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HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

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PROCESSING DATA FOR NIE AND NIN
KER LOOP CHARGES (PT 377)

□

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PROCESSING DATA FOR NIE AND NIN KER LOOP CHARGES
(PT-377)

The following data represents processing conditions used in fabricating prototypic (except for supports) natural and enriched NPR inner fuel elements for Production Test 377. The prototypic NPR inner fuel elements were inserted into zircaloy sleeves prior to charging. In this way it was possible to simulate, in the KER loops, the conditions under which NPR fuel elements would be subjected under irradiation.

The purpose in documenting the data is to provide a permanent record of processing conditions and dimensions which may be referred to for post irradiation analysis and possible future process development work. Post irradiation results will be issued by the Fuels Development Operation, Hanford Laboratories Operation, and the test loop operating conditions will be issued by Process and Reactor Development Operation, Irradiation Processing Department, as outlined in the Production Test Procedure.

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PROCESSING DATA FOR NIE AND NIN LOOP CHARGES (PT 377)I. Prior History and Chemical Analysis of Components

- A. Uranium billets 33246, 33248, 31162, 31166, 31167 and 31170 were used to make up the fuel elements for this production test. These billets were hollow cast to 11" diameter x 22" long castings, triple beta heat-treated and then alpha extruded. Billets 33246, 33248, 31166, 31167 and 31170 were machined at NLO to 5.360 inches OD (nom) 1.340 inches ID (nom) and 19.75 inches long (including 0.75 inches pre shape). Billet 31162 was a HAPO primary extrusion. The charge make-up for the uranium billets was as follows:

<u>Billet Number</u>	<u>Charge Make-Up</u>
31162 33246 33248	100% derby
31166	15% briquette, 35% solid, 50% derby
31167	15% briquette, 35% solid, 50% derby
31170	15% briquette, 15% solid, 70% derby

B. Identification of Components Used in Tubes

<u>Tube Number</u>	<u>U Core</u>	<u>Outer Clad</u>	<u>Inner Clad</u>
89	33246-B-443	1216-715	1216-715
98	33246-C-443	1380-2-R	1216-715
99	33246-A-443	1380-1-R	1216-715
104	33248-C-443	1380-1-R	1216-715
105	31162-A-456	1380-1-R	1216-715
118	31170-3C-460	1391-2 R	1216-715
119	31170-3A-460	1373-1 F	1216-715
130	31167-2A-460	1391-2 R	1216-715
131	31166-2A-460	1373-1 R	1216-715

C. Uranium Chemical Analysis

	<u>Ingot</u>	<u>Ingot</u>	<u>Ingot</u>	<u>Ingot</u>	<u>Ingot</u>	<u>Ingot</u>
	33246	33248	31162	31166	31167	31170
Isotopic Content	Natural	Natural	0.9492	0.9476	0.9488	0.9470
Density (g/cm ³)	18.97	18.98	18.96	18.94	18.96	18.95
C	241 ppm	245 ppm	333 ppm	446 ppm	445 ppm	470 ppm
N	22	15	19	9	15	19
B	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cd	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cr	10	7	<5	<5	5	6
Fe	60	47	38	81	61	89
Mg	<4	<4	4	<4	<4	<4
Mn	<4	5	<4	<4	4	4
Ni	45	40	<10	28	22	63
SiO ₂	18	19	15	22	23	20

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D. Zircaloy Components

1. Chemical Analysis

<u>Element</u>	<u>Heat No.</u> <u>1216-715</u>	<u>Heat No.</u> <u>1380</u>	<u>Heat No.</u> <u>1373</u>	<u>Heat No.</u> <u>1391</u>
Al	44 ppm	35 ppm	43 ppm	38 ppm
B	0.3	<0.3	<0.3	<0.3
C	177	215	160	305
Cd	<0.3	<0.3	<0.3	<0.3
Co	<5	<10	<10	<10
Cr	750	970	980	950
Cu	23	<20	<20	<20
Fe	1255	1330	1290	1250
H	11	10	12	13
Hf	54	<125	<125	<125
Mg	<10	<10	<10	<10
Mn	15	<25	<25	<25
Mo	10	<10	<10	<10
N	28	28	28	27
Na		<10	<10	<10
Ni	460	540	530	600
O	1035	1025	1105	1000
Pb	10	<20	<20	<20
Si	90	155	54	130
Sn	13150	14500	15000	14600
Ti	<20	<20	<20	<20
U	2.1	0.3	1.2	0.3
V	<20	<10	<10	<10
W	40	<20	<20	<20
Zr	balance	balance	balance	balance

2. Corrosion Test

The corrosion test was conducted at 400°C in 1500 psi steam for 72 hours at the vendors site.

<u>Heat Number</u>	<u>Wt Gain (mg/dm²)</u>	<u>Visual Examination</u>
1216-715	Corrosion test waived	
1373-1 F	19	MWCP*
1373-1 R	20	MWCP*
1391-2 R	24	SGBF**
1380-1 R	17	SGBF
1380-2 R	17	

* MWCP = Minute White Corrosion Product

** SGBF = Smooth Glossy Black Finish

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II. Extrusion DataA. Inner Clad Extrusion Data

The inner clad shells were extruded from Heat No. 1216-715 at HAP0 under the following conditions:

Date:	October 11, 1960	<u>Billet</u>
Extrusion No.:	148	Temperature: 1300°F
Ram Speed (ipm):	15	Preheat: 6 hrs.
Upset Pressure (tons):	1600	Lubricant: Aqua dag with water
		Length: 16.00 inches

<u>Die</u>	<u>Mandrel</u>
Number: 1	OD: 0.510 inches
ID: 1.400 inches	Type: Step-Free
Type: 90° - Radius	Temperature: 950°F
Temperature: 950°F	Lubricant: Oil dag
Lubricant: Oil dag	

Cut Off Blocks

<u>Material</u>	<u>Temp (°F)</u>	<u>Length (inches)</u>
Copper	950	2.5
Graphite	950	0.5

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Outer Clad (inches)			Inner Clad (inches)				
WT	Length	Heat No.	OD	ID	WT	Length	Heat No.
0.223	15.875	1216-715	1.321	0.652	0.335	16.75	1216-715
0.228	19.00	1380-2R	1.319	0.654	0.332	19.00	1216-715
0.229	19.00	1380-1R	1.318	0.654	0.332	19.00	1216-715
0.227	19.00	1380-1R	1.321	0.652	0.332		1216-715
0.230	19.00	1380-1R	1.320	0.654	0.333	19.00	1216-715
0.230	19.00	1391-2R	1.319	0.652	0.332	19.00	1216-715
0.229	19.00	1373-1F	1.320	0.652	0.333	19.00	1216-715
Measurements not available		1391-2R	Detailed measurements not available				1216-715
"	"	1373-1F	"	"	"	"	1216-715

$\frac{105}{0.92}$	$\frac{118}{2}$	$\frac{119}{2}$	$\frac{130}{1.25}$	$\frac{131}{1}$
2	2	2	2	2

	$\frac{105}{238}$	$\frac{118}{267}$	$\frac{119}{268}$	$\frac{130}{280}$	$\frac{131}{281}$
1	24.7/1	24.7/1	24.7/1	24.7/1	24.7/1
	15	15	15	15	15
	1375	1400	1320	1300	1350

C. The following conditions were in effect for all of these tubes:

Die

ID: 1.290 inches
Type: 90° - Radius
Temperature: 800°F
Lubricant: Oil dag

Mandrel

OD: 0.426
Type: Step-Free
Temperature: 825-850°F
Lubricant: Oil dag

Billet

Temperature: 1145-1160°F
Lubricant: Aqua dag
Preheat Time: 3.25-7 hrs.

Liner

Temperature: 800°F
Lubricant: Oil dag

Cut Off Blocks

<u>Material</u>	<u>Temp (°F)</u>	<u>Length (inches)</u>
Graphite	850-1165	2.5

Follower Block

Temperature: 800-850°F
Length: 3 inches

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r removal, prior to zircaloy stripping (between steps 3 and 4 on the Process

erface liness(ave.)	Uranium Grain Size (mm)					
	0°			180°		
ID	OD	Center	ID	OD	Center	ID
7	0.110	0.035	0.180	0.110	0.035	0.180
8	0.130	0.035	0.180	0.110	0.035	0.180
7	0.110	0.035	0.150	0.110	0.035	0.150
4	0.180	0.035	0.300	0.300	0.035	0.300
4	0.250	0.035	0.300	0.210	0.045	0.180
7	0.180	0.045	0.210	0.210	0.045	0.500
7	0.180	0.035	0.150	0.150	0.035	0.210
8	0.055	0.035	0.055	0.055	0.035	0.065
6	0.250	0.055	0.300	0.300	0.055	0.300
6	0.065	0.035	0.110	0.065	0.035	0.110
4	0.075	0.035	0.360	0.130	0.035	0.300
6	0.210	0.030	0.300	0.500	0.035	0.250
6	0.150	0.030	0.210	0.090	0.035	0.210
3	0.075	0.030	0.210	0.045	0.030	0.300
6	0.180	0.180	0.300	0.130	0.090	0.360
6	0.090	0.035	0.360	0.300	0.045	0.075
6	0.075	0.035	0.360	0.090	0.035	0.300
6	0.180	0.045	0.360	0.150	0.035	0.300
6	0.110	0.055	0.210	0.110	0.045	0.180
5	0.075	0.045	0.250	0.090	0.035	0.300
4	0.210	0.075	0.300	0.090	0.065	0.300
5	0.090	0.045	0.130	0.110	0.065	0.300
4	0.075	0.045	0.500	0.130	0.045	0.300
6	0.130	0.045	0.210	0.110	0.045	0.500
6	0.055	0.035	0.090	0.055	0.035	0.130

III. Chemical Milling

A. Depth of Etch

<u>Fuel Amount Number</u>	<u>Etch Depth (mils)</u>	
	<u>Numbered End</u>	<u>Unnumbered End</u>
89-91	265-291	265-291
89-119	261-286	261-286
89-258	259-287	255-287
89-283	260-289	260-289
98-123	256-280	267-280
98-174	266-277	271-281
99-278	290-310	285-305
104-118	279-303	290-308
104-159	365-385	276-289
104-206	362-386	277-294
104-230	371-384	282-299
104-258	369-388	277-293
104-309	370-394	275-290
104-333	377-399	279-290
104-379	279-297	282-305
104-401	280-299	283-308
105-94	298-305	300-313
105-297	295-305	298-319
105-320	294-308	299-317
105-371	291-310	285-317
118-202	292-304	303-317
119-320	293-303	307-317
119-371	292-302	304-312
130-148	297-311	300-314
131-72	302-322	298-320

IV. Brazing

A. Cap Dimensions

1. The dimensions of the end caps for fuel elements 104-159, 104-206, 104-230, 104-309, 104-333 are:

<u>OD (inches)</u>	<u>ID (inches)</u>	<u>Thickness (inches)</u>
1.175	0.500	0.245

2. The dimensions of the end caps for fuel elements 89-91, 89-119, 89-258, 89-283, 98-123, 98-174, 99-278, 104-118, 104-258, 104-379, 104-401, 105-94, 105-297, 105-320, 105-371 are:

<u>OD (inches)</u>	<u>ID (inches)</u>	<u>Thickness (inches)</u>
1.185	0.490	0.220

3. The dimensions of the end caps for fuel elements 118-202, 119-320, 119-371, 130-148, 131-72 are:

<u>OD (inches)</u>	<u>ID (inches)</u>	<u>Thickness (inches)</u>
1.175	0.500	0.245

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UNNUMBERED END

Argon Pressure (psi)	Ave. Max. Temp. (°C)	Melting Time (sec.)	Delay (sec.)	Final Heating Time (sec.)	Pressure- initial ($\times 10^{-4}$ mmHg)	Argon Pressure (psi)	Ave. Max. Temp. (°C)
3	1051	40	5	20	3	3	1052
3	1054	45	5	20	4	3	1035
3	1055	45	5	20	3	3	1051
3	1039	45	5	20	1.5	3	1052
4	1040	50	5	20	1.5	4	1052
4	1046	45	5	25	3	4	-
4	1054	70	5	20	4	4	-
4	1054	45	5	20	4	4	1050
4	1037	50	5	20	5	4	1041
4	1053	50	5	20	5	4	1035
4	1033	45	5	20	5	4	1037
4	1033	50	5	20	3	4	1041
4	1033	50	5	20	5	4	1039
4	1046	50	5	20	5	4	1041
4		45	5	20	5	4	1046
4	1050	45	5	20	4	4	1048
4	1052	55	5	20	5	4	1037
4	1034	55	5	20	5	4	1036
4	1048	55	5	15	3	4	1049
4	1035	45	5	20	3	4	1033
4	1036	40	5	20	5	4	1039
4	1039	40	5	20	2	4	1040
4	1045	40	5	20	4	4	1041
4		40	5	20	4	4	1041
4	1046	40	5	20	5	4	1047

V. Heat Treatment

A. Sequence

The fuel elements covered in this document were given the following heat treatment:*

1. a. Heating Bath Nu-Sol
 b. Temperature 730°C
 c. Time 5 min.
2. Delay 18 sec.
3. a. Quench Nitrate Salts
 b. Temperature 300°C
 c. Time 5 min.
4. Delay 18 sec.
5. a. Quench Water
 b. Temperature 20°C
 c. Time To room temperature

* Tube 89 was alpha annealed prior to heat treating and after heating was press straightened and given a second beta heat treatment.

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B. Fuel Element Dimensions - Before and After Beta Heat Treatment

Fuel Element Number	OD (inches)		ID (inches)		Wall Thickness (inches)		Length (inches)		Warp (Mils) /° ****	
	Before	After	Before	After	Before	After	Before	After	Before	After
89-91 F*	1.257	1.252	0.430	0.433	0.412	0.408	24.107	24.006	32/30	62/90***
B**	1.258	1.251	0.429	0.433	0.413	0.411				
89-119 F	1.253	1.251	0.429	0.434	0.413	0.411	24.117	24.032	21/140	54/155
B	1.259	1.253	0.429	0.432	0.414	0.413				
89-258 F	1.258	1.253	0.429	0.434	0.412	0.410	24.088	24.006	26/0	40/0***
B	1.258	1.253	0.429	0.433	0.412	0.412				
89-283 F	1.259	1.252	0.429	0.434	0.416	0.410	24.117	24.030	34/130	50/165***
B	1.259	1.253	0.429	0.433	0.415	0.413				
98-123 F	1.256	1.255	0.429	0.431	0.413	0.411	23.175	23.214	24/180	40/165
B										
98-174 F	1.257	1.255	0.429	0.432	0.415	0.414	23.195	23.232	7/145	33/230
B										
99-278 F	1.257	1.256	0.430	0.433	0.412	0.410	23.173	23.232	18/130	19/30
B	1.257	1.256	0.431	0.433	0.414	0.409				
104-118 F	1.256	1.250	0.430	0.436	0.413	0.403	17.380	17.400	4/45	6/320
B										
104-159 F	1.258	1.251	0.429	0.436	0.413	0.405	23.170	23.208	14/200	30/250
B										
104-206 F	1.258	1.252	0.429	0.435	0.413	0.407	23.175	23.220	6/140	24/270
B										
104-230 F	1.259	1.255	0.429	0.434	0.415	0.409	23.100	23.104	23/70	20/310
B										

* F = Front, the numbered end of the fuel element

** B = Back, the unnumbered end of the fuel element

*** These fuel elements were alpha annealed, beta heat treated, straightened, and then given a second beta heat treatment.

**** 0° is top of die exit.

(Cont'd)

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100-100-1

	ID (inches)		Wall Thickness (inches)		Length (inches)		Warp (Mile) /° ****	
	Before	After	Before	After	Before	After	Before	After
104-258 F	1.258	1.255	0.429	0.433	0.414	0.409	23.175	23.208
B								
104-309 F	1.258	1.255	0.429	0.433	0.414	0.409	23.175	23.208
B								
104-333 F	1.259	1.255	0.429	0.433	0.414	0.410	23.185	23.224
B								
104-379 F	1.259	1.254	0.429	0.434	0.415	0.408	17.401	17.430
B								
104-401 F	1.259	1.254	0.429	0.434	0.414	0.408	17.405	17.435
B								
104-427 F	1.256	1.253	0.431	0.434	0.408	0.409	23.175	23.223
B								
104-320 F	1.255	1.253	0.431	0.434	0.408	0.409	23.180	23.240
B								
104-371 F	1.256	1.254	0.432	0.434	0.408	0.409	23.180	23.228
B								
104-300 F	1.257		0.430		0.408	0.409	23.181	23.244
B								
104-320 F	1.257	1.256	0.430	0.433	0.414		23.180	23.225
B								
104-371 F	1.261	1.260	0.430	0.431	0.416	0.410	23.181	23.227
B								
104-148 F	1.254	1.252	0.431	0.434	0.415	0.413	23.161	23.212
B								
131-72 F	1.254	1.252	0.431	0.433	0.412	0.408	23.171	23.221
B								
							23.186	23.234

5/120 26/235

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ENCLOSURE

VI. Vapor Blast

Prior to welding the fuel elements are vapor blasted under the following process conditions:

Feed: Double pass (both internal and external) at 4 inches per minute

Air Pressure: 90-100 psi

Slurry: 65% water, 35% 220 mesh aluminum oxide

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s.

Spindle Speed (rpm)		Purge Time (sec.)			
		Inner		Outer	
Inner	Outer	Pre	Post	Pre	Post
12	8	10	20	10	20
12	8	10	20	10	20
12	8	10	20	10	20
12	8	10	20	10	20
16	9	15	15	15	15
16	9	15	15	15	15
16	9	15	15	15	15
16	9	15	15	15	15
16	9	10	15	10	15
16	9	10	15	10	15
16	9	10	15	10	15
16	9	10	15	10	15
16	9	10	15	10	15
16	9	10	15	10	15
16	9	15	15	15	15
16	9	15	15	15	15
16	9	15	15	15	15
16	9	15	15	15	15
16	9	15	15	15	15
16	9	15	15	15	15
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

VIII. Nondestructive Testing

The fuel elements covered in this document were tested by nondestructive methods for:

- (1) Quality of Bond between Outer Clad and Uranium Core,
- (2) quality of Bond between Inner Clad and Uranium Core,
- (3) quality of End Closure Bond,
- (4) thickness of Outer Clad,
- (5) thickness of Inner Clad.

All of the fuel elements were acceptable. The analog chart recordings for these fuel elements can be found in notebook HW-67912 NB.

IX. Autoclave Conditions

The fuel element tubes 89, 98 and 99 were given the following autoclave cycle.

	<u>Time (Hrs)</u>	<u>Temperature (°C)</u>	<u>Pressure (psi)</u>
Water	40	350	2400
Steam	36	400	1500

The fuel elements from tubes 104, 105, 118, 119, 130, and 131 were autoclaved in 1500 psi steam at 400°C for 36 hours.

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X. Measurements Prior to Charging

Fuel Element Number	OD (inches)		ID (inches)		Length (inches)		Weight* (grams)	Warp (mils) / °C
	Bare	Clad	Bare	Clad	Bare	Clad		
89-91	1.171	1.247	0.486	0.437	23.566	24.002	7043.608	2/90
89-119	1.178	1.249	0.483	0.437	23.592	24.028	7094.203	14/15
89-258	1.178	1.249	0.483	0.436	23.596	24.002	7070.373	1/0
89-283	1.175	1.250	0.487	0.437	23.590	24.026	7075.775	1/15
98-123	1.166	1.246	0.485	0.439	22.634	23.077	6743.050	1/15
98-174	1.167	1.247	0.485	0.440	22.648	23.075	6763.840	23/230
99-278	1.183	1.247	0.486	0.442	16.801	17.220	5046.100	19/30
104-118	1.167	1.251	0.484	0.442	16.664	17.238	4992.210	1/320
104-159	1.167	1.247	0.485	0.440	22.667	22.996	4993.630	16/230
104-206	1.170	1.250	0.485	0.439	22.681	23.011	5022.135	14/27
104-230	1.170	1.251	0.485	0.438	22.730	22.921	5003.435	1/31
104-258	1.170	1.252	0.485	0.441	22.587	22.980	5015.335	17/230
104-309	1.170	1.250	0.485	0.438	22.663	22.996	5019.280	17/290
104-333	1.171	1.251	0.489	0.437	22.876	23.006	5028.830	12/350
104-379	1.169	1.251	0.487	0.442	16.667	17.255	5020.435	14/260
104-401	1.169	1.251	0.487	0.442	16.657	17.252	5029.810	10/60
105-94	1.151	1.245	0.487	0.438	22.575	23.068	6666.820	22/240
105-297	1.163	1.248	0.494	0.437	22.572	23.096	6722.565	27/195
105-320	1.170	1.249	0.488	0.439	22.570	23.088	-	27/25
105-371	1.171	1.250	0.488	0.439	22.581	23.084	6736.155	14/340
118-202	1.167	1.250	0.486	0.437	22.572	23.052	6716.380	15/15
119-320	1.161	1.252	0.490	0.436	22.571	23.056	-	17/310
119-371	1.165	1.253	0.490	0.435	22.556	23.039	6767.530	12/260
130-148	1.162	1.246	0.489	0.436	22.560	23.050	-	10/55
131-72	1.154	1.248	0.491	0.435	22.565	23.062	-	17/230

* Weight measurements made by the Fuels Design Unit, HLC

** 0° is top center at die exit.

XI. Support Welding

The supports for these fuel elements were welded on by HLC. Photomicrographs of representative welds showed them to be acceptable.

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PROCESS FLOW SHEET - NPR FUEL ELEMENTS

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III COPPER COMPONENTS

1. Receiving Inspection
2. Cleaning
3. Cleaning Inspection
4. Cap Assembly & Welding
5. Cap Assembly Test
6. Can Assembly & Welding
7. Can Assembly Test

I URANIUM BILLETS

1. Receiving Inspection
2. Billet Quality - N.D. Test
3. Billet Pickle
4. Billet Pickle Inspection

II ZIRCALOY-2 COMPONENTS

Billet Clads

1. Receiving Inspection
2. Clad Quality N.D. Tests
3. Cleaning
4. Cleaning Inspection

IV BILLET ASSEMBLY

1. Billet Component Assembly
2. Billet Welding
3. Evacuation & Leak Test
4. Evacuation Tube Cutoff

VII SUPPORTS - STEEL

1. Receiving Inspection
2. Cleaning
3. Cleaning Inspection

V EXTRUSION

1. Billet Lubrication
2. Billet Preheat
3. Tool Preparation
4. Extrusion
5. Extruded Tube Handling

VI FUEL TUBE PREPARATION

1. Cut to Length & Identify
2. Destructive Test Evaluation
3. Copper Removal
4. Zircaloy Stripping
5. Surface, Dimension, N.D. Audit
6. End Closure Recessing
7. End Closure Brazing
8. Beta Heat Treat
9. Heat Treat Inspection
10. Straightening
11. Vapor Blast
12. End Closure Machining
13. End Closure Cleaning
14. End Closure Welding
15. Nondestructive Test
16. Degrease
17. Support Welding
18. Support Weld Inspection
19. Final Etch
20. Assembly & Autoclave
21. Disassembly & Autoclave Inspection
22. Outer Tube Steel Support Assembly
23. Final Assembly
24. Final Inspection & Storage

(II) END CAPS

5. Receiving Inspection
6. Integrity Testing
7. Cleaning
8. Cleaning Inspection

(II) BRAZE PIECES

9. Receiving Inspection
10. Cleaning
11. Cleaning Inspection

(II) SUPPORTS-ZIRCALOY

12. Receiving Inspection
13. Cleaning
14. Cleaning Inspection

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DATE

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END