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WANL-TME-1480

August, 1966

MASTER

Westinghouse Astronuclear Laboratory

SUMMARY OF DEVELOPMENT EFFORT
IN EXTRUDED-TO-SIZE FUEL ELEMENTS

(Title Unclassified)

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Subject: WANL-TME-1480, Summary of Development Effort in Extruded-to-Size Fuel Elements

Dear Mr. Dooling:

Transmitted herewith are ten (10) copies of the subject report. The work described in this report was accomplished about a year ago and reported in the Quarterly Progress report. It is being published in more detail at this time as a result of an oral request from SNPO representatives.

Respectfully,

H. F. Faught, Program Manager
NERVA Nuclear Subsystem

WRE:as

Enclosures - 10

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**SUMMARY OF DEVELOPMENT EFFORT
IN EXTRUDED-TO-SIZE FUEL ELEMENTS**

(Title Unclassified)

Submitted by: F. M. Kotulak
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Classification cancelled (or changed to) _____
by authority of _____
by H. F. C. TIC, date SEP 12 1973

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SPECIAL REVIEW FINAL DETERMINATION	Reviewer	Class.	Date
	<u>TR</u>	<u>U</u>	<u>4-14-82</u>
Class: <u>U</u>			

INFORMATION CATEGORY
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SUMMARY OF DEVELOPMENT EFFORT IN EXTRUDED-TO-SIZE FUEL ELEMENTS

INTRODUCTION

The NRX-A fuel element as currently produced is extruded to 0.815 inches across flats with bore diameters of 0.092 through 0.100 inches. During the course of thermal processing, through cure, bake, and graphitization, the element shrinks to approximately 0.784 inches across flats with bore diameters of approximately 0.086 inches (center hole only) and 0.093 inches. To achieve the required 0.753 inches across flats dimension requires a three-pass sequence in broaching. The bores must be reamed to obtain 0.099 inch diameter channels.

The necessary machining requirements and the movement of elements to and from these machining operations constitute a major part of fuel element production. The logical approach to a reduction in the operations required is to extrude the element to dimensional tolerances requiring a minimum of machining, i.e. extrusion-to-size.

A development program aimed at extrusion "to size" was initiated early this year to acquire sufficient data for evaluation. The results and conclusions presented here were based on an evaluation of the data obtained as of September 8, 1965.

SUMMARY AND CONCLUSIONS

The extrusion-to-size program was directed towards extrusion of an NRX A type fuel element with "as machined" dimensional control while maintaining or hopefully improving upon the structural integrity of the element. The aim was an improvement in element quality through better hole location, lower porosity resulting from non-machined surfaces, and a reduction in machining operations required to produce an element to drawing specifications.

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Approximately nine hundred elements were extruded for evaluation of extrusion-to-size. Of these 723 non-fueled were extruded with both bores and across flats "to size" (after graphitization) and 163 loaded elements were extruded with bores "to size" and across flats "almost to size" (after graphitization). The extrusion of these elements was made with a new extrusion die designed for flexibility in hole diameter and across flats dimension. (Figure 1). All elements were processed through the standard cure, bake, and graphitization cycles, after which dimensional inspection was performed. Randomly selected elements were shipped to WANL for mechanical tests. Non-fuel tips and sleeves were applied to other elements after which they were processed through coating and finally corrosion tested. The non-fuel sleeves and tips used were extruded at WAFF as part of this program.

The following conclusions can be made based on an analysis of the data:

1. Hole diameters of $0.099 \pm .001$ inch in the "as graphitized" condition can be achieved in Code 3 through Code 9 loaded elements. This is based on an analysis of some 2850 hole diameter measurements. In all cases the "as graphitized" hole diameters fell in the range of 0.0984 to 0.0991 with the average at 0.0987 inches. A similar tolerance spread was found in non-fuel hole diameter measurements.
2. The spread in "as graphitized" across flats measurements within any one element is comparable to similar measurements made on "as machined" elements. However, element to element variations within any one extrusion batch exceed the current ± 0.001 inch dimensional specification. Experimental work performed (ref. figures 2 and 3) indicates that this characteristic can at least in part be

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attributed to density variations across the pre-compacted wet mix slug used to charge the extrusion press cylinder.

3. The following factors also affect shrinkage during thermal cycling and will require careful control.

- 3.1 The correct batch formulation with the proper binder addition. Variations can adversely affect the extrusion pressure causing an unbalance in flow and density variations throughout the element.

- 3.2 Consistent extrusion pressure. Extrusion pressure changes disrupt the flow distribution through the die resulting in movement in the extrusion pins and subsequent hole dislocation.

- 3.3 Dimensional changes in extrusion tooling through wear. Feed path wear in parts or pins will affect hole location, and/or size as well as across flats dimensions.

4. The application of the non-fuel tip becomes a problem in extruded-to-size fuel elements. Alignment of the non-fuel tip to the fuel element must be such that no channel mismatch can occur. This requires precise tooling and inspection techniques. The possible adoption of slightly larger bore diameters in the non-fuel tip should be considered.

5. Fuel bead "pop out" on the outside surfaces as well as in the bores is a major problem on extrusion-to-size. The particulate debris surrounding the bead eruption can generally be removed from the outside surfaces by brushing or scraping, and power brushing can be employed to clean the bores with no detrimental

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effects on air flow impedance. It is suspected that partial eruptions (ref. Figure 4) contribute to premature element (corrosion) failure.

6. Hydrogen corrosion test results on coated extruded-to-size elements were not as favorable as on standard reamed elements. Corrosion tests performed at WANL (Ref. TMI-1528) show that ETS elements had an average ΔW of 20.0 grams while standard reamed elements had an average ΔW of 12.3 grams for 30 minutes at IB temperatures.
7. The mechanical strength of extruded-to-size elements for both flexure and compression compares favorably with standard process elements. The average flexure strength for four ETS elements tested was 5333 psi and the average compression strength was 12,517 psi.
8. In view of the results obtained, it appears that additional development is required before adoption of extrusion-to-size. It is possible, however, to adequately control the process so as to provide as graphitized elements to the broaching operation which are $0.759 \pm .002$ inches across flats requiring only a single pass broach as opposed to the three pass broach sequence presently used.

NON-FUEL SLEEVES AND TIPS

The process for extrusion of non-fueled hex shaped sleeve stock developed at WAFF was used to produce the necessary non-fueled sleeves for this program. The sleeves were obtained by extrusion of non-fuel material in a modified die set up to result in an 0.724 inch across flats dimension with an 0.100 inch wall after cure. This permits inside machining to achieve an 0.734 inch across flats roughened surface for bonding to the undercut of a fuel element. In addition to regular hex shaped sleeve stock, non-fuel

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sleeve stock was extruded for the Code 32 (half) element having a major across flats dimension of 0.724 and a minor across flats dimension of 0.428 inches after cure. Non-fuel solids were extruded .815 across flats and machined after cure to provide the necessary non-fuel tips for ETS fueled elements.

RAW MATERIALS

Standard dry carbon ingredients of 85 parts graphite flour to 15 parts carbon black with 28 weight per cent varcum 8251 binder catalyzed with four grams maleic anhydride per 100 ml binder were combined for non-fueled extrusions. Pyrolytic carbon coated uranium dicarbide fuel particles procured from Carbon Products Company and General Atomic Company were combined in the required code quantities for loaded elements. Type "RL" flour (P.O. 46339) from Speer Carbon Company was used in loaded elements and Type "W" flour (P.O. 46346) from Great Lakes Carbon Company was used for non-fueled extrusions.

EXTRUSION

Extrusion-to-size was accomplished through the use of a new die designed for wide range dimensional flexibility in both hole size and across flats measurements. Inter-changeable sizing inserts and adapters as well as a variety of extrusion pin sizes provide capabilities of extrusion of elements to exacting tolerances. (Ref. Figure 1).

1. Die set up used for extrusion of non-fuel elements with both bores and across flats measurements "to size".

Center Hole 10 = .080/.1057 diameter pin
Holes 1, 3, 8, 12, 17 & 19 = .1030 diameter pins
Holes 2, 4, 7, 13, 16 & 18 = .1035 diameter pins
Holes 5, 6, 9, 11, 14 & 15 = .1045 diameter pins
Feed Hole = .160 x .459
Plenum Adapter = .791 A.F. Hex (S/N 24154 through 24243)
Plenum Adapter = .790 A.F. Hex (S/N 24244 through 24915)
Plenum Adapter = .789 A.F. Hex (S/N 24916 through 25225)

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2. Die set up used for extrusion of Code 9 loaded elements with bores "to size" and across flats "almost to size".

Aim Loading 436 mg/cc

Center Hole 10 = .080/.1050 diameter pin

Holes 1, 3, 8, 12, 17 & 19 = .1025 diameter pins

Holes 2, 4, 7, 13, 16, & 18 = .1030 diameter pins

Holes 5, 6, 9, 11, 14 & 15 = .1037 diameter pins

Feed Hole = .160 x .459

Plenum Adapter = .795 A.F. Hex

3. Die set up used for extrusion of Code 3 loaded elements with bores "to size" and across flats "almost to size".

Aim Loading = 139 mg/cc

Center Hole 10 = .080/.1057 diameter pin

Holes 1, 3, 8, 12, 17 & 19 = .1030 diameter pins

Holes 2, 4, 7, 13, 16 & 18 = .1035 diameter pins

Holes 5, 6, 9, 11, 14 & 15 = .1045 diameter pins

Feed Hole = .160 x .459

Plenum Adapter = .795 A.F. Hex

4. Die set up used for extrusion of non-fuel sleeves.

Center Pin = .730 A.F. Hex

Plenum = .925 A.F. Hex

5. Solids for (machined) non-fuel tips were extruded .815 A.F.

FIGURE I CROSS SECTION VIEW OF EXTRUDE-TO-SIZE DIE

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DISCUSSION OF DATA

The processing data on 163 fueled ETS elements is compiled in Tables 1 (Code 3) and 2 (Code 9). These elements were extruded with across flats "almost to size" and bores "to size" (after graphitization). The die set-up was based on a shrinkage rate of approximately 3.89 per cent from extrusion through graphitization, for Code 9 and 4.6 per cent for Code 3. As indicated in the tables, the as-graphitized aim loading for Code 9 as determined by gamma count was within 1.4 per cent of aim and 3.6 per cent of aim on Code 3. The "as-graphitized" bore diameter range for any one element is within 0.001. Bore diameter element to element variation is within .002 inch. Hole locations are all within drawing specification.

The processing data in Tables 3 and 4 was compiled on some 723 non-fuel ETS elements. These elements were extruded with both bores and across flats "to size" (after graphitization). This lot of non-fueled elements was extruded in three groups. The only change from group to group was the extruded "across flats" measurement. Group 1- (S/N 24154 through 24243) was extruded with a 0.791 across flats adapter; Group 2 - (S/N 24244 through 24915) was extruded with a 0.790 across flats adapter; and Group 3 - (S/N 24916 through 25225) was extruded with a 0.789 across flats adapter. The intent was to provide a sufficient quantity of elements for dimensional data as well as supplying elements to WANL for core design studies.

The shrinkage rate from extrusion through graphitization on non-fuel elements was approximately 5 per cent. Bore diameter and across flats dimensional variations on non-fueled elements were similar to loaded elements.

TABLE 1

PROCESSING DATA - CODE 3 LOADED ELEMENTS (EXTRUDED WITH BORES "TO SIZE AND ACROSS FLATS "ALMOST TO SIZE"

As Extruded Across Flats = 0.798				As-Graphitized		Aim Loading = 139 mg/cc		
Batch No.	Element S/N	As-Graphitized Dimensional Range Across Flats	Δ A.F. (Shrinkage)	As-Graphitized Hole Location	As-Graphitized Bore Diameter	Uranium Loading (mg/cc)		Fuel Vendor
				Dimensional Range (From True Position)	Dimensional Range	As Leached	As Graph.	
2651	24091	.7615 - .7629	.0358	.002 - .008	.0979 - .0987		143	CP
2651	24092	.7608 - .7615	.0369	.000 - .005	.0982 - .0988		143	CP
2651	24093	.7598 - .7608	.0377	.001 - .007	.0980 - .0986		143	CP
2651	24094			.000 - .008	.0982 - .0987		143	CP
2651	24095	.7605 - .7618	.0369	*	*			CP
2651	24096	.7599 - .7610	.0376	.001 - .008	.0980 - .0988		143	CP
2651	24097	.7606 - .7615	.0370	*	*	137		CP
2651	24098	.7606 - .7616	.0369	*	*	138		CP
2652	24099	.7598 - .7605	.0379	*	*		143	CP
2652	24100	.7602 - .7617	.0371	.000 - .007	.0982 - .0987		143	CP
2652	24101	.7603 - .7624	.0367	*	*			CP
2652	24102	.7604 - .7617	.0370	.002 - .007	.0979 - .0989		143	CP
2652	24103	.7601 - .7611	.0374	*	*	139		CP
2652	24104	.7604 - .7618	.0369	.003 - .008	.0979 - .0987		143	CP
2652	24105	.7602 - .7615	.0372	*	*	138		CP
2652	24106	.7598 - .7605	.0379	.002 - .008	.0979 - .0985		143	CP
2652	24107	.7600 - .7610	.0375	.001 - .007	.0981 - .0986		143	CP
2652	24108	.7606 - .7615	.0370	*	*			CP
2653	24109	.7610 - .7622	.0364	.001 - .005	.0981 - .0988		144	CP
2653	24110	.7602 - .7611	.0374	.002 - .005	.0981 - .0986		143	CP
2653	24111	.7599 - .7608	.0377	.002 - .005	.0980 - .0987		144	CP
2653	24112	.7599 - .7608	.0377	.003 - .007	.0981 - .0986			CP
2653	24113	.7605 - .7615	.0370	.000 - .009	.0980 - .0988		144	CP
2653	24114	.7599 - .7604	.0379	.002 - .006	.0981 - .0987		143	CP
2653	24115	.7597 - .7604	.0380	.003 - .007	.0981 - .0985		144	CP
2653	24116	.7595 - .7603	.0381	.002 - .006	.0981 - .0986		144	CP

TABLE 1 (CONT.)

Batch No.	Element S/N	As-Graphitized Dimensional Range Across Flats	Δ A.F. (Shrinkage)	As-Graphitized Hole Location Dimensional Range (From True Position)	As-Graphitized Bore Diameter Dimensional Range	Uranium Loading (mg/cc)		Fuel Vendor
						As Leached	As Graph.	
2653	24117	.7598 - .7605	.0379	.000 - .006	.0982 - .0986		143	CP
2653	24118	.7601 - .7609	.0375	.002 - .007	.0981 - .0986		143	CP
2653	24119	.7611 - .7615	.0367	.000 - .006	.0981 - .0985		144	CP
2327	24120	.7611 - .7622	.0364	.000 - .004	.0980 - .0987		142	GA
2327	24121	.7609 - .7617	.0367	.001 - .008	.0983 - .0987		143	GA
2327	24122	.7611 - .7623	.0363	.001 - .007	.0980 - .0987		143	GA
2327	24123	.7605 - .7617	.0369	.002 - .010	.0979 - .0986		140	GA
2327	24124	.7613 - .7619	.0364	.001 - .009	.0983 - .0990		144	GA
2327	24125	.7608 - .7619	.0367	.002 - .006	.0982 - .0988		143	GA
2327	24126	.7610 - .7619	.0366	.002 - .005	.0982 - .0987		144	GA
2327	24127	.7613 - .7624	.0362	.001 - .005	.0981 - .0988		143	GA
2327	24128	.7609 - .7617	.0367	.001 - .007	.0982 - .0987		143	GA
2327	24129	.7609 - .7615	.0368	.001 - .007	.0981 - .0988		143	GA
2327	24130	.7611 - .7617	.0366	*	*	138		GA
2459	24131	.7617 - .7635	.0354	*	*	137		GA
2459	24132	.7611 - .7620	.0365	*	*	137		GA
2459	24133	.7610 - .7619	.0366	*	*			GA
2459	24134	.7604 - .7620	.0368	.001 - .006	.0981 - .0986		143	GA
2459	24135	.7606 - .7617	.0369	.002 - .007	.0978 - .0984		142	GA
2459	24136	.7607 - .7618	.0368	.001 - .006	.0979 - .0987		143	GA
2459	24137	.7607 - .7618	.0368	.000 - .005	.0980 - .0987		143	GA
2459	24138	.7610 - .7618	.0366	.001 - .004	.0981 - .0986		143	GA
2459	24139	.7604 - .7610	.0373	.001 - .003	.0980 - .0986		143	GA
2459	24140	.7603 - .7611	.0373	.001 - .004	.0980 - .0985		143	GA
2459	24141	.7605 - .7615	.0370	.002 - .007	.0980 - .0987		143	GA
2460	24142	.7610 - .7620	.0365	.000 - .005	.0983 - .0988		143	GA
2460	24143	.7605 - .7616	.0371	.002 - .007	.0982 - .0987		143	CP
2460	24144	.7608 - .7617	.0368	.000 - .007	.0979 - .0987		143	CP
2460	24145	.7608 - .7621	.0366	.000 - .006	.0983 - .0987		143	CP
2460	24146	.7605 - .7615	.0370	.000 - .006	.0980 - .0987		142	CP

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TABLE 1 (CONT.)

Batch No.	Element S/N	As-Graphitized Dimensional Range Across Flats	Δ A.F. (Shrinkage)	As-Graphitized Hole Location Dimensional Range (From True Position)	As-Graphitized Bore Diameter Dimensional Range	Uranium Loading (mg/cc)		Fuel Vendor
						As Leached	As Graph.	
2460	24147	.7603 - .7612	.0373	.001 - .005	.0983 - .0987		143	CP
2460	24148	.7609 - .7615	.0368	.001 - .004	.0982 - .0986		143	CP
2460	24149	.7603 - .7611	.0373	*	*		142	CP
2460	24150	.7605 - .7614	.0371	.000 - .004	.0983 - .0987		143	CP
2460	24151	.7605 - .7614	.0371	*	*	138		CP
2460	24152	.7603 - .7615	.0371	.000 - .004	.0981 - .0986		143	CP
2460	24153	.7606 - .7614	.0370	*	*	138		CP

* No Data Available

TABLE 2

PROCESSING DATA - CODE 9 LOADED ELEMENTS (EXTRUDED WITH BORES "TO SIZE" AND
ACROSS FLATS "ALMOST TO SIZE"

As Extruded Across Flats = 0.798				As-Graphitized		Aim Loading = 436 mg/cc		
Batch No.	Element S/N	As-Graphitized Dimensional Range Across Flats	Δ A.F. (Shrinkage)	As-Graphitized Hole Location	As-Graphitized Bore Diameter	Uranium Loading (mg/cc)		Fuel Vendor
				Dimensional Range (From True Position)	Dimensional Range	As Leached	As Graph.	
2620	23993	.7671 - .7678	.0306	.002 - .009	.0980 - .0988		436	GA
2620	23994	.7661 - .7665	.0317	.001 - .006	.0985 - .0988		437	GA
2620	23995	.7664 - .7675	.0311	.003 - .009	.0985 - .0991		436	GA
2620	23996	.7663 - .7672	.0313	.001 - .010	.0985 - .0990		437	GA
2620	23997	.7664 - .7680	.0313	.001 - .012	.0985 - .0990		438	GA
2620	23998	.7662 - .7669	.0315	.002 - .009	.0980 - .0988		436	GA
2620	23999	.7659 - .7665	.0318	*	.0985 - .0990		436	GA
2620	24000	.7662 - .7667	.0316	.002 - .008	.0983 - .0988		436	GA
2621	24001	.7667 - .7681	.0311	.001 - .007	.0982 - .0988	417	437	GA
2621	24002	.7661 - .7670	.0315	.003 - .009	.0983 - .0987		436	GA
2621	24003	.7661 - .7667	.0316	.001 - .007	.0982 - .0987		437	GA
2621	24004	.7661 - .7665	.0317	*	*			GA
2621	24005	.7661 - .7666	.0315	.003 - .010	*	418		GA
2621	24006	.7662 - .7674	.0312	.003 - .010	.0978 - .0989	419	437	GA
2621	24007	.7654 - .7671	.0318	.002 - .008	.0985 - .0988		437	GA
2621	24008	.7661 - .7668	.0316	.003 - .010	.0982 - .0987	421	438	GA
2621	24009	.7660 - .7668	.0316	.002 - .010	.0980 - .0987	418	437	GA
2621	24010	.7662 - .7668	.0315	.002 - .008	.0983 - .0989	419	438	GA
2621	24011	.7664 - .7679	.0309	.002 - .009	.0980 - .0989	407	438	GA
2622	24012	.7671 - .7688	.0301	*	*	418		GA
2622	24013	.7663 - .7672	.0313	.002 - .008	.0983 - .0988	419	438	GA
2622	24014	.7661 - .7671	.0314	*	*	419		GA
2622	24015	.7662 - .7671	.0314	*	*	417		GA
2622	24016	.7663 - .7669	.0314	.002 - .009	.0985 - .0989		437	GA
2622	24017	.7664 - .7671	.0313	.001 - .008	.0984 - .0990		437	GA
2622	24018	.7661 - .7669	.0315	.002 - .007	.0985 - .0988		439	GA

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TABLE 2 (CONT.)

Batch No.	Element S/N	As-Graphitized Dimensional Range Across Flats	Δ A.F. (Shrinkage)	As-Graphitized Hole Location Dimensional Range (From True Position)	As-Graphitized Bore Diameter Dimensional Range	Uranium Loading (mg/cc)		Fuel Vendor
						As Leached	As Graph.	
2622	24019	.7662 - .7670	.0314	.001 - .007	.0984 - .0987		438	GA
2622	24020	.7666 - .7673	.0311	.002 - .007	.0985 - .0989		440	GA
2622	24021	.7662 - .7674	.0312	.001 - .008	.0985 - .0988		440	GA
2623	24022	.7668 - .7680	.0306	.002 - .008	.0985 - .0988		438	GA
2623	24023	.7662 - .7669	.0315	.003 - .009	.0983 - .0987		437	GA
2623	24024	.7663 - .7670	.0314	.002 - .008	.0985 - .0989		437	GA
2623	24025	.7658 - .7654	.0324	.001 - .004	.0986 - .0989		438	GA
2623	24026	.7660 - .7667	.0317	.002 - .011	.0983 - .0989		437	GA
2623	24027	.7662 - .7672	.0313	.003 - .011	.0985 - .0991		436	GA
2623	24028	.7662 - .7668	.0315	.001 - .007	.0980 - .0987		438	GA
2623	24029	.7663 - .7667	.0315	.003 - .008	.0981 - .0987		438	GA
2623	24030	.7661 - .7666	.0317	.002 - .009	.0981 - .0987		438	GA
2623	24031	.7663 - .7669	.0314	.002 - .010	.0980 - .0988	410	440	GA
2624	24032	.7661 - .7680	.0310	.002 - .010	.0983 - .0990		438	GA
2624	24033	.7662 - .7676	.0311	.001 - .007	.0980 - .0987	418	439	GA
2624	24034	.7658 - .7667	.0318	.003 - .009	.0985 - .0989		437	GA
2624	24035	.7662 - .7666	.0316	*	*	419		GA
2624	24036	.7661 - .7666	.0317	*	*	417		GA
2624	24037	.7661 - .7666	.0317	.003 - .010	.0982 - .0989	407	439	GA
2624	24038	.7661 - .7670	.0315	.002 - .009	.0985 - .0990		438	GA
2624	24039	.7661 - .7668	.0316	.002 - .009	.0985 - .0990		438	GA
2624	24040	.7660 - .7670	.0315	.001 - .005	.0985 - .0990		438/437	GA
2624	24041	.7662 - .7670	.0314	.001 - .005	.0985 - .0990		438	GA
2640	24042	.7676 - .7687	.0299	.002 - .009	.0984 - .0989	420	441	CP
2640	24043	.7673 - .7684	.0302	.001 - .010	.0985 - .0991		441	CP
2640	24044	.7677 - .7687	.0298	.001 - .004	.0985 - .0989	419	441	CP
2640	24045	.7678 - .7686	.0298	*	*	420		CP
2640	24046	.7677 - .7685	.0299	*	*			CP
2640	24047	.7677 - .7685	.0299	*	*			CP
2640	24048	.7675 - .7684	.0301	*	*	421		CP

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TABLE 2 (CONT.)

Batch No.	Element S/N	As-Graphitized Dimensional Range Across Flats	Δ A.F. (Shrinkage)	As-Graphitized Hole Location Dimensional Range (From True Position)	As-Graphitized Bore Diameter Dimensional Range	Uranium Loading (mg/cc)		Fuel Vendor
						As Leached	As Graph.	
2640	24049	.7676 - .7685	.0300	.001 - .007	.0986 - .0990		442	CP
2640	24050	.7675 - .7680	.0303	.002 - .007	.0986 - .0990		443	CP
2640	24051	.7671 - .7678	.0306	.001 - .008	.0986 - .0991		443	CP
2640	24052	.7668 - .7678	.0308	.002 - .008	.0985 - .0990		441	CP
2641	24053	.7670 - .7677	.0307	.002 - .010	.0984 - .0991		441	CP
2641	24054	.7662 - .7670	.0314	.001 - .009	.0985 - .0991		434	CP
2641	24055	.7665 - .7675	.0310	.002 - .010	.0985 - .0990		441	CP
2641	24056	.7670 - .7685	.0303	.001 - .009	.0985 - .0991		439	CP
2641	24057	.7660 - .7670	.0315	.001 - .009	.0982 - .0987		439	CP
2641	24058	.7663 - .7673	.0312	.001 - .008	.0983 - .0987		437	CP
2641	24059			*	.0985 - .0990		438	CP
2642	24060	.7656 - .7662	.0321	.001 - .009	.0984 - .0987		438	CP
2642	24061	.7657 - .7670	.0317	.003 - .009	.0985 - .0991		441	CP
2642	24062	.7657 - .7667	.0318	.002 - .007	.0984 - .0991		439	CP
2642	24063	.7665 - .7676	.0310	.002 - .011	.0985 - .0992		439	CP
2642	24064	.7654 - .7662	.0322	.001 - .008	.0984 - .0989		440	CP
2642	24065	.7663 - .7674	.0312	*	*			CP
2642	24066	.7659 - .7670	.0316	*	*	422		CP
2642	24067	.7660 - .7668	.0316	.001 - .006	.0984 - .0989		440	CP
2642	24068	.7658 - .7664	.0319	.003 - .007	.0985 - .0987		438	CP
2642	24069	.7652 - .7660	.0324	.001 - .005	.0985 - .0988		439	CP
2642	24070	.7652 - .7662	.0323	.000 - .007	.0986 - .0989		440/439	CP
2644	24071	.7657 - .7678	.0313	.001 - .008	.0984 - .0990		438	CP
2644	24072	.7651 - .7667	.0321	.001 - .005	.0985 - .0991		439	CP
2644	24073	.7654 - .7675	.0321	.002 - .006	.0985 - .0988		438	CP
2644	24074	.7656 - .7665	.0320	.001 - .009	.0985 - .0988		439	CP
2644	24075	.7648 - .7659	.0327	.001 - .008	.0985 - .0991		439	CP
2644	24076	.7655 - .7666	.0320	.001 - .008	.0985 - .0990		437	CP
2644	24077	.7654 - .7667	.0320	.002 - .006	.0985 - .0989		439	CP
2644	24078	.7654 - .7664	.0321	.001 - .008	.0984 - .0989		439	CP

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TABLE 2 (CONT.)

Batch No.	Element S/N	As-Graphitized Dimensional Range Across Flats	Δ A.F. (Shrinkage)	As-Graphitized Hole Location Dimensional Range (From True Position)	As-Graphitized Bore Diameter Dimensional Range	Uranium Loading (mg/cc)		Fuel Vendor
						As Leached	As Graph.	
2644	24079	.7653 - .7666	.0321	.002 - .007	.0982 - .0987	411	439	CP
2644	24080	.7656 - .7669	.0318	.001 - .005	.0984 - .0989		440/438	CP
2645	24081	.7653 - .7664	.0322	.001 - .011	.0986 - .0991		438	CP
2645	24082	.7649 - .7663	.0324	.001 - .010	.0985 - .0989		438	CP
2645	24083	.7649 - .7657	.0327	.002 - .013	.0978 - .0986	412	440	CP
2645	24084	.7642 - .7663	.0328	.000 - .009	.0979 - .0987		439	CP
2645	24085	.7644 - .7656	.0330	.002 - .006	.0981 - .0986		438	CP
2645	24086	.7645 - .7659	.0328		.0980 - .0987	411	439	CP
2645	24087	.7649 - .7660	.0326	.001 - .008	.0980 - .0987	410	439	CP
2645	24088	.7653 - .7661	.0323	.002 - .009	.0980 - .0987	410	439	CP
2645	24089	.7652 - .7661	.0324	.002 - .011	.0982 - .0987	412	440	CP
2645	24090	.7654 - .7660	.0323	.001 - .010	.0981 - .0987	410	440	CP

* No Data Available

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TABLE 3
TYPICAL AS GRAPHITIZED HOLE LOCATION RESULTS OF NON-FUELED
ELEMENTS EXTRUDED-TO-SIZE

Batch Number	Element S/N	Hole Location Range (From True Position)
2654	24154	.001 - .009
2654	24155	.003 - .009
2654	24156	.001 - .008
2654	24157	.001 - .007
2654	24158	.003 - .009
2654	24159	.001 - .008
2654	24160	.003 - .008
2654	24161	T.P. - .009
2654	24162	.001 - .008
2655	24163	T.P. - .007
2655	24164	T.P. - .008
2655	24165	T.P. - .008
2655	24166	T.P. - .009
2655	24167	.003 - .009
2655	24168	.002 - .008
2655	24169	.001 - .009
2655	24170	.001 - .009
2655	24171	T.P. - .008
2655	24172	.001 - .007
2656	24173	T.P. - .008
2656	24174	.001 - .008
2656	24175	.004 - .008
2656	24176	T.P. - .007
2656	24177	.002 - .007
2656	24178	.001 - .008
2656	24179	.001 - .007
2656	24180	.001 - .007
2656	24181	.003 - .008
2656	24182	.001 - .008
2656	24183	.004 - .007

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TABLE 4
PROCESSING DATA - NON-FUEL ELEMENTS EXTRUDED-TO-SIZE
(Extruded with Bores and Across Flats "To-Size")

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2654	24154	.7542 - .7552	.0403	.0979 - .0989
2654	24155	.7537 - .7544	.0410	.0980 - .0985
2654	24156	.7537 - .7543	.0410	.0980 - .0984
2654	24157	.7539 - .7545	.0408	.0980 - .0987
2654	24158	.7541 - .7545	.0407	.0980 - .0988
2654	24159	.7540 - .7552	.0404	.0980 - .0984
2654	24160	.7542 - .7549	.0405	.0979 - .0984
2654	24161	.7575 - .7567	.0409	.0967 - .0985
2654	24162	.7542 - .7549	.0405	.0978 - .0986
2655	24163	.7532 - .7545	.0412	.0977 - .0985
2655	24164	.7534 - .7542	.0412	.0980 - .0984
2655	24165	.7534 - .7541	.0413	.0981 - .0984
2655	24166	.7533 - .7545	.0411	.0978 - .0986
2655	24167	.7535 - .7546	.0410	.0978 - .0988
2655	24168	.7532 - .7539	.0415	.0979 - .0985
2655	24169	.7530 - .7543	.0414	.0979 - .0984
2655	24170	.7532 - .7540	.0414	.0979 - .0983
2655	24171	.7534 - .7540	.0417	.0978 - .0983
2655	24172	.7535 - .7544	.0411	.0978 - .0984
2656	24173	.7545 - .7553	.0401	.0980 - .0986
2656	24174	.7538 - .7549	.0407	.0978 - .0985
2656	24175	.7538 - .7545	.0408	.0979 - .0984
2656	24176	.7536 - .7546	.0409	.0980 - .0984
2656	24177	.7534 - .7546	.0410	.0981 - .0983
2656	24178	.7535 - .7543	.0411	.0979 - .0983
2656	24179	.7539 - .7548	.0407	.0980 - .0984
2656	24180	.7540 - .7554	.0403	.0981 - .0985
2656	24181	.7544 - .7554	.0401	.0980 - .0985
2656	24182	.7541 - .7551	.0404	.0980 - .0986
2656	24183	.7540 - .7552	.0404	.0978 - .0985

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2657	24184	.7544 - .7562	.0397	.0980 - .0990
2657	24185	.7538 - .7555	.0404	.0978 - .0985
2657	24186	.7537 - .7545	.0409	.0980 - .0986
2657	24187	.7538 - .7547	.0408	.0979 - .0987
2657	24188	.7538 - .7551	.0406	.0979 - .0986
2657	24189	.7544 - .7553	.0404	.0980 - .0985
2657	24190	.7544 - .7558	.0399	.0977 - .0986
2657	24191	.7543 - .7559	.0399	.0977 - .0985
2658	24192	.7549 - .7561	.0395	.0978 - .0984
2658	24193	.7542 - .7558	.0400	.0978 - .0983
2658	24194	.7538 - .7548	.0407	.0979 - .0985
2658	24195	.7538 - .7546	.0408	.0978 - .0986
2658	24196	.7542 - .7550	.0404	.0978 - .0988
2658	24197	.7540 - .7550	.0405	.0979 - .0990
2658	24198	.7544 - .7558	.0349	.0978 - .0989
2658	24199	.7542 - .7552	.0403	.0978 - .0985
2658	24200	.7539 - .7548	.0407	.0979 - .0984
2658	24201	.7538 - .7551	.0406	.0979 - .0984
2658	24202	.7540 - .7553	.0404	.0978 - .0984
2658	24203	.7538 - .7550	.0406	.0979 - .0984
2658	24204	.7539 - .7554	.0404	.0978 - .0985
2658	24205	.7540 - .7551	.0405	.0978 - .0983
2659	24206	.7538 - .7545	.0409	.0980 - .0983
2659	24207	.7537 - .7545	.0409	.0979 - .0984
2659	24208	.7539 - .7552	.0405	.0979 - .0984
2659	24209	.7537 - .7547	.0408	.0979 - .0984
2659	24210	.7533 - .7551	.0408	.0979 - .0984
2659	24211	.7530 - .7539	.0416	.0979 - .0983
2659	24212	.7534 - .7547	.0410	.0979 - .0983
2659	24213	.7532 - .7542	.0413	.0982 - .0989
2659	24214	.7531 - .7540	.0415	.0983 - .0989

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2660	24215	.7542 - .7554	.0392	.0980 - .0990
2660	24216	.7536 - .7552	.0396	.0982 - .0989
2660	24217	.7543 - .7557	.0390	.0980 - .0987
2660	24218	.7537 - .7552	.0398	.0979 - .0985
2660	24219	.7535 - .7544	.0401	.0979 - .0989
2660	24220	.7537 - .7549	.0397	.0976 - .0984
2660	24221	.7538 - .7555	.0394	.0977 - .0985
2660	24222	.7534 - .7550	.0398	.0979 - .0983
2660	24223	.7534 - .7549	.0399	.0979 - .0984
2660	24224	.7535 - .7546	.0400	.0979 - .0984
2660	24225	.7537 - .7549	.0397	.0980 - .0984
2661	24226	.7555 - .7566	.0390	.0974 - .0990
2661	24227	.7546 - .7560	.0397	.0980 - .0985
2661	24228	.7543 - .7554	.0402	.0979 - .0984
2661	24229	.7538 - .7549	.0407	.0976 - .0986
2661	24230	.7536 - .7549	.0408	.0980 - .0984
2661	24231	.7539 - .7548	.0407	
2661	24232	.7539 - .7549	.0406	.0978 - .0986
2661	24233	.7542 - .7554	.0402	.0979 - .0988
2661	24234	.7543 - .7554	.0403	.0978 - .0985
2661	24235	.7547 - .7558	.0398	.0981 - .0988
2662	24236	.7541 - .7551	.0404	.0980 - .0986
2662	24237	.7539 - .7549	.0406	.0978 - .0985
2662	24238	.7548 - .7560	.0396	.0981 - .0988
2662	24239	.7545 - .7552	.0402	.0980 - .0986
2662	24240	.7542 - .7552	.0403	.0979 - .0985
2662	24241	.7543 - .7551	.0403	.0980 - .0985
2662	24242	.7539 - .7549	.0406	.0980 - .0985
2662	24243	.7542 - .7549	.0405	.0979 - .0986
2691	24479	.7554 - .7572	.0367	.0979 - .0990
2691	24480	.7543 - .7559	.0379	.0980 - .0985
2691	24481	.7540 - .7555	.0383	.0981 - .0986
2691	24482	.7542 - .7556	.0381	.0979 - .0990
2691	24483	.7545 - .7561	.0377	.0982 - .0986

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2691	24484	.7541 - .7555	.0382	.0978 - .0988
2691	24485	.7541 - .7552	.0384	.0980 - .0987
2691	24486	.7541 - .7553	.0383	.0981 - .0985
2692	24487	.7555 - .7574	.0366	.0980 - .0990
2692	24488	.7550 - .7564	.0373	.0982 - .0989
2692	24489	.7547 - .7561	.0376	.0981 - .0987
2692	24490	.7546 - .7559	.0378	.0981 - .0985
2692	24491	.7542 - .7554	.0382	.0981 - .0987
2692	24492	.7541 - .7553	.0383	.0981 - .0987
2692	24493	.7542 - .7551	.0384	.0982 - .0986
2692	24494	.7543 - .7554	.0382	.0980 - .0985
2692	24495	.7547 - .7560	.0377	.0980 - .0987
2692	24496	.7551 - .7565	.0372	.0979 - .0989
2693	24497	.7554 - .7570	.0368	.0980 - .0987
2693	24498	.7546 - .7555	.0380	.0979 - .0986
2693	24499	.7538 - .7548	.0387	.0980 - .0989
2693	24500	.7540 - .7550	.0385	.0979 - .0984
2693	24501	.7539 - .7551	.0385	.0979 - .0985
2693	24502	.7540 - .7550	.0385	.0979 - .0984
2693	24503	.7540 - .7549	.0386	.0981 - .0985
2693	24504	.7538 - .7551	.0386	.0984 - .0989
2693	24505	.7541 - .7555	.0382	.0982 - .0989
2693	24506	.7545 - .7558	.0379	.0983 - .0986
2693	24507	.7538 - .7548	.0387	.0983 - .0989
2693	24508	.7537 - .7543	.0390	.0980 - .0984
2694	24509	.7541 - .7556	.0382	.0980 - .0989
2694	24510	.7537 - .7550	.0387	.0981 - .0985
2694	24511	.7537 - .7549	.0387	.0980 - .0985
2694	24512	.7532 - .7544	.0392	.0980 - .0985
2694	24513	.7536 - .7549	.0388	.0981 - .0990
2694	24514	.7538 - .7549	.0387	.0981 - .0987

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2694	24515	.7538 - .7552	.0385	.0982 - .0985
2694	24516	.7533 - .7543	.0392	.0982 - .0984
2694	24517	.7534 - .7541	.0393	.0981 - .0984
2694	24518	.7534 - .7545	.0390	.0980 - .0984
2694	24519	.7533 - .7543	.0392	.0981 - .0985
2695	24520	.7539 - .7555	.0383	.0979 - .0987
2695	24521	.7535 - .7548	.0389	.0980 - .0986
2695	24522	.7534 - .7545	.0392	.0978 - .0987
2695	24523	.7538 - .7549	.0387	.0979 - .0987
2695	24524	.7545 - .7562	.0377	.0984 - .0990
2695	24525	.7539 - .7554	.0384	.0982 - .0990
2695	24526	.7538 - .7551	.0386	.0983 - .0987
2695	24527	.7535 - .7548	.0389	.0982 - .0988
2695	24528	.7533 - .7548	.0390	.0981 - .0985
2695	24529	.7534 - .7543	.0392	.0982 - .0987
2695	24530	.7535 - .7552	.0387	.0982 - .0988
2696	24531	.7547 - .7560	.0377	.0981 - .0990
2696	24532	.7545 - .7559	.0378	.0983 - .0990
2696	24533	.7546 - .7559	.0378	.0983 - .0990
2696	24534	.7539 - .7549	.0386	.0981 - .0989
2696	24535	.7536 - .7546	.0389	.0982 - .0987
2696	24536	.7533 - .7545	.0391	.0982 - .0986
2696	24537	.7532 - .7545	.0392	.0981 - .0986
2696	24538	.7532 - .7542	.0393	.0982 - .0987
2696	24539	.7539 - .7551	.0385	.0983 - .0989
2696	24540	.7538 - .7550	.0386	.0983 - .0984
2696	24541	.7542 - .7555	.0382	.0983 - .0990
2697	24542	.7550 - .7566	.0372	.0982 - .0990
2697	24543	.7539 - .7551	.0385	.0982 - .0988
2697	24544	.7535 - .7549	.0388	.0980 - .0985
2697	24545	.7533 - .7547	.0390	.0982 - .0987

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A.F. Shrinkage	Bore Diameter Range
2697	24546	.7532 - .7546	.0391	.0982 - .0987
2697	24547	.7532 - .7544	.0392	.0980 - .0988
2697	24548	.7531 - .7544	.0393	.0983 - .0987
2697	24549	.7536 - .7546	.0389	.0981 - .0988
2697	24550	.7538 - .7550	.0386	.0982 - .0988
2697	24551	.7539 - .7553	.0384	.0982 - .0989
2697	24552	.7533 - .7554	.0387	.0978 - .0984
2698	24553	.7541 - .7565	.0377	.0979 - .0986
2698	24554	.7540 - .7568	.0376	.0981 - .0984
2698	24555	.7536 - .7557	.0384	.0980 - .0984
2698	24556	.7536 - .7555	.0385	.0980 - .0984
2698	24557	.7537 - .7558	.0383	.0980 - .0984
2698	24558	.7535 - .7560	.0383	.0980 - .0984
2698	24559	.7541 - .7560	.0380	.0981 - .0985
2698	24560	.7542 - .7560	.0379	.0980 - .0985
2698	24561	.7542 - .7559	.0380	.0980 - .0984
2698	24562	.7541 - .7556	.0382	.0980 - .0984
2698	24563	.7542 - .7558	.0380	.0979 - .0984
2699	24564	.7551 - .7571	.0369	.0980 - .0989
2699	24565	.7545 - .7563	.0376	.0980 - .0986
2699	24566	.7540 - .7558	.0381	.0980 - .0987
2699	24567	.7542 - .7561	.0379	.0980 - .0986
2699	24568	.7547 - .7564	.0375	.0979 - .0989
2712	24649	.7545 - .7562	.0377	.0980 - .0985
2712	24650	.7536 - .7546	.0389	.0981 - .0990
2712	24651	.7538 - .7546	.0388	.0982 - .0987
2712	24652	.7537 - .7550	.0387	.0983 - .0989
2712	24653	.7534 - .7541	.0393	.0981 - .0986
2712	24654	.7536 - .7543	.0391	.0981 - .0987
2712	24655	.7535 - .7546	.0390	.0980 - .0984

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2713	24656	.7542 - .7552	.0383	.0979 - .0988
2713	24657	.7540 - .7555	.0383	.0979 - .0985
2713	24658	.7542 - .7550	.0384	.0979 - .0990
2713	24659	.7536 - .7545	.0389	.0978 - .0988
2713	24660	.7535 - .7547	.0389	.0976 - .0983
2713	24661	.7534 - .7543	.0391	.0979 - .0986
2713	24662	.7532 - .7541	.0394	.0979 - .0986
2713	24663	.7534 - .7544	.0391	.0978 - .0983
2713	24664	.7535 - .7545	.0390	.0977 - .0984
2713	24665	.7535 - .7542	.0392	.0979 - .0988
2713	24666	.7538 - .7552	.0385	.0978 - .0985
2714	24667	.7543 - .7561	.0378	.0978 - .0989
2714	24668	.7535 - .7544	.0391	.0981 - .0985
2714	24669	.7530 - .7542	.0394	.0979 - .0984
2714	24670	.7528 - .7535	.0399	.0979 - .0985
2714	24671	.7528 - .7536	.0398	.0979 - .0985
2714	24672	.7527 - .7537	.0398	.0976 - .0983
2714	24673	.7529 - .7538	.0397	.0979 - .0985
2714	24674	.7530 - .7538	.0396	.0979 - .0988
2714	24675	.7535 - .7544	.0391	.0979 - .0984
2714	24676	.7536 - .7552	.0386	.0979 - .0989
2714	24677	.7530 - .7542	.0394	.0979 - .0986
2714	24678	.7528 - .7540	.0396	.0978 - .0984
2715	24679	.7538 - .7552	.0385	.0980 - .0986
2715	24680	.7530 - .7540	.0395	.0980 - .0985
2715	24681	.7534 - .7543	.0392	.0978 - .0985
2715	24682	.7536 - .7544	.0390	.0977 - .0986
2715	24683	.7535 - .7547	.0389	.0981 - .0986
2715	24684	.7534 - .7543	.0392	.0981 - .0986
2715	24685	.7538 - .7547	.0388	.0981 - .0984
2715	24686	.7536 - .7546	.0389	.0982 - .0986
2715	24687	.7531 - .7537	.0396	.0980 - .0985
2715	24688	.7533 - .7544	.0392	.0981 - .0985
2715	24689	.7530 - .7542	.0394	.0978 - .0984

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2716	24690	.7538 - .7563	.0380	.0979 - .0990
2716	24691	.7535 - .7549	.0388	.0980 - .0984
2716	24692	.7536 - .7551	.0387	.0979 - .0983
2716	24693			
2716	24694	.7548 - .7561	.0376	.0976 - .0987
2716	24695	.7539 - .7564	.0374	.0979 - .0985
2716	24696	.7536 - .7546	.0389	.0980 - .0987
2716	24697	.7539 - .7549	.0386	.0980 - .0985
2716	24698	.7539 - .7555	.0383	.0982 - .0987
2716	24699	.7535 - .7545	.0390	.0981 - .0985
2716	24700	.7538 - .7553	.0385	.0980 - .0984
2717	24701	.7544 - .7558	.0389	.0980 - .0990
2717	24702	.7542 - .7558	.0390	.0980 - .0989
2717	24703	.7536 - .7552	.0396	.0981 - .0989
2717	24704	.7534 - .7549	.0399	.0981 - .0988
2717	24705	.7532 - .7546	.0401	.0980 - .0989
2717	24706	.7530 - .7544	.0403	.0982 - .0989
2717	24707	.7522 - .7542	.0408	.0980 - .0985
2718	24708	.7528 - .7545	.0394	.0980 - .0986
2718	24709	.7526 - .7536	.0399	.0979 - .0985
2718	24710	.7528 - .7540	.0396	.0979 - .0986
2718	24711	.7530 - .7551	.0390	.0979 - .0983
2718	24712	.7534 - .7550	.0388	.0980 - .0984
2718	24713	.7530 - .7545	.0393	.0980 - .0985
2718	24714	.7525 - .7544	.0396	.0979 - .0983
2719	24715	.7541 - .7561	.0379	.0980 - .0985
2719	24716	.7537 - .7557	.0383	.0979 - .0985
2719	24717	.7536 - .7556	.0384	.0979 - .0984
2718	24718	.7538 - .7555	.0384	.0977 - .0984
2718	24719	.7537 - .7557	.0383	.0977 - .0984
2718	24720	.7542 - .7560	.0379	.0982 - .0989

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2719	24721	.7539 - .7554	.0384	.0980 - .0988
2719	24722	.7536 - .7552	.0386	.0979 - .0986
2719	24723	.7537 - .7553	.0385	.0979 - .0987
2719	24724	.7533 - .7548	.0390	.0980 - .0986
2719	24725	.7535 - .7546	.0390	.0979 - .0986
2720	24726	.7538 - .7554	.0394	.0979 - .0987
2720	24727	.7537 - .7558	.0394	.0978 - .0984
2720	24728	.7537 - .7554	.0395	.0980 - .0986
2720	24729	.7540 - .7556	.0392	.0981 - .0987
2720	24730	.7534 - .7554	.0396	.0981 - .0986
2720	24731	.7529 - .7548	.0402	.0981 - .0985
2720	24732	.7530 - .7543	.0404	.0981 - .0986
2720	24733	.7531 - .7543	.0403	.0981 - .0985
2720	24734	.7534 - .7549	.0399	
2720	24735	.7533 - .7548	.0400	.0981 - .0985
2720	24736	.7532 - .7548	.0400	.0981 - .0987
2721	24737	.7530 - .7542	.0394	.0981 - .0985
2721	24738	.7535 - .7557	.0384	.0981 - .0989
2721	24739	.7526 - .7534	.0400	.0976 - .0981
2721	24740	.7523 - .7535	.0401	.0976 - .0981
2721	24741	.7520 - .7531	.0405	.0976 - .0981
2721	24742	.7519 - .7533	.0404	.0975 - .0981
2721	24743	.7532 - .7547	.0391	.0976 - .0981
2721	24744	.7518 - .7543	.0400	.0975 - .0981
2721	24745	.7521 - .7531	.0404	.0974 - .0981
2722	24746	.7526 - .7538	.0398	.0976 - .0981
2722	24747	.7527 - .7537	.0398	.0976 - .0981
2722	24748	.7517 - .7539	.0402	.0969 - .0982
2722	24749	.7515 - .7535	.0405	.0960 - .0982
2722	24750	.7522 - .7549	.0395	.0971 - .0985
2722	24751	.7521 - .7541	.0399	.0974 - .0983
2722	24752	.7523 - .7542	.0398	.0975 - .0981

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~~Atomic Energy Act - 1954~~

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~~RESTRICTED DATA~~

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2722	24753	.7521 - .7537	.0401	.0975 - .0981
2722	24754	.7525 - .7542	.0396	.0975 - .0982
2722	24755	.7522 - .7534	.0402	.0975 - .0983
2722	24756	.7515 - .7540	.0408	.0975 - .0984
2722	24757	.7511 - .7547	.0401	.0969 - .0983
2722	24758	.7515 - .7534	.0406	.0968 - .0983
2723	24759	.7535 - .7548	.0389	.0976 - .0982
2723	24760	.7535 - .7548	.0389	.0975 - .0982
2723	24761	.7529 - .7549	.0391	.0975 - .0982
2723	24762	.7526 - .7540	.0397	.0977 - .0981
2723	24763	.7528 - .7542	.0345	.0976 - .0981
2723	24764	.7523 - .7537	.0400	.0975 - .0982
2723	24765	.7525 - .7534	.0401	.0976 - .0982
2723	24766	.7528 - .7539	.0397	.0977 - .0980
2723	24767	.7527 - .7534	.0400	.0977 - .0981
2723	24768	.7526 - .7541	.0397	.0977 - .0981
2723	24769	.7524 - .7533	.0401	.0977 - .0981
2723	24770	.7523 - .7530	.0404	.0976 - .0980
2724	24771	.7526 - .7541	.0397	.0975 - .0980
2724	24772	.7524 - .7536	.0400	.0976 - .0979
2724	24773	.7521 - .7532	.0404	.0980 - .0983
2724	24774	.7528 - .7546	.0398	.0976 - .0981
2724	24775	.7532 - .7540	.0394	.0976 - .0981
2724	24776	.7527 - .7537	.0398	.0976 - .0980
2724	24777	.7526 - .7534	.0400	.0977 - .0980
2724	24778	.7525 - .7534	.0401	.0976 - .0980
2724	24779	.7524 - .7531	.0403	.0978 - .0983
2724	24780	.7522 - .7530	.0404	.0979 - .0982
2724	24781	.7521 - .7531	.0404	.0978 - .0983
2725	24782	.7527 - .7539	.0397	.0975 - .0980
2725	24783	.7525 - .7548	.0394	.0978 - .0984
2725	24784	.7529 - .7545	.0397	.0979 - .0985

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2725	24785	.7529 - .7541	.0395	.0978 - .0986
2725	24786	.7523 - .7535	.0401	.0975 - .0981
2725	24787	.7524 - .7535	.0402	.0976 - .0980
2725	24788	.7522 - .7540	.0399	.0976 - .0980
2725	24789	.7529 - .7541	.0395	.0978 - .0983
2725	24790	.7525 - .7537	.0399	.0975 - .0981
2725	24791	.7522 - .7534	.0402	.0975 - .0980
2725	24792	.7526 - .7549	.0398	.0976 - .0981
2726	24793	.7536 - .7547	.0389	.0975 - .0982
2726	24794	.7530 - .7543	.0394	.0975 - .0981
2726	24795	.7526 - .7537	.0399	.0976 - .0980
2726	24796	.7523 - .7541	.0398	.0976 - .0981
2726	24797	.7522 - .7537	.0401	.0977 - .0981
2726	24798	.7526 - .7548	.0395	.0976 - .0983
2726	24799	.7521 - .7539	.0400	.0974 - .0981
2726	24800	.7527 - .7538	.0398	.0976 - .0986
2726	24801	.7528 - .7539	.0397	.0978 - .0984
2726	24802	.7528 - .7538	.0397	.0978 - .0984
2726	24803	.7525 - .7531	.0402	.0978 - .0984
2727	24804	.7529 - .7546	.0397	.0978 - .0983
2727	24805	.7522 - .7542	.0398	.0977 - .0984
2727	24806	.7523 - .7536	.0401	.0975 - .0983
2727	24807	.7523 - .7530	.0404	.0975 - .0983
2727	24808	.7522 - .7530	.0404	.0976 - .0983
2727	24809	.7521 - .7535	.0402	.0977 - .0983
2727	24810	.7523 - .7533	.0402	.0977 - .0983
2727	24811	.7526 - .7534	.0400	.0973 - .0981
2728	24812	.7528 - .7541	.0396	.0978 - .0983
2728	24813	.7523 - .7538	.0400	.0978 - .0983
2728	24814	.7519 - .7529	.0406	.0978 - .0982
2728	24815	.7515 - .7528	.0409	.0976 - .0980

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2728	24816	.7519 - .7529	.0406	.0976 - .0980
2728	24817	.7519 - .7530	.0406	.0976 - .0984
2728	24818	.7522 - .7534	.0402	.0975 - .0985
2728	24819	.7525 - .7539	.0398	.0974 - .0982
2728	24820	.7526 - .7538	.0398	.0973 - .0982
2728	24821	.7526 - .7542	.0396	.0973 - .0982
2728	24822	.7523 - .7537	.0400	.0973 - .0981
2728	24823	.7521 - .7534	.0403	.0973 - .0980
2728	24824	.7521 - .7539	.0400	.0973 - .0982
2729	24825	.7530 - .7545	.0393	.0975 - .0981
2729	24826	.7526 - .7538	.0398	.0976 - .0980
2729	24827	.7526 - .7548	.0393	.0977 - .0981
2729	24828	.7530 - .7542	.0394	.0977 - .0981
2730	24829	.7543 - .7567	.0385	.0980 - .0989
2730	24830	.7536 - .7546	.0399	.0979 - .0989
2730	24831	.7536 - .7543	.0401	.0979 - .0989
2730	24832	.7535 - .7543	.0401	.0979 - .0990
2730	24833	.7531 - .7545	.0402	.0978 - .0984
2730	24834	.7530 - .7540	.0405	.0979 - .0983
2730	24835	.7531 - .7543	.0403	.0979 - .0983
2730	24836	.7530 - .7543	.0404	.0979 - .0983
2731	24837	.7537 - .7552	.0386	.0977 - .0984
2731	24838	.7528 - .7541	.0396	.0977 - .0986
2731	24839	.7530 - .7544	.0393	.0977 - .0984
2731	24840	.7527 - .7537	.0398	.0978 - .0984
2731	24841	.7524 - .7537	.0400	.0977 - .0984
2731	24842	.7524 - .7536	.0400	.0978 - .0983
2731	24843	.7528 - .7540	.0396	.0978 - .0983
2731	24844	.7528 - .7541	.0396	.0978 - .0983
2731	24845	.7528 - .7537	.0398	.0980 - .0985

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2732	24846	.7537 - .7552	.0386	.0980 - .0985
2732	24847	.7537 - .7545	.0389	.0979 - .0990
2732	24848	.7527 - .7540	.0397	.0980 - .0985
2732	24849	.7528 - .7539	.0398	.0978 - .0984
2732	24850	.7528 - .7537	.0397	.0979 - .0985
2732	24851	.7526 - .7537	.0399	.0977 - .0982
2732	24852	.7525 - .7535	.0400	.0978 - .0982
2732	24853	.7526 - .7542	.0396	.0981 - .0984
2732	24854	.7526 - .7537	.0399	.0980 - .0985
2732	24855	.7529 - .7536	.0398	.0980 - .0985
2732	24856	.7530 - .7545	.0397	.0978 - .0986
2733	24857	.7534 - .7542	.0392	.0978 - .0987
2733	24858	.7531 - .7540	.0395	.0978 - .0987
2733	24859	.7530 - .7547	.0392	.0977 - .0986
2733	24860	.7529 - .7544	.0394	.0979 - .0987
2733	24861	.7523 - .7532	.0403	.0979 - .0984
2733	24862	.7527 - .7535	.0399	.0980 - .0984
2734	24863	.7529 - .7546	.0393	.0979 - .0984
2734	24864	.7531 - .7542	.0394	.0979 - .0985
2734	24865	.7531 - .7548	.0391	.0980 - .0984
2734	24866	.7527 - .7538	.0398	.0980 - .0984
2734	24867	.7528 - .7541	.0396	.0978 - .0985
2734	24868	.7530 - .7542	.0394	.0978 - .0989
2734	24869	.7528 - .7547	.0397	.0978 - .0990
2734	24870	.7530 - .7541	.0395	.0979 - .0989
2734	24871	.7533 - .7548	.0390	.0979 - .0988
2734	24872	.7528 - .7544	.0394	.0975 - .0984
2735	24873	.7532 - .7554	.0387	.0979 - .0984
2735	24874	.7533 - .7548	.0390	.0980 - .0985
2735	24875	.7532 - .7542	.0393	.0979 - .0985
2735	24876	.7530 - .7541	.0395	.0980 - .0985

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2735	24877	.7528 - .7540	.0396	.0978 - .0985
2735	24878	.7529 - .7539	.0396	.0976 - .0985
2735	24879	.7525 - .7538	.0399	.0977 - .0984
2735	24880	.7525 - .7539	.0398	.0978 - .0983
2735	24881	.7528 - .7542	.0395	.0978 - .0984
2735	24882	.7535 - .7554	.0386	.0979 - .0984
2735	24883	.7528 - .7547	.0393	.0979 - .0986
2735	24884	.7522 - .7541	.0399	.0977 - .0984
2736	24885	.7532 - .7554	.0393	.0979 - .0986
2736	24886	.7528 - .7550	.0391	.0980 - .0985
2736	24887	.7528 - .7549	.0392	.0979 - .0984
2736	24888	.7527 - .7549	.0392	.0980 - .0984
2736	24889	.7528 - .7549	.0392	.0979 - .0984
2736	24890	.7521 - .7545	.0397	.0976 - .0982
2736	24891	.7527 - .7543	.0395	.0978 - .0985
2736	24892	.7532 - .7546	.0391	.0978 - .0985
2736	24893	.7529 - .7548	.0392	.0978 - .0984
2736	24894	.7526 - .7540	.0397	.0979 - .0984
2736	24895	.7530 - .7547	.0392	.0979 - .0985
2737	24896	.7530 - .7555	.0388	.0978 - .0986
2737	24897	.7526 - .7554	.0390	.0978 - .0983
2737	24898	.7522 - .7544	.0397	.0977 - .0982
2737	24899	.7524 - .7547	.0395	.0977 - .0982
2737	24900	.7522 - .7547	.0396	.0977 - .0983
2737	24901	.7528 - .7547	.0393	.0976 - .0986
2737	24902	.7531 - .7549	.0390	.0977 - .0985
2737	24903	.7526 - .7547	.0394	.0975 - .0985
2737	24904	.7526 - .7549	.0393	.0976 - .0985
2738	24905	.7524 - .7547	.0395	.0976 - .0984
2738	24906	.7531 - .7560	.0385	.0977 - .0985
2738	24907	.7527 - .7550	.0392	.0978 - .0982
2738	24908	.7528 - .7550	.0391	.0976 - .0984

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2738	24909	.7527 - .7554	.0390	.0977 - .0984
2738	24910	.7532 - .7551	.0389	.0977 - .0984
2738	24911	.7526 - .7548	.0393	.0978 - .0986
2738	24912	.7526 - .7544	.0395	.0979 - .0984
2738	24913	.7527 - .7544	.0395	.0979 - .0984
2738	24914	.7530 - .7547	.0392	.0978 - .0983
2738	24915	.7532 - .7553	.0388	.0980 - .0987
2739	24916	.7521 - .7538	.0401	.0979 - .0987
2739	24917	.7519 - .7528	.0407	.0979 - .0985
2739	24918	.7515 - .7524	.0411	.0980 - .0986
2739	24919	.7513 - .7520	.0414	.0980 - .0984
2739	24920	.7514 - .7532	.0407	.0978 - .0986
2739	24921	.7513 - .7523	.0412	.0979 - .0984
2739	24922	.7511 - .7523	.0413	.0979 - .0984
2739	24923	.7513 - .7521	.0413	.0979 - .0990
2739	24924	.7513 - .7524	.0412	.0980 - .0985
2739	24925	.7514 - .7524	.0411	.0979 - .0984
2740	24926	.7523 - .7539	.0399	.0979 - .0986
2740	24927	.7514 - .7530	.0408	.0979 - .0986
2740	24928	.7515 - .7522	.0412	.0979 - .0986
2740	24929	.7512 - .7520	.0414	.0980 - .0985
2740	24930	.7513 - .7529	.0409	.0980 - .0985
2740	24931	.7515 - .7525	.0410	.0980 - .0986
2740	24932	.7514 - .7522	.0412	.0979 - .0985
2740	24933	.7515 - .7528	.0409	.0979 - .0986
2740	24934	.7517 - .7528	.0408	.0981 - .0986
2740	24935	.7515 - .7523	.0411	.0981 - .0985
2740	24936			.0981 - .0987
2741	24937	.7521 - .7539	.0390	.0978 - .0985
2741	24938	.7514 - .7529	.0399	.0979 - .0985
2741	24939	.7515 - .7531	.0397	.0978 - .0982
2741	24940	.7513 - .7528	.0400	.0979 - .0983

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~~Atomic Energy Act, 1954~~

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~~Atomic Energy Act - 1954~~

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2741	24941	.7515 - .7530	.0398	.0979 - .0986
2741	24942	.7511 - .7525	.0402	.0978 - .0984
2741	24943	.7513 - .7528	.0400	.0979 - .0984
2741	24944	.7513 - .7526	.0401	.0979 - .0984
2741	24945	.7514 - .7530	.0398	.0977 - .0983
2742	24946	.7526 - .7537	.0389	.0980 - .0988
2742	24947	.7518 - .7536	.0393	.0979 - .0985
2742	24948	.7519 - .7535	.0393	.0979 - .0984
2742	24949	.7517 - .7532	.0396	.0979 - .0984
2742	24950	.7519 - .7534	.0394	.0979 - .0983
2742	24951	.7518 - .7534	.0394	.0979 - .0984
2742	24952	.7518 - .7537	.0393	.0979 - .0984
2742	24953	.7520 - .7536	.0392	.0979 - .0984
2742	24954	.7522 - .7542	.0388	.0979 - .0984
2742	24955	.7521 - .7538	.0391	.0979 - .0985
2743	24956	.7518 - .7538	.0402	.0979 - .0986
2743	24957	.7514 - .7529	.0409	.0979 - .0985
2743	24958	.7510 - .7525	.0413	.0977 - .0983
2743	24959	.7511 - .7528	.0410	.0975 - .0983
2743	24960			
2743	24961			
2743	24962			
2743	24963			
2743	24964	.7515 - .7537	.0404	.0979 - .0983
2743	24965	.7512 - .7531	.0409	.0978 - .0983
2743	24966	.7514 - .7533	.0407	.0979 - .0983
2744	24967	.7518 - .7539	.0392	.0978 - .0984
2744	24968	.7514 - .7536	.0395	.0978 - .0982
2744	24969	.7512 - .7534	.0397	.0978 - .0983
2744	24970	.7512 - .7532	.0398	.0977 - .0983
2744	24971	.7512 - .7531	.0399	.0978 - .0984
2744	24972	.7511 - .7529	.0400	.0977 - .0984
2744	24973	.7518 - .7531	.0396	.0977 - .0984

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2744	24974	.7517 - .7533	.0395	.0977 - .0984
2744	24975	.7516 - .7533	.0396	.0978 - .0983
2744	24976	.7515 - .7530	.0398	.0977 - .0983
2744	24977	.7511 - .7524	.0403	.0977 - .0983
2745	24978	.7513 - .7541	.0393	.0976 - .0986
2745	24979	.7513 - .7530	.0399	.0978 - .0983
2745	24980	.7512 - .7525	.0402	.0978 - .0983
2745	24981	.7510 - .7527	.0402	.0978 - .0982
2745	24982	.7518 - .7541	.0391	.0979 - .0984
2745	24983	.7513 - .7528	.0400	.0979 - .0983
2745	24984	.7514 - .7526	.0400	.0979 - .0983
2745	24985	.7515 - .7525	.0400	.0979 - .0982
2745	24986	.7517 - .7530	.0397	.0978 - .0982
2745	24987	.7512 - .7524	.0402	.0978 - .0983
2745	24988	.7512 - .7524	.0402	.0979 - .0982
2746	24989	.7520 - .7537	.0392	.0979 - .0984
2746	24990	.7517 - .7531	.0396	.0980 - .0985
2746	24991	.7519 - .7531	.0395	.0978 - .0984
2746	24992	.7514 - .7525	.0402	.0978 - .0983
2746	24993	.7516 - .7528	.0398	.0979 - .0983
2746	24994	.7512 - .7528	.0400	.0979 - .0983
2746	24995	.7512 - .7529	.0400	.0979 - .0983
2746	24996	.7511 - .7525	.0402	.0978 - .0983
2746	24997	.7516 - .7530	.0397	.0979 - .0984
2746	24998	.7515 - .7528	.0399	.0978 - .0984
2746	24999	.7521 - .7535	.0392	.0979 - .0983
2747	25000	.7527 - .7549	.0382	.0979 - .0985
2747	25001	.7523 - .7533	.0392	.0979 - .0983
2747	25002	.7518 - .7530	.0396	.0979 - .0983
2747	25003	.7518 - .7533	.0395	.0979 - .0983
2747	25004	.7515 - .7526	.0400	.0980 - .0985
2747	25005	.7516 - .7526	.0399	.0977 - .0986

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2747	25006	.7517 - .7528	.0398	.0979 - .0985
2747	25007	.7518 - .7527	.0398	.0979 - .0985
2747	25008	.7520 - .7529	.0396	.0978 - .0984
2747	25009	.7519 - .7529	.0396	.0977 - .0983
2747	25010	.7517 - .7528	.0398	.0977 - .0983
2748	25011	.7522 - .7533	.0393	.0977 - .0983
2748	25012	.7520 - .7530	.0395	.0979 - .0983
2748	25013	.7517 - .7535	.0394	.0978 - .0983
2748	25014	.7515 - .7531	.0397	.0977 - .0985
2748	25015	.7515 - .7530	.0398	.0977 - .0984
2748	25016	.7514 - .7525	.0401	.0976 - .0983
2748	25017	.7519 - .7532	.0395	.0978 - .0984
2748	25018	.7515 - .7530	.0398	.0979 - .0983
2748	25019	.7513 - .7527	.0400	.0979 - .0983
2748	25020	.7511 - .7524	.0403	.0979 - .0982
2748	25021	.7512 - .7528	.0400	.0979 - .0983
2749	25046	.7528 - .7540	.0396	.0976 - .0982
2749	25047	.7523 - .7535	.0401	.0977 - .0982
2749	25048	.7523 - .7535	.0401	.0976 - .0982
2749	25049	.7523 - .7535	.0401	.0977 - .0982
2749	25950	.7524 - .7533	.0402	.0978 - .0983
2749	25951	.7523 - .7533	.0402	.0977 - .0982
2749	25952	.7523 - .7534	.0402	.0975 - .0983
2749	25953	.7525 - .7533	.0401	.0975 - .0983
2750	25054	.7534 - .7546	.0390	.0977 - .0983
2750	25055	.7530 - .7545	.0393	.0978 - .0982
2750	25056	.7528 - .7539	.0397	.0978 - .0982
2750	25057	.7526 - .7538	.0398	.0977 - .0982
2750	25058	.7524 - .7533	.0402	.0977 - .0981
2750	25059	.7525 - .7536	.0400	.0976 - .0981
2750	25060	.7526 - .7537	.0399	.0978 - .0983

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2750	25061	.7524 - .7533	.0402	.0977 - .0982
2750	25062	.7525 - .7535	.0400	.0978 - .0983
2750	25063	.7525 - .7533	.0401	.0978 - .0983
2750	25064	.7527 - .7538	.0398	.0978 - .0983
2751	25065	.7532 - .7548	.0390	.0978 - .0982
2751	25066	.7529 - .7537	.0397	.0978 - .0982
2751	25067	.7526 - .7534	.0400	.0978 - .0982
2751	25068	.7526 - .7534	.0400	.0978 - .0982
2751	25069	.7529 - .7538	.0397	.0977 - .0983
2751	25070	.7529 - .7543	.0396	.0978 - .0984
2751	25071	.7527 - .7542	.0396	.0980 - .0983
2751	25072	.7527 - .7545	.0394	.0980 - .0984
2751	25073	.7526 - .7541	.0393	.0979 - .0984
2751	25074	.7522 - .7538	.0400	.0979 - .0984
2751	25075	.7523 - .7536	.0401	.0979 - .0984
2752	25076	.7522 - .7547	.0396	.0976 - .0984
2752	25077	.7518 - .7535	.0404	.0975 - .0983
2752	25078	.7521 - .7542	.0399	.0975 - .0988
2752	25079	.7520 - .7537	.0402	.0976 - .0984
2752	25080	.7518 - .7534	.0404	.0977 - .0982
2752	25081	.7519 - .7533	.0404	.0978 - .0983
2752	25082	.7518 - .7533	.0405	.0978 - .0983
2752	25083	.7517 - .7531	.0406	.0977 - .0981
2752	25084	.7518 - .7529	.0407	.0977 - .0988
2752	25085	.7518 - .7539	.0402	.0977 - .0983
2753	25086			
2753	25087			
2753	25088	.7523 - .7539	.0399	.0979 - .0983
2753	25089	.7525 - .7542	.0397	.0979 - .0984
2753	25090	.7524 - .7533	.0402	.0976 - .0981
2753	25091	.7532 - .7539	.0395	.0978 - .0985

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2753	25092	.7532 - .7545	.0392	
2753	25093	.7525 - .7538	.0399	.0980 - .0984
2753	25094	.7524 - .7533	.0402	.0979 - .0984
2753	25095	.7526 - .7534	.0400	.0978 - .0984
2753	25096	.7528 - .7535	.0399	.0977 - .0984
2753	25097	.7525 - .7534	.0401	.0980 - .0988
2754	25098	.7527 - .7538	.0398	.0980 - .0984
2754	25099	.7530 - .7546	.0392	.0980 - .0985
2754	25100	.7526 - .7540	.0397	.0978 - .0984
2754	25101	.7524 - .7535	.0401	.0978 - .0984
2754	25102	.7524 - .7541	.0398	.0979 - .0983
2754	25103	.7524 - .7535	.0401	.0980 - .0984
2754	25104	.7521 - .7535	.0402	.0979 - .0983
2754	25105	.7524 - .7533	.0402	.0979 - .0983
2754	25106	.7523 - .7532	.0403	.0979 - .0984
2754	25107	.7522 - .7531	.0404	.0979 - .0983
2755	25108	.7529 - .7545	.0394	.0977 - .0983
2755	25109	.7530 - .7543	.0394	.0979 - .0984
2755	25110	.7526 - .7539	.0398	.0977 - .0981
2755	25111	.7522 - .7531	.0404	.0976 - .0982
2755	25112	.7522 - .7532	.0403	.0975 - .0982
2755	25113	.7522 - .7538	.0400	.0974 - .0988
2755	25114	.7522 - .7540	.0399	.0974 - .0983
2755	25115	.7525 - .7538	.0399	.0976 - .0984
2755	25116	.7525 - .7542	.0397	.0976 - .0983
2755	25117	.7528 - .7539	.0397	.0975 - .0983
2755	25118	.7529 - .7542	.0395	.0976 - .0982
2755	25119	.7526 - .7537	.0399	.0977 - .0983
2756	25120	.7532 - .7540	.0394	.0978 - .0985
2756	25121	.7526 - .7541	.0397	.0976 - .0983
2756	25122	.7524 - .7531	.0403	.0975 - .0983
2756	25123	.7522 - .7532	.0403	.0975 - .0983

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2756	25124	.7520 - .7530	.0405	.0976 - .0982
2756	25125	.7521 - .7535	.0402	.0978 - .0984
2756	25126	.7526 - .7536	.0399	.0979 - .0985
2756	25127	.7526 - .7535	.0400	.0979 - .0986
2756	25128	.7523 - .7532	.0402	.0976 - .0985
2757	25129	.7528 - .7538	.0397	.0977 - .0984
2757	25130	.7526 - .7546	.0399	.0977 - .0985
2757	25131	.7529 - .7541	.0395	.0976 - .0983
2757	25132	.7531 - .7537	.0396	.0975 - .0983
2757	25133	.7526 - .7538	.0398	.0975 - .0999
2757	25134	.7524 - .7534	.0401	.0974 - .0983
2757	25135	.7523 - .7537	.0400	.0975 - .0983
2758	25136	.7532 - .7550	.0389	.0976 - .0986
2758	25137	.7527 - .7537	.0398	.0979 - .0983
2758	25138	.7523 - .7535	.0401	.0979 - .0983
2758	25139	.7524 - .7531	.0403	.0979 - .0983
2758	25140	.7525 - .7530	.0403	.0976 - .0981
2758	25141	.7525 - .7531	.0402	.0979 - .0982
2758	25142	.7525 - .7534	.0401	.0977 - .0983
2758	25143	.7527 - .7542	.0396	.0976 - .0983
2758	25144	.7530 - .7540	.0395	.0976 - .0984
2759	25145	.7527 - .7538	.0398	.0978 - .0982
2759	25146	.7521 - .7534	.0403	.0978 - .0982
2759	25147	.7518 - .7526	.0408	.0977 - .0981
2759	25148	.7518 - .7528	.0407	.0978 - .0982
2759	25149	.7518 - .7526	.0408	.0976 - .0982
2759	25150	.7518 - .7528	.0407	.0977 - .0981
2759	25151	.7518 - .7530	.0406	.0977 - .0981
2759	25152	.7518 - .7526	.0408	.0979 - .0983
2759	25153	.7522 - .7527	.0406	.0978 - .0982
2759	25154	.7524 - .7531	.0403	.0978 - .0983

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A. F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2760	25155	.7534 - .7555	.0386	.0977 - .0986
2760	25156	.7525 - .7535	.0400	.0978 - .0983
2760	25157	.7523 - .7539	.0399	.0978 - .0983
2760	25158	.7525 - .7534	.0401	.0978 - .0982
2760	25159	.7524 - .7535	.0401	.0977 - .0982
2760	25160	.7526 - .7540	.0397	.0978 - .0982
2760	25161	.7524 - .7539	.0399	.0978 - .0982
2760	25162	.7530 - .7544	.0393	.0978 - .0983
2760	25163	.7528 - .7541	.0396	.0977 - .0982
2760	25164	.7526 - .7532	.0401	.0978 - .0982
2760	25165	.7524 - .7531	.0403	.0978 - .0981
2761	25166	.7530 - .7548	.0392	.0977 - .0983
2761	25167	.7527 - .7542	.0396	.0977 - .0982
2761	25168	.7525 - .7538	.0396	.0977 - .0982
2761	25169	.7524 - .7536	.0400	.0977 - .0982
2761	25170	.7525 - .7538	.0399	.0977 - .0981
2761	25171	.7524 - .7537	.0400	.0978 - .0982
2761	25172	.7525 - .7540	.0398	.0978 - .0982
2761	25173	.7523 - .7533	.0402	.0977 - .0982
2761	25174	.7522 - .7531	.0404	.0977 - .0982
2761	25175	.7522 - .7535	.0402	.0978 - .0982
2761	25176	.7522 - .7530	.0404	.0977 - .0982
2762	25177	.7523 - .7533	.0402	.0976 - .0982
2762	25178	.7520 - .7530	.0405	.0977 - .0980
2762	25179	.7519 - .7527	.0407	.0976 - .0981
2762	25180	.7523 - .7531	.0407	.0977 - .0982
2762	25181	.7530 - .7543	.0396	.0978 - .0987
2762	25182	.7528 - .7546	.0393	.0976 - .0987
2762	25183	.7526 - .7545	.0395	.0976 - .0985
2762	25184	.7525 - .7541	.0397	.0979 - .0983
2762	25185	.7526 - .7539	.0398	.0979 - .0984
2762	25186	.7525 - .7534	.0401	.0977 - .0982
2762	25187	.7524 - .7535	.0401	.0978 - .0982

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TABLE 4
(continued)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2763	25188	.7505 - .7519	.0418	.0972 - .0979
2763	25189	.7510 - .7524	.0413	.0973 - .0980
2763	25190	.7506 - .7517	.0419	.0972 - .0978
2763	25191	.7509 - .7521	.0415	.0974 - .0981
2763	25192	.7505 - .7520	.0418	.0975 - .0980
2763	25193	.7503 - .7511	.0422	.0974 - .0980
2763	25194	.7506 - .7516	.0419	.0975 - .0980
2764	25195	.7523 - .7543	.0387	.0977 - .0985
2764	25196	.7519 - .7535	.0393	.0974 - .0980
2764	25197	.7515 - .7527	.0399	.0972 - .0980
2764	25198	.7518 - .7534	.0394	.0975 - .0982
2764	25199	.7518 - .7526	.0398	.0975 - .0981
2764	25200	.7515 - .7525	.0400	.0974 - .0982
2764	25201	.7510 - .7524	.0403	.0975 - .0981
2764	25202	.7514 - .7521	.0403	.0976 - .0983
2764	25203	.7516 - .7526	.0399	.0975 - .0984
2764	25204	.7518 - .7527	.0398	.0975 - .0983
2764	25205	.7518 - .7528	.0397	.0975 - .0983
2765	25206	.7519 - .7529	.0406	.0975 - .0985
2765	25207	.7527 - .7546	.0394	.0976 - .0983
2765	25208	.7530 - .7547	.0392	.0976 - .0982
2765	25209	.7523 - .7537	.0400	.0976 - .0981
2765	25210	.7525 - .7537	.0399	.0975 - .0981
2765	25211	.7524 - .7539	.0399	.0976 - .0981
2765	25212	.7524 - .7536	.0400	.0979 - .0985
2765	25213	.7525 - .7546	.0396	.0979 - .0987
2765	25214	.7521 - .7533	.0403	.0978 - .0985
2765	25215	.7523 - .7543	.0402	.0978 - .0984
2765	25216	.7525 - .7535	.0400	.0978 - .0983
2765	25217	.7525 - .7537	.0399	.0976 - .0982

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TABLE 4
(continue d)

Batch No.	Element S/N	Dim. Range A.F. As Graphitized	Δ A. F. Shrinkage	Bore Diameter Range
2766	25218	.7531 - .7546	.0392	.0975 - .0984
2766	25219	.7526 - .7544	.0395	.0976 - .0981
2766	25220	.7524 - .7533	.0402	.0977 - .0984
2766	25221	.7525 - .7542	.0397	.0977 - .0983
2766	25222	.7525 - .7545	.0400	.0977 - .0982
2766	25223	.7522 - .7535	.0402	.0978 - .0983
2766	25224	.7524 - .7547	.0400	.0978 - .0983
2766	25225	.7526 - .7540	.0397	.0978 - .0983

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DENSITY

In the table below is a comparison of as graphitized density values for extruded-to-size and as machined fuel elements.

Element	Code	Condition	Density
24003	9	ETS	2.244
24013	9	ETS	2.237
24023	9	ETS	2.244
24033	9	ETS	2.245
24083	9	ETS	2.258
24093	3	ETS	2.005
24103	3	ETS	2.004
24113	3	ETS	2.004
24123	3	ETS	2.003
24133	3	ETS	1.988
24143	3	ETS	1.986
24153	3	ETS	1.989
17250	3	As Machined	2.022
22840	3	As Machined	2.007
20548	9	As Machined	2.249
24410	9	As Machined	2.281
24420	9	As Machined	2.272
24430	9	As Machined	2.275

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AIR IMPEDANCE

A typical extruded-to-size element compared to a machined bore show the following:

Fuel Element S/N	Range of Air Flow Impedance "As-Graphitized"	Range of Air Flow Impedance "As-Brushed"	Range of Air Flow Impedance "As-Reamed"
99-24079 (ETS)	.0937 / .0949	.0958 / .0964	- - - - -
99-19101 (NRX A4)	- - - - -	- - - - -	.0949 / .0955

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THERMAL EXPANSION

The thermal expansion data on the two ETS elements presented here are as conducted and reported by WANL: Transmittal Number - TPL 095.

Linear Thermal Expansion of NRX A-4 Experimental
Graphite Element No. 39-24099 Center Section

Temperature °C	Expansion Per Cent	Alpha (Avg.) in/in. °C x 10 ⁻⁶
23.00	0.	
1000.00	0.3841	3.9310
1100.00	0.4371	4.0587
1200.00	0.4925	4.1845
1300.00	0.5502	4.3082
1400.00	0.6100	4.4298
1500.00	0.6719	4.5494
1600.00	0.7360	4.6670
1700.00	0.8020	4.7825
1800.00	0.8700	4.8961
1900.00	0.9399	5.0076
2000.00	1.0117	5.1172
2100.00	1.0852	5.2249
2200.00	1.1605	5.3306
2300.00	1.2374	5.4344
2400.00	1.3160	5.5364
2500.00	1.3962	5.6365

Sample Orientation Transverse Total Time above 2300 C 60 minutes
Cumulative shrinkage of 0.00053 in/in occurred between 2300 and 2500 °C

The equation for the Linear Thermal Expansion (Per Cent) Curve is

Y = -0.568088E-02 X ** 0.
 0.250011E-03 X ** 1.00
 0.150289E-06 X ** 2.00
 -0.106020E-10 X ** 3.00
 0.221053E-16 X ** 4.00
 0.111872E-19 X ** 5.00
 0.244313E-23 X ** 6.00
 0.992815E-27 X ** 7.00

Average Deviation = 0.023439
Standard Deviation = 0.031310
Maximum Deviation = 0.097024
Coefficient of Correlation = 0.995728

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Linear Thermal Expansion of NRX A-4 Experimental
Graphite Element No. 99-23999 Center Section
Transmittal Number - TPL 095

Temperature °C	Expansion Per Cent	Alpha (Avg.) in/in. °C x 10 ⁻⁶
23.00	0.	
1000.00	0.5221	5.3444
1100.00	0.5517	5.1224
1200.00	0.5806	4.9327
1300.00	0.6098	4.7753
1400.00	0.6403	4.6501
1500.00	0.6731	4.5572
1600.00	0.7091	4.4966
1700.00	0.7493	4.4682
1800.00	0.7947	4.4722
1900.00	0.8462	4.5084
2000.00	0.9049	4.5770
2100.00	0.9716	4.6779
2200.00	1.0474	4.8112
2300.00	1.1332	4.9769
2400.00	1.2301	5.1750
2500.00	1.3389	5.4055

Sample Orientation Transverse Total Time above 2300 C 60 minutes
Cumulative Shrinkage of 0.00033 in/in occurred between 2300 and 2500 °C

The equation for the linear thermal expansion (per cent) curve is

Y =	-0.213866E-01 X ** 0.	Average Deviation = 0.038626
	0.946312E-03 X ** 1.00	Standard Deviation = 0.053859
	-0.563813E-06 X ** 2.00	Maximum Deviation + 0.151090
	0.161002E-09 X ** 3.00	Coefficient of Correlation = 0.983429
	0.209503E-16 X ** 4.00	
	0.964665E-20 X ** 5.00	
	0.208348E-23 X ** 6.00	
	0.758734E-27 X ** 7.00	

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MECHANICAL STRENGTH

These are the results of mechanical tests performed at WANL: W.O. 12567

Element S/N	Specimen	Face in Tension	Flexure (Stress)
39-24099	1	2	5740 psi
39-24099	2	6	5140
29-24099	3	3	5910
39-24149	4	2	5950
39-24149	5	5	5920
39-24149	6	2	5890
99-23999	7	2	5410
99-23999	8	4	5280
99-23999	9	3	4990
99-24059	10	2	3880
99-24059	11	2	3880
99-24059	12	3	4720
Average			5333 psi

Element S/N	Specimen	Compression (Stress)	Remarks
39-24099	1	13,790 psi	Long Break
39-24099	2	10,920	Long Split
39-24099	3	13,820	Split on Side
39-24099	4	14,050	Long Split
39-24099	5	13,360	Long Split
39-24099	6	12,730	Long Split
39-24149	7	12,100	Long Wedge Split
39-24149	8	14,220	Long Split
39-24149	9	14,390	Long Split

(continued)

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Element S/N	Specimen	Compression (Stress)	Remarks
39-24149	10	12,730 psi	Long Split
39-24149	11	13,300	Circumferential
39-24149	12	12,790	Long Split
99-23999	13	13,530	Long Split
99-23999	14	11,180	Long Wedge
99-23999	15	13,650	Long Split
99-23999	16	12,160	Circumferential
99-23999	17	12,560	Long Split
99-23999	18	11,530	Circumferential
99-24059	19	11,700	Long Split
99-24059	20	11,120	Long Wedge
99-24059	21	11,350	Long Split
99-24059	22	11,750	Long Split
99-24059	23	11,500	Long Split
99-24059	24	10,180	Circumferential
Average		12,517 psi	

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CORROSION TESTS

A total of 11 ETS elements representing five coating runs and eight extrusion batches were hydrogen tested at WANL to evaluate their corrosion resistance. A summary of test results for ETS is given in Table 5 for comparison to standard processed elements. (Table 6) As reported by WANL-TMI-1528, hydrogen test results show little difference in ten-minute weight losses, but there is a tendency for the ETS elements to have larger 30-minute weight losses than standard elements. The additional weight loss in ETS elements appears to be due to increased corrosion in the mid-band region. As noted, two ETS elements failed in the mid-band region whereas there were no failures in the elements with reamed bores.

Also noted in the summary there are formations of large porous areas near the coating-graphite interface that protrude into the channels. It is likely that these areas form when damaged fuel beads expand (due to the interaction of exposed UC_2 with binder) forcing relatively large volumes of matrix material toward the channel. (Reference Figure 4). This appears to be typical for all ETS elements.

TABLE 5

CORROSION TEST RESULTS ON EXTRUDED-TO-SIZE FUEL ELEMENTS

Run	Batch	Element	Type	Test	ΔW	End	Comments
L-117	2621	99-24005	Leached	1B 5 + 5 1B 20	3.3 16.9	97/97 75/80	Axial Cracks at 50-1/2
L-117	2624	99-24036	Not Leached	1B 5 + 5 1B 40"	4.2 5.6	75/75 10/ 5	Hole Channel 17 and 18 at 50" Failure at 50"
L-117	2327	39-24130	Leached	1B 5 + 5 1B 20	3.7 13.0	97/97 90/90	Hole at 51-1/2" 3 pinholes 50-1/4 - 51-1/4
L-117	2651	39-24097	Not Leached	1B 5 + 5 1B 20	4.0 19.4	100/99 70/65	Coating Flaking All Flats
C-226	2652	39-24105	Not Leached	1B 5 + 5 1B 17" 10"	3.7 22.7	95/80 0/ 0	Hole at 51" Corrosion Failure at 22"
C-226	2460	39-24151	Leached	1B 5 + 5 1B 14" 2"	2.8 20.8	80/80 0/ 0	Holes Flats B & E at 51" Heavy Arcing & Corrosion in Chuck Area
F-193	2459	39-24132	Leached	1B 5 + 5	2.8	80/75	Coating Flaked on Flats
F-193	2652	39-24103	Not Leached	1B 5 + 5	2.9	65/65	Corrosion Around Outer 12
F-192	2459	39-24131	Leached	1B 5 + 5 1B 20	2.8 10.7	90/90 40/40	Hole Face B at 50-1/2" Corr. in End all but 6,10,&14-3/4" deep.
F-194	2624	99-24035	Leached	1B 5 + 5 1B 20	4.0 22.5	30/20 0/ 0	Corrosion end 1/8" deep C.F. at 21" end corr. 5/8" deep
C-226	2652	99-24015	Leached & Hydrolyzed	1B 10	4.1	65/65	CB - 2 channel exposed corr. end outer channel 3/8" deep

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TABLE 6

CORROSION TESTS ON STANDARD ELEMENTS

Run	Batch	Element	Type	Test	ΔW	End	Comments
L-117	2532	89-23368	Std, Not Leached	IB 5 + 5	3.9	90/90	Shoulder Corrosion
L-117	2511	79-23146	Std.	IB 5 + 5 + 20	1.8 2.2 11.5	95/95 94/94 40/40	
C-226	2539	89-23418	Std. Not Leached	IB 10 + 17	2.4 7.7	99/99 90/90	Shoulder Corrosion Aborted Test
C-226	2511	79-23149	Std.	IB 5 + 5	3.1	90/90	
F-193	2528	89-23336	Std., Not Leached	IB 5 + 5 + 20	2.5 9.2	100/99 75/75	Arcing in Chuck Area
F-194	2548	99-23631	Std.	IB 5 + 5 + 20	3.0 8.5	100/98 80/75	

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WET MIX COMPACTING

As noted in the summary, the spread in as graphitized "across flats" dimensions compared favorably to "as machined" elements, but element to element variations within any extrusion batch exceeded the current 0.001 inch spec tolerance. This typical condition is graphically illustrated on non-fuel batches 2696 through 2698 (Figure 2). Since density variations in the green mix, i.e., different binder or DCI content, inconsistent compaction density in the pre-compacted slug (both ends of the slug have somewhat higher mass ratio as a result of the compaction process) have a dimensional effect on extruded elements, an attempt was made to improve this dimensional variation by stabilization of the density factor.

An investigation was therefore conducted to determine the effects of density variations within the precompacted slug to extruded element dimensional stability. Constant batch size quantities of green mix were compacted into charges of one, two, three, and four slugs. These were extruded and processed in the normal manner and dimensional across flats measurements were made after graphitization. These results plotted in Figure 3 verify that density variations in the pre-compacted slug have an effect on extruded element across flats dimensions. As the number of pre-compacted slugs (for a constant batch size) is increased, the dimensional across flats spread decreases.

FIGURE 2

TYPICAL SPREAD IN ACROSS FLATS MEASUREMENTS FROM ELEMENT TO
ELEMENT WITHIN A SINGLE BATCH

(a) Damaged Bead Causing Buckling of Matrix

(b) Porous Area

FIGURE 4

ETS Defects

100X

EXCLUDED FROM AUTOMATIC DOWNGRADING
AND DECLASSIFICATION.

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OF 1954

FACE-A
S/N SIDE

COLD
END

XXXXXXXX-XX-XX

FUEL ELEMENT

NON-FUEL SLEEVE

NON-FUEL PLUG

.002

.75

.017

050 REF.

.020

LENGTH PRIOR TO COATING

WANL-TME-1480

INFORMATION CATEGORY

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M. Palwa
Authorized Classifier

9/16/65
Date

ELEMENT, SLEEVE & PLUG ASSY'D
LARA 9-15-65 APPRD. P.A. Nelson
EDSK-320926-A

FIGURE 5