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DEVELOPMENT
REPORT

**PRTR FUEL ELEMENT
QUALITY CONTROL SYSTEM**

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JANUARY, 1967

BATTELLE-NORTHWEST

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PRTR FUEL ELEMENT
QUALITY CONTROL SYSTEM

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PRTR FUEL ELEMENT QUALITY CONTROL SYSTEM

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INTRODUCTION

A survey of the effectiveness of the quality control system at BNW is part of a continuing program for evaluation and control of PRTR fuel quality. The system is a combination of process steps, product control, records, and assignment of responsibilities. This report describes how all these areas are combined in making this survey.

Control of the final product is the basic consideration; and the effectiveness of this control is a function of the entire system. A graphic picture of the system framework is provided by a process flow diagram (Figure 1), and by the product specifications (Appendix). After the system is described, a method for making a survey is discussed.

SUMMARY

The method for analyzing the effectiveness of quality control procedures in the preparation of PRTR fuels at Pacific Northwest Laboratory includes the areas of process flow, product specifications, record-keeping, and assignment of responsibilities.

Process and product specifications are collected and tabulated. With the aid of these tabulations, a survey will detect any quality control weaknesses which may exist at a given time.

In addition to describing the PRTR fuel element a quality control system and how it functions, the appendix to this document contains a concise tabulation of PRTR quality control specifications.

DISCUSSIONTHE QUALITY CONTROL SYSTEMFuel Description

The product is a nuclear fuel element consisting of 19 six foot rods, 1/2 in. in diameter. The assembly is called a cluster (Figure 2).

The cladding and hardware material is Zircaloy-2, and the fuel or core material is a mixture of UO_2 and 2% PuO_2 by weight. The UO_2 and the PuO_2 are mechanically blended to a homogeneous mixture and pneumatically impacted to produce high density particles of uniformly mixed UO_2 -2 wt% PuO_2 . It is then crushed, screened, and loaded into the fuel rods by vibrational compaction. The rod spacing in the completed fuel assembly is maintained by Zircaloy-2 wire which is wrapped around 12 of the 19 rods to provide annular spacing and coolant mixing within the fuel cluster. Detailed fuel rod and cluster specifications can be obtained from the Appendix and from blueprints and documents referenced in it. Most of the fabrication steps (Figure 1) are reasonably standard within the nuclear fuel fabrication industry.

Organization

The group is organized for developmental work rather than for production. Within the fuels section there are two units: one responsible for the design

FIGURE 1. PRTR Flow Chart

FIGURE 2. PRTR High Power Density Nineteen-Rod Cluster Fuel Element

and evaluation of fuel elements, and the other for fabrication. Generally, the fabrication unit is responsible for all normal elements of the manufacturing function such as materials procurement (orders, inventory, and specifications), process engineering (control and improvement), equipment (design, modification, rearrangement, procurement, installation, maintenance), fabrication, quality control, and customer liaison. The units are composed of engineers and engineering assistants. Throughput is normally quite limited; fuel rods from less than 100 to approximately 2500 of a particular type may be processed in one run through the facility. PRTR type fuel runs have varied over this range, and usually more than one type of fuel is fabricated in the facility during a given time period. Generally, PRTR fuel rod production

rates are about 20 rods per shift. Because fuel material is not handled at all process steps during any particular time period, the fuel material is more readily described as being handled in batches. Individuals within the unit are assigned to particular process steps and have a responsibility for controlling that process step, maintaining process capability, and improving the process. An engineer is responsible for planning, scheduling, coordinating, and directing each job; assignments are temporary and overlay the normal organization. Engineers are also assigned to, and made responsible for, various functional requirements, e.g. UO_2 procurement, inventory and specifications, analytical laboratory liaison, and quality control. The individual always has more than one of these types of responsibilities. Responsibility for action is divided among a number of individuals, and the quality system must be adequate to insure coordination and control within this group.

Process Flow

Process flow is graphically depicted in Figure 1. Inspections or product audits are designated by circled numbers which refer to descriptive material in the product specifications (Appendix). The main product flow stream is in the second column from the right. Contributory product flow streams are illustrated in the other columns.

Product Records

A rod follower card and a fuel cluster (19 rods) data card are shown in Figure 3, and a Final Data card in Figure 4. A rod follower card is identified by number with each Zircaloy-2

[illegible]

CORE DATA	
A. MAJOR	C. GRADED
1. LOT NO.	1. LOT NO.
2. $UO_2=H_2O$ WT.	2. $UO_2=H_2O$ WT.
3. W/O H_2O	3. W/O H_2O
4. U	4. U
5. PU	5. PU
B. GRADED	D. GRADED
1. LOT NO.	1. LOT NO.
2. $UO_2=H_2O$ WT.	2. UO_2
3. W/O H_2O	3. TYPE
4. U	4. U
5. PU	

[illegible]

NO. NUMBER	BAR U	BAR PU	P.U. ISOTOPIC COMPOSITION			PURE DATA
			238U	235U	234U	
(a) FE 30	1548.00	31.59		8.07		52-9
(b) FH 73	"	"		8.15		62-9
(c) FH 57	1546.28	31.56		8.19		62-1
(d) FH 10	"	"		8.15		62-9
(e) FH 01	"	"		8.19		62-1
(f) FE 42	1547.00	31.57		8.15		62-2
(g) FH 85	1548.00	31.58		8.08		62-8
(h) FH 66	1547.44	31.57		"		"
(i) FH 50	1548.00	31.59		"		"
(j) ER 30	1547.15	31.57		"		62-6
(k) FE 28	1537.14	"		8.15		62-9
(l) FE 33	1546.48	31.56		"		"
(m) FH 79	"	"		8.19		62-1
(n) ER 33	1548.87	31.61		8.08		62-6
(o) FE 37	1548.28	31.56		8.15		62-9
(p) FH 25	"	"		"		"
(q) FH 25	1547.14	31.57		8.08		62-8
(r) ER 27	1549.00	31.59		"		62-6
(s) FE 41	"	"		8.15		62-9
TOTAL	59496.40	400.92				

FIGURE 3. An Element Card

Fuel Element 6513

No. of Rods Loaded from Lots			Isotopic Analysis of Pu	
	1 ROD LOADED FROM LOT	52-9	(8.07% Pu ²⁴⁰ , CALCULATED AVERAGE)	
3 RODS LOADED FROM LOT	62-1		(8.14% Pu ²⁴⁰ , ")	
3 " " " "	" " " "	62-6	(8.08% Pu ²⁴⁰ , ")	
4 " " " "	" " " "	62-8	(8.08% Pu ²⁴⁰ , ")	
8 " " " "	" " " "	62-9	(8.15% Pu ²⁴⁰ , ")	

Analyses on Nupaked Fuel

Lot	F (ppm)	Cl (ppm)	Pu (%)	Fe (%)	O/U (ratio)	H ₂ O (ppm)	C (ppm)	Oil (ppm)	Off Gas (cc/gm)	Gas Analysis (Mole %)							
										CO ₂	O ₂	N ₂	CO	H ₂	H ₂ O	CxHy	SO ₂
52-9 (A)	2	<10	1.67	2.0131	8	95	<20	0.043	18.2	149	60.4	2.9	2.3	0.5	<0.4	<0.05	<0.1
(B)	2	<10	1.76	2.0188	8	95	20	0.090	24.2	0.4	5.2	28.9	38.1	1.0	<2.5	<0.1	<0.1
62-1	3	<10	1.63	2.0048	10	95	40	0.052	THIS ANALYSIS IS NOT REQUIRED TO MEET SPECIFICATION FOR INFO.								
62-6	<2	<10	1.65	2.0185	15	40	20	0.029	69.1	0.4	2.4	19.0	6.8	1.5	<0.6	<0.1	0.2
62-8	<2	<10	1.62	2.0125	17	95	50	0.089									
62-9	<2	<10	1.68	2.0169	<10	110	20	0.029									

FIGURE 4. Rod Follower and Fuel Cluster Cards

clad tube from the time the tube enters the process until the rod's final assembly. The tube number is used to provide Zircaloy-2 tube lot identification and, therefore, certification and vendor test data. When the tube is loaded with fuel material, a lot number for the mix is also recorded on this card. This number is then cross-indexed in a log to PuO_2 and UO_2 lot identification, and can be traced back to certification and vendor test data. The records for Zircaloy-2, UO_2 , and PuO_2 are maintained by those responsible for procurement. The other PRTR hardware (wire, rod, banding, etc.) is not presently handled on a lot basis; items are all fabricated from materials meeting product specifications and are segregated no further. The follower card is designed to provide a record of product flow through the process stream. Spaces are provided for each critical fuel rod fabrication step. The date the fuel rod was processed is stamped in this blank, to insure that the operation was performed and also to provide a record of when it was done. These cards are also used to record inspection data and process deviations that are not cause for rejection, but are noteworthy.

The element card provides a record of rod location within the element, and requires a signature denoting final approval of the finished fuel cluster by the person responsible for overall fabrication.

Figure 4 is typical of the form used for recording fuel or core material, final product data. It is maintained and filed at final assembly by fuel

cluster number and it contains data for all rods within the cluster.

Specification Violations

The PRTR fuel fabrication process is audited by a representative from the fuel element design and evaluation group. His approval must be obtained before fuels not meeting product specifications (Appendix) can be accepted for irradiation. These deviations are brought to the attention of the section level manager who requires a written analysis of them (recorded as a waiver of specifications) from the engineer responsible.

PROCESS CONTROL

Specifications can be applied to the process (temperatures, solutions used for cleaning, holding time at a particular step, etc.), or to the product (rod cladding thickness, fuel enrichment, cluster diameter, etc.). Very few process steps are included in the compilation of specifications in the Appendix. As mentioned earlier, the unit is oriented toward development. The product must be specified (limit set), but process limitations primarily trade economic considerations for flexibility. In this organization, engineers, who have flexibility, are responsible for process areas, but they are also responsible for ensuring that the process is correctly controlled to provide an acceptable product. All product characteristics are monitored somewhere in the process; and where the process cannot be monitored by examining the product, the process is specified (see Step 4, Appendix). This type of control has been applied very successfully, with defect levels being very low.

It is general policy, then, that process limits are not rigidly specified or controlled. However, process guides are used and are particularly useful for training. Although not included in this document, these guides will be collected and published at a later date.

PRODUCT CONTROL

Product specifications or limits have been collected from a number of sources⁽¹⁻⁵⁾ and are tabulated in the Appendix. Although a listing of the limits is useful, a method of determining the importance of each limit is also needed for establishing audit priorities, for justifying the limits, and for providing mutually recognized grounds under which specifications might be waived. Therefore, specification criteria were also developed, mutually, between the fuel design unit and the fuel fabrication unit; these are tabulated.

SURVEY ANALYSIS

Once the tabulations and background are provided, a survey is needed to determine whether the product is appropriately and thoroughly specified. Final product specifications are provided by the designers based on final product performance requirements. These specifications should be reviewed with the design people periodically to assure that limits are adequate and are properly interpreted. Then the flow sheet is examined to insure that all process operations are

being adequately monitored by product inspections. Records are examined to confirm adequate compliance and documentation, and criteria is compared with limits to guarantee meaningful, but not too restrictive, specifications.

The system described in this document was used to make the most recent quality surveys of PRTR fuels. This background and these tools will be useful in making future surveys.

The product specification listing is useful as a handy, chronological listing of PRTR product requirements, and when required, it can easily be modified.

Because of the continually changing system environment in a unit oriented toward development (as this one is), surveys at frequent intervals are essential.

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APPENDIX
QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PRIR-HPD FUEL ELEMENTS

Operation, Inspection or Test Step	Location of Test in Process Flow	Reasons for Test or Inspection	Limits	Sample Quantity
I. (a) Procurement of Zirconium tubing (cladding)*	At manufacturing site (BNW field inspector verifies test results where applicable)	To insure the zirconium used is a reactor-grade material (Zircaloy-2) with regard to purity, poisons, strength, and corrosion resistance.	Seamless, per ASTM B-353-64T, Grade RA-1, extra close tolerance (includes hydrostatic chemical, flare tests etc., as designated)	As defined in ASTM B-353-64T, including Appendix A1, A2, and A3.
(b) In addition, the follow- ing tests are specified				
Dimensions	"	Basic design; among the considerations are unifor- mity, strength, over-all cost, and bulk density of rod.	ID 0.505 in. $\pm$ 0.002 in. wall 0.030 in. $\pm$ 0.002 in.; Length 67 in., $\pm$ 1/4 in., -0	100% (audited rou- tinely at BNW)
Oxygen	"	May affect corrosion resistance	1400 ppm maximum	Top, center, and bottom of ingot** (one ingot/lot)
Pneumatic Test	"	Strength and defect detec- tion in tubes	75-100 psi air, under water	100%
Swage Test	"	Ductility	25% diam reduction by free-sink swaging (no cracks, laps, seams or tears allowed)	1 sample/lot
Surface Roughness	"	Inspectability, cleanliness, weldability, and general appearance	Less than 63 μ in.	100% conformance
Hydride Orientation	"	Acceptable ductility or impact strength	<25% radially aligned platelets after 3 day autoclave	1 sample/lot
Ultrasonic Testing	At BNW	Integrity of tubing: Cracks, voids, inclusions, etc.	Reject defects greater than 5% of average wall thickness (0.0015 in. deep) and greater than 0.015 in. long	100%

* Some tubing is required for end brackets. It also is purchased under ASTM B-353-64T. Dimensions are as required on Print H-3-14520. The ultrasonic test, swage test, and hydride orientation tests are not performed on this material.

** A lot is defined as all material of the same size, shape, and condition produced from the same ingot at one time.

APPENDIX
QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PTRR-HPD FUEL ELEMENTS

Operation, Inspection or Test Step	Location of Test in Process Flow	Reasons for Test or Inspection	Limits	Sample Quantity
2. Machined Tube Inspection	BNW Tech Shops	Mating of tube with end cap, uniformity in fuel rod length (dimension on print H-3-25386, 87, H-3-25291 or H-3-25293, whichever is applicable to fuel element being made).	Tube recess ID, 0.0005 in. range Depth, $\pm$ 0.001 in. Tube Length, $\pm$ 0.008 in.	100%
3. (a) Wire, Bar, Flats Bar (end caps and bracket hardware) Wire (rod wrapping) Flats (cluster banding and bracket material)	At manufacturing site. (BNW field inspector verifies test results where applicable)	To insure that material is defect-free, reactor grade Zircaloy-2 with acceptable properties, tolerances and corrosion resistance.	Cold-worked, annealed, generally polished, per ASTM B-352-60T, Grade RA-1.	1 or 2 samples/lot as required by ASTM B-352-60T
(b) In addition the following tests are specified				
Dimensions	"	Basic design; among the considerations are uniformity, strength, and overall cost.	See applicable print H-3-25383 through 87, H-3-25391 through 93, H-3-14520. Tolerances per ASTM B-352-60T.	100% (audited routinely at BNW)
Oxygen	"	May affect corrosion resistance	1400 ppm maximum	Top, center, and bottom of ingots.
Surface Roughness	"	Inspectability, cleanliness, weldability, and general appearance.	Less than 63 μ in.	100% conformance
X-ray or ultrasonic	At BNW	For end cap material to eliminate the possibility of a fuel rod leak through the end cap. For wire wrap to insure strength.	No center line voids or cracks	100%
4. Machined Parts				
(a) End Caps	At manufacturing site by field inspector (parts may be made and inspected at BNW.	Mating with tube, overall fuel length, wire location, alignment and location in end bracket, weight for final fuel core weight.	See applicable print, H-3-25386, 87, 91, and 93.	"

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QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PRTR-HPD FUEL ELEMENTS

Operation, Inspection or Test Step	Location of Test in Process Flow	Reasons for Test or Inspection	Limits	Sample Quantity
(b) End Brackets	At manufacturing site, etc.	PRTR cluster design	See applicable print H-3-14520 and H-3-25385	100%
5. Cleaning Component Parts	After machining	All parts are degreased and washed before etching. Etch removal and appear- ance after autoclaving are measures of cleanli- ness, except on internal rod parts.		"
(a) Tube	"	So that containments on the tube walls are removed before the tube is loaded with fuel material.	Wash in hot water and detergent, scrub inside with a stiff bristle brush. Rinse in clean hot tap water. Air dry. Tube should be visibly clean and dry before welding.	"
(b) End Cap	"	So that contaminants are not introduced into the fuel rods	Wash in an ultrasonic bath with alcohol. Parts should be clean and dry before using	"
6. Weigh Tube	Before welding	Needed eventually to determine final fuel weight (27).		"
7. First End Cap-- Weld Inspection	After removal from welding chamber.	To assure high integrity closure.	Visual appearance satis- factory, welding equipment operating satisfactorily, no flare-ups during weld- ing. Only highly trained welders used.	"
8. PuO ₂ Tests	By vendor. (May be prepared from metal at BNW)	For details, refer to BNWL-42--H. R. Wisely.		
(a) Particle Size	"	To obtain a blend with ade- quate distribution of PuO ₂ in UO ₂ . HW-81259	<325 mesh, nonagglomerating.	"

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QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PTR-HPD FUEL ELEMENTS

Operation, Inspection or Test Step	Location of Test in Process Flow	Reasons for Test or Inspection	Limits	Sample Quantity
(b) Isotopic Composition	At Vendors, on metal buttons.	To assure homogeneous physics properties in reactor.	Agreed isotopic content of Pu ²⁴⁰ (7.75-8.25)	1 representative sample/lot.
(c) Chlorine	By vendor	To prevent corrosion of inside fuel rod tube wall during irradiation.	<10 ppm	1 sample/lot
(d) Fluorine	"	To prevent corrosion of inside fuel rod tube wall during irradiation.	<10 ppm	"
(e) Carbon	"	To prevent combination with O ₂ or H ₂ O to increase gas content of fuel.	<125 ppm	"
(f) Equivalent Boron Content (EBC)	"	To assure known fuel reactivity.	<4 ppm Boron or its equivalent.	"
(g) Plutonium Content of PuO ₂	"	To determine Pu content of fuel and as an indirect assurance of purity of the material.	>87.5%	"
(h) Oxygen/Plutonium Ratio	"	To determine Pu content of fuel.	2.00 ± 0.05	"
9. PuO ₂ Acceptance Testing	BNW	Spot check of selected items from 8 through 8h.	As given above.	"
10. Weight PuO ₂ into sub-lots for blending	After screening and homogenizing.	To control enrichment level of fuel core material.	240 ± 1 g/sub-lot	100%

* A vendor's lot of PuO₂ is defined as the oxide which is uniform in chemical, isotopic, and physical characteristics.

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QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PRTR-HPD FUEL ELEMENTS

Operation Inspection or Test Step	Location of Test in Process Flow	Reasons for Test or Inspection	Limits	Sample Quantity
11. Testing of UO ₂		For details, refer to HW-74204 Rev. 2, H. J. Anderson and R. J. Anicetti.		
(a) Particle Size	By Vendor	To not exceed capability of our crushing equipment	<1/2 in. longest dimension	100%
(b) Apparent Density	"	Needed for process control	>10.80 g/cm ³	1 sample/lot*
(c) Impurities	By Vendor	General purity requirements	<1 wt%	"
(d) O/U Ratio	"	Affects thermal conductivity. Needed for determination of U content of fuel.	2.00 ± 0.02	"
(e) Uranium Content	"	Affects thermal conductivity Needed for analysis of impuri- ties and for accountability.	>88.0 wt% of UO ₂	"
(f) Isotopic Content	"	Physics properties of fuel	As specified in Pur- chase Requisition.	"
(g) Report Ag, B, Cd, Cr, Co, Fe, Pb, Mn, Mo, Na, Si, Sn, Dy, Eu, Gd, Sm contents	"	Reactivity of fuel material.	<4 ppm total EBC	"
(h) Carbon Content	"	Carbon combines with O ₂ or H ₂ O to form gas during irradiation.	<200 ppm	"
(i) Nitrogen Content	"	To assure low gas content in fuel.	<200 ppm	"
(j) Chlorine Content	"	To minimize corrosion of inner surface of cladding	<20 ppm	"

* A lot is defined as a batch of material which has been blended as an entity before packaging.

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QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PRTR-HPD FUEL ELEMENTS

<u>Operation, Inspection or Test Step</u>	<u>Location of Test in Process Flow</u>	<u>Reasons for Test or Inspection</u>	<u>Limits</u>	<u>Sample Quantity</u>
(k) Fluorine	By Vendor	To minimize corrosion of inner surface of cladding	<10 ppm	1 sample/lot
(i) Moisture Content	"	To minimize hydrating of cladding and gas content of fuel.	<200 ppm	"
(m) Gas Content (at 950 °C)	"	"	<0.10 cm ³ /g UO ₂	"
12. Acceptance Testing of UO ₂	BNW	Spot check of selected items from 11a through 11m.	As given above.	"
13. In-process Testing of UO ₂				
(a) O/U	After second crushing.	To control stoichiometry which affects densification.	2.000-2.025	"
(b) Particle Size	By Vendor	For pneumatic-impaction control and for adequate blending with PuO ₂ . HW-812S9.	<65 mesh	100%
(c) Nitrogen	"	To assure low gas content in fuel.	<100 ppm	1 sample/lot
(d) Moisture	"	"	<100 ppm	"
(e) Weight	"	Enrichment control	11.760 ± 5 g Batch Size	100%
(f) Fluorine	"	To minimize corrosion of inner surface of cladding.	<10 ppm	1 sample/lot
(g) Chlorine	"	"	<20 ppm	"

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QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PRIR-HPD FUEL ELEMENTS

Operation, Inspection or Test Step	Location of Test in Process Flow	Reasons for Test or Inspection	Limits	Sample Quantity
(b) Carbon	By Vendor	Carbon combines with O ₂ or H ₂ O to form gas during irradiation	<200 ppm	1 sample/lot
(i) Spectrographic	"	Reactivity of fuel material	4 ppm total EBC	
14. Reweigh UO ₂ and PuO ₂	Prior to blending.	To confirm weights for enrichment control	PuO ₂ : 240 ± 1 g. UO ₂ : 11,760 ± 5 g.	100%
15. Blending UO ₂ and PuO ₂	"	Homogeneity controlled by process conditions--mix by salt shaker technique and V-blend 30 min.	Checked--19i	"
16. UO ₂ -PuO ₂ Particle Density Determination	After Decanning	Assures that fuel density is high enough to achieve required fuel element bulk density.	>97.99% (10.75 g/cm ³)	5 random samples/lot
17. Vacuum Outgas Fuel	After crush and screen.	To drive off residual oil, moisture and gas from fuel immediately prior to fuel loading.	Checked at 19	100%
18. Bottling	After vacuum outgas	To provide the correct quantity of fuel.	1794 ± 1.0 g	"
19. Final UO ₂ -PuO ₂ Sampling (a) Gas Content	"	Ensure that gas content of fuel is within acceptable level.	<0.10 cm ³ /g oxide	1 sample/lot*
(b) Hydrocarbon	After vacuum outgas	Ensure that gas content of fuel is within acceptable level.	<100 ppm	"

* Lot of mixed oxide is defined as 120 kg which contains PuO₂ from one PuO₂ lot and UO₂ from one UO₂ lot, or a mixture of known quantities of recycled lots.

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QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PRTR-HPD FUEL ELEMENTS

<u>Operation, Inspection or Test Step</u>	<u>Location of Test in Process Flow</u>	<u>Reasons for Test or Inspection</u>	<u>Limits</u>	<u>Sample Quantity</u>
(c) Oxygen-Uranium	After vacuum outgas	To assure the desired compromise between control of density and thermal conductivity of fuel.	2.00-2.04	1 sample/lot
(d) Pu Plutonium	"	To confirm no errors in fuel enrichment.	1.76 (+0.00) wt% Pu -0.20	"
(e) (Carbon Content	"	To control gas content	<200 ppm	"
(f) H ₂ O Content	Immediately prior to loading.	To minimize hydriding and control gas content.	<100 ppm	"
(g) Chlorine Content	After vacuum outgas	To minimize zirconium corrosion	<20 ppm	"
(h) Fluorine Content	"	"	<10 ppm	"
(i) Autoradiograph (mixed oxide)	"	To check PuO ₂ distribution and homogeneity	Visual comparison with approved standard	"
(j) History sample	"	Retained for future analyses, if necessary.		1794 g/lot
20. Pellet Inspection*	Following fabrication of pellets			
(a) Length	"	For control of fuel column length	0.385 to 0.415 in.	10% sample size and not less than 10 per batch.
(b) Weight	"	For control of amount of fuel in rods.	11.0 to 14.0 g	"

* UO₂ used for pellets is same as that referred to in Items 11 and 12 above.

APPENDIX

QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PRTR-HPD FUEL ELEMENTS

<u>Operation, Inspection or Test Step</u>	<u>Location of Test in Process Flow</u>	<u>Reasons for Test or Inspection</u>	<u>Limits</u>	<u>Sample Quantity</u>
(c) Outside Diameter	Following fabrication of pellets	So that pellet will go in tube and no oxide will slip past it.	0.490 in. minimum 0.500 in. maximum	10% sample size and not less than 10 per batch.
21. Inspect Springs*				
(a) Weight	After receiving from vendor	Needed later to determine amount of fuel in rod	None	"
(b) Total Length	"	Basic spring properties; b, c, d were specified to keep fuel in place if fuel rods were dropped 1 ft.	8 in. $\pm$ 1/64 in.	"
(c) Wire Diameter	"	"	0.072 in.	"
(d) Spring Constant	"	"	Support 7 1/2 to 10 lb at 6 7/8 in. compressed length.	"
(e) Outside Diameter	"	To assure clearance in tubing and to support walls of cladding in reactor.	0.500 in. maximum 0.490 in. minimum	"
22. Reweigh bottled fuel	Prior to loading	To assure correct fuel loading	1794.0 $\pm$ 1.0 g	100%
23. Load Fuel	Loading	To assure correct fuel loading and distribution in tubing	58.10 in. minimum 58.35 in. maximum	"
24. Check fuel column height	After decontamination	To assure proper space for plenum	7 1/2 $\pm$ 1/8 in. from top of tube	"

*Composition of spring material assured by vendor certification, per ASTM Spec. A-641.

APPENDIX

QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PRTR-HPD FUEL ELEMENTS

<u>Operation Inspection or Test Step</u>	<u>Location of Test in Process Flow</u>	<u>Reasons for Test or Inspection</u>	<u>Limits</u>	<u>Sample Quantity</u>
25. Evacuate Rods and Back-fill with Helium	Before weld	To assure that rod contains helium for leak detection (No. 32 below)	Evacuate rods to 2×10^{-4} mm Hg minimum for 12 hr or store in dry air overnight and evacuate for 2 hr. Fill with helium.	100%
26. Final Weld Inspection	After weld	To assure high integrity closures free from plutonium which might contaminate reactor coolant.	Visual appearance satisfactory. Welding equipment operating properly, no flare-ups during welding. Only highly trained welders used. No detectable plutonium permitted.	"
27. Weigh Fuel Rod	After weld	To check final $\text{UO}_2\text{-PuO}_2$ fuel weight, core weight determined by difference. Only gross errors can be detected at this weighing.	1790 g minimum 1795 g maximum	"
28. X-ray Inspection	After weighing	To check pellet condition and fuel column height.	58.50 to 58.75 in. fuel column height, including both pellets. No damage* permitted.	"
29. Gamma Scan	After X-ray	Uniformity between fuels with regard to bulk density variations and plutonium homogeneity.	Visual comparison	1 rod/ $\text{UO}_2\text{-PuO}_2$ lot
30. Ultrasonic Tests				
(a) Tubing	After X-ray	To detect scratches and crack-type defects which may have developed in the wall of the tubing or in the weld.	Reject defects >0.0015 in. deep and 0.015 in. long.	100%
(b) Weld	"		"	"

* Defined in detail for each job.

APPENDIX

QUALITY CONTROL AND INSPECTION DURING FABRICATION OF PRTR-HPD FUEL ELEMENTS

<u>Operation, Inspection or Test Step</u>	<u>Location of Test in Process Flow</u>	<u>Reasons for Test or Inspection</u>	<u>Limits</u>	<u>Sample Quantity</u>
31. Measure Rod Diameter	Before and after etch.	The etching is to clean metal. Measurement is to check amount of metal removed by etch so that wall thickness is not reduced below acceptable limits.	Metal removal from all surfaces to be at least 0.001 in. and not more than 0.002 in.	10%
32. Leak Check	After etch.	To detect small holes in the weld or cladding.	Leak rate $< 7.75 \times 10^{-8}$ ATM cm ³ /sec.	100%
33. Autoclave	After leak check	1. To test corrosion resistance of Zircaloy. 2. To provide cladding with oxide film.	700 to 1100 psi 390 to 410 °C 18 to 24 hr	"
34. Leak Check	After autoclave	To detect small holes in the weld or cladding.	Leak rate $< 7.75 \times 10^{-8}$ ATM cm ³ /sec	"
35. Visual Inspection of Rods	"	To detect surface flaws, inclusions or abnormalities, to check corrosion resistance of Zircaloy, to visually examine weld quality, to check rod no. versus rod card identification, and check for grease, oil, or handprints.	Reject rods which have marks deeper than 0.0015 in. and/or white oxide spots. Correct other defects.	"
36. End Bracket Inspection	"	Final acceptance of finished part.	Proper assembly, good welds.	"
37. Banding Inspection	After etching	Ensure correct band thickness	0.008 to 0.010 in. thick	"
38. Cluster Inspection	After cluster assembly	a. Cluster passes go-no-go gage to assure meeting proper outside dimensions b. To minimize dirt, fingerprints, dents and scratches. c. Visual conformance with design as regards; band location, wrapped and unwrapped rods, cards complete, overall appearance.	a. 3.220 in. minimum 3.230 in. maximum b. Clean with alcohol if dirty; reject if scratched beyond limit (0.0015 in.) c. Correct any nonconformity with final assembly requirements (print H-3-25383, 84, and H-3-25392).	"

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