Defect Rod.

D. Fuel Rod Gamma Scan Data

The trace of each fuel rod gamma scan was analyzed by NFS Quality

Control personnel and reviewed by the GE Resident Engineer.

The high and low six-second count was recorded for each fuel rod. Also, the data from the Standard Acceptable Rod runs was tabulated to show the average six-second count and the high & low six-second count. The gamma scan data is shown in Table I of this Appendix.

Figure E-1 - Gamma Scan Chart of
Standard Acceptable Rod

E-9

Figure E-2 - Gamma Scan Chart of Standard Defect Rod

TABLE I

FUEL ROD GAMMA SCAN DATA

Run No.	Rod No.	High Six-Second Count Reading 948 Max.	Low Six Second Count Reading 738 Min.	Avg. Six-Second Count Standard Accept. Rod(No.016) 827 to 859	Remarks
1	016	910	770	837	
2	016	910	780	847	
3	-	-	-	-	Recorder failed
4	016	900	770	843	
5	-	-	-	-	Recorder failed
6	016	930	750	839	
7	016	710	750	838	
8	016	900	750	838	
9	016	910	760	848	
10	023	930	770		
11	005	920	750		
12	014	920	770		
13	071	-	-	Standard defect rod Min. Six Sec. Count 270	
14	010	910	750		
15	012	900	760		
16	016	910	760	848	
17	016	930	760	851	
18	017	900	760		
19	-	-	-	-	Void
20	026	910	760		
21	025	910	770		
22	024	920	770		
23	016	910	770	840	
24	022	910	760		
25	021	930	770		
26	016	900	740	833	
27	021	900	770		
28	016	900	760	832	
29	008	910	760		

TABLE I (Continued)

Run No.	Rod No.	High Six-Second Count Reading 948 Max.	Low Six-Second Count Reading 738 Min.	Avg. Six-Second Count Standard Accept. Rod (No.016) 827 to 859	Remarks
30	001	910	750		
31	002	900	760		
32	003	900	770		
33	004	920	760		
34	006	900	760		
35	007	920	750		
36	016	900	780	842	
37	016	910	750	844	
38	009	900	760		
39	011	910	750		
40	013	930	760		
41	015	910	750		
42	018	940	780		
43	019	900	770		
44	020	900	760		
45	028	910	760		
46	030	910	750		
47	016	-	-	-	No data taken
48	016	920	780	840	
49	016	-	-	-	No data taken
50	016	910	780	836	
51	071	-	-		Standard Defect Rod
52	031	900	750		
53	071	-	-		Standard Defect Rod
54	071	-	-		Standard Defect Rod
55	032	950	770		
56	033	900	750		
57	034	920	750		
58	035	910	770		
59	037	900	760		
60	038	900	750		
61	016	900	770	839	

TABLE I (Continued)

Run No.	Rod No.	High Six-Second Count Reading 948 Max.	Low Six-Second Count Reading 738 Min.	Avg. Six-Second Count Standard Accept. Rod. (No. 016) 827 to 859	Remarks
62	016	910	750	847	
63	042	920	750		
64	043	-	-	-	Rod 043 Rejected after Gamma Scan
65	040	930	770		
66	041	920	780		
67	045	930	760		
68	046	940	780		
69	047	900	760		
70	048	900	750		
71	050	920	790		
72	016	930	780	850	
73	016	Data Not Recorded			
74	016	930	780	851	
75	051	-	780		Several count off scale rerun
76	051	920	790		
77	051	940	750		
78	043	-	-		Rod 043 Rejected after Gamma Scan
79	043	-	-		Rod 043 Rejected after Gamma Scan
80	022	910	760		
81	021	930	770		
82	016	940	770	858	Problem with electronic read out of gamma scan equipment occurred after Run 82 and was not resolved until the start of Run No. 109.
83	016	No Data recorded			
84	016	No Data Recorded			
85	016	No data recorded			
86	Void				
87	016	900	-	829	
88	052	910	-		Rescanned Run No.
89	053	910	-		Rescanned Run No. 113
90	054	940	-		Rescanned Run No. 114

TABLE I (Continued)

Run No.	Rod No.	High Six-Second Count Reading 948 Max.	Low Six-Second Count Reading 738 Min.	Avg. Six-Second Count Standard Accept. Rod (No. 016) 827 to 859	Remarks
91	Void				
92	Void				
93	055	930	-		Rescanned Run No. 115
94	Void				
95	016	980		859	
96	056	950	-		Rescanned Run No. 176
97	057	-	-		Rod unloaded for rework of Batch 804
98	059	-	-		Rod unloaded for rework of Batch 804
99	060	910	-		
100	061	-	-		Rescanned Run No. 219
101	062	-	-		Rod unloaded for rework of Batch 804
102	043	-	-		Rod rejected after gamma scan
103	016	920	-	840	
104	016	No data recorded			
105	Void				
106	Void				
107	Void				
108	Void Equipment Electronic problem resolved.				
109	016	900	760	851	
110	016	910	755	845	
111	016	915	760	847	
112	052	920	780		
113	053	930	780		
114	054	910	770		
115	055	920	760		
116	016	915	755	847	
117	071	Standard defect rod			
118	071	Standard defect rod			
119	016	950	765	843	
120	016	900	750	845	

TABLE I (Continued)

Run No.	Rod No.	High Six-Second Count Reading 948 Max.	Low Six-Second Count Reading 738 Min.	Avg. Six-Second Count Standard Accept. Rod (No. 01.6) 827 to 859	Remarks
121	016	910	755	849	
122	077	900	765		
123	075	910	760		
124	069	910	780		
125	016	915	760	849	
126	016	No data recorded			
127	016	No data recorded			
128	016	No data recorded			
129	016	No data recorded			
130	016	No data recorded			
131	016	910	765	846	
132	016	885	755	830	
133	016	910	770	848	
134	072	920	760		
135	074	920	745		
136	070	-	-	-	Rod rejected after gamma scan
137	073	900	760		
138	076	900	745		
139	078	900	760		
140	070	-	-		Rod rejected after gamma scan
141	016	900	760	849	
142	016	915	770	847	
143	016	905	760	846	
144	016	905	755	843	
145	079	900	775		
146	016	905	745	846	
147	016	920	770	852	
148	016	910	770	850	
149	016	960	750	846	
150	931	905	745		
151	930	895	780		
152	100	895	750		

TABLE I (Continued)

Run No.	Rod No.	High Six-Second Count Reading 948 Max.	Low Six-Second Count Reading 738 Min.	Avg. Six-Second Count Standard Accept. Rod (no. 016) 827 to 859	Remarks
153	093	900	740		
154	099	920	765		
155	016	900	750	839	
156	016	900	755	839	
157	016	900	760	839	
158	016	910	770	844	
159	095	900	770		
160	097	970	785		Only one six second count above 948
161	098	900	750		
162	089	915	740		
163	080	905	775		
164	081	900	750		
165	082	920	740		
166	083	905	750		
167	016	905	740	842	
168	016	925	750	857	
169	016	905	760	854	
170	016	930	750	856	
171	084	925	770		
172	085	910	750		
173	086	880	735		Only one six-second count below 738
174	087	880	740		
175	088	930	800		
176	056	920	800		
177	933	940	755		
178	934	935	770		
179	016	895	760	847	
180	016	890	745	835	
181	016	895	765	839	
32	016	895	750	840	
183	935	890	750		
184	936	890	740		

TABLE I (Continued)

<u>Run No.</u>	<u>Rod No.</u>	<u>High Six-Second Count Reading 948 Max.</u>	<u>Low Six-Second Count Reading 738 Min.</u>	<u>Avg. Six-Second Count Standard Accept. Rod (No. 016) 827 to 859</u>	<u>Remarks</u>
185	937	905	740		
186	938	930	745		
187	939	905	750		
188	940	900	765		
189	941	900	770		
190	942	890	770		
191	016	905	770	842	
192	016	910	760	844	
193	016	915	750	842	
194	016	905	740	843	
195	943	890	740		
196	944	905	770		
197	945	910	760		
198	948	910	750		
199	946	910	775		
200	949	900	760		
201	950	900	770		
202	951	910	760		
203	953	905	780		
204	016	900	750	848	
205	016	905	760	849	
206	016	905	795	852	
207	016	915	790	851	
208	954	900	760		
209	067	920	750		
210	068	920	750		
211	096	900	750		
212	947	900	740		
213	016	895	755	849	
214	016	No data recorded			
215	016	No data recorded			
216	016	895	750	840	
217	016	900	750	840	

TABLE I (Continued)

<u>Run No.</u>	<u>Rod No.</u>	<u>High Six-Second Count Reading 948 Max.</u>	<u>Low Six-Second Count Reading 738 Min.</u>	<u>Avg. Six-Second Count Standard Accept. Rod(No.016) 827 to 859</u>	<u>Remarks</u>
218	016	900	760	842	
219	061	915	755		
220	044	920	760		
221	016	900	770	845	

APPENDIX F

NFS CERTIFICATION OF THE SEFOR FUEL RODS AND REPAIR RODS

PACKING AND SHIPPING LIST OF FUEL ROD, REPAIR RODS, AND LOOSE FUEL PELLETS

Erwin, Tennessee

CERTIFICATE OF ANALYSISMaterial UO₂-PuO₂ Fuel RodsDate February 23, 1971Customer General Electric CompanyP. O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NGSales Order No. 256-A

ELEMENT	ANALYSIS, ppm			
	Specification 22A1548, Rev. 4			
	The following fuel rods conform with the applicable specification and purchase order requirements.			
Serial Number	Fuel Weight	Pu Weight	Pu 239 + 241 Weight	
001	3368.37	608.33	555.78	
002	3359.57	606.74	554.33	
003	3357.55	606.37	554.00	
004	3357.07	606.29	553.92	
005	3362.35	607.24	554.79	
006	3355.27	605.96	553.62	
007	3358.93	606.62	554.22	
008	3351.15	605.22	552.94	
009	3366.17	607.93	555.42	
010	3366.25	607.94	555.43	
011	3354.43	605.81	553.48	
012	3363.75	607.49	555.02	
013	3353.83	605.70	553.38	
014	3353.25	605.60	553.29	
015	3355.30	605.97	553.62	
016	3365.07	607.73	555.24	
017	3341.35	603.45	551.32	
018	3360.27	606.86	554.44	
019	3353.17	605.58	553.27	
020	3344.47	604.01	551.84	
021	3342.27	603.61	551.47	
022	3332.47	601.84	549.86	
023	3342.35	603.63	551.49	
024	3339.17	603.05	550.96	
025	3339.27	603.07	550.98	
026	3344.07	603.94	551.77	
027	3347.87	604.63	552.40	
028	3335.67	602.42	550.38	

Erwin, Tennessee

CERTIFICATE OF ANALYSISMaterial UO₂-PuO₂ Fuel RodsDate February 23, 1971Customer General Electric CompanyP. O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NGSales Order No. 256-A

ELEMENT	ANALYSIS, ppm				
	Serial	Fuel	Pu	Pu 239 + 241	
	Number	Weight	Weight	Weight	
	029	3344.67	604.05	551.87	
	030	3338.67	602.96	550.88	
	031	3355.67	606.03	553.69	
	032	3342.77	603.70	551.56	
	033	3349.47	604.91	552.66	
	034	3376.27	609.75	557.08	
	035	3371.27	608.85	556.26	
	037	3373.27	609.21	556.59	
	038	3372.27	609.03	556.42	
	040	3369.97	608.62	556.05	
	041	3377.67	610.01	557.32	
	042	3380.57	610.53	557.79	
	045	3374.77	609.48	556.84	
	046	3384.97	611.33	558.52	
	047	3386.87	611.67	558.83	
	048	3382.07	610.80	558.04	
	050	3382.97	610.96	558.19	
	051	3391.57	612.52	559.61	
	052	3387.47	611.78	558.93	
	053	3383.47	611.05	558.27	
	054	3374.87	609.50	556.85	
	055	3379.37	610.31	557.60	
	056	3371.57	608.91	556.31	
	061	3376.47	609.79	557.12	
	067	3360.07	606.83	554.41	
	068	3368.17	608.29	555.75	
	069	3358.90	606.62	554.22	
	072	3360.17	606.85	554.43	
	073	3357.57	606.38	554.00	
	074	3363.47	607.44	554.97	
	075	3366.37	607.97	555.45	
	076	3364.07	607.55	555.07	
	077	3371.07	608.82	556.23	
	078	3375.07	609.54	556.89	

Certified By: Clayton Brown

QUALITY CONTROL DEPARTMENT

F-5

NUCLEAR FUEL SERVICES, INC.

Erwin, Tennessee

GEAP-13745

CERTIFICATE OF ANALYSIS

Material UO₂-PuO₂ Fuel RodsDate February 23, 1971Customer General Electric CompanyP. O. Box 254

Date Shipped _____

San Jose, California

Bill of Lading No. _____

Purchase Order No. 205-58226-NGSales Order No. 256-A

ELEMENT	ANALYSIS, ppm					
	Serial	Fuel	Pu	Pu 239 + 241		
	Number	Weight	Weight	Weight		
	079	3371.27	608.85	556.26		
	080	3361.17	607.03	554.59		
	081	3367.77	608.22	555.68		
	082	3367.97	608.26	555.72		
	083	3372.07	609.00	556.39		
	084	3370.27	608.67	556.09		
	085	3374.67	609.47	556.82		
	086	3362.57	607.28	554.82		
	087	3363.57	607.46	554.99		
	088	3377.57	609.99	557.30		
	089	3364.57	607.64	555.15		
	093	3363.57	607.46	554.99		
	095	3378.57	610.17	557.46		
	096	3366.17	607.93	555.42		
	097	3368.57	608.36	555.81		
	098	3369.67	608.56	556.00		
	099	3366.17	607.93	555.42		
	100	3365.47	607.80	555.30		
	930	3373.07	609.18	556.56		
	931	3369.97	608.62	556.05		
	933	3378.37	610.13	557.43		
	934	3373.27	609.21	556.59		
	935	3371.57	608.91	556.31		
	936	3368.37	608.33	555.78		
	937	3383.50	611.06	558.28		
	938	3368.17	608.29	555.75		
	939	3368.57	608.36	555.81		
	940	3371.84	608.95	556.35		
	941	3382.37	610.86	558.09		
	942	3370.37	608.69	556.11		
	943	3371.77	608.94	556.34		
	944	3369.97	608.62	556.05		
	945	3374.27	609.39	556.75		
	946	3359.07	606.65	554.25		

Certified By: Clayton Brown

QUALITY CONTROL DEPARTMENT

F-4

CERTIFICATE OF ANALYSIS

Date February 23, 1971

P. O. Box 254 Date Shipped _____

San Jose, California Bill of Lading No. _____

Purchase Order No. 205-58226-NG Sales Order No. 256-A

Certified By:

QUALITY CONTROL DEPARTMENT

CERTIFICATE OF ANALYSIS

Date November 23, 1970

Date Shipped.

Bill of Lading No.

Sales Order No. 256-A

Certified By:

QUALITY CONTROL DEPARTMENT

SEFOR P.O. No. 205-58226-NG
PACKING AND SHIPPING

SS Net

Fuel Rod Serial No.	Rod Gross Weight	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu-239 + Pu-241
A-13 ✓	5024.0	627	3343.70	804.49	738.29▲
473 ✓	4999.0	616	3322.30	599.21	569.18 "
497 ✓	5005.0	617	3323.90	599.50	550.10 "
499 ✓	5000.0	617	3321.70	599.11	549.74 "
509 ✓	5001.0	617	3321.80	599.12	549.76 "
518	5005.0	617	3325.20	600.05	550.32 "
525	5011.0	618	3324.20	599.87	550.15
537	5009.0	618	3322.20	599.51	549.82
549	5018.0	CD	3330.17	600.95	550.48
552	5002.0	CD	3321.37	599.00	549.02
557	5031.0	CD	3348.90	604.33	553.57
559	5030.0	CD	3353.90	605.23	554.40
563	5012.0	CD	3324.53	599.93	549.54

TOTAL RODS = 13

GROSS WEIGHTS = 65,147

TOTAL FUEL WEIGHT = 43,283.87

PU WT. = 8010.30 grams

PU FISSILE WT. = 7364.37 grams

CONTAINER NO. = 1

SEFOR P.O. No. 205-58226-NG
PACKING AND SHIPPING

Fuel Rod Serial No.	Rod Gross Weight	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu 239 + Pu-241
564	5014.0	CD	3323.40	599.37	549.36
569	4970.0	614	3289.30	593.22	543.72
592	5009.0	619	3326.77	600.33	550.58
679	5005.0	621	3329.43	601.49	551.02
710	4988.0	622	3314.40	598.82	548.53
717	5020.0	623	3353.90	605.95	555.07
597*	5020.5	619	3333.73	601.59	551.73
A14*	5021.5	627	3337.20	802.93	736.85

* Unrepaired

TOTAL RODS = 8

GROSS WEIGHT = 40,048

TOTAL FUEL WEIGHT = 26,608.13

PU WT. = 5,003.70 grams

PU FISSILE WT. = 4,586.86

CONTAINER NO. = 1

SEFOR P.O. No. 205-58226-NG
PACKING AND SHIPPING

Fuel Rod Serial No.	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu-239 + Pu-241
001	802	3368.37		
002	802	3359.57		
003	802	3357.55		
004	802	3357.07		
005	802	3362.35		
006	802	3355.27		
007	802	3358.93		
009	802	3366.17		
014	802	3353.25		
017	802	3341.35		
018	802	2041.10		
019	802	3353.17		
020	802	3344.47		
		42,318.62	18.08	7651.21
018	701	1319.17	18.20	240.09

TOTAL RODS = 13

TOTAL NET WT. 43,637.79 grams

TOTAL PU WT. = 7,891.30 grams

% Pu-239+241 = 91.40%

TOTAL Pu Fissile Wt. 7,212.65 grams

CONTAINER NO. = 2

SEFOR P.O. No. 205-58226-NG
PACKING AND SHIPPING

Fuel Rod Serial No.	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu-239 + Pu-241
021	802	3342.27		
022	802	3332.47		
023	802	3342.35		
024	802	3339.17		
026	802	3344.07		
028	802	3335.67		
029	802	3344.67		
030	802	2034.30		
		25,414.97	18.08	4,595.03
030	803	1304.37		
032	803	3342.77		
033	803	3349.47		
034	803	3376.27		
035	803	3371.27		
040	803	3369.97		
		18,114.12	18.24	3,304.02

TOTAL RODS = 13

TOTAL NET WT. = 43,529.09 grams

TOTAL PU WT. = 7,899.05 grams

% Pu-239 + 241 = 91.40%

TOTAL PU FISSILE WT. = 7,219.73 grams

CONTAINER NO. = 2

SEFOR P.O. No. 205 59226-NG
PACKING AND SHIPPING

Fuel Rod Serial No.	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu-239 + Pu-241
041	803	3377.67		
045	803	3374.77		
046	803	3384.97		
047	803	3386.87		
050	803	3382.97		
051	803	3391.57		
052	803	3387.47		
053	803	3383.47		
054	803	3374.87		
5055	803	3379.37		
		33,824.00	18.24	6,169.50

TOTAL RODS = 10

TOTAL NET WT. = 33,824.00 grams

TOTAL PU WT. = 6,169.50 grams

% Pu-239 + 241 = 91.40%

TOTAL PU FISSILE WT. = 5,638.92 grams

CONTAINER NO. = 2

SEFOR P.O. No. 205-58226-NG
PACKING AND SHIPPING

Fuel Rod Serial No.	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu-239 + Pu-241
008	802	3351.15		
010	802	3366.25		
011	802	3354.43		
012	802	3363.75		
013	802	3353.83		
015	802	3355.30		
025	802	3339.27		
027	802	3347.87		
		26,831.85	18.06	4651.20
016	701	3365.07	18.20	612.44
031	803	3355.67		
037	803	3373.27		
038	803	3372.27		
042	803	3380.57		
		13,481.78	18.24	2459.08

TOTAL RODS = 13

TOTAL NET WT. = 43,678.78 grams

TOTAL Pu Wt. = 7,922.72 grams

% Pu-239 + 241 = 91.40%

TOTAL PU FISSILE WT. = 7,241.37 grams

CONTAINER NO. = 3

SEFOR P.O. No. 205-58226-RG
PACKING AND SHIPPING

Fuel Rod Serial No.	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu-239 + Pu-241
048	803	3382.07		
069	803	3358.90		
077	803	3371.07		
078	803	3375.07		
079	803	3371.27		
080	803	3361.17		
		20,219.55	18.24	3688.05
056	804	3371.57		
072	804	3360.17		
073	804	3357.57		
074	804	3363.47		
075	804	3366.37		
076	804	3364.07		
081	804	3367.77		
		23,550.99	18.15	4274.50

TOTAL RODS = 13

TOTAL NET WT. = 43,770.54 grams

TOTAL PU WT. = 7,962.55 grams

% PU-239 + 241 = 91.40%

TOTAL PU FISSILE WT. = 7,277.77 grams

CONTAINER NO. = 3

SEIOR P.O. No. 205-58226-NG
PACKING AND SHIPPING

Fuel Rod Serial No.	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu-239 + Pu-241
082	804	3367.97		
083	804	3372.07		
084	804	3370.27		
085	804	3374.67		
086	804	3362.57		
		16,847.55	18.15	3057.83
087	805	3363.57		
088	805	3377.57		
089	805	3364.57		
093	805	3363.57		
095	805	3378.57		
		16,847.85	18.25	3,074.73

TOTAL RODS = 10

TOTAL NET WT. = 33,695.40grams

TOTAL PU WT. = 6,132.56 grams

Pu-239 + 241 = 91.40%

TOTAL PU FISSILE WT. = 5,605.16

CONTAINER NO. = 3

SEFOR P.O. No. 205-56226-NG
PACKING AND SHIPPING

Fuel Rod Serial No.	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu-239 + Pu-241
097	805	3368.57		
098	805	3369.67		
099	805	3366.17		
100	805	3365.47		
930	805	3373.07		
931	805	3369.97		
933	805	3378.37		
934	805	3373.27		
935	805	3371.57		
936	805	3368.37		
937	805	3383.50		
938	805	3368.17		
939	805	3368.57		
		43,824.74	18.25	7,998.02

TOTAL RODS = 13

TOTAL NET WT. = 43,824.74grams

TOTAL PU WT. = 7,998.02 grams

% Pu-239 + 241 = 91.40%

TOTAL PU FISSILE WT. = 7,310.19 grams

CONTAINER NO. = 4

SEFOR P.O. No. 205-58226-NG
PACKING AND SHIPPING

Fuel Rod Serial No.	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu-239 + Pu-241
940	805	3371.84		
941	805	3382.37		
942	805	3370.37		
943	805	3371.77		
944	805	3369.97		
945	805	3374.27		
		20,240.59	18.25	3693.91
946	804	3359.07		
947	804	3361.77		
948	804	3359.67		
949	804	3361.97		
950	804	3361.17		
951	804	3360.67		
953	804	3361.87		
		23,526.19	18.15	4270.00

TOTAL RODS = 13

TOTAL NET WT. = 43,766.78 grams

TOTAL PU WT. = 7,963.91 grams

% Pu-239 + 241 = 91.40%

TOTAL PU FISSILE WT. = 7,279.01 grams

CONTAINER NO. = 4

SEFOR P.O. No. 205-58226-NG
PACKING AND SHIPPING

Fuel Rod Serial No.	Pellet Stack Identification	Pellet Stack Weight	Pu	Pu-239 + Pu-241
954	804	3357.67		
044	804	3345.90		
067	804	3360.07		
		10,063.64	18.15	1826.55
061	805	3376.47		
068	805	3368.17		
096	805	3366.17		
		10,110.81	18.25	1845.22
Dummy UO2		3497.80	NONE	

TOTAL RODS = 7

TOTAL NET WT. = 20,174.45 grams

TOTAL PU WT. = 3,671.77 grams

% Pu-239 + 241 = 91.40%

TOTAL PU FISSILE WT. = 3356.00 grams

CONTAINER NO. = 4

SEFOR PuO₂-UO₂ PELLETSPACKING AND SHIPPING

G.E. P.O. NO. 205-58226-NG

Pu Composition - 18.06%

Pu 239 + 241 Composition - 16.50%

Date: February 23, 1971

Shipping Container No. 65

Stack No.	Pellet Stack Ident	Net Weight	Pu Weight	Pu 239 + 241 Weight
1	256B-110-701	501.2	90.52	82.70
2	256B-110-701	491.2	88.71	81.05
3	256-B-110-802	491.2	88.71	81.05
4	256B-110-804	483.5	87.32	79.78
5	256B-110-804	485.3	87.65	80.07
6	256B-110-804	471.2	85.10	77.75
7	256B-110-804	479.0	86.51	79.04
8	256B-110-804	489.0	88.31	80.69
9	256B-110-804	477.9	86.31	78.85
10	256B-110-804	476.5	86.06	78.62
11	256B-110-806	467.5	84.43	77.14
12	256B-110-806	468.0	84.52	77.22
13	256B-110-806	473.3	85.48	78.09
14	256B-110-806	468.5	84.61	77.30
15	256B-110-806	468.1	84.54	77.24

Total Net Weight - 7191.4Total Pu Weight - 1298.77Total Pu 239 + 241 Weight - 1186.58

APPROVED:

Howard Strub
Production Supervisor

Clayton Brown
Quality Control Supervisor

2-23-71
Date

SEFOR PuO₂-UO₂ PELLETSPACKING AND SHIPPING

G.E. P.O. NO. 205-58226-NG

Pu Composition - 18.06%

Pu 239 + 241 Composition - 16.50%

Date: February 23, 1971

Shipping Container No. 67

Stack No.	Pellet Stack Ident	Net Weight	Pu Weight	Pu 239 + 241 Weight
31	256B-110-806	482.9	87.21	79.68
32	256B-110-806	484.3	87.46	79.91
33	256B-110-806	486.4	87.84	80.26
34	256B-110-804	479.2	86.54	79.07
35	256B-110-804	490.5	88.58	80.93
36	256B-110-804	476.5	86.06	78.62
37	256B-110-804	478.1	86.34	78.89
38	256B-110-804	491.9	88.84	81.16
39	256B-110-804	491.5	88.76	81.10
40	256B-110-804	492.2	88.89	81.21
41	256B-110-804	483.8	87.37	79.83
42	256B-110-701	507.2	91.60	83.69
43	256B-110-701	475.1	85.80	78.39

Total Net Weight - 6319.6Total Pu Weight - 1141.32Total Pu 239 + 241 Weight - 1042.73

APPROVED:

Howard Strick
Production Supervisor

Walter Brown
Quality Control Supervisor

2-23-71
Date

SEFOR PuO₂-UO₂ PELLETSPACKING AND SHIPPING

G.E. P.O. NO. 205-58226-NG

Pu Composition - 18.06%

Pu 239 + 241 Composition - 16.50%

Date: February 23, 1971

Shipping Container No. 68

Stack No.	Pellet Stack Ident	Net Weight	Pu Weight	Pu 239 + 241 Weight
16	256B-110-806	463.0	83.62	76.40
17	256B-110-806	472.4	85.32	77.95
18	256B-110-806	474.0	85.60	78.21
19	256B-110-806	471.5	85.15	77.80
20	256B-110-806	464.8	83.94	76.69
21	256B-110-806	478.0	86.33	78.87
22	256B-110-806	471.7	85.19	77.83
23	256B-110-806	472.1	85.26	77.90
24	256B-110-806	476.5	86.06	78.62
25	256B-110-806	474.0	85.60	78.21
26	256B-110-806	474.0	85.60	78.21
27	256B-110-806	485.5	87.68	80.11
28	256B-110-806	476.4	86.04	78.61
29	256B-110-806	485.0	87.59	80.03
30	256B-110-806	487.8	88.10	80.49

Total Net Weight - 7126.7Total Pu Weight - 1287.08Total Pu 239 + 241 Weight - 1175.91

APPROVED:

Howard Strick
Production Supervisor

Clayton Brown
Quality Control Supervisor

2-23-71
Date

APPENDIX G

GE RECEIVING INSPECTION

Fuel Rods

Loose Fuel Pellets

SEFOR SITE FUEL ROD RECEIVING INSPECTION

GEAP-13745

Rod No.	Check ID No.	Weight Grams	"C" Dia.		Welds	Tube Dia.	Weld Dia.	Hole & Top E.P.		Bottom E.P. Clearance	Concentricity (TIR)			Room Temp. Leak Check 1x10 ⁻⁶ Max	800°F Leak Check		Remarks	X-Ray Eng. Co. Evaluation		Rod No.
			Top	End Plug				Slot	Clearance		Top E.P. .006"Max.	Bottom E.P. .006"Max.	Middle .019 Max.		1x10 ⁻⁶ Max	1x10 ⁻⁶ Max		T	B	
001	✓	5045	.731		✓	✓	✓	✓	✓	✓	.004	.003	.005	✓	✓			A	A	001
002	✓	5043	.730		✓	✓	✓	✓	✓	✓	.003	.005	.011	✓	✓			CV	P.020	002
003	✓	5039	.730		✓	✓	✓	✓	✓	✓	.002	.002	.005	✓	✓			P.016	A	003
004	✓	5035	.729		✓	✓	✓	✓	✓	✓	.004	.004	.003	7.6x10 ⁻⁶	Not done	Recheck cold leak rate 4.4x10 ⁻⁶		P.020	P.020	004
005	✓	5041	.730		✓	✓	✓	✓	✓	✓	.005	.003	.017	✓	✓			P.020	P.020	005
006	✓	5037	.730		✓	✓	✓	✓	✓	✓	.002	.003	.002	✓	✓			P.013	P.016	006
007	✓	5037	.729		✓	✓	✓	✓	✓	✓	.006	.002	.002	✓	✓			P.020	A	007
008	✓	5029	.730		✓	✓	✓	✓	✓	✓	.002	.003	.005	✓	✓			CV	P.020	008
009	✓	5045	.730		✓	✓	✓	✓	✓	✓	.003	.003	.007	✓	✓			P.015	A	009
010	✓	5046	.730		✓	✓	✓	✓	✓	✓	.002	.002	.004	✓	✓			P.020	P.019	010
011	✓	5032	.729		✓	✓	✓	✓	✓	✓	.004	.005	.003	✓	✓			P.013	A	011
012	✓	5045	.730		✓	✓	✓	✓	✓	✓	.003	.012	.010	✓	✓			P.018	P.020	012
013	✓	5035	.730		✓	✓	✓	✓	✓	✓	.001	.003	.007	✓	✓			A	IF	013
014	✓	5035	.730		✓	✓	✓	✓	✓	✓	.004	.005	.008	✓	✓			P.020	A	014
015	✓	5032	.730		✓	✓	✓	✓	✓	✓	.009	.003	.008	✓	2x10 ⁻⁸	Recheck cold leak rate .2x10 ⁻⁸		A	A	015
016	✓	5040	.729		✓	✓	✓	✓	✓	✓	.002	.003	.010	✓	✓			P.020	A	016
017	✓	5025	.729		✓	✓	✓	✓	✓	✓	.003	.004	.011	✓	✓			CV	A	017
018	✓	5045	.730		✓	✓	✓	✓	✓	✓	.002	.002	.003	✓	✓			P.020	P.025	018
019	✓	5042	.730		✓	✓	✓	✓	✓	✓	.002	.003	.004	✓	✓			P.012	P.018	019
020	✓	5029	.730		✓	✓	✓	✓	✓	✓	.003	.001	.006	✓	1x10 ⁻⁵	Recheck cold leak rate 7.8x10 ⁻⁶		A	P.022	020
021	✓	5020	.730		✓	✓	✓	✓	✓	✓	.002	.005	.006	✓	✓			A	P.017	021
022	✓	5014	.729		✓	✓	✓	✓	✓	✓	.002	.004	.004	3x10 ⁻⁶	Not done	Recheck cold leak rate .4x10 ⁻⁸		A	P.020	022
023	✓	5030	.730		✓	✓	✓	✓	✓	✓	.005	.002	.005	✓	1x10 ⁻⁵	Recheck cold leak rate 1x10 ⁻⁵		P.010	P.022	023
024	✓	5015	.729		✓	✓	✓	✓	✓	✓	.005	.002	.011	✓	✓			A	P.020	024
025	✓	5021	.730		✓	✓	✓	✓	✓	✓	.003	.004	.007	✓	1.5x10 ⁻⁷			A	P.020	025
026	✓	5027	.730		✓	✓	✓	✓	✓	✓	.002	.002	.008	2x10 ⁻⁸	Not done	Recheck cold leak rate .2x10 ⁻⁸		P.019	P.018	026
027	✓	5025	.730		✓	✓	✓	✓	✓	✓	.004	.003	.004	✓	7x10 ⁻⁸	Recheck cold leak rate 3x10 ⁻⁸		A	P.012	027
028	✓	5010	.730		✓	✓	✓	✓	✓	✓	.004	.002	.016	✓	✓			P.018	A	028
029	✓	5022	.730		✓	✓	✓	✓	✓	✓	.004	.003	.002	✓	✓			P.016	A	029
030	✓	5015	.730		✓	✓	✓	✓	✓	✓	.005	.004	.010	✓	✓			A	A	030
031	✓	5032	.729		✓	✓	✓	✓	✓	✓	.003	.003	.001	✓	✓			P.020	A	031

*T - Top end plug weld A - Acceptable CV - Concavity
 B - Bottom end plug weld P - Porosity & IP - Incomplete Fusion
 Estimated Size

SEFOR SITE FUEL ROD RECEIVING INSPECTION

Rod No.	Check ID No.	Weight Grams	"C" Dia.		Welds	Tube Dia.	Weld Dia.	Hole & Top E.P. Slot	Top E.P. Clearance	Bottom E.P. Clearance	Concentricity (TIR)			Room Temp. Leak Check		800°F Leak Check		Remarks	X-Ray Eng. Co. Evaluation		Rod No.
			Top	End Plug							Top E.P. .006"Max.	Bottom E.P. .006"Max.	Middle .019 Max.	1x10 ⁻⁸ Max	1x10 ⁻⁸ Max	T	B				
001	✓	5045	.731		✓	✓	✓	✓	✓	✓	.004	.003	.005	✓	✓	A	A		A	A	001
002	✓	5043	.730		✓	✓	✓	✓	✓	✓	.003	.005	.011	✓	✓	CV	P.020		P.020	P.020	002
003	✓	5039	.730		✓	✓	✓	✓	✓	✓	.002	.002	.005	✓	✓	P.016	A		A	A	003
004	✓	5035	.729		✓	✓	✓	✓	✓	✓	.004	.004	.003	7.6x10 ⁻⁶	Not done	Recheck cold leak rate 4.4x10 ⁻⁶		P.020	P.020	P.020	004
005	✓	5041	.730		✓	✓	✓	✓	✓	✓	.005	.003	.017	✓	✓	P.020	P.020		P.020	P.020	005
006	✓	5037	.730		✓	✓	✓	✓	✓	✓	.002	.003	.002	✓	✓	P.013	P.016		P.016	P.016	006
007	✓	5037	.729		✓	✓	✓	✓	✓	✓	.006	.002	.002	✓	✓	P.020	A		A	A	007
008	✓	5029	.730		✓	✓	✓	✓	✓	✓	.002	.003	.005	✓	✓	CV	P.020		P.020	P.020	008
009	✓	5045	.730		✓	✓	✓	✓	✓	✓	.003	.003	.007	✓	✓	P.015	A		A	A	009
010	✓	5046	.730		✓	✓	✓	✓	✓	✓	.002	.002	.004	✓	✓	P.020	P.019		P.019	P.019	010
011	✓	5032	.729		✓	✓	✓	✓	✓	✓	.004	.005	.003	✓	✓	P.013	A		A	A	011
012	✓	5045	.730		✓	✓	✓	✓	✓	✓	.003	.012	.010	✓	✓	P.018	P.020		P.020	P.020	012
013	✓	5035	.730		✓	✓	✓	✓	✓	✓	.001	.003	.007	✓	✓	A	IF		IF	IF	013
014	✓	5035	.730		✓	✓	✓	✓	✓	✓	.004	.005	.008	✓	✓	P.020	A		A	A	014
015	✓	5032	.730		✓	✓	✓	✓	✓	✓	.009	.003	.008	✓	2x10 ⁻⁸	Recheck cold leak rate .2x10 ⁻⁸		A	A	A	015
016	✓	5040	.729		✓	✓	✓	✓	✓	✓	.002	.003	.010	✓	✓	P.020	A		A	A	016
017	✓	5025	.729		✓	✓	✓	✓	✓	✓	.003	.004	.011	✓	✓	CV	A		A	A	017
018	✓	5045	.730		✓	✓	✓	✓	✓	✓	.002	.002	.003	✓	✓	P.020	P.025		P.025	P.025	018
019	✓	5042	.730		✓	✓	✓	✓	✓	✓	.002	.003	.004	✓	✓	P.012	P.018		P.018	P.018	019
020	✓	5029	.730		✓	✓	✓	✓	✓	✓	.003	.001	.006	✓	1x10 ⁻⁵	Recheck cold leak rate 7.8x10 ⁻⁶		A	P.022	P.022	020
021	✓	5020	.730		✓	✓	✓	✓	✓	✓	.002	.005	.006	✓	✓	A	P.017		P.017	P.017	021
022	✓	5014	.729		✓	✓	✓	✓	✓	✓	.002	.004	.004	3x10 ⁻⁶	Not done	Recheck cold leak rate .4x10 ⁻⁸		A	P.020	P.020	022
023	✓	5030	.730		✓	✓	✓	✓	✓	✓	.005	.002	.005	✓	1x10 ⁻⁵	Recheck cold leak rate 1x10 ⁻⁵		P.010	P.022	P.022	023
024	✓	5015	.729		✓	✓	✓	✓	✓	✓	.005	.002	.011	✓	✓	A	P.020		P.020	P.020	024
025	✓	5021	.730		✓	✓	✓	✓	✓	✓	.003	.004	.007	✓	1.5x10 ⁻⁷	A	P.020		P.020	P.020	025
026	✓	5027	.730		✓	✓	✓	✓	✓	✓	.002	.002	.008	2x10 ⁻⁸	Not done	Recheck cold leak rate .2x10 ⁻⁸		P.019	P.018	P.018	026
027	✓	5025	.730		✓	✓	✓	✓	✓	✓	.004	.003	.004	✓	7x10 ⁻⁸	Recheck cold leak rate 3x10 ⁻⁸		A	P.012	P.012	027
028	✓	5010	.730		✓	✓	✓	✓	✓	✓	.004	.002	.016	✓	✓	P.018	A		A	A	028
029	✓	5022	.730		✓	✓	✓	✓	✓	✓	.004	.003	.002	✓	✓	P.016	A		A	A	029
030	✓	5015	.730		✓	✓	✓	✓	✓	✓	.005	.004	.010	✓	✓	A	A		A	A	030
031	✓	5032	.729		✓	✓	✓	✓	✓	✓	.003	.003	.001	✓	✓	P.020	A		A	A	031

*T - Top end plug weld A - Acceptable CV - Concavity
 B - Bottom end plug weld P - Porosity & IF - Incomplete Fusion
 Estimated Size

Rod No.	Check ID No.	Weight Grams	"C" Dia.		Welds	Tube Dia.	Weld Dia.	Hole & Slot	Top E.P. Clearance	Bottom E.P. Clearance	Concentricity (TIR)			Room Temp. Leak Check 1×10^{-8} Max	800°F Leak Check 1×10^{-8} Max	Remarks	X-Ray Eng. Co. Evaluation*		Rod No.
			Top	End Plug							Top E.P. .006 Max.	Bot. E.P. .006 Max.	Middle .019 Max				T	B	
032	✓	5021	.730		✓	✓	✓	✓	✓	✓	.004	.001	.008	✓	✓		P.015	A	032
033	✓	5025	.730		✓	✓	✓	✓	✓	✓	.002	.003	.004	✓	✓		A	A	033
034	✓	5050	.730		✓	✓	✓	✓	✓	✓	.003	.002	.013	✓	✓		IF	A	034
035	✓	5050	.729		✓	✓	✓	✓	✓	✓	.004	.002	.003	✓	✓		P.030	P.019	035
037	✓	5052	.730		✓	✓	✓	✓	✓	✓	.002	.003	.010	✓	3×10^{-8}	Recheck cold leak rate $.8 \times 10^{-8}$	CV	P.018	037
038	✓	5050	.730		✓	✓	✓	✓	✓	✓	.004	.001	.003	✓	✓		A	A	038
040	✓	5050	.730		✓	✓	✓	✓	✓	✓	.004	.002	.010	✓	✓		P.016	P.015	040
041	✓	5054	.729		✓	✓	✓	✓	✓	✓	.003	.001	.006	✓	✓		P.018	A	041
042	✓	5058	.729		✓	✓	✓	✓	✓	✓	.004	.003	.007	✓	✓		A	A	042
044	✓	5025	.729		✓	✓	✓	✓	✓	✓	.006	.001	.006	✓	✓		P.015	A	044
045	✓	5057	.729		✓	✓	✓	✓	✓	✓	.001	.002	.010	✓	✓		A	P.017	045
046	✓	5067	.730		✓	✓	✓	✓	✓	✓	.001	.002	.003	✓	1.5×10^{-7}	Recheck cold leak rate 7×10^{-8}	A	P.017	046
047	✓	5067	.730		✓	✓	✓	✓	✓	✓	.003	.004	.005	✓	1×10^{-7}	Recheck cold leak rate 1.2×10^{-7}	A	IF	047
048	✓	5063	.730		✓	✓	✓	✓	✓	✓	.003	.001	.004	✓	✓		A	A	048
050	✓	5062	.729		✓	✓	✓	✓	✓	✓	.002	.002	.003	✓	✓		A	A	050
051	✓	5068	.730		✓	✓	✓	✓	✓	✓	.003	.004	.008	✓	✓		P.012	P.019	051
052	✓	5070	.730		✓	✓	✓	✓	✓	✓	.002	.003	.016	✓	✓		A	P.020	052
053	✓	5060	.730		✓	✓	✓	✓	✓	✓	.004	.003	.008	✓	1.4×10^{-7}	Recheck cold leak rate 2×10^{-8}	P.019	A	053
054	✓	5056	.730		✓	✓	✓	✓	✓	✓	.004	.002	.010	✓	4.9×10^{-7}	Recheck cold leak rate 2×10^{-8}	A	P.019	054
055	✓	5060	.729		✓	✓	✓	✓	✓	✓	.005	.002	.003	✓	9×10^{-8}	Recheck cold leak rate 3×10^{-8}	A	P.015	055
056	✓	5052	.729		✓	✓	✓	✓	✓	✓	.004	.003	.003	✓	1×10^{-5}	Recheck cold leak rate 8.3×10^{-7}	P.018	A	056
061	✓	5058	.730		✓	✓	✓	✓	✓	✓	.002	.003	.008	✓	✓		A	A	061
067	✓	5038	.729		✓	✓	✓	✓	✓	✓	.007	.002	.011	✓	✓		A	A	067
068	✓	5047	.730		✓	✓	✓	✓	✓	✓	.002	.005	.009	✓	✓		P.016	A	068
069	✓	5040	.729		✓	✓	✓	✓	✓	✓	.004	.001	.003	✓	✓		A	A	069
072	✓	5035	.730		✓	✓	✓	✓	✓	✓	.003	.001	.007	✓	✓		A	A	072
073	✓	5043	.729		✓	✓	✓	✓	✓	✓	.004	.000	.005	✓	1.5×10^{-6}	Recheck cold leak rate 6.5×10^{-7}	P.030	P.020	073
074	✓	5049	.729		✓	✓	✓	✓	✓	✓	.002	.003	.002	✓	2.5×10^{-7}	Recheck cold leak rate 1×10^{-7}	P.018	P.020	074
075	✓	5055	.730		✓	✓	✓	✓	✓	✓	.004	.004	.004	✓	✓		P.020	A	075
076	✓	5045	.730		✓	✓	✓	✓	✓	✓	.003	.003	.006	✓	✓		P.018	A	076
077	✓	5054	.730		✓	✓	✓	✓	✓	✓	.004	.004	.010	✓	6.5×10^{-6}	Recheck cold leak rate 3.2×10^{-6}	A	A	077

Rod No.	Check ID No.	Weight Grams	"C" Dia.		Welds	Tube Dia.	Weld Dia.	Hole & Slot	Top E.P. Clearance	Bottom E.P. Clearance	Concentricity (TIR)			Room Temp. Leak Check 1x10 ⁻⁸ Max	800°F Leak Check 1x10 ⁻⁸ Max	Remarks	X-Ray Eng. Co. Evaluation*		Rod No.	
			Top	End Plug							Top E.P.	Bot. E.P.	Middle				T	B		
			.730+	.000-.002							.006 Max.	.006 Max.	.019 Max							
032	✓	5021	.730		✓	✓	✓	✓	✓	✓	.004	.001	.008	✓	✓		P.015	A	032	
033	✓	5025	.730		✓	✓	✓	✓	✓	✓	.002	.003	.004	✓	✓		A	A	033	
034	✓	5050	.730		✓	✓	✓	✓	✓	✓	.003	.002	.013	✓	✓		IF	A	034	
035	✓	5050	.729		✓	✓	✓	✓	✓	✓	.004	.002	.003	✓	✓		P.030	P.019	035	
037	✓	5052	.730		✓	✓	✓	✓	✓	✓	.002	.003	.010	✓	3x10 ⁻⁸	Recheck cold leak rate .8x10 ⁻⁸	CV	P.018	037	
038	✓	5050	.730		✓	✓	✓	✓	✓	✓	.004	.001	.003	✓	✓		A	A	038	
040	✓	5050	.730		✓	✓	✓	✓	✓	✓	.004	.002	.010	✓	✓		P.016	P.015	040	
041	✓	5054	.729		✓	✓	✓	✓	✓	✓	.003	.001	.006	✓	✓		P.018	A	041	
042	✓	5058	.729		✓	✓	✓	✓	✓	✓	.004	.003	.007	✓	✓		A	A	042	
044	✓	5025	.729		✓	✓	✓	✓	✓	✓	.006	.001	.006	✓	✓		P.015	A	044	
045	✓	5057	.729		✓	✓	✓	✓	✓	✓	.001	.002	.010	✓	✓		A	P.017	045	
046	✓	5067	.730		✓	✓	✓	✓	✓	✓	.001	.002	.003	✓	1.5x10 ⁻⁷	Recheck cold leak rate 7x10 ⁻⁸	A	P.017	046	
047	✓	5067	.730		✓	✓	✓	✓	✓	✓	.003	.004	.005	✓	1x10 ⁻⁷	Recheck cold leak rate 1.2x10 ⁻⁷	A	IF	047	
048	✓	5063	.730		✓	✓	✓	✓	✓	✓	.003	.001	.004	✓	✓		A	A	048	
050	✓	5062	.729		✓	✓	✓	✓	✓	✓	.002	.002	.003	✓	✓		A	A	050	
051	✓	5068	.730		✓	✓	✓	✓	✓	✓	.003	.004	.008	✓	✓		P.012	P.019	051	
052	✓	5070	.730		✓	✓	✓	✓	✓	✓	.002	.003	.016	✓	✓		A	P.020	052	
053	✓	5060	.730		✓	✓	✓	✓	✓	✓	.004	.003	.008	✓	1.4x10 ⁻⁷	Recheck cold leak rate 2x10 ⁻⁸	P.019	A	053	
054	✓	5056	.730		✓	✓	✓	✓	✓	✓	.004	.002	.010	✓	4.9x10 ⁻⁷	Recheck cold leak rate 2.2x10 ⁻⁸	A	P.019	054	
055	✓	5060	.729		✓	✓	✓	✓	✓	✓	.005	.002	.003	✓	9x10 ⁻⁸	Recheck cold leak rate 3x10 ⁻⁸	A	P.015	055	
056	✓	5052	.729		✓	✓	✓	✓	✓	✓	.004	.003	.003	✓	1x10 ⁻⁵	Recheck cold leak rate 8.3x10 ⁻⁷	P.018	A	056	
061	✓	5058	.730		✓	✓	✓	✓	✓	✓	.002	.003	.008	✓	✓		A	A	061	
067	✓	5038	.729		✓	✓	✓	✓	✓	✓	.007	.002	.011	✓	✓		A	A	067	
068	✓	5047	.730		✓	✓	✓	✓	✓	✓	.002	.005	.009	✓	✓		P.016	A	068	
069	✓	5040	.729		✓	✓	✓	✓	✓	✓	.004	.001	.003	✓	✓		A	A	069	
072	✓	5035	.730		✓	✓	✓	✓	✓	✓	.003	.001	.007	✓	✓		A	A	072	
073	✓	5043	.729		✓	✓	✓	✓	✓	✓	.004	.000	.005	✓	1.5x10 ⁻⁶	Recheck cold leak rate 6.5x10 ⁻⁷	P.030	P.020	073	
074	✓	5049	.729		✓	✓	✓	✓	✓	✓	.002	.003	.002	✓	2.5x10 ⁻⁷	Recheck cold leak rate 1x10 ⁻⁷	P.018	P.020	074	
075	✓	5055	.730		✓	✓	✓	✓	✓	✓	.004	.004	.004	✓	✓		P.020	A	075	
076	✓	5045	.730		✓	✓	✓	✓	✓	✓	.003	.003	.006	✓	✓		P.018	A	076	
077	✓	5054	.730		✓	✓	✓	✓	✓	✓	.004	.004	.010	✓	6.5x10 ⁻⁶	Recheck cold leak rate 3.2x10 ⁻⁶	A	A	077	

od No.	Check ID No.	Weight Grams	"C" Dia.		Wells	Tube Dia.	Weld Dia.	Hole & Slot	Bottom		Concentricity(TIR)			Room Temp. 800°F		Remarks	X-Ray Eng. Co. Evaluation		Rod No
			Top	End Plug					Top E.P.	E.P.	Top E.P.	Bot. E.P.	Middle	Leak Check	Leak Check		T	B	
			.730+.000-.002						Clearance	Clearance	.006"Max.	.006"max.	.019 Max.	1x10 ⁻⁸ Max	1x10 ⁻⁸ Max				
078	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.004	.003	.013	✓	✓		P.019	P.016	078
079	✓	5052	.729	✓	✓	✓	✓	✓	✓	✓	.002	.004	.002	✓	2.6x10 ⁻⁶	Recheck cold leak rate 1.55x10 ⁻⁶	A	A	079
080	✓	5044	.729	✓	✓	✓	✓	✓	✓	✓	.005	.005	.001	✓	✓		A	A	080
081	✓	5049	.730	✓	✓	✓	✓	✓	✓	✓	.004	.007	.006	✓	✓		A	A	081
082	✓	5051	.729	✓	✓	✓	✓	✓	✓	✓	.006	.003	.007	✓	✓		A	A	082
083	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.007	.005	.009	✓	✓		P.017	A	083
084	✓	5054	.729	✓	✓	✓	✓	✓	✓	✓	.004	.007	.009	✓	✓		A	P.015	084
085	✓	5056	.730	✓	✓	✓	✓	✓	✓	✓	.002	.002	.006	✓	✓		P.020	P.015	085
086	✓	5043	.730	✓	✓	✓	✓	✓	✓	✓	.003	.002	.003	✓	✓		A	A	086
087	✓	5045	.729	✓	✓	✓	✓	✓	✓	✓	.004	.004	.003	✓	✓		P.010	P.014	087
088	✓	5056	.730	✓	✓	✓	✓	✓	✓	✓	.005	.004	.005	✓	✓		P.010 CV	P.015	088
089	✓	5050	.730	✓	✓	✓	✓	✓	✓	✓	.005	.004	.014	✓	1x10 ⁻⁷	Recheck cold leak rate .3x10 ⁻⁸	A	P.016	089
093	✓	5048	.729	✓	✓	✓	✓	✓	✓	✓	.006	.004	.008	✓	✓		A	P.021	093
095	✓	5060	.730	✓	✓	✓	✓	✓	✓	✓	.004	.004	.009	✓	✓		A	P.020	095
096	✓	5047	.729	✓	✓	✓	✓	✓	✓	✓	.004	.003	.007	✓	✓		P.025	A	096
097	✓	5054	.729	✓	✓	✓	✓	✓	✓	✓	.001	.002	.004	✓	5x10 ⁻⁸	Recheck cold leak rate .3x10 ⁻⁸	P.018	P.017	097
098	✓	5056	.729	✓	✓	✓	✓	✓	✓	✓	.005	.004	.003	✓	✓		P.020	A	098
099	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.008	.006	.003	✓	1.5x10 ⁻⁷	Recheck cold leak rate 2x10 ⁻⁸	A	P.016	099
100	✓	5046	.730	✓	✓	✓	✓	✓	✓	✓	.005	.002	.007	✓	✓		CV	P.019	100
930	✓	5056	.370	✓	✓	✓	✓	✓	✓	✓	.005	.004	.004	✓	✓		A	P.020	930
931	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.006	.001	.005	✓	✓		P.020	P.020	931
933	✓	5064	.730	✓	✓	✓	✓	✓	✓	✓	.004	.002	.004	✓	✓		CV	P.015	933
934	✓	5058	.730	✓	✓	✓	✓	✓	✓	✓	.005	.004	.006	✓	✓		A	P.019	934
935	✓	5054	.730	✓	✓	✓	✓	✓	✓	✓	.005	.003	.003	✓	✓		P.016	P.017	935
936	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.004	.001	.003	✓	✓		P.011	P.018	936
937	✓	5065	.730	✓	✓	✓	✓	✓	✓	✓	.004	.002	.004	✓	✓		P.020	A	937
938	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.002	.003	.001	✓	✓		A	A	938
939	✓	5052	.730	✓	✓	✓	✓	✓	✓	✓	.004	.002	.003	✓	✓		P.020	P.020	939
940	✓	5052	.730	✓	✓	✓	✓	✓	✓	✓	.004	.002	.003	✓	✓		CV	A	940
941	✓	5058	.730	✓	✓	✓	✓	✓	✓	✓	.004	.003	.006	✓	✓		A	A	941
942	✓	5053	.730	✓	✓	✓	✓	✓	✓	✓	.004	.005	.003	✓	✓		P.021	A	942

Ord No.	Check ID No.	Weight Grams	"C" Dia.		Welds	Tube Dia.	Weld Dia.	Hole & Slot	Top E.P. Clearance	Bottom E.P. Clearance	Concentricity (TIR)			Room Temp. 800°F		Remarks	X-Ray Eng. Co. Evaluation		Rod No
			Top	End Plug							Top E.P. .006" Max.	Bot. E.P. .006" max.	Middle .019 Max.	Leak Check 1x10 ⁻⁸ Max	Leak Check 1x10 ⁻⁸ Max		T	B	
078	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.004	.003	.013	✓	✓		P.019	P.016	078
079	✓	5052	.729	✓	✓	✓	✓	✓	✓	✓	.002	.004	.002	✓	2.6x10 ⁻⁶	Recheck cold leak rate 1.55x10 ⁻⁶	A	A	079
080	✓	5044	.729	✓	✓	✓	✓	✓	✓	✓	.005	.005	.001	✓	✓		A	A	080
081	✓	5049	.730	✓	✓	✓	✓	✓	✓	✓	.004	.007	.006	✓	✓		A	A	081
082	✓	5051	.729	✓	✓	✓	✓	✓	✓	✓	.006	.003	.007	✓	✓		A	A	082
083	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.007	.005	.009	✓	✓		P.017	A	083
084	✓	5054	.729	✓	✓	✓	✓	✓	✓	✓	.004	.007	.009	✓	✓		A	P.015	084
085	✓	5056	.730	✓	✓	✓	✓	✓	✓	✓	.002	.002	.006	✓	✓		P.020	P.015	085
086	✓	5043	.730	✓	✓	✓	✓	✓	✓	✓	.003	.002	.003	✓	✓		A	A	086
087	✓	5045	.729	✓	✓	✓	✓	✓	✓	✓	.004	.004	.003	✓	✓		P.010	P.014	087
088	✓	5056	.730	✓	✓	✓	✓	✓	✓	✓	.005	.004	.005	✓	✓		P.010 CV	P.015	088
089	✓	5050	.730	✓	✓	✓	✓	✓	✓	✓	.005	.004	.014	✓	1x10 ⁻⁷	Recheck cold leak rate .3x10 ⁻⁸	A	P.016	089
093	✓	5048	.729	✓	✓	✓	✓	✓	✓	✓	.006	.004	.008	✓	✓		A	P.021	093
095	✓	5060	.730	✓	✓	✓	✓	✓	✓	✓	.004	.004	.009	✓	✓		A	P.020	095
096	✓	5047	.729	✓	✓	✓	✓	✓	✓	✓	.004	.003	.007	✓	✓		P.025	A	096
097	✓	5054	.729	✓	✓	✓	✓	✓	✓	✓	.001	.002	.004	✓	5x10 ⁻⁸	Recheck cold leak rate .3x10 ⁻⁸	P.018	P.017	097
098	✓	5056	.729	✓	✓	✓	✓	✓	✓	✓	.005	.004	.003	✓	✓		P.020	A	098
099	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.008	.006	.003	✓	1.5x10 ⁻⁷	Recheck cold leak rate 2x10 ⁻⁸	A	P.016	099
100	✓	5046	.730	✓	✓	✓	✓	✓	✓	✓	.005	.002	.007	✓	✓		CV	P.019	100
930	✓	5056	.370	✓	✓	✓	✓	✓	✓	✓	.005	.004	.004	✓	✓		A	P.020	930
931	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.006	.001	.005	✓	✓		P.020	P.020	931
933	✓	5064	.730	✓	✓	✓	✓	✓	✓	✓	.004	.002	.004	✓	✓		CV	P.015	933
934	✓	5058	.730	✓	✓	✓	✓	✓	✓	✓	.005	.004	.006	✓	✓		A	P.019	934
935	✓	5054	.730	✓	✓	✓	✓	✓	✓	✓	.005	.003	.003	✓	✓		P.016	P.017	935
936	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.004	.001	.003	✓	✓		P.011	P.018	936
937	✓	5065	.730	✓	✓	✓	✓	✓	✓	✓	.004	.002	.004	✓	✓		P.020	A	937
938	✓	5055	.730	✓	✓	✓	✓	✓	✓	✓	.002	.003	.001	✓	✓		A	A	938
939	✓	5052	.730	✓	✓	✓	✓	✓	✓	✓	.004	.002	.003	✓	✓		P.020	P.020	939
940	✓	5052	.730	✓	✓	✓	✓	✓	✓	✓	.004	.002	.003	✓	✓		CV	A	940
941	✓	5058	.730	✓	✓	✓	✓	✓	✓	✓	.004	.003	.006	✓	✓		A	A	941
942	✓	5053	.730	✓	✓	✓	✓	✓	✓	✓	.004	.005	.003	✓	✓		P.021	A	942

GEAP-13745

No.	Check ID No.	Weight Grams	"C" Dia.		Welds Tube Dia.	Weld Dia.	Hole & Slot	Top E.P. Clearance	Bottom E.P. Clearance	Concentricity(TIR)			Room Temp. 800°F		Remarks	X-Ray Eng. Co. Evaluation		Rod No.
			Top End Plug	.730+.000-.002						Top E.P. .006"Max.	Bot.E.P. .006"Max.	Middle .019 Max.	Leak Check 1x10 ⁻⁸ Max.	Leak Check 1x10 ⁻⁸ Max.		T	B	
943	✓	5053	.730	✓	✓	✓	✓	✓	✓	.005	.005	.006	✓	✓		CV	A	943
944	✓	5053	.730	✓	✓	✓	✓	✓	✓	.001	.002	.003	✓	✓		CV	P.013	944
945	✓	5057	.730	✓	✓	✓	✓	✓	✓	.001	.004	.002	✓	✓		P.017	A	945
946	✓	5039	.729	✓	✓	✓	✓	✓	✓	.002	.003	.006	✓	✓		A	A	946
947	✓	5047	.730	✓	✓	✓	✓	✓	✓	.002	.001	.007	✓	✓		A	A	947
948	✓	5046	.730	✓	✓	✓	✓	✓	✓	.003	.003	.002	✓	✓		P.020	A	948
949	✓	5041	.730	✓	✓	✓	✓	✓	✓	.004	.005	.001	✓	✓		CV	P.016	949
950	✓	5041	.730	✓	✓	✓	✓	✓	✓	.003	.002	.012	✓	✓		A	A	950
951	✓	5041	.730	✓	✓	✓	✓	✓	✓	.003	.006	.004	✓	✓		CV	A	951
953	✓	5043	.730	✓	✓	✓	✓	✓	✓	.001	.002	.007	✓	✓		A	P.020	953
954	✓	5038	.730	✓	✓	✓	✓	✓	✓	.006	.003	.007	✓	✓		P.017	P.014	954
Dummy	✓	5031	.730	✓	✓	✓	✓	✓	✓	.004	.001	.006	✓	✓		P.013	A	Dummy

No.	Check ID No.	Weight Grams	"C" Dia.	Welds	Tube Dia.	Weld Dia.	Hole & Slot	Top E.P. Clearance	Bottom E.P. Clearance	Concentricity (TIR)			Room Temp. 800°F		Remarks	X-Ray Eng. Co. Evaluation		Rod No.
			Top End Plug							Top E.P.	Bot. E.P.	Middle	Leak Check	Leak Check		T	B	
			.730+.000-.002							.006"Max.	.006"Max.	.019 Max.	1x10 ⁻⁸ Max.	1x10 ⁻⁸ Max.				
943	✓	5053	.730	✓	✓	✓	✓	✓	✓	.005	.005	.006	✓	✓		CV	A	943
944	✓	5053	.730	✓	✓	✓	✓	✓	✓	.001	.002	.003	✓	✓		CV	P.013	944
945	✓	5057	.730	✓	✓	✓	✓	✓	✓	.001	.004	.002	✓	✓		P.017	A	945
946	✓	5039	.729	✓	✓	✓	✓	✓	✓	.002	.003	.006	✓	✓		A	A	946
947	✓	5047	.730	✓	✓	✓	✓	✓	✓	.002	.001	.007	✓	✓		A	A	947
948	✓	5046	.730	✓	✓	✓	✓	✓	✓	.003	.003	.002	✓	✓		P.020	A	948
949	✓	5041	.730	✓	✓	✓	✓	✓	✓	.004	.005	.001	✓	✓		CV	P.016	949
950	✓	5041	.730	✓	✓	✓	✓	✓	✓	.003	.002	.012	✓	✓		A	A	950
951	✓	5041	.730	✓	✓	✓	✓	✓	✓	.003	.006	.004	✓	✓		CV	A	951
953	✓	5043	.730	✓	✓	✓	✓	✓	✓	.001	.002	.007	✓	✓		A	P.020	953
954	✓	5038	.730	✓	✓	✓	✓	✓	✓	.006	.003	.007	✓	✓		P.017	P.014	954
Dummy	✓	5031	.730	✓	✓	✓	✓	✓	✓	.004	.001	.006	✓	✓		P.013	A	Dummy

		"C" Dia.						Bottom	
Check Weight		Top End Plug			Hole & Top E.P.		E.P.		
No.	ID No.	Grams	.730+.000-.002	Welds	Tube Dia.	Weld Dia.	Slot	Clearance	Clearance
REPAIR RODS									
473	✓	5002	.729	✓	✓	✓	✓	✓	✓
497	✓	5005	.729	✓	✓	✓	✓	✓	✓
499	✓	5004	.730	✓	✓	✓	✓	✓	✓
509	✓	5001	.729	✓	✓	✓	✓	✓	✓
518	✓	5005	.730	✓	✓	✓	✓	✓	✓
525	✓	5012	.730	✓	✓	✓	✓	✓	✓
537	✓	5011	.730	✓	✓	✓	✓	✓	✓
549	✓	5018	.730	✓	✓	✓	✓	✓	✓
552	✓	5001	.729	✓	✓	✓	Not Aligned	✓	✓
557	✓	5032	.730	✓	✓	✓	✓	✓	✓
559	✓	5032	.730	✓	✓	✓	✓	✓	✓
563	✓	5011	.728	✓	✓	✓	✓	✓	✓
564	✓	5016	.730	✓	✓	✓	✓	✓	✓
569	✓	4969	.730	✓	✓	✓	✓	✓	✓
592	✓	5009	.730	✓	✓	✓	✓	✓	✓
597	✓	5020	.729	✓	✓	✓	✓	✓	✓
679	✓	5006	.730	✓	✓	✓	✓	✓	✓
710	✓	4990	.730	✓	✓	✓	✓	✓	✓
717	✓	5021	.730	✓	✓	✓	✓	✓	✓
A13	✓	5025	.722	✓	✓	✓	✓	✓	✓
A14	✓	5021	.725	✓	✓	✓	Pinched Slot	✓	✓

Concentricity (TIR)			Room Temp. 800°F		Remarks	X-Ray		Rod No.
Top E.P.	Bot. E.P.	Middle	Leak Check	Leak Check		Eng. Co.	Evaluation	
.006" Max.	.006" Max.	.019 Max.	1x10 ⁻⁸ Max.	1x10 ⁻⁸ Max.		T	B	
.005	.008	.003	✓	✓	Upper pellet stack displaced	CV	P.015	473
.005	.006	.003	✓	✓	Upper pellet stack displaced	A	P.015	497
.006	.003	.002	✓	3x10 ⁻⁷	Recheck cold leak rate 1x10 ⁻⁷	A	A	499
.002	.005	.003	✓	✓		A	P.016	509
.004	.004	.004	✓	7.1x10 ⁻⁶	Recheck cold leak rate 9.5x10 ⁻⁷	P.016	A	518
.005	.007	.006	✓	✓	Upper pellet stack displaced	CV	P.016	525
.003	.006	.001	2x10 ⁻⁶	Not done	Recheck cold leak rate 1.05x10 ⁻⁶	A	A	537
.007	.002	.003	✓	✓		A	A	549
.001	.001	.006	✓	7.5x10 ⁻⁷	Hole & Slot Misaligned	A	P.012	552
.002	.002	.003	✓	6.8x10 ⁻⁷	Recheck cold leak rate 5x10 ⁻⁷	CV	P.015	557
.004	.002	.003	✓	✓		A	A	559
.006	.003	.005	✓	2x10 ⁻⁸	Recheck cold leak rate .8x10 ⁻⁸	A	P.015	563
.004	.004	.015	✓	✓		A	A	564
.005	.002	.006	5x10 ⁻⁷	Not done	Recheck cold leak rate 3.2x10 ⁻⁷	CV	P.018	569
.010	.005	.013	✓	8.4x10 ⁻⁶	Recheck cold leak rate 5x10 ⁻⁶	A	A	592
.038	.021	.200	-	-	Not repaired	-	-	597
.004	.003	.001	✓	✓		A	P.019	679
.005	.003	.004	2.2x10 ⁻⁷	Not done	Recheck cold leak rate 2x10 ⁻⁷	A	P.020	710
.001	.001	.005	✓	✓		P.015	P.018	717
.005	.002	.004	3.6x10 ⁻⁶	Not done	Recheck cold leak rate 3.5x10 ⁻⁶	A	IF	A13
.080	.036	7.200	-	-	Not Repaired	-	-	A14

No.	Check ID No.	Weight Grams	"C" Dia.		Welds	Tube Dia.	Weld Dia.	Hole & Slot	Top E.P. Clearance	Bottom E.P. Clearance	Concentricity (TIR)			Room Temp. 800°F		Remarks	X-Ray Eng. Co. Evaluation		Rod No.
			Top End Plug								Top E.P.	Bot. E.P.	Middle	Leak Check	Leak Check		T	B	
			.730+.000-.002								.006"Max.	.006"Max.	.019 Max.	1x10 ⁻⁸ Max.	1x10 ⁻⁸ Max.				
REPAIR RODS																			
473	✓	5002	.729	✓	✓	✓	✓	✓	✓	✓	.005	.008	.003	✓	✓	Upper pellet stack displaced	CV	P.015	473
497	✓	5005	.729	✓	✓	✓	✓	✓	✓	✓	.005	.006	.003	✓	✓	Upper pellet stack displaced	A	P.015	497
499	✓	5004	.730	✓	✓	✓	✓	✓	✓	✓	.006	.003	.002	✓	3x10 ⁻⁷	Recheck cold leak rate 1x10 ⁻⁷	A	A	499
509	✓	5001	.729	✓	✓	✓	✓	✓	✓	✓	.002	.005	.003	✓	✓		A	P.016	509
518	✓	5005	.730	✓	✓	✓	✓	✓	✓	✓	.004	.004	.004	✓	7.1x10 ⁻⁶	Recheck cold leak rate 9.5x10 ⁻⁷	P.016	A	518
525	✓	5012	.730	✓	✓	✓	✓	✓	✓	✓	.005	.007	.006	✓	✓	Upper pellet stack displaced	CV	P.016	525
537	✓	5011	.730	✓	✓	✓	✓	✓	✓	✓	.003	.006	.001	2x10 ⁻⁶	Not done	Recheck cold leak rate 1.05x10 ⁻⁶	A	A	537
549	✓	5018	.730	✓	✓	✓	✓	✓	✓	✓	.007	.002	.003	✓	✓		A	A	549
552	✓	5001	.729	✓	✓	✓	Not Aligned	✓	✓	✓	.001	.001	.006	✓	7.5x10 ⁻⁷	Hole & Slot Misaligned	A	P.012	552
557	✓	5032	.730	✓	✓	✓	✓	✓	✓	✓	.002	.002	.003	✓	6.8x10 ⁻⁷	Recheck cold leak rate 5x10 ⁻⁷	CV	P.015	557
559	✓	5032	.730	✓	✓	✓	✓	✓	✓	✓	.004	.002	.003	✓	✓		A	A	559
563	✓	5011	.728	✓	✓	✓	✓	✓	✓	✓	.006	.003	.005	✓	2x10 ⁻⁸	Recheck cold leak rate .8x10 ⁻⁸	A	P.015	563
564	✓	5016	.730	✓	✓	✓	✓	✓	✓	✓	.004	.004	.015	✓	✓		A	A	564
569	✓	4969	.730	✓	✓	✓	✓	✓	✓	✓	.005	.002	.006	5x10 ⁻⁷	Not done	Recheck cold leak rate 3.2x10 ⁻⁷	CV	P.018	569
592	✓	5009	.730	✓	✓	✓	✓	✓	✓	✓	.010	.005	.013	✓	8.4x10 ⁻⁶	Recheck cold leak rate 5x10 ⁻⁶	A	A	592
597	✓	5020	.729	✓	✓	✓	✓	✓	✓	✓	.038	.021	.200	-	-	Not repaired	-	-	597
679	✓	5006	.730	✓	✓	✓	✓	✓	✓	✓	.004	.003	.001	✓	✓		A	P.019	679
710	✓	4990	.730	✓	✓	✓	✓	✓	✓	✓	.005	.003	.004	2.2x10 ⁻⁷	Not done	Recheck cold leak rate 2x10 ⁻⁷	A	P.020	710
717	✓	5021	.730	✓	✓	✓	✓	✓	✓	✓	.001	.001	.005	✓	✓		P.015	P.018	717
A13	✓	5025	.722	✓	✓	✓	✓	✓	✓	✓	.005	.002	.004	3.6x10 ⁻⁶	Not done	Recheck cold leak rate 3.5x10 ⁻⁶	A	IF	A13
A14	✓	5021	.725	✓	✓	✓	Pinched Slot	✓	✓	✓	.080	.036	7.200	-	-	Not Repaired	-	-	A14

RECEIVING INSPECTION SEFOR LOOSE PELLETS
 AT PLUTONIUM LAB GE VALLECITOS NUCLEAR CENTER

<u>Stack</u>	<u>Batch</u>	<u>Weight grams</u>	<u>Stack</u>	<u>Batch</u>	<u>Weight grams</u>
1	701A	501.7	23	806	472.5
2	701A	491.7	24	806	476.8
3	802	491.4	25	806	474.3
4	804	484.9	26	806	482.6
5	804	486.3	27	806	486.2
6	804	472.4	28	806	477.0
7	804	480.0	29	806	485.2
8	804	489.5	30	806	488.3
9	804	478.2	31	806	483.3
10	804	476.8	32	806	484.8
11	806	467.9	33	806	486.9
12	806	468.1	34	804	479.9
13	806	473.6	35	804	490.9
14	806	469.0	36	804	477.1
15	806	468.7	37	804	478.5
16	806	463.5	38	804	492.2
17	806	472.7	39	804	491.9
18	806	474.7	40	804	492.3
19	806	472.1	41	804	484.3
20	806	464.9	42	701A	507.8
21	806	478.5	43	701A	475.4
22	806	472.0			

Visual inspection of all pellet stacks was made. No discrepancies were noted.

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