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MASTER

FABRICATION OF NON-FUEL CORE COMPONENTS FOR SEFOR

D.T. IKEUYE
F.E. YOUNG

U. S. ATOMIC ENERGY COMMISSION
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GEAP-13595
AEC Research
and Development
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D. T. Ikeuye
F. E. Young

Approved:

G. R. Pflasterer
G. R. Pflasterer, Development Project Engineer
SEFOR Research and Development

Approved:

M. F. Lyons
M. F. Lyons, Manager
Fuel Development — Water Reactors

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1. INTRODUCTION

This report documents the fabrication data and processes for the production of the core components (excluding fuel) of the Southwest Experimental Fast Oxide Reactor (SEFOR) made in General Electric's Fuels Laboratory, Uranium Fuel Development.

The Southwest Experimental Fast Oxide Reactor (SEFOR) is a 20 MWt fast spectrum reactor fueled with mixed $\text{PuO}_2\text{-UO}_2$ and cooled with sodium. SEFOR will have characteristics similar to large, soft spectrum, fast breeder reactors fueled with mixed $\text{PuO}_2\text{-UO}_2$. Economic studies of these large power reactors indicate significant potential for producing low cost power. SEFOR will be used to obtain physics and engineering data at fuel compositions, temperatures, and crystalline states characteristic of power reactor operating conditions. SEFOR 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 are being 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&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.

2. SUMMARY

The Uranium Fuel Development Subsection of the Nuclear Fuels Department was responsible for the materials procurement and fabrication of the extension rods, tightener rods, tightener sleeves and special rods for the SEFOR reactor. These core components were fabricated under the SEFOR R&D program funded by the AEC. The extension rods provide the neutron and gamma shielding above the core. The functions of the tightener rods are to lock the surrounding "fuel rod-extension rod" assembly in position

in the fuel channel, to provide additional shielding above the core, and to increase the Doppler effect. The tightener sleeve is the basic internal structural member of the fuel assembly and serves to provide spacing between the fuel rods.

This report describes the major tooling, techniques of fabrication, fabrication processes, and quality control efforts used in the fabrication of the non-fuel core components.

3. REFERENCE DRAWINGS

The following is a list of the drawing numbers and the quantities of each component fabricated.

Component	Quantity	Drawing No.			
Extension Rod	660	112C2072-G1	Tightener Sleeve	119	706E958
	18	112C2072-G2	Upper Tightener Sleeve	9	886D587
	36	112C2072-G3	Lower Tightener Sleeve	9	719E669
	29	112C2072-G4	Surveillance Specimen		
			Holder	10	135C4892
Tightener Rod	113	846D777	Foil Holder Rod	7	135C4801

4. DESCRIPTION

4.1 PLANT DESCRIPTION

SEFOR is an experimental fast reactor utilizing a mixed oxide ($\text{PuO}_2\text{-UO}_2$) fuel with liquid sodium as the coolant. The core is composed of a series of fuel assemblies arranged in a hexagonal pattern as shown in Figure 4-1. A fuel assembly consists of one tightener sleeve, one tightener rod, six fuel rods, and six extension rods assembled into a hexagonal channel. A drawing of the assembly is shown in Figure 4-2.

4.2 COMPONENT DESCRIPTION

4.2.1 Extension Rods

The extension rods consist of Type 316 stainless steel tubes filled with boron-carbide (B_4C) powder. These rods provide a blanket of B_4C over the core of the reactor and serve as the neutron and gamma shield. A drawing and photo of the component are shown in Figures 4-3 and 4-4, respectively.

4.2.2 Tightener Rod

The tightener rod basically consist of beryllium oxide (BeO) pellets in the lower section of the rod, which extends the length of the fuel column, and solid Type 304 stainless steel in the upper section of the rod. The tightener rod is inserted into the tightener sleeve which locks the surrounding "fuel rod-extension rod" unit in position. The BeO serves to increase the Doppler effect by softening the

neutron flux spectrum. The stainless steel in the upper portion of the rod functions as part of the neutron-gamma shield above the core. A drawing and photo of the tightener rod are shown in Figures 4-5 and 4-6, respectively.

4.2.3 Tightener Sleeve

The tightener sleeve is the basic structural member of the fuel assembly. It functions as a rod-to-rod spacer and it includes the springs by which the rods are locked into position. A drawing and photo of the tightener sleeve are shown in Figures 4-7 and 4-8, respectively.

4.2.4 Upper and Lower Tightener Sleeves

The upper and lower tightener sleeves are used in the instrumented fuel assembly and are basically similar to the regular tightener sleeve. These components are shown by Figures 4-9 through 4-11.

4.2.5 Surveillance Specimen Holder

These rods contain the tensile specimens taken from the pressure vessel material for the surveillance program. The drawings and photo are shown in Figures 4-12 and 4-13.

4.2.6 Foil Holder Rods

These rods contain foils for physics measurements and are designed for easy disassembly. A drawing and photo are shown in Figures 4-14 and 4-15, respectively.

Figure 4-1. Cross Section of SEFOR Core

Figure 4-2. Core Element Arrangement

Figure 4-4. Extension Rod

REV.	BY	DATE	QUANTITY	PART NO.	NAME	DRAWING NO., DESCRIPTION, MATERIAL, WEIGHT
3				1	PIPE END PLUG	117C1376 P1
3				2	BORON CARBIDE	P50YP3
3				3	TUBE	112C3856 P1
3				4	SPACER	150A2789 P1
				5	BERYLLIUM OXIDE ROD	155A2789 P1 SEE NOTE-6
				6	BERYLLIUM OXIDE ROD	155A2789 P2 SEE NOTE-6
				7	TUBE	135B9710 P1
				8	REFLECTOR	175A9931 P1
				9	SPRING	175A9931 P1
				10	BOTTOM END RING	154A2789 P1
				11	REFLECTOR	159A2789 P1
3				12	SHOT	1/2 DIA., 420 SST FOOTER BALL PLATE 2180 AP10, 1000
3				13	FILLER	STAINLESS STEEL WOOL-FINE M2-1
3				14	UPPER ROD	185C4992 P1
3				15	SLEEVE	211A5931 P1
3				16	DWG. LIST	194X791

FCF-191 X 653

NOTES:

1. FABRICATION AND QUALITY CONTROL PRACTICES SHALL CONFORM WITH SPEC. 22A165B.
2. WELD SPACER (P4) USING ELECTRON BEAM WELD.
3. FILL ASSEMBLY AS SHOWN WITH APPROX. 50 PERCENT BORON CARBIDE (P2) AND 50 PERCENT SST SHOT (P12). MIN. ACCEPTABLE WEIGHT OF BORON CARBIDE (P2) AND SST SHOT (P12) IS 3.9 LBS.
4. ASSEMBLY TO BE STRAIGHT WITHIN .005/FT.
5. OUTSIDE DIA. OF WELD SHALL BE .880 MAX.
6. DRY BERYLLIUM OXIDE RODS (P5&P6) AT 300°C FOR 3 HOURS PRIOR TO INSERTING THEM INTO TUBE (P7) AT ASSEMBLY.

Figure 4-5. Drawing of Tightener Rod

Figure 4-6. Tightener Rod

Figure 4-7. Drawing of Tightener Sleeve

Figure 4-8. Tightener Sleeve

REV	BY	CHK	DATE	GT	PART NO.	NAME	DRAWING NO.	DESCRIPTION	MATERIAL	WEIGHT
1					1	UPPER SPRING HOLDER	112C3433PI			
2					2	SPRING, EXTERNAL	135B9239PI			
2					3	SPRING, INTERNAL	117C1383PI			

FCF 886D515

(G1) SEE NOTES 1, 2, 3 & 4

NOTES:

- ③ 1. SUGGESTED ASSEMBLY PROCEDURE:
 - A. INSTALL P2 & P3 AT 100.188 ELEV. PER SECT. A-A.
 - B. GAGE PER NOTE-3.
 - C. INSTALL P2 & P3 AT 76.562 ELEV. PER SECT. A-A.
 - D. GAGE PER NOTE-3.
- ③ 2. CLEAN ALL PARTS PER G.E. SPEC. P4CYP3 PRIOR TO ASSEMBLING. HANDLE PARTS WITH WHITE COTTON GLOVES DURING ASSEMBLY. FINAL CLEANING SHALL BE BY WIPING ALL SURFACES WITH ACETONE, OR IMMERSING TIGHTENING SLEEVE IN ACETONE.
- ④③②⑦ 3. INSERT A .8900 ± .0005 DIA. X 6 1/4 ± 1/8 LG. GAGE INTO TIGHTENING SLEEVE AND 1/2 INCH MIN. DISTANCE INTO I.D. OF INTERNAL SPRING (P3). TYP BOTH ENDS OF SPRING. FINISHED UPPER TIGHTENING SLEEVE I.D. MUST MOVE AXIALLY WHEN ASSEMBLED OVER TIGHTENER ROD 112C3435 (886D515 ASM-REF) WITH AN APPLIED FORCE OF LESS THAN 35 LBS.
- ⑦ 4. ASSEMBLY TO BE STRAIGHT WITHIN .020 / FT.

Figure 4-9. Drawing of Upper Tightener Sleeve

Figure 4-10. Drawing of Lower Tightener Sleeve

Figure 4-11. Upper and Lower Tightener Sleeves

Figure 4-12. Drawing of Surveillance Specimen Holder

Figure 4-13. Surveillance Specimen Holder

NOTES

- 1 LEAK CHECK WELD WITH HELIUM MASS SPECTROMETER LEAK DETECTOR MAX PERMISSIBLE LEAK RATE IS 1×10^{-8} CC/SEC
- 2 CONTENTS OF P4 TO BE PROVIDED BY EXPERIMENTOR

Figure 4-14. Drawing of Foil Holder Rod

Figure 4-15. Foil Holder Rod

5. EXTENSION ROD

5.1 TOOLING

5.1.1 Welding Fixtures

Special weld fixtures were required to make the initial welds in both the extension rods and tightener rods because of the long length of the mating pieces. A fixture was designed and fabricated to help maintain alignment and allow the parts to rotate together during welding. The fixture utilizes two heavy duty indexing heads, synchronously driven by a 1/3-h.p. motor. The fixture has a hydraulic speed reducer to allow variable speed adjustment. Special soft jaws were adapted to the indexing heads. A photo of the setup is shown in Figure 5-1. Figure 5-2 shows the welding chamber used for the final end weld.

5.2 FABRICATION DEVELOPMENT

5.2.1 Welding

Welds for the extension and tightener rods were made by TIG fusion on a Miller ESR 150 welding machine. Typical weld parameters established using automatic sequence welding are given in Figures 5-3 and 5-4. The weld designs on all weld joints are identical; however, the weld parameters differ for out-of-box and in-chamber welding conditions. Each operator was qualified by welding five consecutive welds which were acceptable by metallographic examination. Minimum leak path requirement was 93% of wall thickness. To overcome gas blowout through the molten weld metal, it was necessary to drill a vent hole in the final end plugs and plug weld them after the circumferential weld was completed. Typical welds are shown by the photomicrographs in Figures 5-5 and 5-6.

5.2.2 Tube Forming

The tubes for the extension rods were expanded by the magnaforming process at Advanced Kinetics, Inc., Costa Mesa, California. Further technical development of this technique is necessary and furthermore, the process is not at present capable of high production rates. Therefore, this is not recommended for future application without adequate process hardware development. The expansion for the extension rod tubes is from 0.875 inch o.d. to 0.970 inch o.d. or 10.9% circumferential deformation. Tensile tests performed on tensile specimens obtained from the expanded section are given below.

The die for tube expansion in the magnaforming operation was slightly oversize; consequently, the expanded

Sample No.	Yield Strength ksi	Ultimate Strength ksi	% Elongation
1	94.4	107.0	26.3
2	94.3	105.5	23.2
3	90.0	104.5	27.4
4	97.0	105.0	25.3
Average	94.1	105.5	25.5

section resulted in an average o.d. of 0.983 inch. This problem was solved by swaging the sections to 0.970 inch o.d. Crater-like defects were discovered on the i.d. surface of the expanded areas of some of the tubes. This defect was caused by the arcing from the electrode to the tube surface during the expansion process. A photomicrograph take of a cratered area is shown in Figure 5-7. Structural change due to the arcing is very superficial and, therefore, was judged acceptable.

5.2.3 B₄C Loading

Special precautions were taken to prevent fatigue cracking in the welds during the vibratory compaction of B₄C powder. The adapter to the vibrator was designed to clamp onto the tube above the bottom end plug weld, thus minimizing stresses on the weld. Metallographic examination of welds severely vibrated in excess of normal process time showed no evidence of damage to the welds.

5.3 ASSEMBLY

The tubes were formed and cut to length at Advanced Kinetics, Inc. These tubes were cleaned by brushing and immersion into a Kelite 236 caustic bath and passivated with 18-25% by volume nitric acid. The first weld was made on the bottom end plug. Because of the full penetration requirement of the weld, the inside of the tubes were purged with helium to provide a cover gas on the backside of the weld. The boron carbide (B₄C) powder was then prepared for loading by drying at 100°C for 1 hour. Samples were obtained periodically to assure that the moisture content did not exceed 500 ppm. Groups 1 and 2 rods were vibratory compacted with B₄C powder to a minimum of 70% of theoretical density. Groups 3 and 4 rods were loaded with a charge composed of 50% by volume B₄C and 50% by volume 1/8 inch diameter Type 430 stainless steel balls. The final weld (top end plug) was made in the weld chamber after the chamber was pumped down to 80

Figure 5-1. First-End Weld Fixture

Figure 5-2. Weld Chamber for Final Weld

Rod Type . . . Extension Rod and Tightener Rod
 End Plug First End Plug (Out-of-Box)
 Weld Machine . . . Miller ESR 160 (Unit No. 1)
 Material 316 SS Tube- 304 SS End Plug
 Tube Size 0.875 in. o.d. × 0.040 in. Wall
 Torch Angle 60° from Horizontal
 Electrode Diameter 0.040 in.
 Weld Current 22–25 amps
 Up-Slope Time 1/2 sec
 Weld Time 19 sec
 Down-Slope Time 2 sec
 Collet Aluminum
 Part Rotation Speed 17.5 sec/rev
 Cover Gas Flow (Outside)* 45 cfh Helium
 Cover Gas Flow (Inside)* 5 cfh Helium

*Note: Provide helium purge cover gas inside and outside of tube.

Figure 5-3. Weld Parameters

Rod Type . . . Extension Rod and Tightener Rod
 End Plug Final End Plug (In-Chamber)
 Weld Machine . . . Miller ESR 150 (Unit No. 2)
 Material 316 SS Tube- 304 SS End Plug
 Tube Size 0.875 in. o.d. × 0.040 in. Wall
 Torch Angle 60° from Horizontal
 Electrode Diameter 1/16 in.
 Weld Current 21–22 amps
 Up-Slope Time 1/2 sec
 Weld Time 19 sec
 Down-Slope Time 2 sec
 Collet Aluminum
 Part Rotation Speed 17 sec/rev
 Cover Gas Helium Atmosphere

Note:

1. Vent pin weld for extension rod — Use hot start to 118 amps and tail off to 0 amps in 2 sec
2. Vent pin weld for tightener rod — Use hot start to 100 amps and tail off to 0 amps in 2 sec.

Figure 5-4. Weld Parameters

Figure 5-5. Typical End Plug Weld Section

Figure 5-6. Typical Vent Plug Weld for Extension Rod

Figure 5-7. Arched Area of Tube I.D. Surface

microns and backfilled with reactor grade helium to one atmosphere. First the top end plug circumferential weld was made followed by the vent pin weld. The rods were

then 100% leak checked and the welds x-rayed.

A description of further nondestructive testing at the SEFOR site is found in Appendix IV.

6. TIGHTENER ROD

6.1 TOOLING

6.1.1 Welding Fixture

The same tooling as that developed for welding the extension rods was used for the tightener rods.

6.1.2 BeO Loading Box

Because of the toxicity of BeO, a glove box was constructed for loading BeO into the tightener rods. The box has a negative pressure to prevent any BeO particulate release to the work area atmosphere. The box has a 1 inch port to allow insertion of one end of the tightener rod for loading. The BeO box is shown in Figure 6-1.

6.2 FABRICATION DEVELOPMENT

6.2.1 Welding

The weld design for the tightener rod is identical to that of the extension rod so that the same weld parameters were used. However, the body of the end plugs differs and the vent hole was placed in a different location. A typical vent plug weld for the tightener rod is shown in Figure 6-2.

6.2.2 Tube Forming

The tubes for the tightener rods originally were to be magnaformed, but due to vendor fabrication problems it appeared that the tubes could not be fabricated within a reasonable time. Therefore, the upper section of the tightener rod was redesigned to use solid stainless steel bar machined to the tube contour instead of the formed tube filled with B₄C powder. In addition, an alternate process was developed to fabricate the lower section tube. The method utilized a modified pipe cutter mounted to the lathe bed and the tube was spin-reduced. This method is feasible and tubes of adequate quality were formed.

6.2.3 BeO Pellets

There was concern about excessive moisture in the as-fabricated BeO pellets. Results of moisture analyses on the BeO pellets are given below:

BeO Moisture Content, ppm*

Lot No.	Before Drying	After Drying	Subsequent 24-hr Exposure to Air
D-2 Run 01	30	7	18
D-3 Run 02	45	4	7
D-3 Run 03	25	—	—

*Analyzed with CEC Moisture Analyzer

Based on these analyses, it was decided to dry the pellets. All the pellets were dried by Anamet Laboratories, Berkeley, California, at 300°C for 3 hours before loading into the tightener rods.

The final design of the tightener rods has a solid Type 304 stainless steel bar in the upper section of the rod and a straight Type 316 stainless steel tube filled with BeO pellets and nickel reflectors. The long BeO pellet was relocated to the bottom of the BeO column with a Type 316 stainless steel tube sleeve around the long pellet.

6.3 ASSEMBLY

The tubes and upper rods were cleaned with Kelite 236 and passivated with 18-25% nitric acid. The first weld was made at the middle junction of the rod (rod-to-tube weld). The first weld procedure was similar to the first weld on the extension rods utilizing a helium purge gas on the inside of the tube. Beryllium oxide pellets which had been dried at 300°C for 3 hours were then loaded into the tube in a glove box exposure. The final weld was made in the weld chamber in the identical sequence as the final weld for the extension rods. The rods were 100% leak checked and X-rayed.

Figure 6-1. BeO Handling Glove Box

Figure 6-2. Typical Tightener Rod Vent Plug Weld

7. TIGHTENER SLEEVE

7.1 TOOLING

7.1.1 Dimpling Tools

Figure 7-1 shows the various tools which were designed for making the dimples in the hexagonal tubes.

7.1.2 Spring Welding Tools

The three basic tools required to make the welds on the tightener sleeve springs are shown in Figures 7-2 and 7-3. The expander tool is operated by pulling on the De Staco clamp which draws the tapered mandrel into the tool housing which, in turn, forces out the copper buttons against the internal springs. The expander tool serves a dual function. The copper buttons hold the internal spring snugly against the inside surface of the hexagonal tube and acts as a chill and bearing surface at the weld location.

7.1.3 Tightener Sleeve Assembly Stations

Figure 7-4 shows the dimpling station. Figure 7-5 shows a typical spring welding operation. The fin welding station shown in Figure 7-6 was optically aligned so that when the hexagonal tube is placed in the cradle and the fins clamped into position, the fins are in axial alignment.

7.2 FABRICATION DEVELOPMENT

7.2.1 Hexagonal Tubes

One of the basic sources of the problems in the fabrication of the tightener sleeves was the direct result of the nonuniform (unequal sides) hexagonal tubes. A few of the spring holder tubes had inside diameters (flat-to-flat) that varied between 0.952 to 0.968 inch in any given cross section. The remainder of the tubes were within specification (0.955 to 0.965 inch across inside flats) but the flat-to-flat dimensions varied from the high side to the low side of the tolerance over a given cross section. This severely restricted the fit-up of the internal springs and contributed to the somewhat higher pull force than anticipated to remove the tightener rod from the tightener sleeve. Further development effort would be recommended to form hexagonal tubes of more uniform dimensions if a similar design were to be employed in the future.

7.2.2 Springs

As a result of the nonuniform dimensions of the flats on the hexagonal tubes the internal springs as originally designed would not fit in the tightener sleeve tube. The misfit accumulates along the sides of the hexagon. The sides

of the springs were shortened and the corners were made with a sharper radius, thereby allowing the proper seating of the springs on the inside surface of the hexagonal tube. Other minor modifications were made to the internal springs to allow the protruding weld locating button to clear the hexagonal tube diameter. No major problem was encountered on the external springs. It appears that a greater degree of misfit can be tolerated on the external spring dimensions. The internal and external springs are shown in Figure 7-7.

The precipitation hardening heat treatment of a sample batch of springs in air resulted in a black, lustrous oxide film which resisted removal by HF-HNO₃ cleaning treatment. Consequently, the springs were cleaned by the Kolene DGS process at California-Doran Heat Treating Co., Los Angeles, California. Kolene DGS is an anhydrous molten oxidizing salt bath using a sodium hydroxide base. From this experience it is recommended that Inconel 718 spring material be heat treated in a dry hydrogen atmosphere or in vacuum to eliminate the oxide problem.

7.2.3 Fins

The design required annealed precision sheet metal parts. Because the dimensional tolerances of these complex formed parts were difficult to maintain during annealing without extensive precision fixturing, a final reforming step was required after annealing.

7.2.4 Design Modifications

Design changes were necessary to make the tightener sleeve functional. The design was based on the assumption that the tightener rod, when inserted into the tightener sleeve, would snake around opposing dimples in the upper section above the core. However, the tightener sleeve was too stiff; consequently, the tightener rod could not be inserted in the first prototype assembly. It was subsequently determined that the tightener springs themselves were adequate to maintain the tightener rod in a center position in the upper section of the sleeve. As a result, four (4) sets of dimples in the upper section were eliminated from the original design.

The original design of the tightener sleeve also included a bottom spring to temporarily hold the tightener rod in an intermediate (or unlocked) position to relax the tightening springs during fuel rod removal and insertion. However, pull tests performed on mock-up assemblies indicated that the bottom spring added significantly to the pull force necessary to lift the tightener rod into the unlocked

Figure 7-1. Tightener Sleeve Tooling: Dimpling Tools

Figure 7-2. Tightener Sleeve Tooling: Spring Welding Tools

Figure 7-3. Tightener Sleeve Tooling: Spring Weld Tool Detail

Figure 7-4. Tightener Sleeve Dimpling Station

Figure 7-5. Tightener Sleeve Spring Weld Station

Figure 7-6. Tightener Sleeve Fin Assembly Station

INTERNAL SPRING

EXTERNAL SPRING

Figure 7-7. Tightener Sleeve Springs

position. Additional tests were also made which showed there was sufficient friction force from the tightener spring contacts to hold the tightener rod in any desired partially withdrawn position. Based on these tests, the bottom spring was determined to be unnecessary and was eliminated from the final design.

7.3 ASSEMBLY AND FINAL TESTING

The detailed fabrication procedure is given in Appendix II.

A mock-up assembly was fabricated and assembled using dummy components. Tests using the mock-up showed that the tightener rod could not be easily inserted or withdrawn because of the tight tolerance through the internal spring region. It was found that adequate clearance could be obtained by running a 0.894 inch diameter mandrel

through the spring area of each tightener sleeve to seat the internal springs against the hexagonal tubes.

After the fabrication of the tightener sleeves was completed, each assembly was given a mock-up test and a pull test was performed to insure that each tightener rod could be withdrawn with a pull force of less than 75 pounds.

Welds in the tightener sleeve fabrication were all made by manual control. Photographs of typical weld sections are shown in Figures 7-8 and 7-9.

A test was performed to thermally shock stress the spring assembly in excess of conditions expected during the life of the tightener sleeves. The thermal shock test is described in Appendix V.

The cut-aways in the hexagonal tubes were stamped out by Reliance Tool and Die, Inc., San Jose, California. Deburring was a major problem due to the inaccessibility of the burr and the gummy nature of 304 stainless steel.

TYPICAL SPRING FINGER-TIP WELD

Figure 7-8. Tightener Sleeve Spring Weld: Typical Upper Weld (External Spring-to-Internal Spring Weld) and Typical Spring Finger-Tip Weld

Figure 7-9. Tightener Sleeve Spring Weld: Typical Lower Weld (Internal Spring-to-Hexagonal Tube Weld)

8. INSTRUMENTED TIGHTENER SLEEVE (UPPER AND LOWER)

The hexagonal tubes for these assemblies were machined by GE-Vallecitos Nuclear Center machine shop. The instrumented tightener sleeves were assembled in the

identical manner as the regular tightener sleeves described above. A subsequent report will describe the instrumented fuel assembly fabrication.

9. FOIL HOLDER ROD AND SURVEILLANCE RODS

These rods were machined and assembled in a routine hardware fabrication procedure similar to those described in Sections 5 and 6.

10. QUALITY CONTROL

10.1 PROCESS GUIDES

The general instructions for fabrication procedures were outlined in the "Development Guide for the Fabrication of Extension and Tightener Rods" and "Procedures for Assembly of Tightener Sleeves" and are presented in Appendix I and II, respectively.

10.2 QUALITY CONTROL PLAN

The Project Quality Control Plan (Appendix III) was followed to maintain product quality. In-process quality control was maintained by a constant audit of the fabrication processes and travel cards. Final inspection was

performed on 100% of the rods and tightener sleeves produced.

10.3 PROCESS CONTROL

Process control of the extension and tightener rods was maintained by a travel card which accompanied the rods through the entire processing sequence.

Control of the fabrication process for the tightener sleeves was maintained by a work station log. After each series of operation, the operator initialed the checklist to certify that the operation was performed.

ACKNOWLEDGEMENT

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A special thanks goes to each and every member of the Fuels Laboratory for their extraordinary response to the difficult and urgent demands for the production of the SEFOR core components.

APPENDIX I

Development Guide for Fabrication of SEFOR R&D Extension and Tightener Rods

FUEL DEVELOPMENT MEMORANDUM NO. 56

DEVELOPMENT GUIDE FOR FABRICATION OF
SEFOR R&D EXTENSION AND TIGHTENER RODS

Prepared by: D. T. Ikeuye
D. T. Ikeuye, Project Engineer

Approved by: I. B. Klepfer
I. B. Klepfer, Mgr., Fuels & Materials Development

Reviewed by: W. H. [Signature]
San Jose Nuclear Safety Council

December 14, 1967

DEVELOPMENT GUIDE FOR FABRICATION OF SEFOR R&D EXTENSION AND TIGHTENER RODS1.0 General

This development guide describes the procedures for the fabrication of the SEFOR R&D Extension and Tightener Rods in the Fuels Laboratory.

2.0 Special Requirements

- 2.1 All persons assigned to this project shall read guides for his work assignment prior to performing his particular task. Any deviations from the guides shall be brought to the attention of the process engineer immediately.
- 2.2 All persons assigned to this project shall read and be thoroughly familiar with the safety instructions described herein prior to performing his particular task.
- 2.3 Beryllium oxide (BeO) pellets will be used in the tightener rods. BeO is a highly toxic material; therefore, all personnel handling BeO must be thoroughly familiar with the safety instructions described herein.
- 2.4 Boron carbide (B_4C) is a nuclear poison. It is absolutely essential that no B_4C powder be allowed to contaminate UO_2 fuel. Therefore, all personnel must handle B_4C powder in a manner that absolutely prevents cross-contamination possibilities.

3.0 General Description of the Rods

- 3.1 Extension Rods are Type 316 stainless steel formed tubes filled with B_4C powder or B_4C powder-stainless steel ball mixture. These rods are to be assembled onto the upper end of the core fuel rods.
- 3.2 Tightener rods are Type 316 stainless steel formed tubes consisting of two adjoining parts, upper and lower sections. The lower sections, loaded with BeO pellets and nickel reflectors, comprise the center rod of the fuel rod cluster. The upper section will contain a B_4C powder-stainless steel ball mixture and become part of the extension rod region.

The tightener rods, located in the center position of a six-rod cluster of fuel, holds the fuel rods in position.

4.0 Drawings

The principal drawings are:

<u>Drawing No.</u>	<u>Title</u>
112C2072	Extension Rod
846F777	Tightening Rod

5.0 Flow Charts

General flow charts for the fabrication process are shown in Figures 1 and 2.

6.0 Process Check List Procedure

6.1 Each batch of in-process tubes shall be accompanied by a travel card.

The travel card is a flow diagram giving specific parts to be used at their respective step in the process.

6.2 The process operator shall enter fabrication data onto the travel card, where required, and place his initial adjacent to the appropriate step upon completion of his task.

7.0 Quality Control Procedure

7.1 OC-Purchased Materials shall provide inspection of incoming materials.

7.2 OC-Fuels shall perform in-process audit and final inspection of the rods.

7.3 Parts and rods which do not meet specifications shall be rejected by the blue tag procedure.

7.4 Disposition of the rejected parts will be determined by the I. R. procedure.

8.0 In-process Tube Identification

A series of numbers have been assigned to each group of tubes. These numbers shall be electroetched near the ends of each tube.

FIGURE I-1

Extension Rods

112C2072

FIGURE I-2
Tightener Rods

846D777

GEAP-13595

9.0 Cleaning

9.1 Special Instructions

- a. Thoroughly clean all tanks before charging.
- b. Check purity of deionized water with the solubridge.
- c. Turn on agitator pump in Tank #1.

9.2 Safety Instructions

- a. Operator must wear a face mask, plastic apron, and gloves when handling cleaning solutions.
- b. In preparing cleaning solutions, the Oakite 90 or nitric acid must be poured into the water, not vice versa.

9.3 Preparation of Cleaning Tank

<u>Tank No.</u>	<u>Fill with</u>	<u>Heated</u>	<u>Temp.</u>	<u>Purity of Water Required</u>
1	10% by vol. Oakite 90 Balance - - Tap water	Yes	150°F	- -
2	Soft water	No	- -	- -
3	Deionized Water	Yes	125°F	<5.0 ppm NaCl equiv
4	18 - 25% by vol. HNO ₃ 42° Be Balance - - Tap water			

9.4 Procedure

- a. Place parts in hot Oakite 90 solution (Tank 1) for a total residence time of 10 minutes.
- b. Rinse in soft water (Tank 2).
- c. Place parts into nitric acid tank (Tank 4) for 10 minutes.
- d. Rinse in soft water (Tank 2).
- e. Drain rinse water thoroughly; then soak in hot deionized water (Tank 3) for 10 minutes.
- f. Air-dry tubes in an upright position for at least 15 minutes.
- g. Put cleaned parts into plastic bags.

9.5 Process Control

- a. A cotton swab dampened with acetone shall be passed through two

tubes per batch. If the swab is discolored, the entire batch of tubes must be recleaned.

- b. . Visually check for moisture in the tubes.
- c. Process engineer shall make periodic inspection of the tubes.

10.0 Weld Qualification

- 10.1 Weld parameters shall give a minimum weld penetration of 100% of tube wall thickness.
- 10.2 Weld samples shall be examined for minimum and maximum weld current fluctuations.
- 10.3 After the final weld parameters are established, five (5) consecutive welds shall be made and examined metallographically. All welds must have a minimum of 100% penetration.
- 10.4 Retain strip chart recordings of qualifying welds for use as a reference standard.

11.0 First End Plug Welds (Out-of-box welds)

11.1 Special Instructions

- a. At the beginning of each shift, check the inert gas tanks.
- b. Trace all welds on recorder.

11.2 Procedure

- a. Check weld settings.
- b. Check timing of tube revolution.
- c. Weld on automatic sequence.
- d. Make weld samples at the beginning of each shift and after every twenty (20) welds thereafter.
- e. Check each weld for completeness, appearance, and bead contour.
- f. Check weld trace and identify by tube numbers. Deviations from the reference trace shall be brought to the attention of the process engineer.

11.3 Process Control

- a. Weld samples shall be examined metallographically by the process engineer.
- b. The process engineer shall make periodic examinations of weld appearance.

12.0 B₄C Loading12.1 Special Instructions

- a. The tubes shall be loaded as follows:

Extension Rods (Dwg 112C2072)

G1 and G2 Min. 70% T.P. B₄C

G3 and G4 50% by vol. B₄C
50% by vol. Stainless steel shot

Tightener Rods (Dwg 846D777)

G1 50% by vol. B₄C
50% by vol. Stainless steel shot

- b. The B₄C powder must be used in the following weight fraction:

35%	14 - 20 mesh
45%	60 - 80 mesh
10%	200 - 325 mesh
10%	-200 mesh

- c. After drying the B₄C powder, exposure to the atmosphere shall be kept to a minimum.

12.2 Safety Instructions

- a. Before loading B₄C powder, all fuel and fuel containers in the South Lab must be covered with paper or polyethylene sheets.
- b. The B₄C powder loading area shall be segregated from the fuels area.
- c. The B₄C powder must be contained at all times to prevent particles becoming airborne or spilled on the floor and tracked into the controlled fuel area.
- d. Good housekeeping must be maintained to prevent potential spread of B₄C particles.
- e. Rubber gloves and rubber shoes used in the B₄C area must be segregated and cleaned separately from those used in the fuel area.

12.3 Preparation of B₄C Powder

- a. Weigh and blend the B₄C powder to the weight fraction specified above.

- b. Dry the powder at 100°C for 1 hour.
- c. Weigh amounts required per tube directly from the oven and put in polyethylene bottles. Tape the cap with plastic tape to seal the bottle.

12.4 Procedure

- a. For the Extension Rods (G1 and G2), fill the tubes with the pre-weighed B_4C powder and vipak to 73% of theoretical density.
- b. For the Extension Rods (G3 and G4) and Tightener Rods, the B_4C powder shall be blended with the stainless steel shot and vipaked into the tubes.

12.5 Process Control

- a. Random samples of the B_4C and B_4C -stainless steel shot charges will be check-weighed by the process engineer.
- b. Column height of filled tubes will be randomly checked by the process engineer.
- c. Rods will be randomly x-rayed to check for segregation of stainless steel balls and position of internal components of the tightener rods.

13.0 Beryllium Oxide (BeO) Loading

13.1 Special Instructions

- a. All personnel who will be handling BeO shall read APED - Industrial Hygiene Standard 4.A.2-1 prior to performing his task.
- b. All operations involving BeO must be performed in a glove box.
- c. No BeO bearing rod shall be removed from the glove box without end plugs or plastic caps on the ends of the tubes.
- d. Smears taken on areas exposed to BeO shall not exceed 5 micrograms/square foot.

13.2 Safety Instructions

- a. BeO must never be stored adjacent to any nuclear material. BeO is a moderator with capability for substantially diminishing the minimum critical mass compared to the unmoderated condition.
- b. BeO is a very toxic material when ingested and therefore should be handled with the same care as with radioactive materials.
- c. BeO must not be handled with the bare hands.
- d. Anyone receiving the slightest wound which could possibly be contaminated with BeO will report for medical treatment immediately.

13.3 Procedure

- a. Weigh one long BeO pellet (Dwg 159A2789-P2) and record weight on travel card.
- b. Insert the long BeO pellet and nickel reflector (Dwg 175A9312-P1) into the bottom end of Tightener Rod tube (Dwg 135B8710-P1).
- c. Weld the bottom end plug.
- d. Mock-up 25 short BeO pellets (Dwg 159A2789-P1) on loading channel. Obtain BeO weight and record on travel card.
- e. Load the short BeO pellets into Tightener Rod tube.
- f. Weigh one long BeO pellet (Dwg 159A2789-P2) and record weight

on travel card.

- g. Insert the long BeO pellet and nickel reflector (Dwg 159A2792-P1) into the Tightener Rod tube.
- h. Place plastic cap on open end of tube until ready for final weld closure.

13.4 Process control

- a. Process engineer shall audit BeO pellet weights.
- b. Process engineer shall check the initial mock-up of short pellets.
- c. Process engineer shall check the loading sequence.

14.0 Closure Welds (In-box welds)

14.1 Special Instructions

- a. At the beginning of each shift, check the inert gas tanks.
- b. Trace all welds on recorder and identify strip chart by tube numbers.

14.2 Procedure

- a. Evacuate weld chamber to a minimum of 500 micron and backfill with helium to one atmosphere.
- b. Check weld setting.
- c. Check timing of tube revolution.
- d. Weld on automatic sequence.
- e. Make weld samples at the beginning of each shift and in each weld chamber load.
- f. Check each weld for completeness, appearance, and bead contour.
- g. Check weld trace. Deviations shall be reviewed by the process engineer.

14.3 Process Control

- a. Weld samples shall be examined metallographically by the process engineer.
- b. The process engineer shall make periodic examination of weld appearance.

15.0 Helium Leak Check

15.1 Helium leak rate shall not exceed 1×10^{-8} std. cc/sec with a vacuum of less than 5 microns.

15.2 A second leak check shall be made on 10 percent of the rods two weeks after the first check.

16.0 Final Inspection

Final inspection shall be performed by OC - Fuels.

17.0 Final Cleaning

17.1 Fuel rods shall be cleaned with acetone after helium leak check.

17.2 White lint-free gloves shall be worn to handle cleaned rods.

17.3 After cleaning, fuel rods shall be packaged in polyethylene tubes.

Addendum to Development Guide

1. Para. 5.0 - Fig. 2 was revised as in attached travel card.
2. Para. 9.2b - Delete Oakite 90 and insert Kelite 236.
3. Para. 9.3 -

<u>Tank No.</u>	<u>Fill With</u>	<u>Heated</u>	<u>Temp.</u>
1	8 - 10 oz/gal Kelite 236	Yes	170° - 200°F

4. Para. 9.4
 - a. Substitute Kelite 236 for Oakite 90.
 - c. 10 minutes should read "30" minutes.
5. Para. 10.1 - Should read, "minimum weld penetration of 93% of tube wall thickness."
6. Para. 10.3 - Should read, "93% penetration."

Tightener Rod
(846D777)

*See backside for BeO Weights.

APPENDIX II

Procedures for Assembly of Tightener Sleeves

APPENDIX II

PROCEDURES FOR ASSEMBLY OF TIGHTENER SLEEVES

General Instructions:

1. Wear cotton gloves to handle parts.
2. Hole at bottom of hex tube is reference orientation index. Side with hole is side #1. Sides are numbered clockwise, looking at bottom end view.
3. Line up reference marker of each tool with hole on side #1 of hex tube.
4. Operations in numerical series are for forming dimples. Operations in alphabetical series are for welding springs.
5. Each operator must perform pertinent tests as required in the procedure below. If the test results are satisfactory, he must mark his initial in the appropriate place on the checklist.

Assembly Procedure:

1. Push pusher through to check for dents in hex tube.
2. Stamp tube number in numerical sequence.
3. Mark tube side orientation number. Side 1 is side with reference hole punched at bottom end. Sides are to be numbered clockwise, looking at bottom end view.
4. Operation A
 - a. Insert long internal spring into position using spring pusher. (Station #2)
 - b. Slide long external spring onto hex tube but do not position in place yet. (Station #2)
 - c. Position and expand expander tool at dimples at base of spring. (Station #2)
 - d. Now slide external spring into position.
 - e. Clamp down base edge of external spring with external spring holder. (Station #3)
 - f. Weld spring finger tips. (Station #3)
 - g. Weld external spring to internal spring at the base of the springs. (Station #3)
 - h. Re-position expander at lower end of spring. (Station #3)

- i. Weld lower end of spring. (Station #3)
 - j. Remove external spring holder and expander tool. (Station #3)
 - k. Check for excessive weld bead buildup, incomplete fusion, shrinkage cracks and general quality of welds. (Station #3)
 - l. Check for free motion of spring fingers. (Station #3)
 - m. Check to insure spring-to-spring contact at converging point of spring fingers. (Station #3)
 - n. Insert .875" tube gage to check for tube clearance. (Station #2)
 - o. Drive .894" driver through the spring from the bottom end of the tube.
 - p. Check spring clearance with .890" gage.
5. Operation B (Long Spring)
- Same as for Operation A.
6. Operation C (Long Spring)
- Same as for Operation A.
7. Fin #1 (Plain Fin) - (Station #4)
- a. Place hex tube in holding fixture with side 2 up.
 - b. Weld on sides 2 - 4 - 6.
 - c. Insert and position aluminum chill block.
 - d. Clamp fins into position using length gage marked, "42-5/32".
 - e. Make fusion weld.
 - f. Rotate 2 faces.
 - g. Repeat steps c, d, and e.
 - h. Rotate 2 more faces.
 - i. Repeat steps c, d, and e.
8. Operation #1 (Station #1)
- a. Slide on external punch guide.
 - b. Align holes and dimple OUT on sides 2 - 4 - 6.
 - c. Remove tools.
 - d. Check dimple heights with "GO - NO GO" gage.

9. Operation #2 (Station #1)
 - a. Place hex tube with reference hole on top side.
 - b. Slide on external punch guide with length gage arm on side 1.
 - c. Insert Tool H - H. Match side 1 of tool to side 1 of hex tube.
 - d. Dimple IN on sides 6 - 1 - 2.
 - e. Removal tools.
 - f. Check dimples with internal dimple "GO - NO GO" gage.
10. Fin #2 (Lipped Fin) - (Station #4)
 - a. Place hex tube in holding fixture with side 1 up.
 - b. Weld on sides 1 - 3 - 5.
 - c. Same as for Fin #1 except use length gage marked "33-21/32".
11. Operation #3 (Station #1)
 - a. Slide on external punch guide.
 - b. Align holes and dimple OUT on sides 1 - 3 - 5.
 - c. Remove tools.
 - d. Check dimple heights with "GO - NO GO" gage.
12. Operation D (Long Spring)

Same as for Operation A.
13. Fin #3 (Plain Fin) - (Station #4)
 - a. Same as for Fin #1 except use length gage marked "17-17/32".
 - b. Weld on sides 2 - 4 - 6.
14. Operation #4 (Station #1)
 - a. Slide on external punch guide.
 - b. Align holes and dimple OUT on sides 2 - 4 - 6.
 - c. Remove tools.
 - d. Check dimple heights with "GO - NO GO" gage.
15. Operation #5 (Station #1)
 - a. Place hex tube with reference hole on top side.
 - b. Slide on external punch guide with length gage arm on side 1.
 - c. Insert Tool G - G. Match side 1 of tool to side 1 of hex tube.
 - d. Dimple IN on sides 3 - 4 - 5.
 - e. Remove tools.
 - f. Check dimples with internal dimple "GO - NO GO" gage.

16. Operation #6 (Station #1)
 - a. Slide on external punch guide.
 - b. Align holes and dimple OUT on sides 1 - 3 - 5.
 - c. Remove tools.
 - d. Check dimple heights with "GO - NO GO" gage.
17. Fin #4 (Long Fin)
 - a. Place hex tube in holding fixture with side 1 up.
 - b. Weld on side 1 - 3 - 5.
 - c. Insert and position aluminum chill block for welding the fins at the taper position first.
 - d. Clamp fins into position.
 - e. Make fusion welds.
 - f. Reposition chill block and weld progressively to the top end of the tube.
 - g. Rotate 2 faces.
 - h. Repeat steps c, d, and e.
 - i. Rotate 2 more faces.
 - j. Repeat steps c, d, and e.
18. Deleted
19. Spot Weld Fins
 - a. Clamp the fin tabs together with a vise grip to cinch down the fins snugly against the hex tube.
 - b. Spot weld the tabs.

Sequence: Spot weld the 2 tabs on the same edge first; then rotate tube to the next position.
20. Make casting-to-hex tube weld.

Make sure one of the casting legs is aligned with the reference hole in the tube.
21. Visually inspect assembly for fabrication defects.
22. Test tightener sleeve by assembling a mock-up.
23. Wipe assembly with acetone for final cleaning and shipping.

APPENDIX III

SEFOR R&D (Tightener and Tightener Rods) Project Quality Control Plan

ATOMIC POWER EQUIPMENT DEPARTMENT

PROJECT QUALITY CONTROL PLAN

TITLE: SEFOR R & D (TIGHTENER & EXTENSION RODS)

Part	Drawing	Prepared by	<u>ACB</u>	Date	<u>9/14/67</u>
Name	General	Approved by	<u>[Signature]</u>	Date	<u>9-14-67</u>
	No. <u>-</u>	Reviewed by	<u>[Signature]</u>	Date	<u>9-26-67</u>

1.0 PURPOSE

This Quality Plan sets forth the practices, kinds and frequencies of tests and inspections necessary to demonstrate that the product design has been fulfilled on all items produced.

This plan does not circumvent any inspection or requirement as defined by Specification 22A1658, applicable code, purchase orders or drawings.

2.0 SCOPE

Prior to production, the vendor for formed tubing (Drawing Nos. 112C3406 and 135B8710) shall submit for approval by General Electric NID-NL the complete process outline, quality control plan and design of special inspection and test devices. No material having operations performed prior to this approval shall be used in the final product.

3.0 SOURCE INSPECTION AND AUDIT

General Electric APED shall have the right to inspect the work and activities of a vendor for tube material and tube forming at such reasonable times and in such manner as is necessary. A vendor shall notify General Electric at least 48 hours in advance of any qualification testing so that a General Electric representative may witness the tests.

3.1 Shipping

When a product is ready for shipment a vendor shall give the same advance notice and prior to shipment shall submit to General Electric APED the following:

- (a) Evidence that all applicable practices, tests and inspections required in the final product and in all components and materials has been performed satisfactorily with acceptable results.

SUPPORT & D (TIGHTENER & EXTENSION RODS)

General

- (b) Certification to the above and to all specifications and drawing requirements.

No release of a shipment shall be made unless the shipment is accompanied by the requisite certifications.

- 3.2 If non-conformance of a material or process is established, a vendor shall quarantine all material not clearly identifiable as acceptable and shall submit for General Electric NID-NL approval:

- (a) The nature and extent of deviating material.
- (b) Planned disposition of deviating material.
- (c) Changes in process or methods to reduce or eliminate non-conformance to specifications or drawing requirements.

4.0 RESPONSIBILITIES

4.1 NTD-NL

It is the responsibility of NTD-NL to:

- (a) Perform disposition of discrepant material.
- (b) Maintain copies of vendor certifications, test results and all in-process inspections, audits and final inspection documents.

4.2 Quality Control - Purchased Materials

It is the responsibility of Quality Control-Purchased Materials to:

- (a) Perform source inspections and audits as applicable and to furnish to NTD-NL copies of vendor inspections.
- (b) Perform inspection and tests on in-coming material as required and to furnish to NTD-NL copies of certificates and test results accompanying each shipment.

4.3 Quality Control - Fuels

It is the responsibility of Quality Control Fuels to:

SELFOR R & D (TIGHTENER & EXTENSION RODS)

General

- (a) Witness and audit work performed at General Electric San Jose and to ensure that proper in-process documentation is maintained.
- (b) Perform final inspection services for those product characteristics verifiable at the product stage.

ATOMIC POWER EQUIPMENT DEPARTMENT

PROJECT QUALITY CONTROL PLAN

TITLE: SEFOR R & D (TIGHTENER & EXTENSION RODS)

Part

Name Bottom End Plug

Drawing

No. 159A2799Prepared by MCJ Date 9/14/67
Approved by TLJ Date 9-14-67
Reviewed by DTI Date 9-26-671.0 SPECIFICATIONS

The following specifications shall apply to this part:

- (a) GE Specification B50YP17 A2 or B2
- (b) Specification ESDYP3
- (c) ASTM-A276

2.0 CERTIFICATIONS2.1 Chemical Composition

Vendor shall certify that impurities and alloying elements conform to the requirements of ASTM-A276. Chemical composition shall be determined for each heat.

<u>ELEMENT</u>	<u>PER CENT</u>
Carbon	0.08 (max)
Phosphorus	0.045 (max)
Sulfur	0.030 (max)
Silicon	1.00 (max)
Chromium	18.00 - 20.00
Nickel	8.00 - 12.00

2.2 Mechanical Properties

Vendor shall certify that mechanical properties conform to the requirements of ASTM-A276. Certification shall be submitted for ultimate tensile, yield strength (offset), reduction in area, % elongation and hardness for each heat. Acceptable limits for these properties are listed in General Electric Specification B50YP17 A2 or B2.

2.3 Physical Integrity

Vendor shall certify that physical integrity of the material has been tested per General Electric Test Method ESDYP3 "Ultrasonic Inspection" for 100% of product.

SEFOR R & D (TIGHTENER & EXTENSION RODS)

Bottom End Plug - Tightener Rod

- 2.3.1 Vendor shall submit Ultrasonic test plan for approval by General Electric NTD-NL prior to production.

3.0 PREPRODUCTION

Vendor shall submit three (3) samples for approval by NTD-NL of dimensional characteristics prior to full production. Quality Control-Purchased Materials shall perform the pre-production inspections as directed by NTD-NL.

4.0 RECEIVING INSPECTION OF PRODUCTION LOTS

Quality Control-Purchased Materials shall perform the following inspections to verify that dimensional characteristics conform to drawing requirements and that vendor inspection results are as stated.

4.1 Weld Prep Zone

Weld prep zone end shall be visually inspected for 100% of end plugs. Ends are to be sharp, clean and free of damage (nicks, scratches, pits, etc.).

I.D. of weld prep zone ($0.795^{+0.000}_{-0.002}$) and wall thickness and angle of cut to wall shall be inspected on 20% of a lot. The lot is acceptable if one (1) or less rejects are found. If two or more rejects are found, 100% inspection for these characteristics shall be performed.

4.2 Other Dimensional Inspection

All other dimensional inspections for drawing requirements shall be performed on ten (10) end plugs selected at random. If one (1) or more causes for rejection are found, an additional ten (10) end plugs shall be selected at random and inspected. If one (1) or more causes for rejection are found in the second group, 100% inspection shall be performed on the remainder of the lot. (If less than 300 end plugs are shipped at one time, scale sample sizes proportionately).

4.3 Discrepant Material

Non-conforming material shall be segregated and disposition determined by NTD-NL.

ATOMIC POWER EQUIPMENT DEPARTMENT

PROJECT QUALITY CONTROL PLAN

TITLE: SEFOR R & D (TIGHTENER & EXTENSION RODS)

Part	Drawing	Prepared by <u>ECU</u>	Date <u>8/14/67</u>
Name <u>Bottom End Plug</u>	No. <u>117C1378</u>	Approved by <u>TLD</u>	Date <u>8-14-67</u>
		Reviewed by <u>DTI</u>	Date <u>9-26-67</u>

1.0 SPECIFICATIONS

The following specifications shall apply to this part:

- (a) GE Specification B50YP17 A2 or B2
- (b) Specification E5DYP3
- (c) ASTM-A276

2.0 CERTIFICATIONS

2.1 Chemical Composition

Vendor shall certify that impurities and alloying elements conform to the requirements of ASTM-A276. Chemical composition shall be determined for each heat.

<u>ELEMENT</u>	<u>PER CENT</u>
Carbon	0.08 (max)
Phosphorus	0.045 (max)
Sulfur	0.030 (max)
Silicon	1.00 (max)
Chromium	18.00 - 20.00
Nickel	8.00 - 12.00

2.2 Mechanical Properties

Vendor shall certify that mechanical properties conform to the requirements of ASTM-A276. Certification shall be submitted for ultimate tensile, yield strength (offset), reduction in area, % elongation and hardness for each heat. Acceptable limits for these properties are listed in General Electric Specification B50YP17 A2 or B2.

2.3 Physical Integrity

Vendor shall certify that physical integrity of the material has been tested per General Electric Test Method E5DYP3 "Ultrasonic Inspection" for 100% of product.

SEFOR R & D (TIGHTENER & EXTENSION RODS)

Bottom End Plug - Extension Rod

- 2.3.1 Vendor shall submit Ultrasonic test plan for approval by General Electric NTD-NL prior to production.

3.0 PREPRODUCTION

Vendor shall submit three (3) samples for approval by NTD-NL of dimensional characteristics prior to full production. Quality Control-Purchased Materials shall perform the pre-production inspections as directed by NTD-NL.

4.0 RECEIVING INSPECTION OF PRODUCTION LOTS

Quality Control-Purchased Materials shall perform the following inspections to verify that dimensional characteristics conform to drawing requirements and that vendor inspection results are as stated.

4.1 WELD PREP ZONE

Weld prep zone end shall be visually inspected for 100% of end plugs. Ends are to be sharp, clean and free of damage (nicks, scratches, pits, etc.).

I.D. of weld prep zone ($0.795" \pm 0.002$) and wall thickness and angle of cut to wall shall be inspected on 20% of a lot. The lot is acceptable if one (1) or less rejects are found. If two or more rejects are found, 100% inspection for these characteristics shall be performed.

- 4.2 Inspection shall be performed on the following characteristics for the sample sizes listed:

<u>CHARACTERISTIC</u>	<u>SAMPLE SIZE</u>			
	Part No.1	Part No.2	Part No.3	Part No.4
"C" Dimension	70	10	10	10
"B" Dimension	70	10	10	10
Distance from right hand end (Drawing reference) to center of countersunk hole ($0.594" \pm 0.003"$)	30	5	5	5
Countersunk holes, diameter and centering	30	5	5	5

Inspect 100% if one (1) or more defects are found per the above table.

SEFOR R & D (TIGHTENER & EXTENSION RODS)

Bottom End Plug - Extension Rod

- 4.3 All other dimensional inspections for drawing requirements shall be performed on ten (10) end plugs for Part 1, and two (2) each of Part Nos. 2, 3 and 4. selected at random from each lot. If one or more causes for rejection are found, an additional sample shall be drawn and inspected. If one or more causes for rejection are found in a second sample, 100% inspection shall be performed.

4.4 Discrepant Material

Non-conforming material shall be segregated and disposition determined by NTD-NL.

ATOMIC POWER EQUIPMENT DEPARTMENT

PROJECT QUALITY CONTROL PLAN

TITLE: SEFOR R & D (TIGHTENER & EXTENSION RODS)Part _____ Drawing _____
Name Top End Plug No. 117C1376Prepared by MCU Date 8/14/67
Approved by TJZ Date 9-14-67
Reviewed by DTI Date 9-26-671.0 SPECIFICATIONS

The following specifications shall apply to this part:

- (a) GE Specification B50YP17 A2 or B2
- (b) Specification E5DYP3
- (c) ASTM-A276

2.0 CERTIFICATIONS

2.1 Chemical Composition

Vendor shall certify that impurities and alloying elements conform to the requirements of ASTM-A276. Chemical composition shall be determined for each heat.

<u>ELEMENT</u>	<u>PER CENT</u>
Carbon	0.08 (max)
Phosphorus	0.045 (max)
Sulfur	0.030 (max)
Silicon	1.00 (max)
Chromium	18.00 - 20.00
Nickel	8.00 - 12.00

2.2 Mechanical Properties

Vendor shall certify that mechanical properties conform to the requirements of ASTM-A276. Certification shall be submitted for ultimate tensile, yield strength (offset), reduction in area, % elongation and hardness for each heat. Acceptable limits for these properties are listed in General Electric Specification B50YP17 A2 or B2.

2.3 Physical Integrity

Vendor shall certify that physical integrity of the material has been tested per General Electric Test Method E5DYP3 "Ultrasonic Inspection" for 100% of product.

SEFOR R & D (TIGHTENER & EXTENSION RODS)

Top End Plug

- 2.3.1 Vendor shall submit Ultrasonic test plan for approval by General Electric NTD-NL prior to production.

3.0 PREPRODUCTION

Vendor shall submit three (3) samples for approval by NTD-NL of dimensional characteristics prior to full production. Quality Control-Purchased Materials shall perform the pre-production inspections as directed by NTD-NL.

4.0 RECEIVING INSPECTION OF PRODUCTION LOTS

Quality Control-Purchased Materials shall perform the following inspections to verify that dimensional characteristics conform to drawing requirements and that vendor inspection results are as stated.

4.1 Weld Prep Zone

Weld prep zone end shall be visually inspected for 100% of end plugs. Ends are to be sharp, clean and free of damage (nicks, scratches, pits, etc.).

I.D. of weld prep zone ($0.795''^{+0.000}_{-0.002}$) and wall thickness and angle of cut to wall shall be inspected on 20% of a lot. The lot is acceptable if one (1) or less rejects are found. If two or more rejects are found, 100% inspection for these characteristics shall be performed.

- 4.2 Inspection shall be performed visually on 100% of a lot for verification that identification machining conforms to drawing.

- 4.3 Inspection shall be performed on the following characteristics for the sample sizes listed:

CHARACTERISTICSAMPLE SIZE

	Part No.1	Part No.2	Part No.3	Part No.4	Part No.5
Shank diameter ($0.375'' \pm 0.003''$)	10	20	5	5	5
Shank concentricity ($0.002''$ TIR to A)	10	20	5	5	5

Inspect 100% if one (1) or more defects are found per the above table.

SEFOR R & D (TIGHTENER & EXTENSION RODS)

Top End Plug

4.4 All other dimensional inspections for drawing requirements shall be performed on five end plugs for Part No. 1, ten end plugs for Part No.2 and two each of Part Nos. 3, 4 and 5 selected at random from each lot. If one or more causes for rejection are found, an additional sample shall be drawn and inspected. If one or more causes for rejection are found in a second sample, 100% inspection shall be performed.

4.5 Discrepant Material

Non-conforming material shall be segregated and disposition determined by NID-NL.

GEAP-13595

Section 5 of 10

Deleted

ATOMIC POWER EQUIPMENT DEPARTMENT

PROJECT QUALITY CONTROL PLAN

TITLE: SEFOR R & D (TIGHTENER & EXTENSION RODS)Part Drawing
Name Reflector No. 159A2792Prepared by ACU Date 1/11/67
Approved by [Signature] Date 1-14-67
Reviewed by [Signature] Date 1-26-671.0 SPECIFICATIONS

The following specifications shall apply to this part:

(a) ASTM-B160

2.0 CERTIFICATIONS

2.1 Chemical Composition

Vendor shall certify that impurities and alloying elements conform to the requirements of ASTM-B160. Chemical composition shall be determined for each heat.

<u>ELEMENT</u>	<u>PER CENT</u>
Nickel*	99.0 (min)
Copper	0.25 (max)
Iron	0.40 (max)
Manganese	0.35 (max)
Carbon	0.15 (max)
Silicon	0.35 (max)
Sulfur	0.01 (max)

* Cobalt counting as nickel

3.0 RECEIVING INSPECTIONQuality Control - Purchased Materials shall inspect five (5) reflector rods selected at random from a lot for O.D. verification ($0.655'' +0.000''$ to $-0.005''$). If one or more rods is rejected, 100% inspection shall be performed.3.1 DISCREPANT MATERIAL

Non-conforming material shall be segregated and disposition determined by NTD-NL.

SEFOR R & D (TIGHTENER & EXTENSION RODS)

Reflector

4.0 NTD-NL PRODUCTION (FUEL LAB)

Machining of reflector stock shall be qualified by complete inspection of dimensional characteristics for first piece and at any set-up change. Bow characteristic shall be inspected for first five pieces produced consecutively and if no rejection, one in every twenty pieces produced. If a reject occurs, five consecutive pieces shall be found free of defects before inspection may again revert to one in twenty.

4.1 DISCREPANT MATERIAL

Non-conforming material shall be segregated and disposition determined by NTD-NL.

ATOMIC POWER EQUIPMENT DEPARTMENT
PROJECT QUALITY CONTROL PLAN

TITLE: SEFOR R & D (TIGHTENER & EXTENSION RODS)

Part _____ Drawing _____
Name Reflector No. 175A9312

Prepared by WJ Date 9-11-67
Approved by WJ Date 9-11-67
Reviewed by DTI Date 9-26-67

1.0 SPECIFICATIONS

The following specifications shall apply to this part:

(a) ASTM-B160

2.0 CERTIFICATIONS

2.1 Chemical Composition

Vendor shall certify that impurities and alloying elements conform to the requirements of ASTM-B160. Chemical composition shall be determined for each heat.

<u>ELEMENT</u>	<u>PER CENT</u>
Nickel*	99.0 (min)
Copper	0.25 (max)
Iron	0.40 (max)
Manganese	0.35 (max)
Carbon	0.15 (max)
Silicon	0.35 (max)
Sulfur	0.01 (max)

* Cobalt counting as nickel

3.0 RECEIVING INSPECTION

Quality Control - Purchased Materials shall inspect five (5) reflector rods selected at random from a lot for O.D. verification ($0.780''^{+0.000''}_{-0.005''}$). If one or more rods is rejected, 100% inspection shall be performed.

3.1 DISCREPANT MATERIAL

Non-conforming material shall be segregated and disposition determined by NID-NL.

SEFOR R & D (TIGHTENER & EXTENSION RODS)Reflector4.0 NTD-NL PRODUCTION (FUEL LAB)

Machining of reflector stock shall be qualified by complete inspection of dimensional characteristics for first piece and at any set-up change. Bow characteristic shall be inspected for first five pieces produced consecutively and if no rejection, one in every twenty pieces produced. If a reject occurs, five consecutive pieces shall be found free of defects before inspection may again revert to one in twenty.

4.1 DISCREPANT MATERIAL

Non-conforming material shall be segregated and disposition determined by NTD-NL.

ATOMIC POWER EQUIPMENT DEPARTMENT
PROJECT QUALITY CONTROL PLAN

TITLE: SEFOR R & D (TIGHTENER & EXTENSION RODS)

Part Drawing
Name Spring No. 175A8428

Prepared by per Date 9/11/67
Approved by TJL Date 9-11-67
Reviewed by DTI Date 9-26-67

1.0 SPECIFICATIONS

The following specifications shall apply to this part:

(a) ASTM-A313

2.0 CERTIFICATIONS2.1 Chemical Composition

Vendor shall certify that impurities and alloying elements conform to the requirements of ASTM-A313. Chemical composition shall be determined for each heat.

<u>ELEMENT</u>	<u>PER CENT</u>
Carbon	0.15 (max)
Manganese	2.00 (max)
Silicon	1.00 (max)
Phosphorus	0.04 (max)
Sulfur	0.03 (max)
Chromium	18.00 - 20.00
Nickel	8.00 - 9.50

2.2 Tensile Properties

Vendor shall certify that tensile strength conforms to the requirements of ASTM-A213 (min. 260,000; max 290,000).

3.0 RECEIVING INSPECTION

Quality Control-Purchased Materials shall select five samples at random from a lot and perform inspections and tests for those characteristics specified in the reference drawing. If one or more causes for rejection are found, an additional sample of five shall be selected at random. If one or more causes for rejection are found in the second sample, 100% inspection shall be performed.

3.1 Discrepant Material

Non-conforming material shall be segregated and disposition determined by NTD-NL.

ATOMIC POWER EQUIPMENT DEPARTMENT

PROJECT QUALITY CONTROL PLAN

TITLE: SEFOR R & D (TIGHTENER & EXTENSION RODS)

Part	Drawing	Prepared by	Date
Name	No.	Approved by	Date
<u>Tube</u>	<u>See Below</u>	<u>NTV</u>	<u>8/14/67</u>
		<u>DTI</u>	<u>9-26-67</u>

1.0 SPECIFICATIONS

The following specifications shall apply to this part:

- (a) G. E. Specification B50YP79 A1 or A2
- (b) G. E. Test Method ESDYP3
- (c) ASTM-A269

- 1.1 This quality plan references all applicable provisions for Tube Drawing Nos: 135B8710, 129B2368 and 112C3406.

2.0 CERTIFICATIONS

2.1 Chemical Composition

Vendor shall certify that impurities and alloying elements conform to the requirements of ASTM-A269. Chemical composition shall be determined for each heat.

2.2 Mechanical Properties

Vendor shall certify that mechanical properties conform to the requirements of ASTM-A269 and B50YP79A1 or A2. Certification shall be submitted for ultimate tensile, yield (offset), % elongation, flaring or flange, or reverse flattening.

2.3 Physical Integrity

Vendor shall certify that hardness, grain size, surface finish requirements conform to ASTM-A269 and B50YP79A1 or A2 and shall also certify that physical integrity has been tested per General Electric Test Method ESDYP3 "Ultrasonic Inspection" for 100% of product.

- 2.3.1 Vendor shall submit Ultrasonic test plan for approval by General Electric NID-NL prior to production.

3.0 PREPRODUCTION - INITIAL TUBE

Vendor shall submit one (1) full length tube sample from which a three (3) foot long section will be cut and prepared by Quality Control-Purchased Materials for use as an u/s standard by vendor.

SEFOR R & D (TIGHTENER & EXTENSION RODS)

Tube

Quality Control-Purchased Materials shall submit the remainder of the tube for verification of chemical, mechanical and physical properties required by B50YP79 A1 or A2.

4.0 SOURCE INSPECTION

A Q.C. representative shall audit the Quality Control efforts of the vendor to assure compliance to the requirements of the Purchase Order, specifications, codes and drawings. Source inspection shall be performed at the site of the vendor supplying initial tubes and at the site of the vendor supplying formed tubes.

5.0 PREPRODUCTION - FORMED TUBE

Vendor shall submit four (4) formed tubes for qualification of tube-forming process. Each tube shall be inspected for conformance to all drawing dimensions except wall thickness by Quality Control-Purchased Materials. Wall thickness measurements shall be performed by NTD-NL. Approval for tube-forming process shall be done by NTD-NL.

6.0 RECEIVING INSPECTION - FORMED TUBE

Except for as-formed tubing, all tube ends and weld prep zones shall be sharp, free of burrs and undamaged as determined by 100% visual inspection.

6.1 All other drawing dimensions shall be inspected per the following sampling plan:

<u>LOT SIZE</u>	<u>SAMPLE SIZE</u>	<u>NUMBER OF REJECTS ALLOWED</u>
101-200	15	0
601-800	35	0

The tube length for as-formed tubes shall be at least 4" beyond the dimension given in Dwg. 135B8710, Rev. 1.

If one or more causes for rejection are found, 100% inspection shall be instituted.

7.0 RECEIVING INSPECTION - EB WELDED TUBE

Quality Control-Purchased Materials shall inspect EB welded tubes 100% for spacer location, and visually for weld zone discoloration and tube surface appearance.

SEFOR R & D (TIGHTENER & EXTENSION RODS)

Tube

NTD-NL shall section and examine one (1) EB welded tube for weld integrity. No production lot received shall be released until NTD-NL has approved the weld.

8.0 EB WELD QUALIFICATION

Vendor shall submit samples of EB welds to NTD-NL for approval of weld process prior to production. No tubes welded before approval shall be acceptable.

ATOMIC POWER EQUIPMENT DEPARTMENT

PROJECT QUALITY CONTROL PLAN

TITLE: SEFOR R & D (TIGHTENER & EXTENSION RODS)Part Quality Control
Name In-Process Audit & Final InspectionPrepared by JCL/2/7/77 Date 4/8/77Approved by JCL Date 4/8/77Reviewed by D.T.1 Date 4-30-77Drawing 112C2072 Extension Rod
No. 846F777 Tightener Rod1.0 SPECIFICATIONS

The following specifications shall apply:

- (a) APO Spec 22A1658
- (b) GE Spec P4AYP1
- (c) GE Spec P4CYP3

2.0 CERTIFICATIONS2.1 Release for shipping

Quality Control shall verify that all material acceptable at final inspection has met the criteria established in this Quality Plan; that vendor material certifications are complete and that disposition of any material not meeting drawings and specifications has been documented and resolved.

3.0 MATERIAL CONTROL

3.1 A record shall be made for each type tube by serial number, which shall accompany the tube through the process and shall show each operation as complete; and after loading, shall show the contained weight of BeO and/or B₄C and steel shot.

3.2 Scales used for weighing BeO, B₄C and steel shot shall be calibrated at the start of each shift.

4.0 PROCESS CONTROL

4.1 Control of the passivation process shall be demonstrated by chemical analysis of the acid bath prior to start of production and by further analyses made at least once a week. Chloride ion content of the deionized water rinse shall be no greater than 15.0 ppm NaCl equivalent.

SEFOR R & D (TIGHTENER & EXTENSION RODS)

- 4.2 Welding Control shall be demonstrated prior to start of production by qualification of the weld parameters and operators as follows:
- (a) Five consecutive welds shall be made and examined metallographically. All welds must have a minimum of 93% penetration. (These welds shall be made at the nominal weld current setting)
 - (b) An operator shall not be considered qualified until he has made at least two consecutive successful welds using established parameters for this process.

All welds shall be recorded on a weld trace chart. Any weld which has been made by parameters exceeding the standard limits shall be considered discrepant and shall be segregated and identified. Special disposition shall be made in these cases.

Weld in-process qualification shall be performed during each shift by making one weld which meets penetration requirements as examined metallographically and visual requirements on completeness, appearance and bead contour. Failure of the in-process qualification samples shall mean that all subsequent welds must be identified and segregated, and further that 100% X-ray examination be made of all suspect welds.

- 4.3 Rod weight control (B_4C) shall be maintained by audit examination of the B_4C charges and by stack height examination of filled extension rods. Rod weight control of these blended B_4C and stainless steel shot-filled tubes shall be audited similarly.
- 4.4 Control of BeO rod weights shall be maintained by audit examination of mockup charge weights and lengths.

5.0 FINAL INSPECTION

- 5.1 Helium leak check shall be performed on 100% of all rod types initially and on 10% of all rod types after a two week time lapse. If one or more leaking rods are found, all rods shall be re-leak checked.

The leak detector shall be calibrated at least once every four hours of operation. A station log shall be maintained which shall show that this operation has been performed and shall be initialed by the operator.

- 5.2 At least 10% of rods shall be inspected dimensionally for conformance to drawing requirements. Particularly, dimple and spring location and bow shall be inspected. Runout up to .050" TIR shall be examined on formed tubes using Vee-blocks at tube expanded area and measuring TIR at these locations.

SEFOR R & D (TIGHTENER & EXTENSION RODS)

- 5.3 All welds shall be inspected visually for surface smoothness, weld soundness (craters, lack of fusion, undercutting, etc.).
- 5.4 All rods shall be inspected visually for physical integrity (scratches, nicks, dents, etc.).

6.0 RECORDS AND DOCUMENTATION

- 6.1 An Audit Report shall be written for each audit tour conducted by Q.C.-Fuels during in-process operations which shall indicate degree of conformance to the Process Development Guide and to applicable drawings, specifications and Quality Control Requirements.
- 6.2 All records required by the Process Development Guide shall be filed and maintained for a period to be determined by the customer.
- 6.3 All certifications and material releases from Receiving Inspection and Source Inspection shall be filed and maintained for a period to be determined by the customer.

ATOMIC POWER EQUIPMENT DEPARTMENT
PROJECT QUALITY CONTROL PLAN
P-2288-68

Title: SEFOR R & D

Part	Dwg.	Proposed by: <u>[Signature]</u>	Date: <u>5-14-68</u>
Name: <u>Tightener Sleeve</u>	No.: _____	Approved by: <u>[Signature]</u>	Date: <u>5-14-68</u>
		Reviewed by: <u>[Signature]</u>	Date: <u>5-22-68</u>

1.0 PURPOSE AND SCOPE:

This Quality Plan describes the method of inprocess control and the final inspection to be performed to demonstrate that the product design has been fulfilled.

2.0 INPROCESS CONTROL:

- 2.1 The F.&M.D. Project Engineer shall prepare a detailed procedure guide for the assembly of the tightener sleeves. The procedure shall include a check list where the operators shall record the satisfactory completion of the assembly operations and checks.
- 2.2 Q.C. Fuels Auditors shall audit the operations for compliance to instructions. Particular attention to inprocess measurements will be necessary since measurements at final inspection are extremely impractical for many of the product characteristics.
- 2.3 F.&M.D. shall make mock-up assemblies of tightener sleeves, dummy rods, and channels until 10 successive assemblies have been made which require no repair, rework, or modifications to the tightener sleeves. After 10 sequentially successful assemblies, reduce the mock-up testing to 1 per 10 assemblies (i.e., 1 per lot). If a failure occurs, test the representative lot 100% and the next lot 100%. If all assemblies in the lot after the failure are successful, again reduce the testing to 1 per lot.
- 2.4 Q.C. Fuels shall observe the assembly of the first 10 mock-ups. Additional mock-ups shall be observed by Q.C. Fuels on an audit basis.

3.0 FINAL INSPECTION:

- 3.1 Q.C. Fuels shall perform a 100% visual inspection prior to packaging.
- 3.2 Q.C. Fuels shall review the check lists for completion.
- 3.3 Q.C. Fuels shall test 1 assembly per lot (10 assemblies) per drawing note 3.
- 3.4 Q.C. Fuels shall test 1 assembly per lot for dimple, fin and spring locations and visually examine the 10 assemblies per lot for symmetry.

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APPENDIX IV

Experiments Conducted with Extension Rod Tubing

APPENDIX IV

It was found after assembly that a portion of the tubing used in the extension rod fabrication contained shallow-stress corrosion attack. This possibility was recognized from the investigation into the attack found on the I.D. of the original order of tightener rod tubing when it was noted both tube orders were made from the same heat.

All of the tubes had been ultrasonically inspected to discriminate for defects greater than 10% of the wall thickness (.004 inches). Since the minimum attack was less than 2-1/2 mils deep and because of the random nature of the attack, the surface defect was undetected during the extension rod fabrication.

An ultrasonic test was devised to determine the number of extension rods so affected and to determine the degree, if any, of the attack.⁽¹⁾ An attenuation measurement technique was devised to grade the full cladding surface finish. The basic technique measured the decay curve of the reflections within the material. The material with the shorter time constant decay curve contained the greater number of imperfections. The tests determined that of the 743 extension rods tested, 98 were found to possess surface cracks between 1 to 2-1/2 mils deep. The grading of each rod was recorded.

An experiment was conducted to determine the susceptibility of the tubing to propagation of the intergranular attack under SEFOR conditions.⁽²⁾ Autoclave tests were conducted with saturated steam at 350°F, 546°F, and 800°F on specimens under no load, below yield, at yield, and plastically deformed. No progression of the original 2 mil intergranular attack occurred.

Furnace tests at 800°F with closed capsules made from affected tubing filled with B_4C were also conducted.⁽²⁾ Three conditions of B_4C were used; 1) vacuum dried, 2) air dried, and 3) exposed to air for 36 hours. Again no progression of the intergranular attack was detected.

From these tests, it was concluded that failure of extension rods by propagation of surface cracking was of low probability. Rods that were determined to have the greatest surface effects will be held in reserve.

References

1. T.G. Lambert, V.J. Lovelace, "Ultrasonic Inspection of Extension Rods for Stress Corrosion Attack", letter to F.E. Young, November 6, 1968.
2. G.G. Gaul, C.N. Spalaris, "Experiments with Tubing from SEFOR Fuel Extension Rods", to Distribution, November 12, 1968.

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APPENDIX V

Thermal Cycling Tests on Tightener Sleeve Spring Assemblies

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APPENDIX V

INTRODUCTION

Metallographic examination of a production run SEFOR tightener sleeve revealed some lack of fusion in the finger weld and around the circumference of the upper weld (Figure V-1 (Dwg. 706E958), Section B-B). Since these are only location welds the primary concern is that the cracks do not propagate from the roots of the cold-shuts during service.

It was determined the most severe condition imposed upon the spring was during the planned thermal cycle transients. The design basis for the spring was 30 cycles with a 150°F temperature differential between the outside and inside spring fingers.

TEST DESCRIPTION

A test program was established to thermal-stress the spring assembly while under compression in excess of the thermal-stresses expected during the life of the tightener sleeve. The test was accomplished by heating the spring within an RF field. By this means differential eddy-current heating of the inner and outer spring fingers caused differential expansion creating shear forces across the welds.

The test set-up is shown in Figure V-2 where the test spring assembly is shown inserted within an RF coil. The RF coil is attached to the 45 KVA Lapel RF generator in the background. Figure V-3 shows the thermocouple locations on the test assembly.

Figure V-1. Tightener Sleeve

Figure V-2. Thermal Cycle Test Set-Up Showing Spring Assembly Inserted within the RF Coil

Figure V-3. Thermocouple Locations

RESULT

Measured temperature differentials were as follows:

$$\Delta T = \text{T.C. \#1} - \text{T.C. \#2} = 195^{\circ}\text{F to } 270^{\circ}\text{F (225}^{\circ}\text{F average)}$$

$$\Delta T = \text{T.C. \#3} - \text{T.C. \#4} = 150^{\circ}\text{F}$$

Figure V-4 is a typical thermocouple trace during the thermal cycling. Metallographic examination showed no weld failure at these more rigid thermal stress conditions (Figures V-5 and V-6).

QUENCHED IN WATER
0-3 sec
GRID 40
P.C. 100
T.C. NO. 1
8-3-68-12C

T.C. NO. 2
8-3-68-12d

Figure V-4. Typical Time-Temperature Trace for Spring Assembly No. 4

Figure V-5. Spring Assembly No. 4 Finger Weld, Post Thermocycle

Figure V-6. Spring Assembly No. 4 Upper Weld, Post Thermocycle

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APPENDIX VI

Beryllium Oxide Specifications and Certification

GENERAL ELECTRIC

ADVANCED PRODUCTS OPERATION

P.O. BOX 254

175 CURTNER AVENUE

SAN JOSE, CALIFORNIA

PROJECT: SEFORSPECIFICATION AND REV. NO. 22A1585 Rev. 010/14/65
DATESPECIFICATION TITLE Beryllia Rods for SEFORTABLE OF CONTENTS

<u>SECTION</u>	<u>TITLE</u>	<u>PAGE</u>
1.0	Scope & Definitions	1
2.0	Beryllia Rod	1
3.0	Quality Control	3

ISSUED BY

SEFOR Engineering

1.0 SCOPE AND DEFINITIONS

- 1.1 This specification defines the requirements for sintered BeO which will be used in the tightening rod of the Southwest Experimental Fast Oxide Reactor (SEFOR).
- 1.2 The work done by the Seller in accordance with this specification shall include all procurement of raw material, fabrication, quality control, preparation for shipment, and shipment.
- 1.3 The Seller shall accept full responsibility for his work and for compliance with this specification. Review or approval of the Seller's processes, procedures or equipment by the General Electric Company, Advanced Products Operation (GE-APD) in no way waives requirements established by this specification and the purchase contract.
- 1.4 The term "powder lot" shall refer to all beryllia powder which has been prepared from raw materials at one time under identical conditions, and is uniform in composition for sampling purposes. The term "batch" shall refer to all BeO rods prepared from the powder at one time by one process.

2.0 BERYLLIA ROD**2.1 Process, Composition, Density and Grain Size**

- 2.1.1 BeO shall be prepared by the process of cold-pressing (for length/diameter ratios of 1.25 or less) or extruding sinterable powder (for length-diameter ratios greater than 1.25) and firing in air, nitrogen, or helium. Average rod density shall be 2.9 gm/cc or greater. Minimum rod density shall be 2.85 gm/cc.
- 2.1.2 Average grain size in the sintered rod shall be 25 microns or less.
- 2.1.3 The sum of the impurities listed in Table I shall not exceed 6000 ppm by weight in the finished rod. Levels of individual elements shall not exceed the values stated. Binders, lubricants, cleaning solutions, additives and dye penetrants, if used, shall be classed as impurities.

PREPARED BY M. L. Johnson	ENGINEERED BY / / /	GENERAL ELECTRIC ADVANCED PROD. OPER. P.O. BOX 24 175 CURTNER AVE SAN JOSE, CALIFORNIA		TITLE Beryllia Rod for SEFOR	
APPROVED BY	DATE			SPEC. NO. 22A1585	REV. NO. 0
		PROJECT SEFOR			
		ISSUED BY SEFOR Engineering	ENGINEERING	DATE 10/14/66	SAT. CONT.

GENERAL ELECTRIC

ORDERS AND CORRESPONDENCE
MUST SPECIFY COMPLETE NUMBERSH 2 OF 5SPECIFICATION

TITLE

beryllia Rods for SEFOR

TABLE IMAXIMUM PERMISSIBLE IMPURITY LEVELS

<u>Element</u>	<u>Limit (ppm.)</u>	<u>Element</u>	<u>Limit (ppm)</u>
Al	500	H	50
Ag	10	Li	20
B	20	Mg	4000
Ba	100	Mn	20
C	600	Mo	40
Ca	500	Na	250
Cd	20	Ni	150
Cl	20	Pb	40
Co	10	Si	500
Cr	100	Sn	20
Cu	100	Sr	200
F	200	Ti	20
Fe	200	Zn	40

2.2 Identification

Powder lots and batches shall be segregated throughout production, and records maintained so that any rod may be traced to its batch and powder lot.

2.3 Physical Integrity

2.3.1 Modulus of rupture for the rods shall be 25000 psi or greater.

2.3.2 Total surface area of end chips shall not exceed 20 per cent of the surface area of the end of the rod.

2.3.3 Depth of surface pits shall not exceed .020 inch. Rods having cracks detectable by an approved dye check shall be rejected.

GENERAL ELECTRIC

ORDERS AND CORRESPONDENCE
MUST SPECIFY COMPLETE NUMBER

SH 3 OF 5

SPECIFICATION

TITLE

Beryllia Rods for SEFOR

2.4 Dimensions

Drawing 159A2789 shows all dimensional requirements. Rods of each size shall be inspected for straightness by passing through a hardened steel or ceramic ring gage having a ground bore 0.003 inch larger than the maximum rod diameter plus bow. Gage length shall be greater than rod length.

2.5 Cleaning

Rods shall be cleaned by an approved cleaning process. BeO powder removable by a wipe test shall not exceed 200 micrograms/ft². Cleaning shall follow the dye-penetrant check.

2.6 Packing and Shipping

Rods shall be furnace dried after cleaning and packaged in sealed containers containing suitable desiccants. Shipping containers shall be of materials and construction proven suitable for BeO shipments by past experience. Containers and packaging shall comply with all existing applicable regulations. Rods shall be packed to prevent chipping and dusting during shipment. Destination of shipment will be San Jose, California.

3.0 QUALITY CONTROL3.1 Inspection by the Buyer

A representative of the Buyer shall be granted access to the Seller's production facility at any time during production of the rods and may require performance in his presence of any of the inspections specified herein.

3.2 Inspection Requirements

3.2.1 An inspection plan shall be established and conducted by the Seller to insure compliance with these specifications. Minimum inspection requirements are tabulated below.

<u>Paragraph</u>	<u>Inspection Required</u>	<u>Method</u>	<u>Frequency</u>
2.1.1	Density	Weight and measured volume	90-95 confidence level*
2.1.2	Grain Size	Linear analysis of polished sections as described in ASTM E-112-65	Minimum of three rods from each powder lot and process

GENERAL ELECTRIC

ORDERS AND CORRESPONDENCE
MUST SPECIFY COMPLETE NUMBERSH 4 OF 5SPECIFICATIONTITLE

Beryllia Rods for SEFOR

<u>Paragraph</u>	<u>Inspection Required</u>	<u>Method</u>	<u>Frequency</u>
2.1.3	Impurities	Emission spectro- meter and other approved methods as required	Minimum of three rods from each powder lot and process
2.3.1	Modulus of Rupture	As approved	Minimum of five tests from each powder lot and process
2.3.2	Chips	Visual	90-95 confidence level*
2.3.3	Pits & Cracks	Visual & dye penetrant	90-95 confidence level*
2.4	Dimensions	As approved	90-95 confidence level**
2.5	Surface Powder	As approved	90-95 confidence level*
2.6	Packing	Visual	Each container

* Sampling sufficient to assure with 90% confidence that at least 95 per cent of the rods meet specification.

** Sampling sufficient to assure with 95% confidence that at least 95 per cent of the rods meet specification.

3.2.2 Rejection of any batch or lot shall result in an extensive re-sampling plan approved by GE-APTD to determine extent of defective material.

3.2.3 One hundred pre-production pieces from each production process representing equally each size of rod shall be shipped to the Buyer at San Jose, California prior to further production. Further production shall not be permitted until the pre-production pieces are approved by the Buyer. If the pre-production rods do not meet the requirements of the specification, additional lots shall be submitted until acceptable rods are produced.

GENERAL ELECTRIC

ORDERS AND CORRESPONDENCE
MUST SPECIFY COMPLETE NUMBERSH 5 OF 5SPECIFICATION

TITLE

Per Alia Rods for SLEOP

3.3 Records and Reports

Records of all measurements made in compliance with Section 3.2 of this specification shall be maintained by the Seller and approved by the Buyer prior to shipping production material. Records shall relate each test piece to its batch and powder lot.

GEAP-13595

QUALITY CONTROL - PURCHASED MATERIALS
SAN JOSE - CALIF.

DT IKWYE

Work No. 20

Tg Report Number

5/1/67

Purchase Order No. K-10809

ECT

EMO

VISIT DATE

12/21/67

DATE OF REPORT

12/22/67

COMPONENT

Beryllium Oxide Rods

VENDOR

Brush Beryllium Co.

LOCATION

Elmore, Ohio

CONTACT

D. Vanbort O.E. Supervisor

ALTERNATE FOR

CONTACT

RECEIVED BY

DRAWING

159 A 2709 Rev 0 Items 2

SPECIFICATIONS

22A1585

Purpose of trip: Source inspection of beryllium rods

Results:

(4700) Rods item no. 1 released for shipment.

(120) Rods item no. 2 released for shipment.

Summary:

The writer reviewed the vendor material certification and found them to be acceptable to specification 22A1585, with these exceptions. The specification wire test requires that 200/ft. shall not be exceeded, the actual readings were 467 for item no. 1 and 239 for item no. 2. The wire test requirements were relieved as per FAX from W H Rodgers of San Jose 12/21/67. The Hydrogen test for powder lot C-1 was not completed at the time of the inspection, the writer contacted Mr. M Bicknell of QCPM and we agreed to let the shipment come to San Jose, the vendor will forward the certification upon completion, of the test.

Item no. 1 consists of Powder lot D-2 Run 0-1, and Powder lot D-3 Runs 0-2, 0-3.

Item no. 2 consists of Powder lot C-1

THIS PURCHASE ORDER IS COMPLETE

RECEIVED
DEC 20 1967

R. G. BURGER

SIGNATURE

William M. Phillips

ATTACHMENTS

None

GEAP-13595

THE BRUSH BERYLLIUM COMPANY
ELMORE, OHIO

CERTIFICATE OF COMPLIANCE

To: <u>GENERAL ELECTRIC COMPANY</u>	Date <u>12/22/67</u>
<u>175 CURTNER AVENUE</u>	Your PO <u>205-K1080-G</u>
<u>SAN JOSE, CALIFORNIA 95125</u>	Our SO <u>U-961</u>
	Item No. <u>1 - RUN 01</u>
	Quantity <u>3,662 PCS.</u>

It is hereby certified that all articles herewith furnished in the quantities as called for in the above purchase order are in conformance with the requirements, specifications, and drawings applicable to that order.

All physical, chemical or other tests applicable to your order are on file, and copies of such reports will be furnished upon request.

POWDER LOT - D-2

Chemical Analysis - See attached sheet

Grain Size:

Sample 1	Sample 2	Sample 3
10.0 Microns	10.3	11.0

Density - 2.879 g/cc average

Modulus of Rupture - 33,486 PSI

Surface Powder - 467 Micrograms Per Sq. Ft.

THE BRUSH BERYLLIUM COMPANY

Don E. Yambert
Quality Control Supervisor
Ceramic Department

GEAP-13595

POWDER LOT D-2
CHEMICAL ANALYSIS

SAMPLE #1

Al	50 PPM
Ag	-1 "
B	-1 "
Ba	2 "
C	64 "
Ca	50 "
Cd	ND
Co	-1 "
Cr	6 "
Cu	2 "
F	70 "
Fe	50 "
H	18 "
Li	3 "
Mg	680 "
Mn	-2 "
Mo	-3 "
Na	50 "
Ni	10 "
Pb	-2 "
Si	165 "
Sn	1 "
Sr	2 "
Ti	-2 "
Zn	-20 "

SAMPLE #2

Al	55 PPM
Ag	-1 "
B	-1 "
Ba	2 "
C	26 "
Ca	50 "
Cd	ND
Co	-1 "
Cr	7 "
Cu	-2 "
F	85 "
Fe	50 "
H	10 "
Li	2 "
Mg	760 "
Mn	-2 "
Mo	-3 "
Na	30 "
Ni	10 "
Pb	-2 "
Si	180 "
Sn	2 "
Sr	2 "
Ti	2 "
Zn	-20 "

SAMPLE #3

Al	90 PPM
Ag	-1 "
B	-1 "
Ba	2 "
C	11 "
Ca	50 "
Cd	ND
Co	-1 "
Cr	9 "
Cr	-2 "
F	78 "
Fe	80 "
H	9 "
Li	3 "
Mg	780 "
Mn	-2 "
Mo	-3 "
Na	80 "
Ni	12 "
Pb	-2 "
Si	180 "
Sn	1 "
Sr	2 "
Ti	-2 "
Zn	-20 "

(ND) - Not Detected
(-) - Less Than

BRUSH BERYLLIUM COMPANY
 RE, OHIO

CERAMIC DEPARTMENT
 INSPECTION REPORT

NO. 4-961-1-01	From: <i>Machine Shop</i>	To: <i>G. E.</i>
NAME <i>40-797-730</i>	MAT'L (INT) <i>D-2</i>	QTY RECD. <i>4,344 pcd</i>
E <i>Dec 20, 1967</i>	MAT'L (EXT) <i>999</i>	QTY OK'D <i>3,662 pcd</i>
		DYE: <i>Blue</i>
		CLEANSER: <i>Final - G. 66</i>

EP	DESCRIPTION OF INSPECTION	DISPOSITION
	(3) <i>Microplastic</i> <i>lines in decolored</i>	ACCEPT REJ.
	(4) <i>Microplastic</i> <i>lines in decolored</i>	
1	<i>Parts checked to dimensions per Draw # 159 A2739 Part 1, Rev B. To 1.5% A.P.L. See below.</i>	✓
	<i>Visual - 100% Saw below</i>	
	<i>pi 293 saw saw chips</i>	✓
	<i>10' 634 pcd saw chips</i>	✓
	<i>(a) 51 pcd saw chips</i>	✓
	<i>(b) 176 pcd 1/3 Right (not enough stock to make final part)</i>	✓

INSPECTED BY: <i>W. H. H.</i>	QTY. REQ'D FOR SHIPMENT	OVERAGE: _____
	QTY. REL'D FOR SHIPMENT <i>3,662 pcd</i>	COMPLETE: ☒ YES ☐ NO ☐ OTHER
REMARKS: <i>Visual Density - 2.379 g/cc</i>		
<i>Chemistry checked within spec.</i>		
<i>Grain Size 10.0 - 10.3 - 11.0 microns</i>		
<i>Modulus of Rupture - 33,480 psi</i>		

<i>747 ± .003</i>				
<i>730 ± .003</i>	<i>1.5% A.P.L.</i>			
<i>700 ± .003</i>	<i>Acc - 3</i>			
<i>1.000 ± .003</i>				
<i>1.000 ± .003</i>				
<i>1.000 ± .003</i>				
<i>1.000 ± .003</i>				
<i>1.000 ± .003</i>				
<i>1.000 ± .003</i>				
<i>1.000 ± .003</i>				

APPROVED *Ben Effendy* DATE *12/21/67*

INSPECTION WAS MADE IN ACCORDANCE WITH APPROPRIATE DRAWINGS AND SPECIFICATIONS ON EACH ITEM FOR PURCHASE ORDER. ABOVE PARTS CHECKED IN ACCORDANCE WITH MIL STD. 105D, 29 APRIL 1963.

INSPECTION LEVEL (CIRCLE ONE):
 (I) II III OTHER _____

GEAP-13595

THE BRUSH BERYLLIUM COMPANY
ELMORE, OHIO

CERTIFICATE OF COMPLIANCE

To: <u>GENERAL ELECTRIC COMPANY</u>	Date <u>12/22/67</u>
<u>175 CURTNER AVENUE</u>	Your PO <u>205-K1080-G</u>
<u>SAN JOSE, CALIFORNIA 95125</u>	Our SO <u>U-961</u>
	Item No. <u>1 - RUN 02</u>
	Quantity <u>785 PCS.</u>

It is hereby certified that all articles herewith furnished in the quantities as called for in the above purchase order are in conformance with the requirements, specifications, and drawings applicable to that order.

All physical, chemical or other tests applicable to your order are on file, and copies of such reports will be furnished upon request.

POWDER LOT - D-3

Chemical Analysis - See attached sheet

Grain Size:

Sample 1	Sample 2	Sample
10.5 Microns,	12.3	11.3

THE BRUSH BERYLLIUM COMPANY

Density - 2.883 g/cc average

Modulus of Rupture - 25,708 PSI

Surface Powder - 467 Micrograms Per Sq. Ft.

Don E. Yambert
Don E. Yambert
Quality Control Supervisor
Ceramic Department

POWDER LOT D-3
CHEMICAL ANALYSIS

SAMPLE #1		SAMPLE #2		SAMPLE #3
Al	110 PPM	Al	60 PPM	Al 65 PPM
Ag	-1 "	Ag	-1 "	Ag -1 "
B	-1 "	B	-1 "	B -1 "
Ba	2 "	Ba	2 "	Ba 2 "
C	10 "	C	12 "	C 12 "
Ca	50 "	Ca	60 "	Ca 50 "
Cd	ND	Cd	ND	Cd ND
Co	-1 "	Co	-1 "	Co -1 "
Cr	4 "	Cr	4 "	Cr 4 "
Cu	-2 "	Cu	-2 "	Cu -2 "
F	63 "	F	72 "	F 61 "
Fe	60 "	Fe	70 "	Fe 60 "
H	12 "	H	15 "	H 13 "
Li	3 "	Li	3 "	Li 2 "
Mg	700 "	Mg	680 "	Mg 740 "
Mn	-2 "	Mn	-2 "	Mn -2 "
Mo	-3 "	Mo	-3 "	Mo -3 "
Na	40 "	Na	40 "	Na 40 "
Ni	10 "	Ni	12 "	Ni 10 "
Pb	-2 "	Pb	-2 "	Pb -2 "
Si	320 "	Si	270 "	Si 280 "
Sn	1 "	Sn	2 "	Sn -1 "
Sr	2 "	Sr	2 "	Sr 2 "
Ti	-2 "	Ti	-2 "	Ti -2 "
Zn	-20 "	Zn	-20 "	Zn -20 "

(ND) - Not Detected
(-) - Less Than

NO U-761-1-02	From: J. H. H. H. H.	To: G. B.
NAME: 82-777-780	MAT'L (INT) D-3	QTY RECD. 961 pcs.
E Date: 19, 1967	MAT'L (EXT) 999	QTY OK'D 785 pcs
		DYE: Blue ✓
		CLEANSER: Triclor P666
P	DESCRIPTION OF INSPECTION	DISPOSITION ACC. REJ.
1)	Parts checked. Dimensions per Orig #159A2789 Part 1, Rev O to 1.5% A/D. (See below)	✓
2)	Visuals (100% See below) (A) 40 pcc. Prod. carbide. (B) 40 pcc. Prod. chips (C) 4 pcc. Prod. chips (D) 31 pcc. Prod. chips (Not enough stock to inspect final p.p.)	V ✓ ✓ ✓

GEAP 13595

EXPECTED BY: <i>5/27/11</i>	QTY REQ'D FOR SHIPMENT	OVERAGE: <i>_____</i>
	QTY REL'D FOR SHIPMENT <i>785 pwr.</i>	COMPLETE: ☒ YES ☐ NO ☐ OTHER
REMARKS: <i>Rejection - 520330/ce</i>		

MENTS *Analysis Results - 2.033 g/cc*
Chromium (Hb) within spec.
Main Size 10.5 - 12.3 - 11.3 microns
Grid. No. of R. plate 02 - 25, 708, 021

APPROVED *[Signature]* DATE *12/21/67*

INSPECTION WAS MADE IN ACCORDANCE WITH
APPROPRIATE DRAWINGS AND SPECIFICATION,
ON EACH ITEM FOR PURCHASE ORDER ABOVE.
PARTS CHECKED IN ACCORDANCE WITH MIL
STD. 105D, 29 APRIL 1963.

INSPECTION LEVEL (CIRCLE ONE)

I II III OTHER _____

THE BRUSH BERYLLIUM COMPANY
ELMORE, OHIO

CERTIFICATE OF COMPLIANCE

To:	<u>GENERAL ELECTRIC COMPANY</u>	Date	<u>12/22/67</u>
	<u>175 CURTNER AVENUE</u>	Your PO	<u>205-K1080-G</u>
	<u>SAN JOSE, CALIFORNIA 95125</u>	Our SO	<u>U-961</u>
		Item No.	<u>1 - RUN 03</u>
		Quantity	<u>253 PCS.</u>

It is hereby certified that all articles herewith furnished in the quantities as called for in the above purchase order are in conformance with the requirements, specifications, and drawings applicable to that order.

All physical, chemical or other tests applicable to your order are on file, and copies of such reports will be furnished upon request.

POWDER LOT - D-3

Chemical Analysis - See attached sheet

Grain Size:

Sample 1	Sample 2	Sample 3
10.5 Microns,	12.3	11.3

Density - 2.883 g/cc average

Modulus of Rupture - 25,708 PSI -

Surface Powder - 467 MICROGRAMS Per Sq. Ft.

THE BRUSH BERYLLIUM COMPANY

Don E. Lambert
Quality Control Supervisor
Ceramic Department

POWDER LOT D-3
CHEMICAL ANALYSIS

SAMPLE #1

Al	110	PPM
Ag	-1	"
B	-1	"
Ba	2	"
C	10	"
Ca	50	"
Cd	ND	"
Co	-1	"
Cr	4	"
Cu	-2	"
F	63	"
Fe	60	"
H	12	"
Li	3	"
Mg	700	"
Mn	-2	"
Mo	-3	"
Na	40	"
Ni	10	"
Pb	-2	"
Si	320	"
Sn	1	"
Sr	2	"
Ti	-2	"
Zn	-20	"

SAMPLE #2

Al	60	PPM
Ag	-1	"
B	-1	"
Ba	2	"
C	12	"
Ca	60	"
Cd	ND	"
Co	-1	"
Cr	4	"
Cu	-2	"
F	72	"
Fe	70	"
H	15	"
Li	3	"
Mg	680	"
Mn	-2	"
Mo	-3	"
Na	40	"
Ni	12	"
Pb	-2	"
Si	270	"
Sn	2	"
Sr	2	"
Ti	-2	"
Zn	-20	"

SAMPLE #3

Al	65	PPM
Ag	-1	"
B	-1	"
Ba	2	"
C	12	"
Ca	50	"
Cd	ND	"
Co	-1	"
Cr	4	"
Cu	-2	"
F	61	"
Fe	60	"
H	13	"
Li	2	"
Mg	740	"
Mn	-2	"
Mo	-3	"
Na	40	"
Ni	10	"
Pb	-2	"
Si	280	"
Sn	-1	"
Sr	2	"
Ti	-2	"
Zn	-20	"

(ND) - Not Detected

(-) - Less Than

CERAMIC DEPARTMENT
INSPECTION REPORT

T

REMARKS: *See 2nd Density - 2.883 g/cc* ☒ YES ☐ NO ☐ OTHER

Chemistrip strips entitled spec.

Chain Size - 10.5 - 12.3 - 17.3 mm

Wash. Div. of Pu. H. - 25, 708 pgs										APPROVED <i>Don [Signature]</i> DATE 12/21/67
------------------------------------	--	--	--	--	--	--	--	--	--	---

[illegible]

1974-1980	(1974-1980)			APPROPRIATE DRAWINGS AND SPECIFICATIONS
1981-1985	(1981-1985)			ON EACH ITEM FOR PURCHASE ORDER. ABOVE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141
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[illegible]

INSPECTION LEVEL (CIRCLE ONE):

		I	II	III	OTHER _____
--	--	---	----	-----	-------------

53643-377 7/66

APPROVED Don E. H. [Signature] DATE 12/21/67

INSPECTION WAS MADE IN ACCORDANCE WITH APPROPRIATE DRAWINGS AND SPECIFICATIONS ON EACH ITEM FOR PURCHASE ORDER. ABOVE PARTS CHECKED IN ACCORDANCE WITH MIL STD. 105D. 29 APRIL 1963.

INSPECTION LEVEL (CIRCLE ONE):
(I) II III OTHER _____

GEAP-13595

THE BRUSH BERYLLIUM COMPANY
ELMORE, OHIO

CERTIFICATE OF COMPLIANCE

To:	<u>GENERAL ELECTRIC COMPANY</u>	Date	<u>12/22/67</u>
	<u>175 CURTNER AVENUE</u>	Your PO	<u>205-K1080-G</u>
	<u>SAN JOSE, CALIFORNIA 95125</u>	Our SO	<u>U-961</u>
		Item No.	<u>2 - RUN 01</u>
		Quantity	<u>120 PCS.</u>

It is hereby certified that all articles herewith furnished in the quantities as called for in the above purchase order are in conformance with the requirements, specifications, and drawings applicable to that order.

All physical, chemical or other tests applicable to your order are on file, and copies of such reports will be furnished upon request.

POWDER LOT - C-1

Chemical Analysis - See attached sheet

Grain Size:

Sample 1	Sample 2	Sample 3
14.3 Microns	16.4	14.5

THE BRUSH BERYLLIUM COMPANY

Density - 2.907 g/cc average

Modulus of Rupture - 28,940 PSI

Surface Powder - 239 Micrograms Per Sq. Ft.

Don E. Yambert
Quality Control Supervisor
Ceramic Department

POWDER LOT C-1
CHEMICAL ANALYSIS

SAMPLE #1			SAMPLE #2			SAMPLE #3		
Al	45	PPM	Al	50	PPM	Al	55	PPM
Ag	-1	"	Ag	-1	"	Ag	-1	"
B	-1	"	B	1	"	B	-1	"
Ba	-2	"	Ba	-2	"	Ba	-2	"
C	38	"	C	22	"	C	34	"
Ca	40	"	Ca	40	"	Ca	40	"
Cd	ND	"	Cd	ND	"	Cd	ND	"
Co	-1	"	Co	-1	"	Co	-1	"
Cr	12	"	Cr	12	"	Cr	12	"
Cu	-2	"	Cu	-2	"	Cu	-2	"
*F								
Fe	65	"	Fe	70	"	Fe	70	"
*H								
Li	2	"	Li	3	"	Li	2	"
Mg	800	"	Mg	800	"	Mg	750	"
Mn	-2	"	Mn	-2	"	Mn	-2	"
Mo	-3	"	Mo	-3	"	Mo	-3	"
Na	60	"	Na	60	"	Na	60	"
Ni	12	"	Ni	12	"	Ni	12	"
Pb	-2	"	Pb	-2	"	Pb	-2	"
Si	300	"	Si	330	"	Si	280	"
Sn	-1	"	Sn	-1	"	Sn	-1	"
Sr	-2	"	Sr	-2	"	Sr	-2	"
Ti	-2	"	Ti	-2	"	Ti	-2	"
Zn	-20	"	Zn	-20	"	Zn	-20	"

(ND) - Not Detected

(-) - Less Than

* Hydrogen and Fluorine Analysis not yet available, will forward as soon as possible.

BRUSH BERYLLIUM COMPANY
 RE, OHIO

CERAMIC DEPARTMENT
 INSPECTION REPORT

NO. <i>4-961-2-01</i>	From: <i>G. E. 1000000000</i>	To: <i>G. E.</i>
NAME <i>C-1-6-1-1-1-1</i>	MAT'L (INT) <i>C-1</i>	QTY RECD. <i>162 pcs</i>
E <i>19, 1967</i>	MAT'L (EXT) <i>999</i>	QTY OK'D <i>120 pcs</i>
DESCRIPTION OF INSPECTION		DISPOSITION
		ACC. REJ.
1) <i>Parts checked to dimensions per Drawg #159A2737 Part 2, Row 0</i>		<i>✓</i>
2) <i>Visual - 100% See below</i>		
<i>(A) 3 pcs have chips</i>		<i>✓</i>
<i>(B) 8 pcs have cracks</i>		<i>1</i>
<i>(C) 7 pcs have pits</i>		<i>1</i>
<i>(D) 2 pcs have spots</i>		<i>1</i>

EXPECTED BY: *W. H. C. C. C.* QTY. REQ'D FOR SHIPMENT *120 pcs* OVERAGE: _____

QTY. REL'D FOR SHIPMENT *120 pcs* COMPLETE: ☒ YES ☐ NO ☐ OTHER

MENTS: *1.141 gms density - 2.907 g/cc*
Chemical checked with 100% spec.
Thermal Size - 14.3 - 16.4 - 14.5 microns
99.9% purity of Purity - 23,940 psi

<i>65.2 ± .003</i>	<i>1.5% A.D.</i>	
<i>1.142 ± .030</i>		
<i>1.142 ± .030</i>		
<i>1.010</i>		
<i>Visual</i>		
<i>100% Spec</i>		
<i>100% Spec</i>		

APPROVED *Donfamlet* DATE *12/21/67.*

INSPECTION WAS MADE IN ACCORDANCE WITH
 APPROPRIATE DRAWINGS AND SPECIFICATIONS
 ON EACH ITEM FOR PURCHASE ORDER. ABOVE
 PARTS CHECKED IN ACCORDANCE WITH MIL
 STD. 105D, 29 APRIL 1963.

INSPECTION LEVEL (CIRCLE ONE):
 (I) II III OTHER _____

THE BRUSH BERYLLIUM COMPANY
METAL AND OXIDE DIVISION
ELMORE, OHIO 43416

CERAMICS AND NON-METALLIC
PRODUCTS DEPARTMENT

AREA CODE 419
PHONE: 864-2715
TWX: 863-0960

January 22, 1968

Mr. George Barry
G.E. Atomic Power Equipment
Q. C. Dept.
175 Curtner Avenue
San Jose, California 95125

Dear Mr. Barry,

Please find inclosed the Hydrogen and Fluorine Analysis that were not available at the time of shipment. These values were added to the original certification of chemical analysis.

We are truly sorry for any inconvenience we may have caused you by the delay of this information.

Sincerely yours,

Don E. Lambert
Quality Control Supervisor
Ceramic Department

IVED

APR 08 1968
W. H. RODGERSTHE BRUSH BERYLLIUM COMPANY
ELMORE, OHIOAPR 11 1968
2 11 PM '68CERTIFICATE OF COMPLIANCE
For December 22, 1967 Shipment

To:	<u>General Electric Company</u>	Date	<u>April 5, 1968</u>
	<u>175 Curtner Avenue</u>	Your PO	<u>205-K1080-6</u>
	<u>San Jose, California 95125</u>	Our SO	<u>U-961</u>
		Item No.	<u>2 Run 01</u>
		Quantity	<u>120 pcs.</u>

It is hereby certified that all articles herewith furnished in the quantities as called for in the above purchase order are in conformance with the requirements, specifications, and drawings applicable to that order.

All physical, chemical or other tests applicable to your order are on file, and copies of such reports will be furnished upon request.

Chlorine Content 1.2 ppm.

THE BRUSH BERYLLIUM COMPANY

Don E. Yambert
Don E. Yambert
Quality Control Supervisor
Ceramic Department

THE BRUSH BERYLLIUM COMPANY
ELMORE, OHIO

CERTIFICATE OF COMPLIANCE
For December 22, 1967 Shipment

To:	<u>General Electric Company</u>	Date	<u>April 5, 1968</u>
	<u>175 Curtner Avenue</u>	Your PO	<u>205-K1080-6</u>
	<u>San Jose, California 95125</u>	Our SO	<u>U-961</u>
		Item No.	<u>1 Run 03</u>
		Quantity	<u>253 pcs.</u>

It is hereby certified that all articles herewith furnished in the quantities as called for in the above purchase order are in conformance with the requirements, specifications, and drawings applicable to that order.

All physical, chemical or other tests applicable to your order are on file, and copies of such reports will be furnished upon request.

Chlorine Content 1.4 ppm.

THE BRUSH BERYLLIUM COMPANY

Don E. Yambert
Quality Control Supervisor
Ceramic Department

GEAP-13595

THE BRUSH BERYLLIUM COMPANY
ELMORE, OHIO

CERTIFICATE OF COMPLIANCE
For December 22, 1967 Shipment

To:	<u>General Electric Company</u>	Date	<u>April 5, 1968</u>
	<u>175 Curtner Avenue</u>	Your PO	<u>205-K1080-6</u>
	<u>San Jose, California 95125</u>	Our SO	<u>U-961</u>
		Item No.	<u>1-Run 01</u>
		Quantity	<u>3,662 pcs.</u>

It is hereby certified that all articles herewith furnished in the quantities as called for in the above purchase order are in conformance with the requirements, specifications, and drawings applicable to that order.

All physical, chemical or other tests applicable to your order are on file, and copies of such reports will be furnished upon request.

Chlorine Content 2.7 ppm.

THE BRUSH BERYLLIUM COMPANY

Don E. Lambert
Quality Control Supervisor
Ceramic Department

THE BRUSH BERYLLIUM COMPANY
ELMORE, OHIO

CERTIFICATE OF COMPLIANCE
For December 22, 1967 Shipment

To:	<u>General Electric Company</u>	Date	<u>April 5, 1968</u>
	<u>175 Curtner Avenue</u>	Your PO	<u>205-K1080-6</u>
	<u>San Jose, California 95125</u>	Our SO	<u>U-961</u>
		Item No.	<u>1 Run 02</u>
		Quantity	<u>785</u>

It is hereby certified that all articles herewith furnished in the quantities as called for in the above purchase order are in conformance with the requirements, specifications, and drawings applicable to that order.

All physical, chemical or other tests applicable to your order are on file, and copies of such reports will be furnished upon request.

Chlorine Content 1.4 ppm.

THE BRUSH BERYLLIUM COMPANY

Don E. Lambert
Quality Control Supervisor
Ceramic Department

APPENDIX VII

Boron Carbide Specifications and Certifications

GENERAL ELECTRIC

STANDARDS

Atomic Power Equipment Department
SPECIFICATION

A 50YP 3 -S 3

ORDERS AND CORRESPONDANCE
MUST SPECIFY COMPLETE NUMBER

SH 1 OF 2

Supersedes A50YP3 -S2

TITLE BORON CARBIDE - COMPACTABLE GRADE

REFERENCE DOCUMENTS

The latest issues of the following publications form a part of this specification.

ASTM B214 "Sieve Analysis of Granular Metal Powder"

"Scott's Standard Methods of Chemical Analysis" - Vol. 1, Edited by N. H. Furman, published by D. Van Nostrand Company, Inc., Princeton, N.J.

1.0 SCOPE

1.1 This specification, identified as A50YP3, defines the requirements for boron carbide in granular form.

1.2 The requirements of the specification are for lots of blended powder of a given particle size distribution. The size of a lot shall be established by the Seller and shall be no larger than can be blended at any one operation.

2.0 CHEMICAL COMPOSITION

The chemical composition shall be determined by the Scott's Standard Method of Chemical Analysis (Analysis of Boron Carbide) where applicable. The analyses for other elements shall be by agreement.

2.1 Major Constituents% by Weight

Boron, min.	76.5
Carbon	Remainder

2.2 Impurities, max.

Boron Anhydride	0.1
Iron	0.8
Titanium	0.1
Chlorine & Fluorine, Total	100 ppm
Cobalt	50 ppm
Copper	100 ppm
Manganese	100 ppm
Sodium	100 ppm

(Continued on Page 2)

STANDARDS

GENERAL ELECTRIC
Atomic Power Equipment Department

A50 YP 3 -83

SH. NO. 2

SPECIFICATION2.3 Weight Loss on Drying

The weight loss of the material when heated for a minimum of one hour at a temperature of $400^{\circ}\text{C} \pm 10^{\circ}$ in an inert atmosphere shall not exceed 500 ppm.

♣ 2.4 Isotopic Composition

The isotopic composition shall be that which is normally found in Boron - 19.8 ± 0.3 atomic per cent or 18.3 ± 0.3 weight per cent of B^{10} .

3.0 PHYSICAL CHARACTERISTICS3.1 Particle Size Distribution - As specified on Purchasing Contract

The particle size distribution shall be uniform and shall be achieved through blending. The uniformity of the distribution shall be verified through a sieve analysis per ASTM B214, "Sieve Analysis of Granular Metal Powder," made by the Seller on two representative samples per lot of powder. The results of the test shall be reported to the Buyer as sieve fractions in the U.S. Standard Sieve Series.

3.2 Particle Density, min.

2.38 g/cc
(95% Theoretical)

4.0 CERTIFICATE OF TEST

The Seller shall certify in triplicate compliance with all requirements of the specification. The certification shall include a certified report of the results of the required tests: Chemical analysis, isotopic composition, weight loss on drying, and particle size distribution. The certification shall specify the lot size, purchase order number, and the G.E. specification designation.

5.0 PACKING AND MARKING

Material shall be shipped in standard commercial water-proof and air-tight containers to meet ICC and carriers' regulations. Each container shall be legibly marked with the purchase order number, the manufacturer's name or trade name, lot number, container number, shipper's gross, tare, net weights, and the G.E. designation.

HERMANN C. STARCK BERLIN

WERK GOSLAR
RECEIVED

APR 10 1967

O. E. GABRIEL

Korrespondenz. 338-GOSLAR (HARZ), POSTFACH 12

Telegramm: AMPERE GOSLAR

Telefon: (05321) 6501

Telex: 0953826

April 3, 1967

MH

Shieldalloy, NewfieldAnalysis No. 665

Date of Shipment:

A, B, C: March 22, 1967

D: March 23, 1967

		<u>14-20 mesh</u>	<u>60-80 mesh</u>	<u>200-325 mesh</u>	<u>-200 mesh</u>
14 drums	B	79,40	79,75	80,33	78,99
TAP 1904	C	20,34	19,90	19,00	19,47
A 1-5	Fe	0,06	0,06	0,12	0,075
B 1-7	B203	0,01	0,04	0,05	0,085
C 1-2	H	0,001	0,002	0,004	0,013
NEW YORK	N	0,03	0,11	0,20	0,60
B4C	O	0,075	0,10	0,25	0,60
D 1-2	1.0.1.	./.	./.	0,02	0,04

Screen Analysis

<u>525 lbs</u>		<u>675 lbs</u>		<u>150 lbs</u>		<u>150 lbs</u>	
<u>14-20 mesh</u>		<u>60-80 mesh</u>		<u>200 -325 mesh</u>		<u>-200 mesh</u>	
+14	0%	+50	0,05 %	+170	0,2 %	+170	42,4 %
-14 +18	37 %	-50 +60	5,85 %	-170+200	35,8 %	-170 +200	37,3 %
-18 +20	51 %	-60 +70	38,40 %	-200 +270	21,8 %	-200 +270	13,8 %
-20	12 %	-70 +100	54,90 %	-270 +325	31,3 %	-270 +400	3,6 %
		-100	0,80 %	-325	10,9 %	-400	2,9 %

General Electric
San Jose, Calif.
PO#K0214Dr. H. H. S.

29. Hd ch 01

-142-

CARBORUNDUM

The Carborundum Company • Electro Minerals Division • Post Office Box 423 • Niagara Falls, New York 14302

CERTIFICATE OF QUALITY

VENDOR: The Carborundum Company
Electro Minerals Division
Niagara Falls, New York

CUSTOMER: General Electric Company
Atomic Power Equipment Department
175 Curtner Avenue
San Jose, California 95125

MATERIAL: Boron Carbide Powder - Nuclear Grade
14/20 mesh
~~Lot 68-1~~
100 pounds
Customer Order No. 205 A4847G
Carborundum Order No. 01-268-302 Item 1
Shipped 2/13/68

SPECIFICATION: A 50YP3-53
Dated 5/5/66

Seller certifies compliance with all requirements of the certification,
except as herein noted.

Signed;

A. S. Labl

Title: Senior Engineer
Quality Control Department
Technical Branch

Date: 13 February 1968

ANALYTICAL DATA

Data in percent unless otherwise indicated. X indicates average.

	<u>1</u>	<u>2</u>	<u>3</u>	<u>X</u>
Boron	81.56	81.56	81.18	81.43
Carbon	16.40	16.54	16.43	16.46
*Boron Anhydride	0.31	0.32	0.32	0.32
Iron	0.87	0.77	0.75	0.79
Titanium	<0.05	<0.05	<0.05	<0.05
**Chloride, ppm	-	-	-	10 <25
Fluorine	-	-	-	0.095
Cobalt, ppm	<25	<25	<25	<25
Copper, ppm	<50	<50	<50	<50
Manganese, ppm,	<50	<50	<50	<50
Sodium, ppm	<100	<100	<100	<100
***Drying Moisture	-	-	-	0.000
Density- grams/cc	2.38	2.37	2.38	2.38

The isotopic composition is that which is normally found in Boron - 18.3 ± 0.3 weight percent of B10.

*Specification 0.1% max.

**Specification chlorine + Fluorine 100 ppm

***Dried at 200°C for one hour.

Particle Size Distribution

U.S.Standard Sieve Series

	<u>1</u>	<u>2</u>
+14	0.7	0.6
-14+20	69.7	69.9
-20	29.6	29.5

CARBORUNDUM

The Carborundum Company • Electro Minerals Division • Post Office Box 423 • Niagara Falls, New York 14302

CERTIFICATE OF QUALITY

VENDOR: The Carborundum Company
Electro Minerals Division
Niagara Falls, New York

CUSTOMER: General Electric Company
Atomic Power Equipment Department
175 Curtner Avenue
San Jose, California 95125

MATERIAL: Boron Carbide Powder - Nuclear Grade
60/80 mesh
Lot 68-2
200 pounds
Customer Order No. 205 A4847G
Carborundum Order No. 91-268-302 Item 2
Shipped 2/13/68

SPECIFICATION: A 50YP3-53
Dated 5/5/66

Seller certifies compliance with all requirements of the certification, except as herein noted.

Signed:

A. S. Labi

Title: Senior Engineer
Quality Control Department
Technical Branch

Date 13 February 1968

ANALYTICAL DATA

Data in percent unless otherwise stated. X indicates average.

	<u>1</u>	<u>2</u>	<u>3</u>	<u>X</u>
Boron	79.11	78.95	79.20	79.09
Carbon	19.57	19.53	19.52	19.54
*Boron Anhydride	0.14	0.10	0.08	0.11
Iron	0.48	0.52	0.52	0.51
Titanium	<0.05	<0.05	<0.05	<0.05
Chlorine + Fluorine, Total ppm	-	-	-	<20
Cobalt, ppm	<25	<25	<25	<25
Copper, ppm	<50	<50	<50	<50
Manganese, ppm	<50	<50	<50	<50
Sodium, ppm	<100	<100	<100	<100
**Drying Moisture	-	-	-	0.005
Density - grams/cc	2.45	2.46	2.47	2.46

The isotopic composition is that which is normally found in Boron - 18.3 ± 0.9 weight percent of B10.

*Specification 0.1% max.

**Dried at 200°C for one hour

Particle Size Distribution

U.S. Standard Sieve Series

	<u>1</u>	<u>2</u>
+60	10.3	10.4
-60+80	38.5	38.6
-80	51.2	51.0

CARBORUNDUM

GEAP-13595

The Carborundum Company · Electro Minerals Division · Post Office Box 423 · Niagara Falls, New York 14302

CERTIFICATE OF QUALITY

VENDOR: The Carborundum Company
Electro Minerals Division
Niagara Falls, New York

CUSTOMER: General Electric Company
Atomic Power Equipment Department
175 Curtner Avenue
San Jose, California 95125

MATERIAL: Boron Carbide Powder - Nuclear Grade
200/Finer mesh
Lot 68-3
30 pounds
Customer Order No. 205-A4847G
Carborundum Order No. 01-268-302 Item 3
Shipped 2/13/68

SPECIFICATION: A 50YP3-53
Dated 5/5/66

Seller certifies compliance with all requirements of the certification, except as herein noted.

Signed:

A. S. Labi

Title: Senior Engineer
Quality Control Department
Technical Branch

Date: 13 February 1968

ANALYTICAL DATA

Data in percent unless otherwise stated. X indicates average.

	<u>1</u>	<u>2</u>	<u>3</u>	<u>X</u>
Boron	79.74	79.71	79.70	79.72
Carbon	18.30	18.36	18.41	18.36
Boron Anhydride	0.02	0.02	0.02	0.02
Iron	0.46	0.44	0.43	0.44
Titanium	<0.05	<0.05	<0.05	<0.05
Chlorine+Fluorine, Total ppm	-	-	-	<20
Cobalt, ppm	<25	<25	<25	<25
Copper, ppm	<50	<50	<50	<50
Manganese, ppm	<50	<50	<50	<50
Sodium, ppm	<100	<100	<100	<100
*Drying moisture	-	-	-	0.007
Density - grams/cc	2.47	2.47	2.48	2.47

The isotopic composition is that which is normally found in Boron - 18.3 ± 0.3 weight percent of B10.

*Dried at 200°C for one hour.

Particle Size Distribution

U.S. Standard Sieve Series

	<u>1</u>	<u>2</u>
+200	1.8	1.4
-200+325	26.6	27.2
-325	71.6	71.3

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GEAP-13595

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Mr. L. W. Fromm, Manager 1000 MWe LMFBR Follow-On Study Project Building 208 Argonne National Laboratory 9800 South Cass Avenue Argonne, Illinois 60439	2
USAEC Scientific Representative United States Embassy, Box 40 FPO New York, N. Y. 09510	1