CERTIFICATE AND RECORDS OF HALDEN IFA-529 TEST FUEL RODS IN PNC IRRADIATION PROGRAM

March 1980

Tokai Works
Power Reactor & Nuclear Fuel Development Corporation

CERTIFICATE AND RECORDS OF HALDEN IFA-529 TEST FUEL RODS IN PNC IRRADIATION PROGRAM

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Contents

1. General remarks

Halden IFA-529 irradiation test is planned to examin the fuel behavier of BWR type fuel under reactor operation.
Twelve fuel rods for this irradiation test were fabricated in Research & Development Section of Plutonium Fuel Div. in P.N.C.
These fuel rods have instrumentations for the measurement of fuel column elongation, cladding elongation, plenum pressure and fuel center temperature.
The fuel pellets were made from two type of raw materials. One was obtained by precipitation - calcination process, and another was direct denitration process.
The fuel composition is 8.3% PuO_2-UO_2 (natural), and the pellet nominal dimension is 10.56 mm dia. and 10 mm height.

2. Fabrication process of the fuel

2-1 Pellet fabrication flow sheet and sampling position ..... Fig. 2-1

2-2 Fabrication process of the fuel rods ..... Fig. 2-2

3. Fabrication records of the fuel pellets and the rod components

3-1 Fuel pellets

3-1-1 Pellet fabrication lots and sampling

1) Fabrication lot numbers and pellet types are shown in Table 3-1-1.

2) Samples were taken out at random from each sintering lot for the following examinations.

   a) Plutonium content
   b) Impurities (spectroscopy)
   c) " (chemical analysis)
   d) Amount of released gas (include moisture)
   e) O/M
   f) Ceramography, α-autoradiography and X-ray diffraction analysis.

3-1-2 Methods of examination and analysis

The examination and analysis listed above, were performed by

methods which are in the routine work at P.N.C. .

3-1-3 Inspection results

1) Isotopic composition of plutonium is shown in Table 3-1-2.

2) Chemical analysis

Plutonium content, impurities, released gas and O/M ratio in the mixed oxide fuels are shown in Table 3-1-3.

3) PuO_2 spot

Uniformity of PuO_2 in the fuel pellets was inspected by α-autoradiograph. There was no any harmful PuO_2 spot in all fabricated lots. The α-autoradiographs are shown in Photo 3-1-1 to 3-1-6.

4) Dimensions and density of pellets

The diameter, height, and weight of all pellets were measured for determination of geometrical density.
Chamfer sizes were measured on one pellet by projector. The values of height and width of the chamfer were 0.35 mm and 0.28 mm, respectively, and these values were taken into density calculations.
The measured values of diameter and density are shown in the form of average and standard deviation for each sintering lot.
They are listed in Table 3-1-4 to 3-1-15 as the component of fuel rods.

3-2 Insulator pellets

3-2-1 Inspection results

The same methods which applied to the inspection of fuel pellets were used for determination of following items.

1) Chemical analysis

The results of chemical analysis are shown in Table 3-1-3.

2) Dimension and density

Measured values of dimensions, weight and calculated densities are shown in Table 3-1-4 to 3-1-15.

3-3 Cladding

3-3-1 Inspection results

1) Chemical composition

Results of chemical analysis of cladding which were reported by manufacturer are shown in Table 3-3-1.

2) Mechanical properties

Mechanical properties which were measured by manufacturer are shown in Table 3-3-2.

3) Metallography

Metallographic tests such as grain size and hydride orientation were performed by manufacturer the results are shown Table 3-3-2 and Photo 3-3-1.

4) Dimensions, defect, surface and straightness

Dimensional measurements, ultrasonic defects detection, visual observation and straightness inspection were done by P.N.C. The results are shown in Table 3-3-3.

3-4 End plug

Instrumented end plugs and normal end plugs were fabricated at Holden site and shipped to P.N.C..

3-5 Spring

Material : AISI 304-WPB

Spring constant : 0.114 kg/mm

Weight and free length : Shown in Table 3-1-4 to 3-1-15 for each fuel rod.

3-6 Disc

Material : Zry - 2

Weight and thickness : Shown in Table 3-1-4 to 3-1-15.

4. Records of fabrication and inspection for fuel rods

4-1 Components of fuel rod

Weight and length of rod components are shown in Table 3-1-4 to 3-1-15. The Combination of end plugs and each rod are shown in Table 4-1-1.

4-2 Weight and length of fuel stacks and fuel rods

Fuel stack length and weight were measured by a varnier caliper on a balance. These values are shown in Table 4-1-1.

4-3 Nondestractive inspection

The results of He leak test, X-ray inspection, contamination inspection are summarized in Table 4-3-1.

5. Fuel Material

Weight of fuel material contained in the twelve fuel rods are listed in Table 5-1-1.

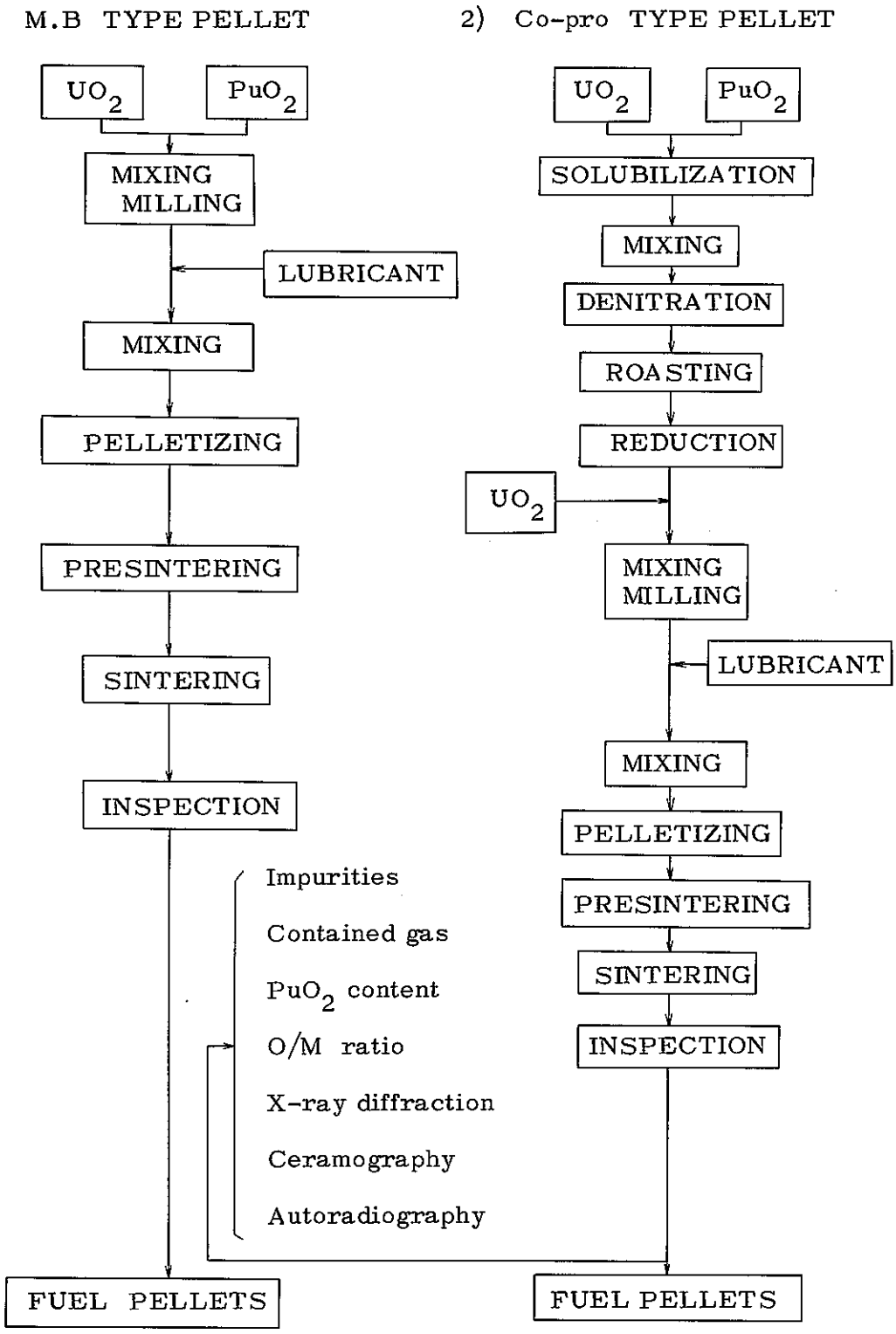


Fig. 2-1 Pellets fabrication process and sampling position

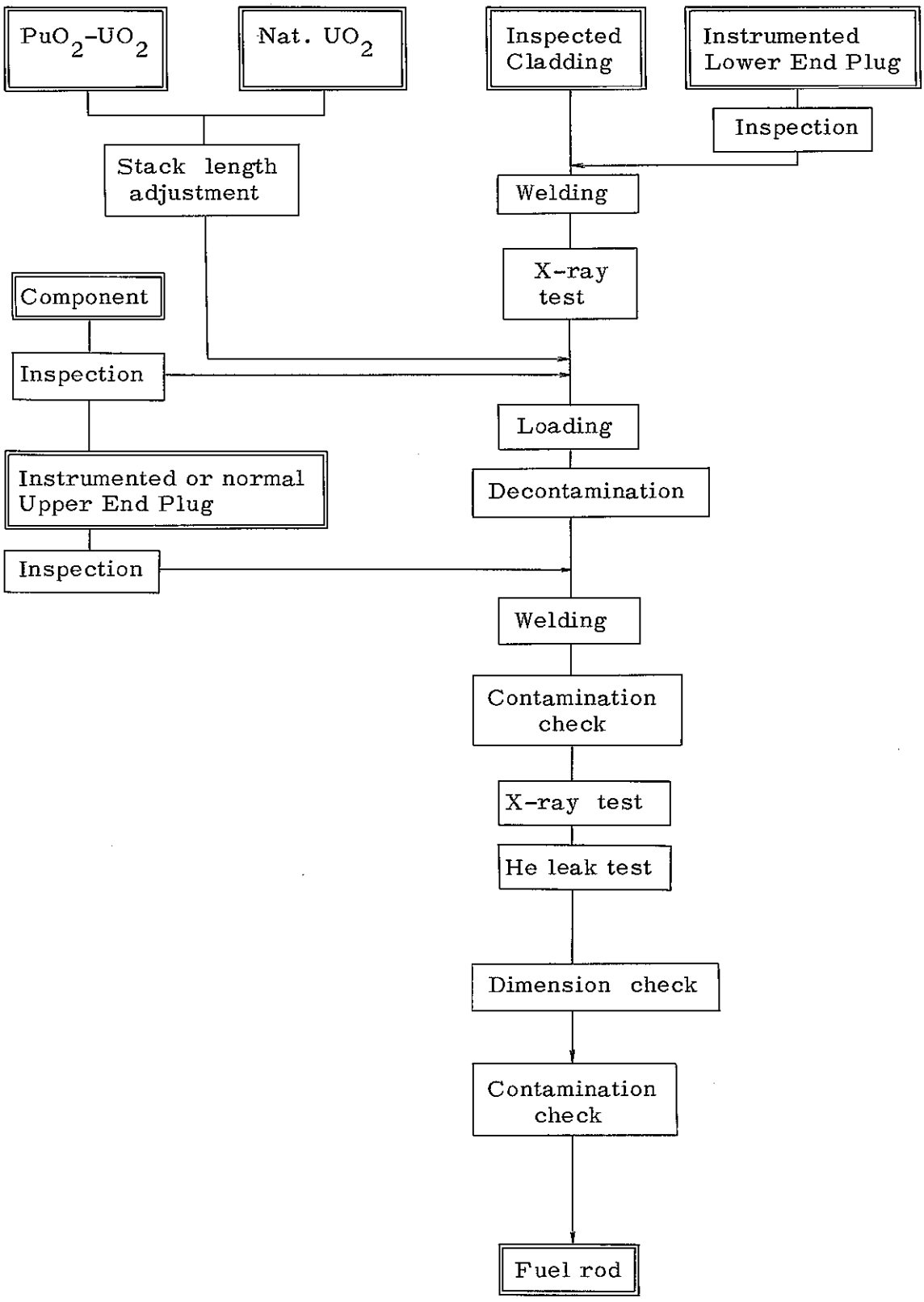


Fig. 2-2 Fabrication process of fuel rod

Table 3-1-1 Isotopic composition of Plutonium

Lot No.	Pellet Size	Pellet Types			
		M. B Pellet	Co-pro Pellet	Solid	Hollow
HT-20-20	G_3	○		○	
HT-20-30	G_3	○		○	
HT-20-40	G_1 & G_3	○			○
HT-30	G_3	○		○	
HT-60-10	G_2 & G_3	○		○	
HT-60-20	G_1	○		○	
HT-70-10	} G_3		○	○	
HT-70-20			○	○	
HT-70-30	} G_2		○	○	
HT-70-40			○	○	
HT-70-50	G_3		○	○	
HT-70-60	G_1		○	○	
HT-80-10	G_2		○	○	
HT-80-20	G_3		○	○	
HT-90	G_2	○		○	

Note : G_1 $10.66^{+0.04}_{-0.07}$ mmφ
G_2 10.56 ± 0.04 〃
G_3 10.44 ± 0.04 〃

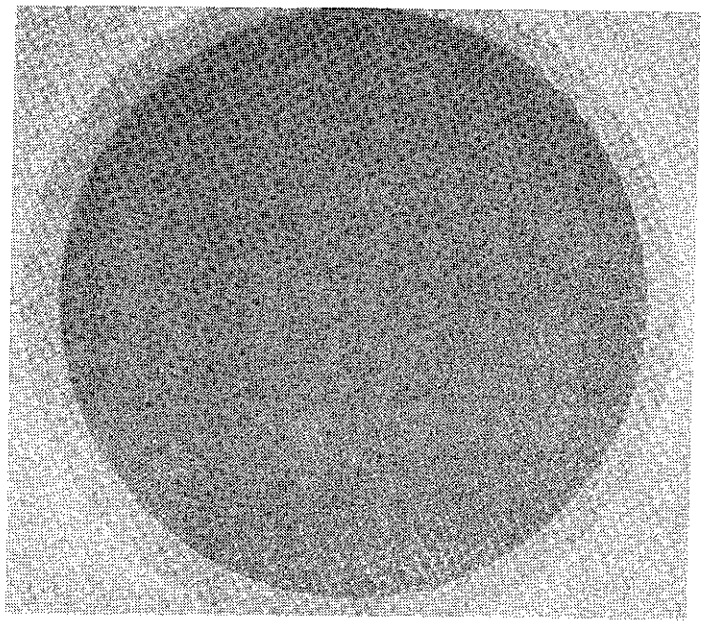
Table 3-1-2 Results of chemical analysis of fuel pellet

Isotope	Isotopic Composition (Analysis date)
U	Natural
Pu - 238	0.85 (w/o)
Pu - 239	66.60
Pu - 240	22.18
Pu - 241	7.34
Pu - 242	3.03
Am - 241	24,000 ppm (May. 30. 1979)

Table 3—1—3 Results of chemical analysis of fuel pellet and insulator pellet

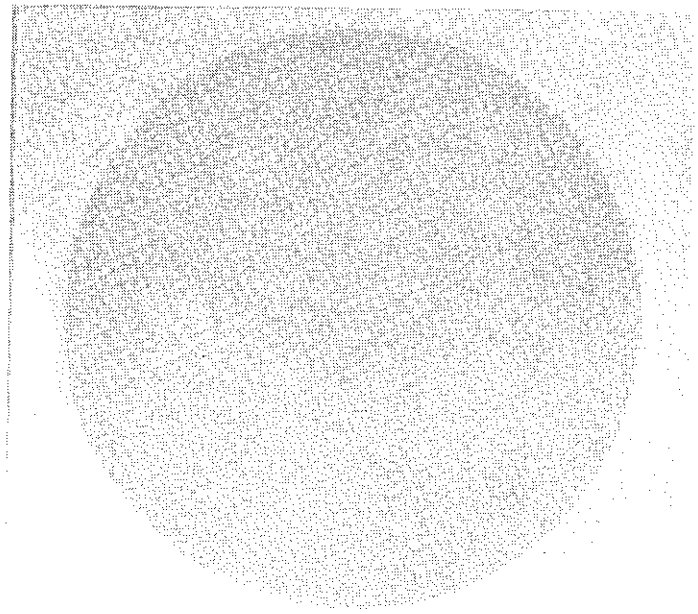
Item	Specification	M. B Pellet							Co-pro Pellet					Insulator Pellet	
		HT-20			HT-30	HT-60		HT-90	HT-70			HT-80			
		-20,-30	-40 (G_1)	-40 (G_2)	—	-10,-20	-10 (G_3)	—	-10,-20,-30	-40	-50,-60	-10	-20	Solid	Hollow
O/M Ratio	1.97 ~ 2.02	1.98	1.98	1.97	1.98	1.99	1.97		1.97	1.98	1.98	1.98	1.98	2.01	2.01
Released gas	< 40 μℓ/g · MO_2 (1700℃ 30 min)	17	12	< 10	16	< 10	31	16	17	16	31	24	25	28	< 10
Moisture	< 10 〃 (400℃)	< 5	< 5	< 5	8	7	< 5	< 5	< 5	< 5	< 5	6	5	< 5	< 5
Plutonium content	6.0 ± 0.3 fissile %	6.27			6.28	6.21			6.01			5.92		—	—
Pu+U/M.O	≥ 87.7 %	88.3			88.3	88.2			88.3			88.3		—	—
Pu Spot	< 500 μm	< 50			< 50	< 50		< 50	< 50			< 50		—	—
Impurities															
Ag	≤ 10 [PPM]	< 0.2		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2			< 0.2		< 0.2	< 0.2
Al	≤ 300	20		20	< 10	110	120	90	35			20		55	50
B	≤ 1.0	< 0.3		0.5	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3			< 0.3		< 0.3	< 0.3
Ca	≤ 200	< 10		30	< 10	< 15	< 15	< 10	20			15		15	35
Cd	≤ 1.0	< 1		< 1	< 1	< 1	< 1	< 1	< 1			< 1		< 1	< 1
Cr	≤ 200	< 10		< 10	< 10	< 10	< 10	< 10	< 10			< 10		< 10	< 10
Cu	≤ 50	< 1		< 1	< 1	< 1	< 1	< 1	< 1			< 1		< 1	< 1
Fe	≤ 400	15		< 10	< 20	20	20	10	10			15		< 10	25
Mg	≤ 100	3		15	< 2	4	4	< 2	< 2			< 2		< 2	7
Mn	≤ 200	< 6		< 6	< 6	< 6	< 6	< 6	< 6			< 6		< 6	< 6
Mo	≤ 300	< 10		< 10	< 10	< 10	< 10	< 10	< 10			< 10		< 10	< 10
Ni	≤ 300	< 15		< 10	25	15	15	< 10	< 10			< 10		< 10	< 10
Pb	≤ 100	< 10		< 10	< 10	< 10	< 10	< 10	< 10			< 10		< 10	< 10
Si	≤ 300	25		35	30	50	50	35	25			45		20	< 10
Sn	≤ 100	< 10		< 10	< 10	< 10	< 10	< 10	< 10			< 10		< 10	< 10
C	≤ 200	90		90	45	< 30	< 30	35	< 30			< 30		< 30	< 30
F	≤ 15	< 10		< 10	< 10	< 10	< 10	< 10	< 10			< 10		< 10	< 10
Cl	≤ 25	< 10		< 10	< 10	< 10	< 10	< 10	< 10			< 10		< 10	< 10
N	≤ 100	< 50		< 50	< 50	< 50	< 50	< 50	< 50			< 50		60	60
Zn	≤ 400	< 50		< 50	< 50	< 50	< 50	< 50	< 50			< 50		< 50	< 50
Dy+Eu+Gd	≤ 2.0	< 0.9		< 0.9	< 0.9	< 0.9	< 0.9	< 0.9	< 0.9			< 0.9		< 0.9	< 0.9
Total impurity	≤ 1500	< 340.1		< 379.6	< 321.4	< 413.4	< 423.4	< 361.4	< 301.4			< 306.4		< 321.4	< 346.4

Note : Pellet size G_1 ; $10.66^{+0.04}_{-0.07}$ mm (O.D)
G_2 ; 10.56 ± 0.04
G_3 ; 10.46 ± 0.04



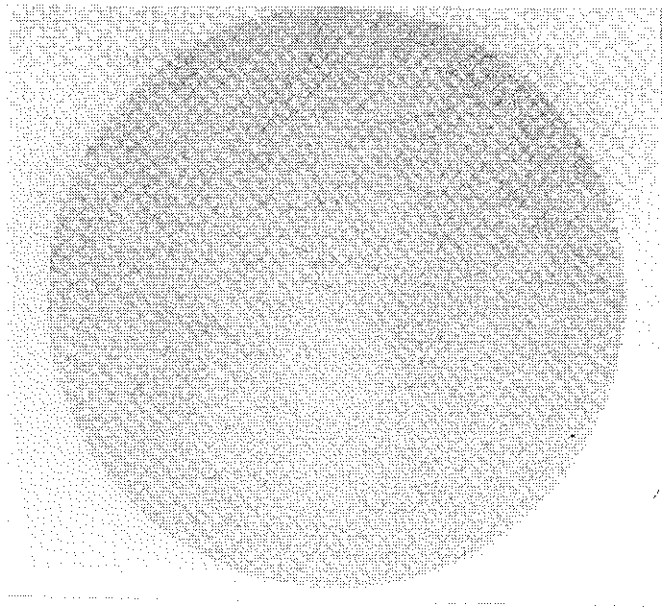
MACRO 1 mm

Photo 3−1−1 HT−20



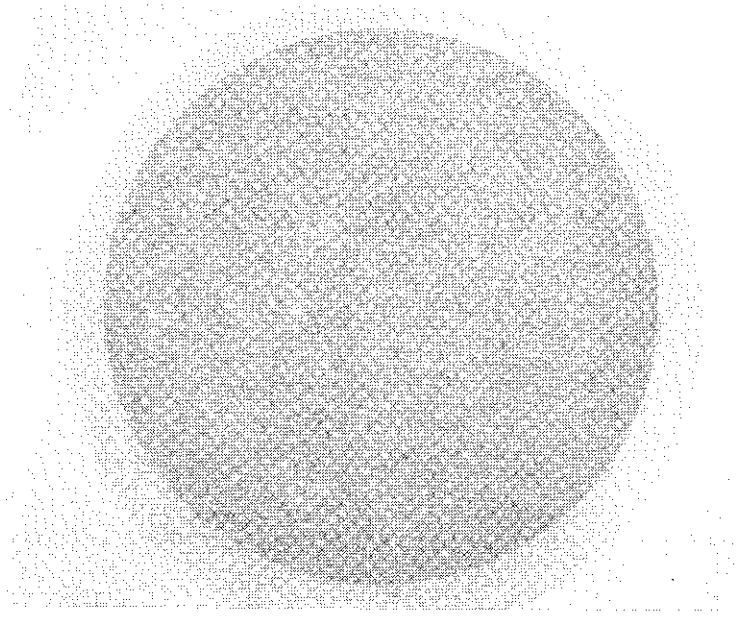
MACRO 1 mm

Photo 3−1−2 HT−30



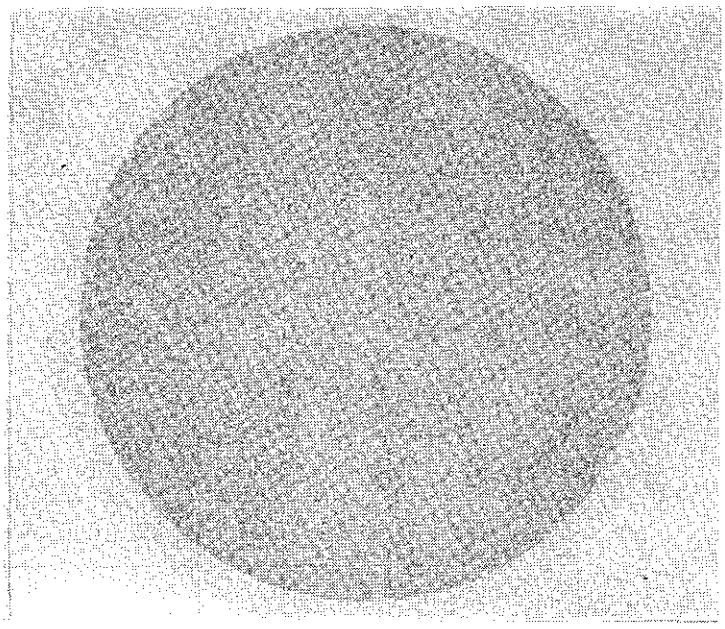
MACRO 1mm

Photo 3−1−3 HT−60



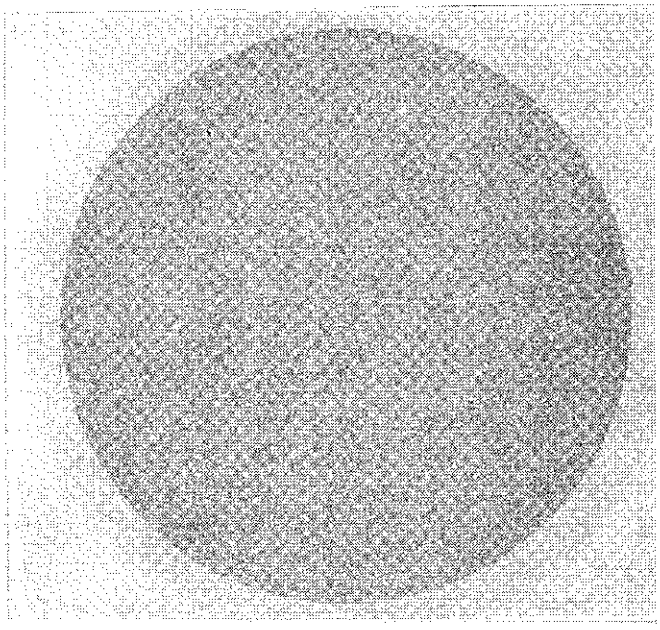
MACRO 1mm

Photo 3−1−4 HT−70



MACRO 1 mm

Photo 3−1−5 HT−80



MACRO 1 mm

Photo 3−1−6 HT−90

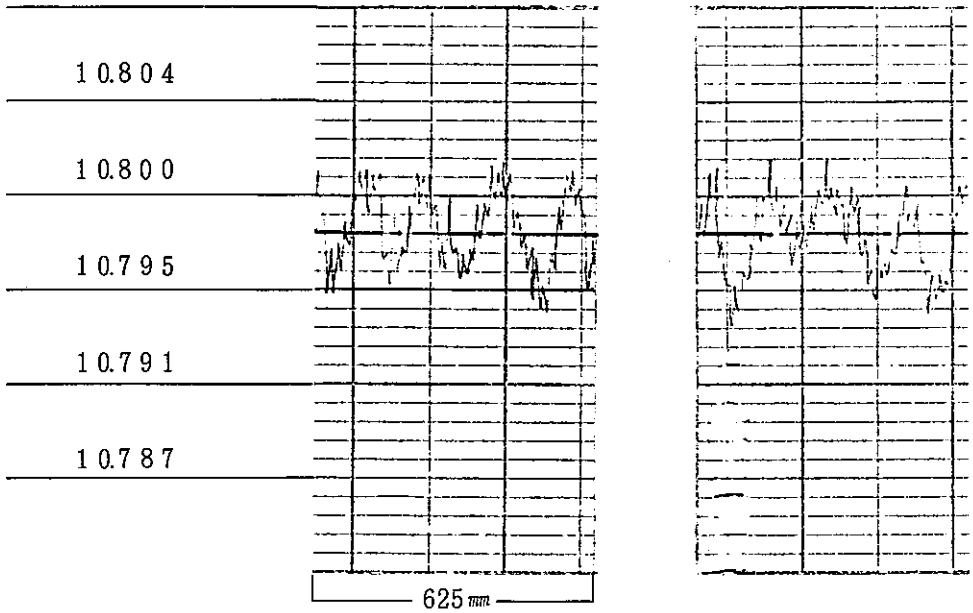
Table 3-1-4

ROD No. IFA 529-01 (Cladding No. 14-2)

Pellet Lot No.			HT-70-60	HT-80-20	
Pellet O.D (mm)	Av.		10.597	10.682	
	S.D		0.009	0.010	
Density (%T.D)	Av.		95.31	92.72	
	S.D		0.262	0.186	
Length (mm)			291.30	257.00	
Cladding I.D (mm)	Av.	10.798			
	S.D	0.002			
Length (mm)		625.06			
Weight (g)		130.16			

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.25 *	1.05	7.43	7.13	—	41.0	10 *
Weight (g)	39.46	0.53	6.79	6.49		7.62	22.69
Density (%)	—	—	94.20	94.20	—	—	—

* insert length



X-direction Y-direction (90°)

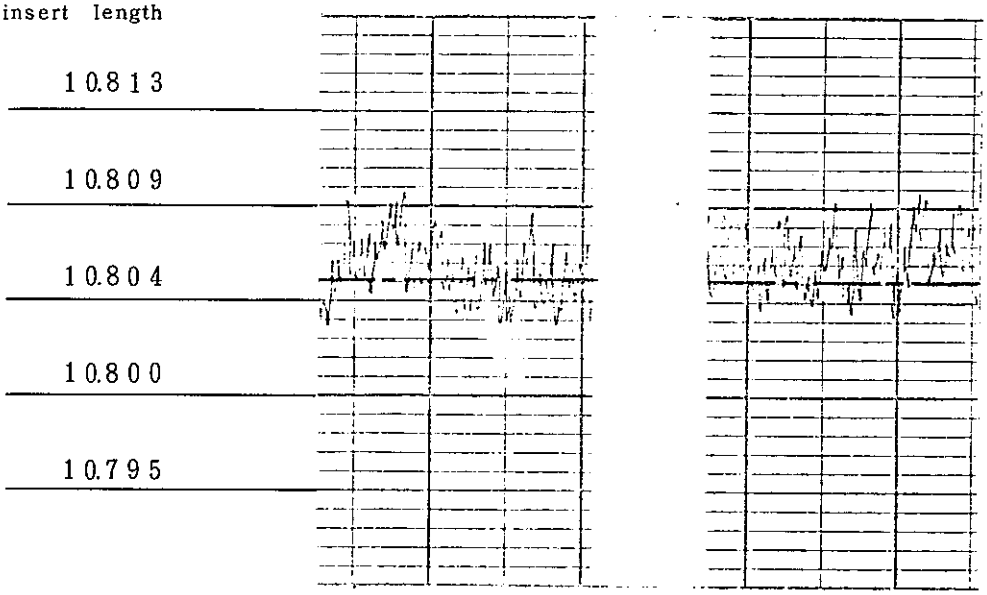
Table 3-1-5

ROD No. IFA 529-02 (Cladding No. 15-2)

Pellet Lot No.			HT-70-40	HT-80-10	HT-70-30
Pellet O.D (mm)	Av.		10.529	10.571	10.565
	S.D		0.011	0.012	0.014
Density (%T.D)	Av.		94.67	92.20	92.03
	S.D		0.335	0.321	0.119
Length (mm)			155.45	331.40	61.20
Cladding I.D (mm)	Av.	10.805			
	S.D	0.002			
Length (mm)		625.00			
Weight (g)		129.39			

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.45 *	1.05	7.47	7.51	—	40.5	10 *
Weight (g)	39.53	0.54	6.82	6.86		7.62	22.67
Density (%)	—	—	94.47	94.34	—	—	—

* insert length



X-direction Y-direction (90°)

Table 3-1-6

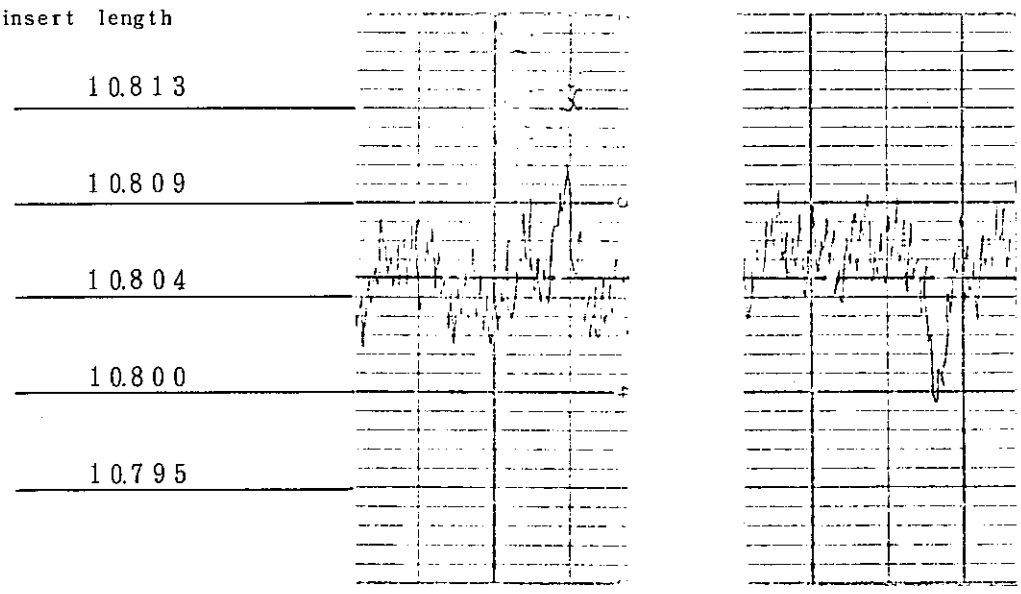
ROD No. IFA 529-03 (Cladding No. 15-3)

Pellet Lot No.			HT-70-50	HT-70-10	HT-70-20
Pellet O.D (mm)	Av.		10.478	10.432	10.450
	S.D		0.012	0.008	0.020
Density (%T.D)	Av.		93.44	95.43	93.25
	S.D		0.499	0.953	0.397
Length (mm)			421.65	49.90	80.30
Cladding I.D (mm)	Av.	10.805			
	S.D	0.002			
Length (mm)		625.00			
Weight (g)		129.57			

* insevt levgth

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.45 *	1.15	7.05	7.22	—	37.5	10 *
Weight (g)	39.55	0.57	6.42	6.59		7.66	22.69
Density (%)	—	—	94.61	94.46	—	—	—

* insert length



X-direction Y-direction (90°)

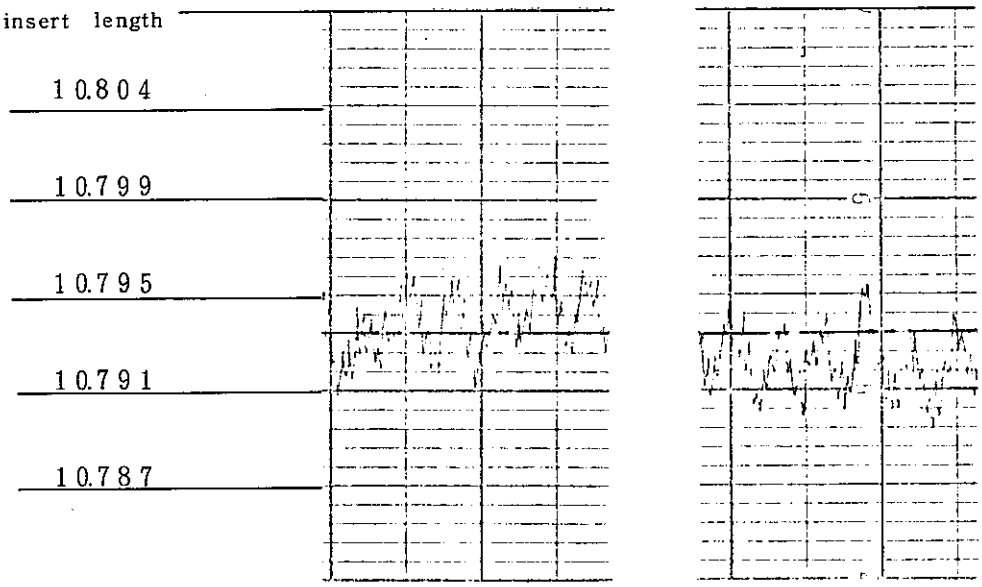
Table 3-1-7

ROD No. IFA 529-04 (Cladding No. 18-2)

Pellet Lot No.			HT-30-10		
Pellet O.D (mm)	Av.		10.602		
	S.D		0.010		
Density (%T.D)	Av.		93.62		
	S.D		0.231		
Length (mm)			547.10		
Cladding I.D (mm)	Av.	10.793			
	S.D	0.002			
Length (mm)		624.96			
Weight (g)		130.26			

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.30 *	1.10	7.21	7.07	—	41.5	10 *
Weight (g)	39.58	0.55	6.57	6.44		7.58	22.68
Density (%)	—	—	94.48	94.28	—	—	—

* insert length



X-direction Y-direction (90°)

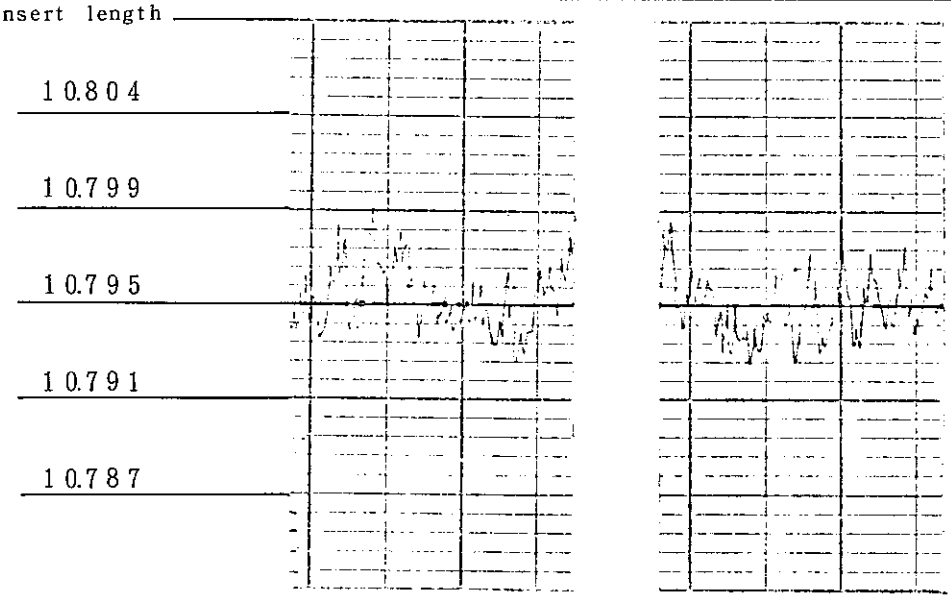
Tabble 3 - 1 - 8

ROD No. IFA 529-05 (Cladding No. 20-1)

Pellet Lot No.			HT-60-10		
Pellet O.D (mm)	Av.		10.558		
	S.D		0.017		
Density (% T.D)	Av.		93.724		
	S.D		0.459		
Length (mm)			551.10		
Cladding I.D (mm)	Av.	10.795			
	S.D	0.002			
Length (mm)		625.00			
Weight (g)		130.09			

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.40 *	1.05	7.13	7.26	—	37.5	10 *
Weight (g)	39.57	0.55	6.50	6.64		7.60	22.74
Density (%)	—	—	94.53	94.65	—	—	—

* insert length



X-direction Y-direction (90°)

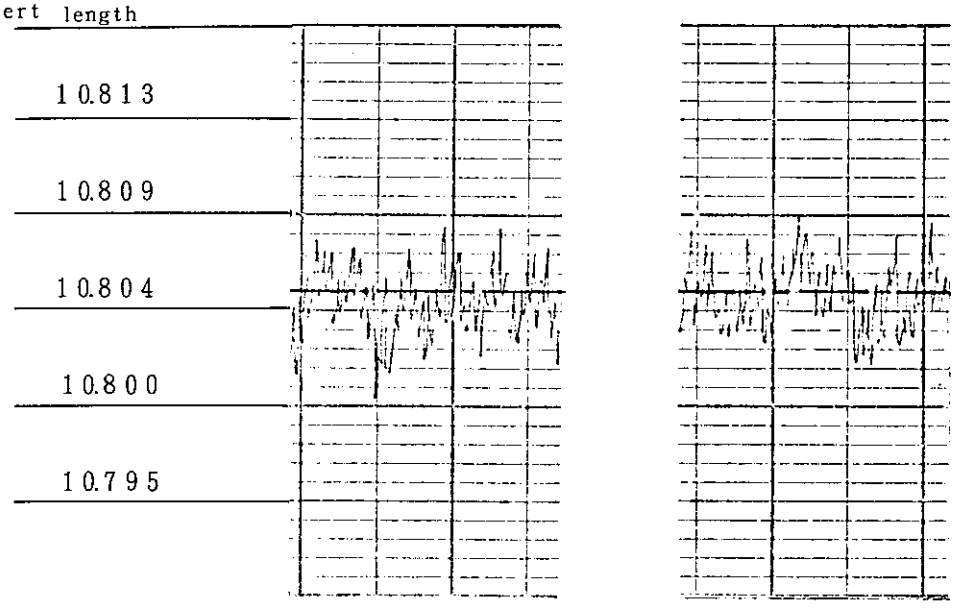
Tabble 3-1-9

ROD No. IFA 529-06 (Cladding No. 15-4)

Pellet Lot No.			HT-20-20		
Pellet O.D (mm)	Av.		10.479		
	S.D		0.009		
Density (%T.D)	Av.		94.01		
	S.D		0.276		
Length (mm)			547.10		
Cladding I.D (mm)	Av.	10.805			
	S.D	0.002			
Length (mm)		625.08			
Weight (g)		129.65			

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.25 *	1.10	7.14	7.33	—	41.5	10 *
Weight (g)	39.72	0.54	6.51	6.70		7.64	22.67
Density (%)	—	—	94.54	94.59	—	—	—

* insert length



X-direction Y-direction (90°)

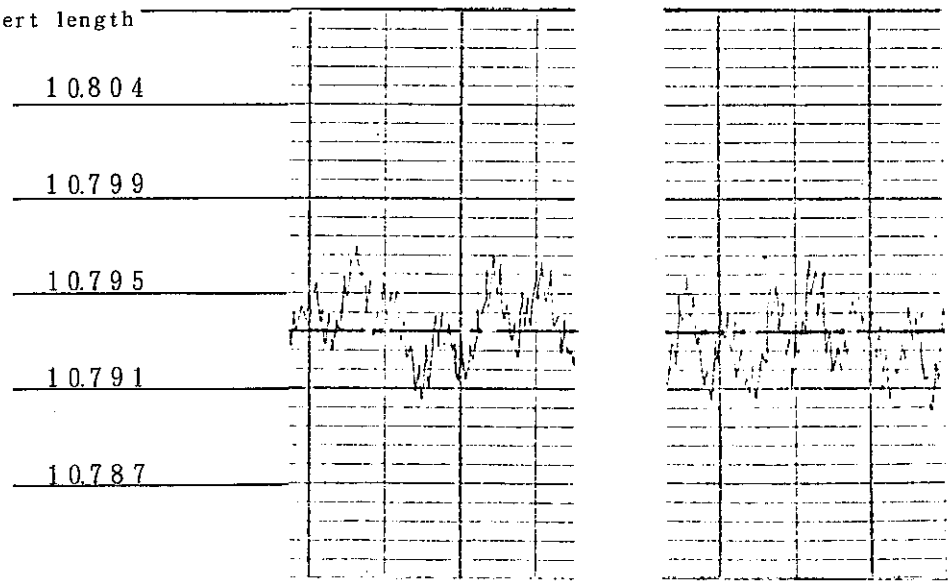
Table 3-1-10

ROD No. IFA 529-07 (Cladding No. 18-3)

Pellet Lot No.			HT-30		
Pellet O.D (mm)	Av.		10.605		
	S.D		0.010		
Density (%T.D)	Av.		93.63		
	S.D		0.244		
Length (mm)			547.20		
Cladding I.D (mm)	Av.	10.793			
	S.D	0.002			
Length (mm)		624.98			
Weight (g)		130.26			

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.95 *	—	7.18	7.10	3.15	43.0	10 *
Weight (g)	34.37		6.54	6.47	1.67	6.59	46.96
Density (%)	—	—	94.27	94.49	—	—	—

* insert length



X-direction Y-direction (90°)

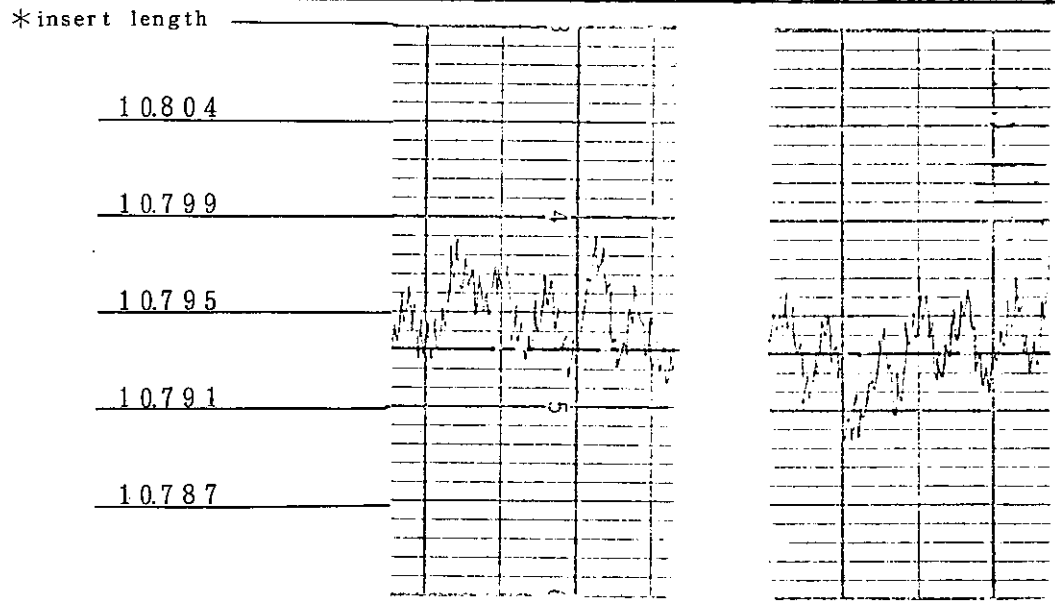
Table 3-1-11

ROD No. IFA 529-08 (Cladding No. 18-4)

Pellet Lot No.			HT-20-40	HT-60-20	HT-30
Pellet O.D (mm)	Av.		10.591	10.624	10.603
	S.D		0.004	0.013	0.012
Density (% T.D)	Av.		93.40	93.58	93.63
	S.D		0.255	0.290	0.279
Length (mm)			148.90	368.80	30.60
Cladding I.D (mm)	Av.	10.793			
	S.D	0.002			
Length (mm)		625.00			
Weight (g)		130.25			

* insevt levgth

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.20 *	1.10	6.60	7.07	—	42.0	10 *
Weight (g)	99.44	0.58	5.70	6.43		7.62	31.59
Density (%)	—	—	93.50	94.13	—	—	—



X-direction Y-direction (90°)

Table 3-1-12

ROD No. IFA 529-09 (Cladding No.8-2)

Pellet Lot No.			HT-60-10	HT-90	
Pellet O.D (mm)	Av.		10.556	10.550	
	S.D		0.019	0.012	
Density (%T.D)	Av.		93.81	94.24	
	S.D		0.522	0.941	
Length (mm)			501.70	46.30	
Cladding I.D (mm)	Av.	10.796			
	S.D	0.002			
Length (mm)		624.98			
Weight (g)		130.46			

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.90*	—	7.34	7.44	1.10	41.0	10*
Weight (g)	34.14		6.71	6.86	0.55	6.59	46.94
Density (%)	—	—	94.24	94.87	—	—	—

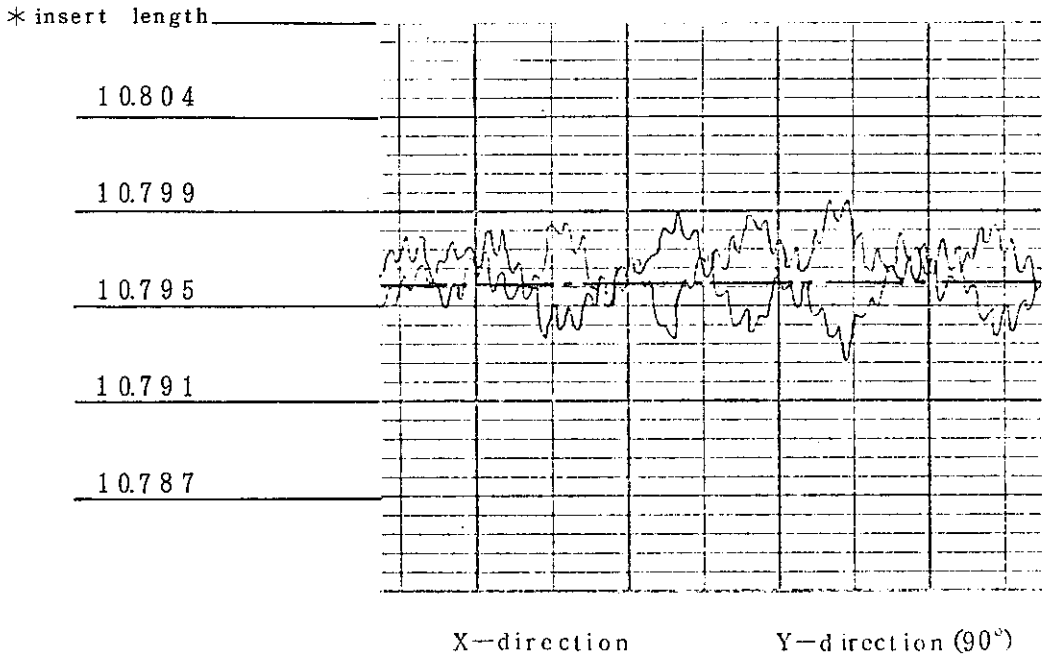


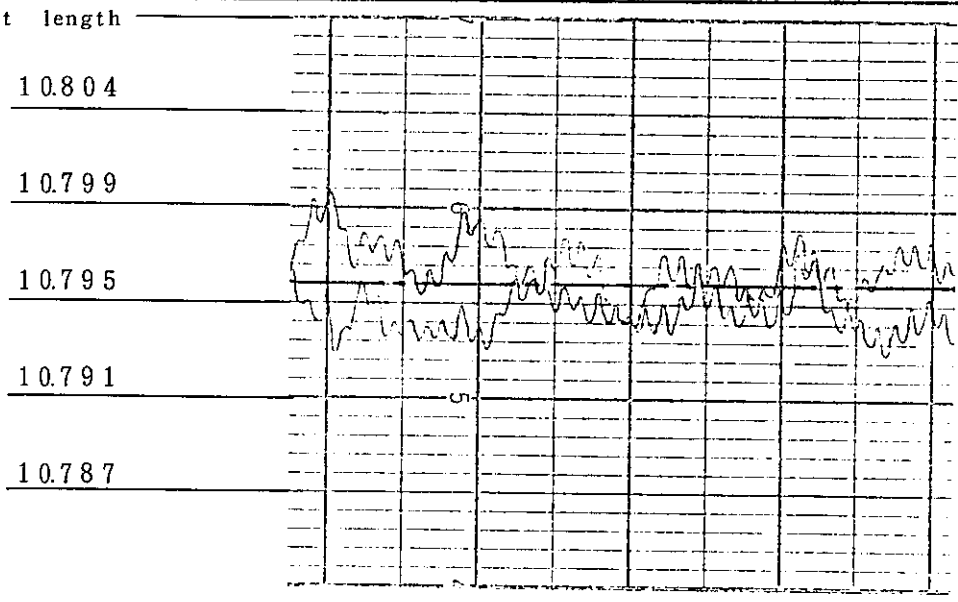
Table 3-1-13

ROD No. IFA 529-10 (Cladding No. 9-1)

Pellet Lot No.			HT-90		
Pellet O.D (mm)	Av.		10.555		
	S.D		0.023		
Density (%T.D)	Av.		93.17		
	S.D		0.512		
Length (mm)			549.10		
Cladding I.D (mm)	Av.	10.796			
	S.D	0.002			
Length (mm)		624.98			
Weight (g)		130.45			

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.90*	—	7.24	7.27	—	40.5	10*
Weight (g)	34.08		6.62	6.63		7.60	31.44
Density (%)	—	—	94.45	94.55	—	—	—

* insert length



X-direction Y-direction (90°)

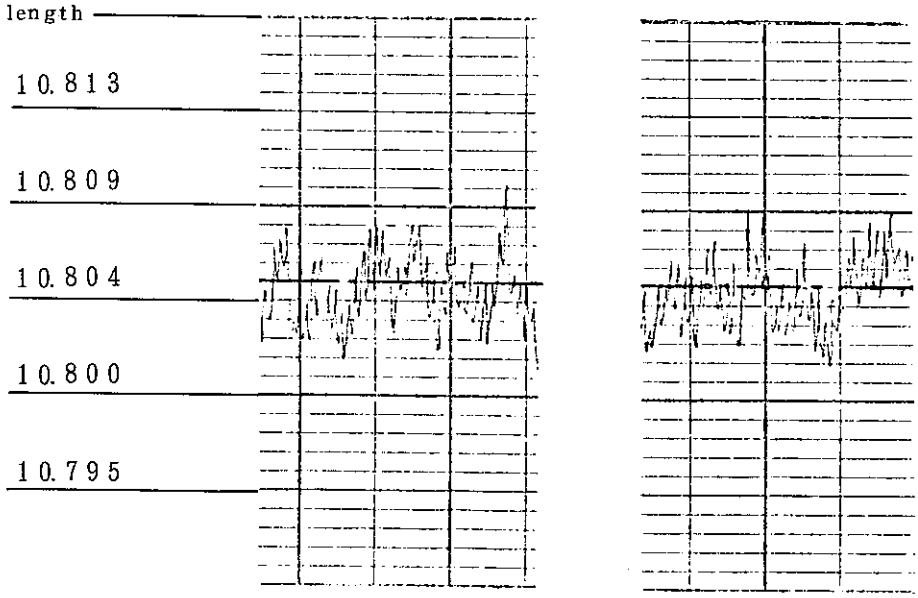
Table 3-1-14

ROD No. IFA 529-11 (Cladding No. 15-5)

Pellet Lot No.			HT-20-30		
Pellet O.D (mm)	Av.		10.475		
	S.D		0.011		
Density (% T.D)	Av.		94.03		
	S.D		0.332		
Length (mm)			550.90		
Cladding I.D (mm)	Av.	10.805			
	S.D	0.002			
Length (mm)		625.00			
Weight (g)		129.59			

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.95 *	—	6.94	6.87	—	39.5	10 *
Weight (g)	34.21		6.33	6.26		6.59	47.04
Density (%)	—	—			—	—	—

* insert length



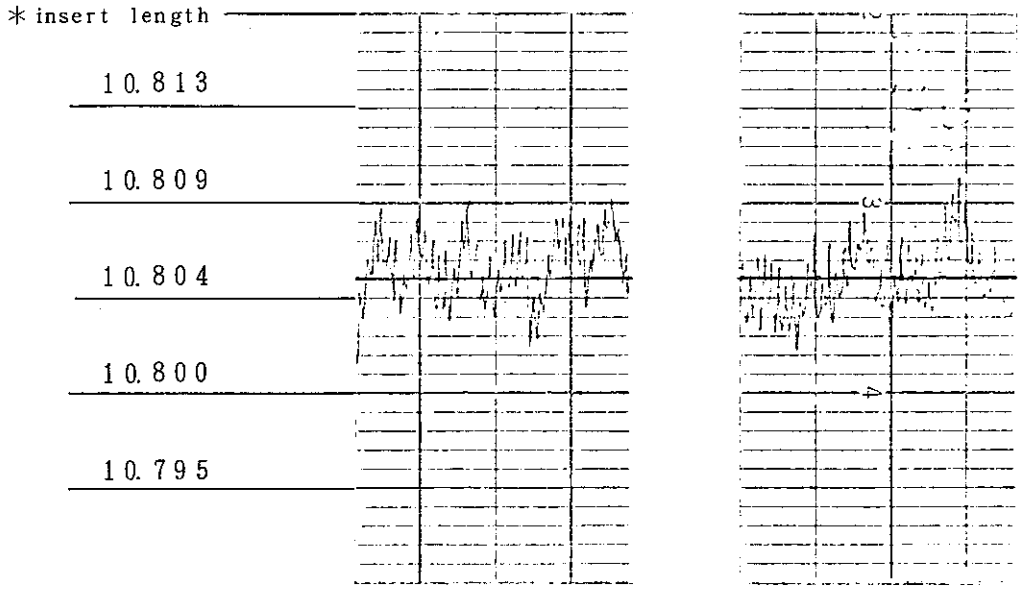
X-direction Y-direction (90°)

Table 3-1-15

ROD No. IFA 529-12 (Cladding No. 15-12)

Pellet Lot No.		HT-20-40	HT-20-20	HT20-30	HT-60-10
Pellet O.D (mm)	Av.	10.450	10.480	10.472	10.490
	S.D	0.001	0.001	0.030	0.011
Density (%T.D)	Av.	94.61	93.99	93.92	94.48
	S.D	0.424	0.309	0.218	0.227
Length (mm)		148.65	70.75	50.90	278.50
Cladding I.D (mm)	Av.	10.805			
	S.D	0.002			
Length (mm)		624.98			
Weight (g)		129.40			

Parts	Lower End Plug	Disc	Insulator Pellet (bottom)	Insulator Pellet (top)	Disc (for stack adj.)	Spring (Plenum)	Upper End plug
Length (mm)	10.05*	1.10	7.04	7.46	----	40.0	10*
Weight (g)	100.02	0.55	5.99	6.78		7.61	31.65
Density (%)	—	—			—	—	—



X-direction Y-direction (90°)

Table 3-3-1 Chemical composition of cladding

	Specification	Results		
Ingot				
		Top	Mid	Bot
1. Composition	%			
Sn	1.20～1.70	1.54	1.54	1.59
Fe	0.07～0.20	0.14	0.14	0.16
Cr	0.05～0.15	0.10	0.10	0.11
Ni	0.03～0.08	0.05	0.05	0.06
Fe+Cr+Ni	0.18～0.38			
Zn				
2 Impurities	PPM			
Al	≦75	54	54	54
B	≦0.5	<0.25	<0.25	<0.25
Cd	≦0.5	<0.25	<0.25	<0.25
C	≦270	130	100	120
Co	<20	<10	<10	<10
Cu	≦50	14	14	17
Hf	≦100	54	62	50
H	≦25	5	7	9
Mn	≦50	<25	<25	<25
N	≦80	36	34	28
Ca	≦30	<10	<10	<10
Si	≦120	52	57	69
Pb	≦130	<25	<25	<25
Ti	≦50	<25	<25	<25
Cl	≦20	<5	<5	<5
W	≦100	<25	<25	<25
Mg	≦20	<10	<10	<10
U	≦3.5	1.6	1.9	0.9
O	700～1500	1210	1210	1160

Table 3-3-2 Mechanical properties of cladding.

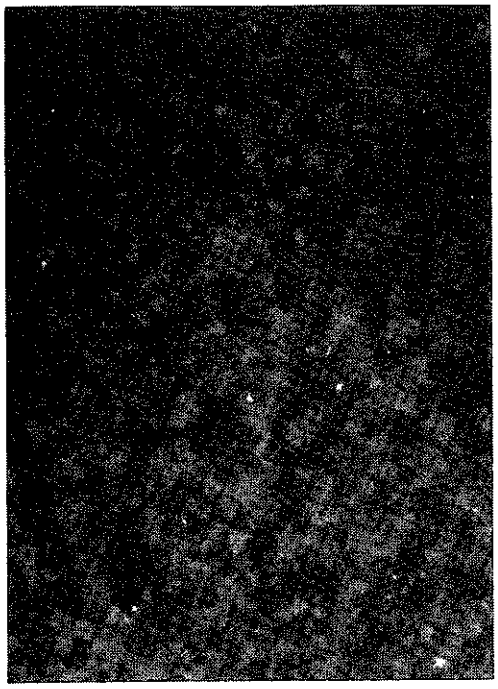
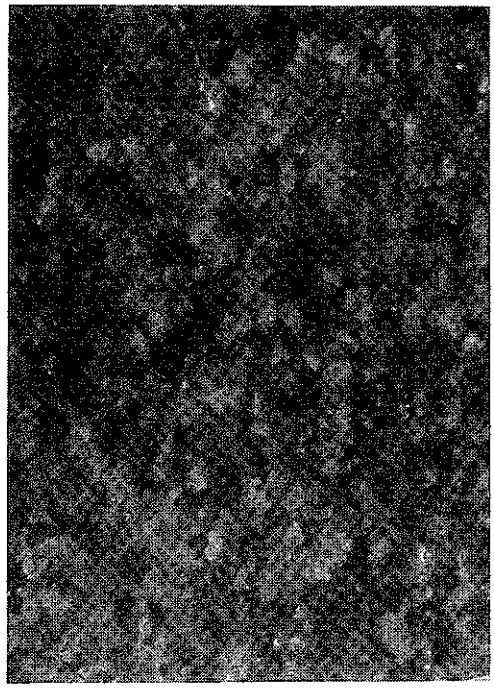
	Specifications	Test Results
Burst Pressure (kg/cm²)	≧ 640	791, 800
Cir. Elongation (%)	≧ 20	30.9, 33.4
Yield Strength (kg/mm²)	≧ 33.8	37.16, 37.95
U.T.S. (〃)	≧ 49.2	55.32, 55.76
Elongation (%)	≧ 30	33.6, 34.0
650°F Yield Strength (kg/mm²)	≧ 11.3	13.51, 13.65
〃 U.T.S. (〃)	≧ 25.3	26.09, 26.38
〃 Elongation (%)	≧ 30	42.5, 44.0
Crain Size, (ASTM No)	Finner than No 11	12.5, 12.5
Corrosion (mg/dm²)	≦22mg/dm²/72hrs. (ASTM B353-71)	15.93, 16.59
Hydride Orientation (FN)	≦ 0.45	0.20
Hardness (30T)	≦83	77.8
Flare (%)	≧15 of O.D.	Accept.

Photo 3-3-1

Lot No. 173

Micrograph of Grain Size

(×400)

Transverse Direction	Longitudinal Direction
	

Hydride Metallographic

(×100)

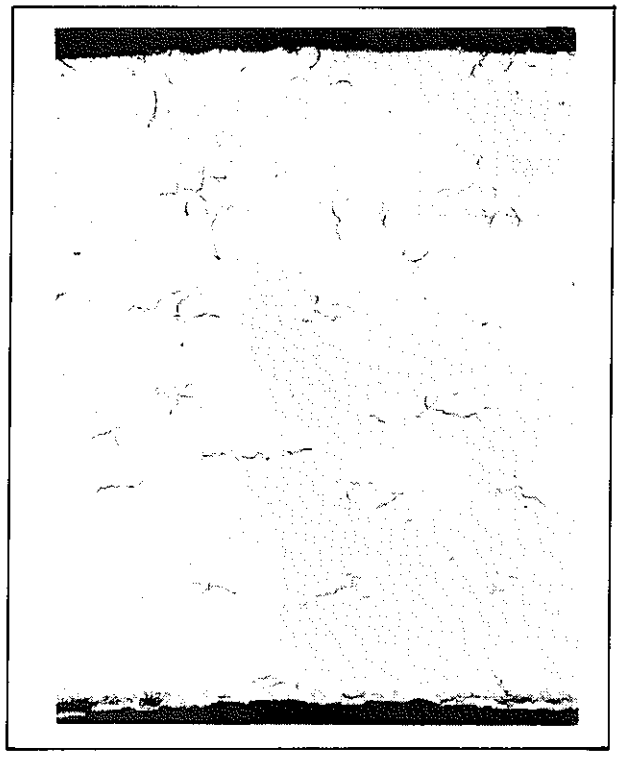


Table 3-3-3 The results of cladding inspection.

Item \ Rod No.	Specification	529-01	529-02	529-03	529-04	529-05	529-06	529-07	529-08	529-09	529-10	529-11	529-12
Outer Diameter (mm) Max.		12.532	12.529	12.534	12.535	12.533	12.534	12.534	12.535	12.538	12.535	12.534	12.533
Min.		12.538	12.537	12.539	12.547	12.538	12.541	12.539	12.544	12.544	12.539	12.540	12.540
		12.523	12.523	12.529	12.525	12.526	12.530	12.526	12.530	12.532	12.530	12.526	12.524
Inner Diameter (mm) Max.	10.795±0.037	10.798	10.805	10.805	10.793	10.795	10.805	10.793	10.793	10.796	10.796	10.805	10.805
Min.		10.801	10.810	10.811	10.797	10.799	10.809	10.797	10.799	10.799	10.800	10.810	10.811
		10.794	10.803	10.800	10.789	10.792	10.800	10.790	10.789	10.793	10.793	10.801	10.801
Thickness (mm) Max.	0.864±0.076	0.890	0.893	0.895	0.882	0.886	0.899	0.884	0.884	0.884	0.886	0.890	0.895
Min.		0.856	0.863	0.861	0.865	0.858	0.861	0.861	0.861	0.867	0.858	0.863	0.863
Defects inspection (by Ultrasonic) Axial Direction	Less than 5% of minimum wall thickness	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K
Circumferential Direction		O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K
Visual observation	· not exist harmfull scale and oxide. · not exist more than 50 μm of pit, dint and hair seam.	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K
Straightness	< 0.4mm	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K	O.K
Reference	cladding No.	14-2	15-2	15-3	18-2	20-2	15-4	18-3	18-4	8-2	9-1	15-5	15-6

Table 4-1-1 Weight and length of fuel stacks and fuel rods.

Item / Rod No.	End Lug		Fuel Stack			Fuel Rod		Reference
	Lower	Upper	Length (mm)	Length *1)	Weight (g)	Length *2) (mm)	Weight (g)	
529-01	Type PF-937	Normal	548.30	562.65	504.16	635.20	716.66	
-02	Type PF-938	Normal	548.05	562.10	489.19	635.00	702.58	
-03	Type PF-939	Normal	551.85	566.20	487.88	635.00	700.91	
-04	Type PF-940	Normal	547.10	561.15	497.50	634.80	710.18	
-05	Type PF-941	Normal	551.10	565.60	496.33	635.00	709.72	
-06	Type PF-942	Normal	547.10	562.40	487.09	635.00	700.32	
-07	Type EC	EF-952	547.20	561.30	498.62	634.80	730.09	Added 3.15 mm thick Zry-2 Disc
-08	Type TF-A	PF-944	548.30	562.15	493.00	632.85	775.39	
-09	Type EC	EF-951	548.00	563.00	494.56	634.90	726.18	Added 1.10 mm thick Zry-2 Disc
-10	Type EC	PF-943	549.10	563.65	491.40	634.90	708.76	
-11	Type EC	EF-950	550.90	564.50	488.94	634.60	719.92	
-12	Type TF-B	PF-945	548.80	563.10	486.50	632.80	767.31	

Notes *1) Include insulator pellets.

2) Rod length means the interval between "V" grooves.

Table 4-3-1 The results of non destructive inspection of fuel rods.

Item / Rod No.	Helium Leak Test	X-ray Inspection		Contamination	
		Lower E.P	Upper E.P	Loose	Fixed
	Spec. $<1\times10^{-8}$ atm.cc/sce	<0.5 mmϕ	<0.5 mmϕ	<20 dpm	<1000 dpm
529-01	0.0196×10^{-8} atm.cc/sec	O.K	O.K	<3	64
-02	〃	〃	〃	〃	50
-03	〃	〃	〃	〃	37
-04	0.0185×10^{-8}	〃	〃	〃	387
-05	0.0196×10^{-8}	〃	〃	〃	23
-06	0.0185×10^{-8}	〃	〃	〃	19
-07	0.0196×10^{-8}	〃	〃	〃	323
-08	0.0185×10^{-8}	〃	〃	〃	41
-09	〃	〃	〃	〃	60
-10	0.0196×10^{-8}	〃	〃	〃	46
-11	0.0185×10^{-8}	〃	〃	〃	178
-12	0.0196×10^{-8}	〃	〃	〃	32

Table 5-1-1 Weights of fuel materials.

Rod No.	Fuel Pellet						Insulator Pellet	
	M.O (g)	Plutonium			Nat. Uranium		Nat. Uranium	
		PuO_2 (g)	Pu (g)	Pu·fissile (g)	N·UO_2 (g)	N·U (g)	N·UO_2 (g)	N·U (g)
529-01	504.16	42.00	37.04	27.54	462	407	13	11
-02	489.19	40.75	35.94	26.73	448	395	14	12
-03	487.88	40.64	35.84	26.65	447	394	13	11
-04	497.50	41.44	36.55	27.18	456	402	13	11
-05	496.33	41.34	36.47	27.12	455	401	13	11
-06	487.09	40.57	35.79	26.61	447	393	13	11
-07	498.62	41.54	36.63	27.24	457	403	13	11
-08	493.00	41.07	36.22	26.93	452	398	13	11
-09	494.56	41.20	36.34	27.02	453	399	14	12
-10	491.40	40.93	36.10	26.85	450	397	13	11
-11	488.94	40.73	35.92	26.71	448	395	13	11
-12	486.50	40.53	35.74	26.58	446	393	13	11
Total	5915.17	492.74	434.58	323.16	5421	4777	158	134

Notes 1. PuO_2 enrichment ; 8.33 %

2. Pu fissile ratio ; 74.36 %

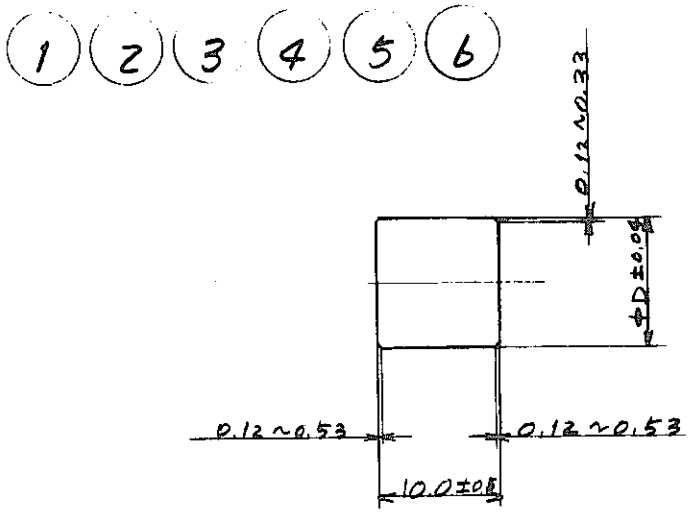
6. Drawings of the IFA-529 fuel rods

DRAWING LIST

PROJECT NAME IFA-529 FUEL ASSEMBLY

DRAWING NO.	TITLE	
EH5-110M	Fuel Pellet (A) - (F)	790118
" -111M	Fuel Pellet (G), (H)	790119
" -130M	Thermal Insulator (A)	790120
" -131M	Thermal Insulator (B)	790121
" -202M	Fuel Rods	790026
" -210M	Cladding	790122
" -220M	Upper End Plug	790123
" -222M	T.E. Assy.	790140
" -230M	Lower P.F. End Plug Assy.	790137
" -231M	Upper P.F. End Plug Assy.	790138
" -232M	E.F. End Plug Assy.	790139
" -250M	Spring (A)	790124
" -251M	Spring (B)	790125
" -260M	Disc. Hollow	790142
" -261M	Disc.	790143

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



Job.No.	D	Gap size(μm)	Blending	Numbers	Remarks
(A)	10.66	140	M.B	150	529 -4.-7.-8
(B)	10.56	240	M.B	165	-5.-9.-10
(C)	10.46	340	M.B	150	-6.-11.-12
(D)	10.66	140	C.P	55	-1
(E)	10.56	240	C.P	55	-2
(F)	10.46	340	C.P	55	-3

ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
6		Fuel Pellet (F)	PuO_2-UO_2		6.0 w/o Pu fissile
5		〃 (E)	〃		〃
4		〃 (D)	〃		〃
3		〃 (C)	〃		〃
2		〃 (B)	〃		〃
1		Fuel Pellet (A)	PuO_2-UO_2		6.0 w/o Pu fissile

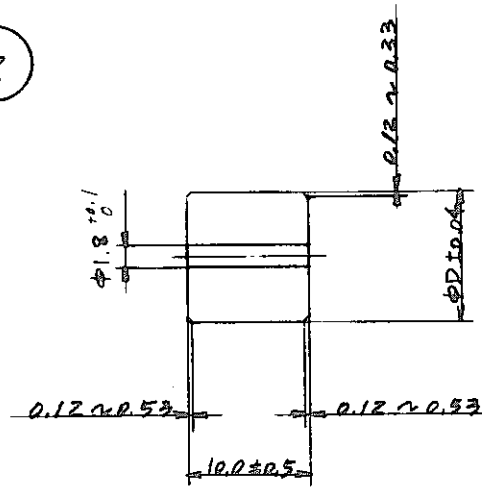
	NAME	DATE	DIVISION	TITLE
DESIGN	M.Hamano	78-11-6	Pu-Thermal-A4	Fuel Pellet (A) ~ (F)
DWG.	S.Kiriharai	78-11-17		
CHECK	M.Kaneko	79-3-10		
APPR.	R.Yamato	-4-24		

ANGLE	SCALE	CODE.NO	DWG.NO	SEQ.NO
THIRD	2/1 ( )	405755	EHS-110M	790118

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME

1 2



Job. No.	D	Gap size(μm)	Blending	Numbers	Remarks
(G)	10.66	190	M.B	15	529-8
(H)	10.86	380	M.B	15	529-12

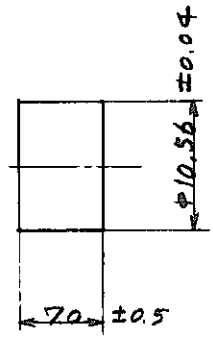
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
2		Fuel Pellet (H)	PuO_2-UO_2		6.0 w/o Pu fissile
1		Fuel Pellet (G)	PuO_2-UO_2		6.0 w/o Pu fissile

	NAME	DATE	DIVISION	TITLE
DESIGN	M. Hirasawa	'79-3-20	Pu-Thermal-A4	Fuel Pellet (G),(H)
DWG.	S. Kirihara	'79-4-12		
CHECK	M. Kajitani	'79-4-12		
APPR.	R. Yamamoto	−4-24		

ANGLE	SCALE	CODE.NO	DWG. NO / SEQ. NO
THIRD	2/1 ( )	405755	DWG. NO EM5-111M SEQ. NO 790119

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



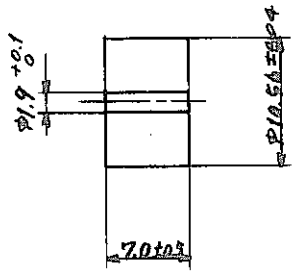
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
1		Thermal Insulator(A)	N, UO_2	22	529-1 ~ 529-12

	NAME	DATE	DIVISION	TITLE
DESIGN	M. Hirasawa	'78-11-6	Pu-Thermal-A4	Thermal Insulator (A)
DWG.	S. Kishihara	'78-11-17		
CHECK	M. Kajifuji	'79-3-10		
APPR.	R. Yumoto	-4-24		

ANGLE	SCALE	CODE.NO	DWG. NO / SEQ. NO
THIRD	2/1 ( )	405765	EH5-130M / 790120

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
1		Thermal Insulator	Al, UO_2	2	529-R,-12

	NAME	DATE	DIVISION	TITLE
DESIGN	M. Hiraoka	'79-3-20	P_u-Thermal-A4	Thermal Insulator (B)
DWG.	S. Kiriyama	79-4-12		
CHECK	M. Kojitani	79-4-12		
APPR.	R. Yamamoto	-4-24		

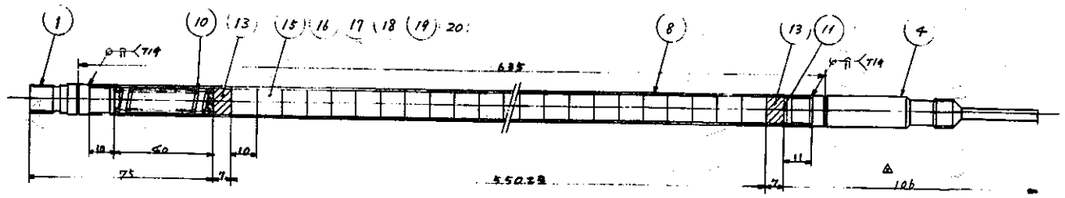
ANGLE	SCALE	CODE NO	DWG. NO / SEQ. NO
THIRD	2/1 ( )	405765	DWG. NO EH5-131M SEQ. NO 790121

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION. TOKAI

REFERENCE

MARK	NOTE	DISCRIPTION	DATE	SIGN NAME
△		~142 → ~145	77 9/10	
△		102 → 106	〃	

Rod No. 529-1,-2,-3,-4,-5,-6



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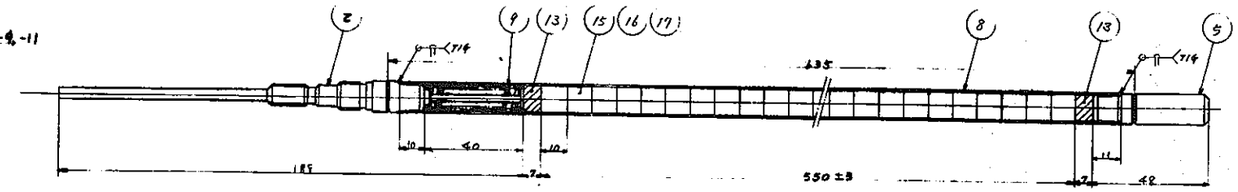
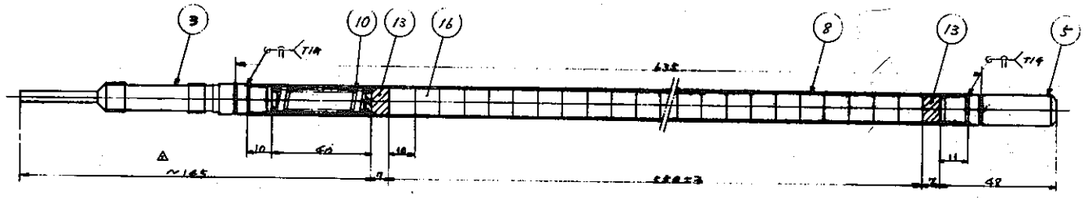


Rod No. 529-10



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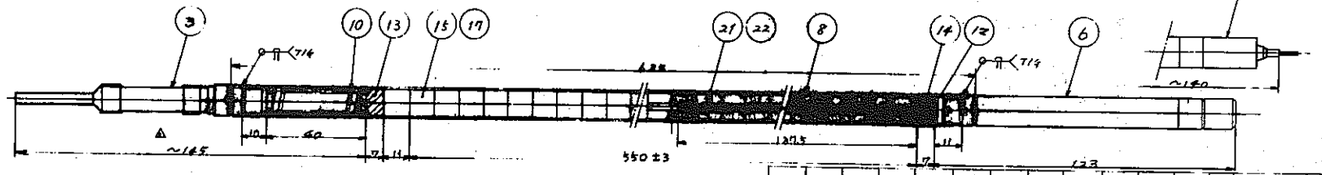


ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
22	EMS-111M	Fuel Pellet (h)	PuO2-UO2	15	Hollow
21	〃 -111M	〃 (g)	〃	15	Hollow
20	〃 -110M	〃 (f)	〃	55	
19	〃 -〃	〃 (E)	〃	55	
18	〃 -〃	〃 (D)	〃	55	
17	〃 -〃	〃 (C)	〃	150	
16	〃 -〃	〃 (B)	〃	165	
15	〃 -110M	Fuel Pellet (A)	PuO2-UO2	150	
14	〃 -131M	Thermal Insulator (B)	N. UO2	2	Hollow
13	〃 -130M	Thermal Insulator (A)	N. UO2	22	
12	〃 -260M	Disc. Hollow	Zry-2	7	
11	〃 -261M	Disc.	Zry-2	4	
10	〃 -251M	Spring (h)	AISI 304 -WPB-	9	
9	〃 -250M	Spring (A)	AISI 304 -WPB-	3	
8	〃 -210M	Cladding	Zry-2	12	
7		T.C. Cable Assy.		2	
6	〃 -222M	T.C. Assy.		2	
5	〃 -223M	C.C. End Plug. Cover	Zry-2	4	
4	〃 -230M	F.F. End Plug Assy.		6	
3	〃 -231M	F.F. End Plug Assy. Upper		7	
2	〃 -232M	F.F. End Plug Assy.		3	
1	EMS-220M	Upper End Plug	Zry-2	4	

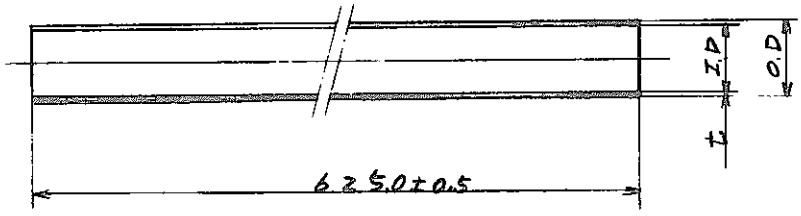
Pellet Type	D	E	F	A	B	C	A	A,G	B	B	C	C,H
Blending	C.P	C.P	C.P	H.B.	H.B.	H.B	H.B.	H.B.	H.B.	H.B.	H.B.	H.B.
Diametral Clearance (μm)	140	240	340	140	240	340	140	140	240	240	240	240
	-PF	-BP	-BF	-PF	-PP	-PF	BF -BC	PP -TB	BF -BC	PP -BC	BF -BC	PF -TB
Fuel Rod No. 529	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12

ANGLE	THIRD	SCALE	1/1 ( )	
		NAME	DESIGN	DWG. / CHECK / APPR.
		DATE	77-8-30 / 77-8-30 / 77-8-31 / 77-9-29	
DIVISION	Pu-Thermal-A1	TITLE	Fuel Rods	
CODE NO	6A5219	DWG. NO	EMS-2027M	
		SEQ. NO	280026	

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

* PPG-18

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



	Dimension
O.D	φ12.523
I.D	φ10.795±0.037
t	0.864±0.076

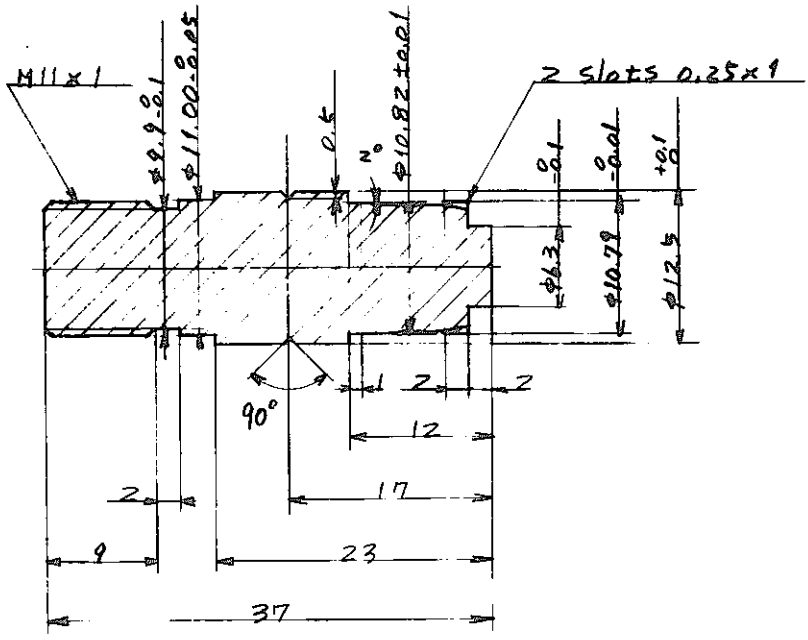
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
1		Cladding	Zry-2	12	

	NAME	DATE	DIVISION	TITLE
DESIGN	M. Hirosawa	'78 11-6	Pu-Thermal-A4	Cladding
DWG.	[illegible]	'78 11-17		
CHECK	M. Kajitani	'79 3-10		
APPR.	A. Yamato	-4-29		

ANGLE	SCALE	CODE.NO	DWG. NO	SEQ. NO
THIRD	1/1 ( )	405035	EH5-210M	090122

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



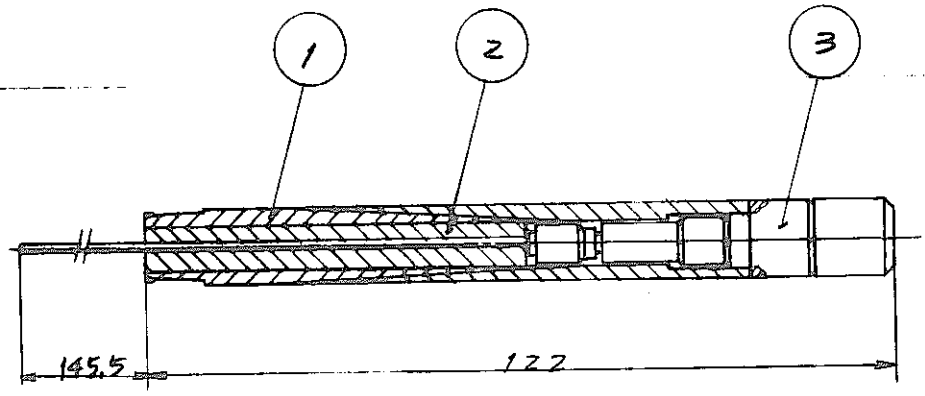
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
1		Upper End Plug	2xy-2	6	529-1 ~ 529-6

	NAME	DATE	DIVISION	TITLE
DESIGN	[illegible]	'77 2-23	Pu-Thermal-A4	Upper End Plug
DWG.	S. Kiriharu	'78-11-17		
CHECK	M. Kajitani	'79-3-10		
APPR.	R. Yamato	'79-4-24		

ANGLE	SCALE	CODE. NO	DWG. NO	SEQ. NO
THIRD	2/1 ( )	405725	EH5-220M	790123

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION. TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



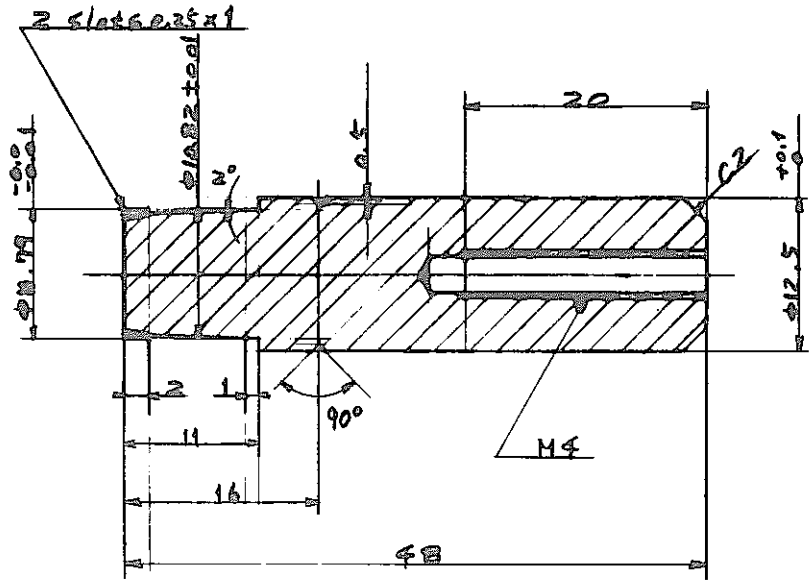
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
3		T.E Assy.		2	〃
2		Filler Body	Zry-2	2	〃
1		Co-Extruded End Plug	Zry-2 / 10C-600	2	529-8, -12

	NAME	DATE	DIVISION	TITLE
DESIGN	HBWR Proj.	'79-3-19	Pu-Thermal-A4	T.E. Assy.
DWG.	S. Kinoshita	'79-5-15		
CHECK	M Himeno	'79-5-21		
APPR.	R. Y	-5-21		

ANGLE	SCALE	CODE. NO	DWG. NO	SEQ. NO
THIRD	1/1 ( )	405805	EH5-222M	790140

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



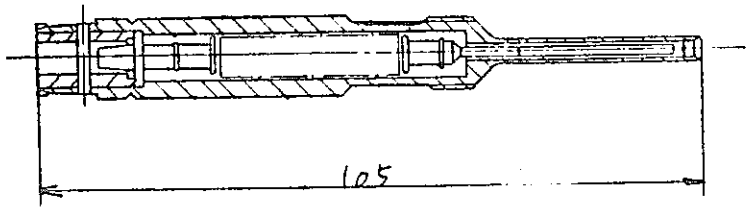
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
1		E.C End plug	Zry-2	4	529-7,-9,-10,-11

	NAME	DATE	DIVISION	TITLE
DESIGN	[illegible]	77-2-28	Pu-Thermal-A4	E.C End Plug
DWG.	[illegible]	77-11-17		
CHECK	[illegible]	77-5-21		
APPR.	R.Y	-5-21		

ANGLE	SCALE	CODE.NO	DWG. NO	SEQ. NO
THIRD	2/1 ( )	405725	EH5-223M	790141

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



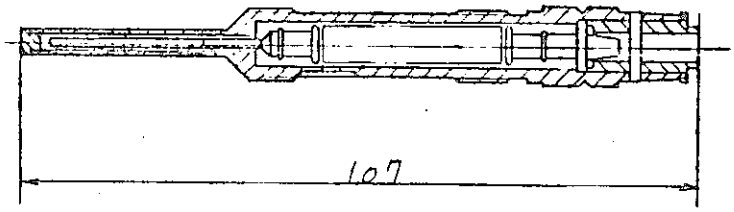
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
1		Lower P.F. End Plug Assy.		6	529-1 ~ -6

	NAME	DATE	DIVISION	TITLE
DESIGN	HBWR Proj.	'79-8-9	Pu-Thermal-A4	Lower P.F. End Plug Assy.
DWG.	S. Kirihara	'79-5-15		
CHECK	M. Hirasawa	'79-5-21		
APPR.	R. Y	-5-21		

ANGLE	SCALE	CODE NO	DWG. NO	SEQ. NO
THIRD	1/1 ( )	405805	EH5-230M	79C137

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



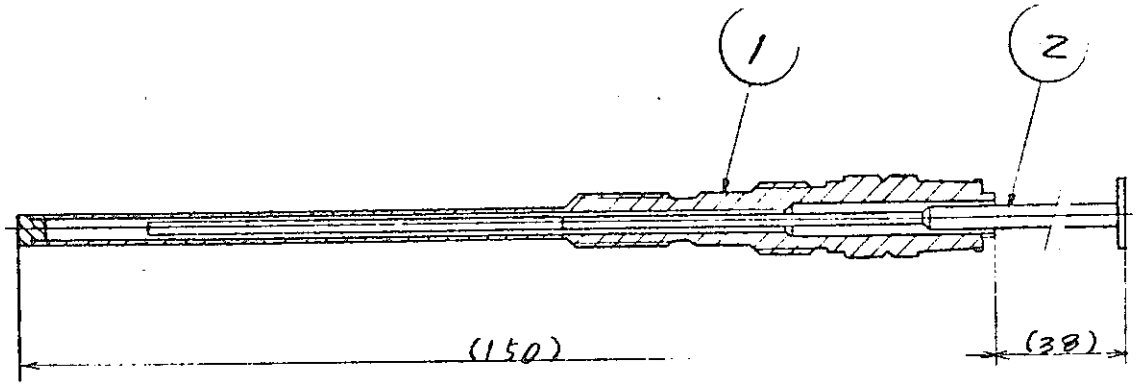
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
1		Upper P.F. End Plug Assy.	Zry-2	3	529-8, -10, -12

	NAME	DATE	DIVISION	TITLE
DESIGN	HBWR Proj.	'79-3-19	Pu-Thermal-A4	Upper P.F. End Plug Assy.
DWG.	S. Kishi	'79 5-15		
CHECK	M. Hirasawa	'79 5-21		
APPR.	R.Y	-5-21		

ANGLE	SCALE	CODE NO	DWG. NO	SEQ. NO
THIRD	1/1 ( )	405805	EH5-231M	790138

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



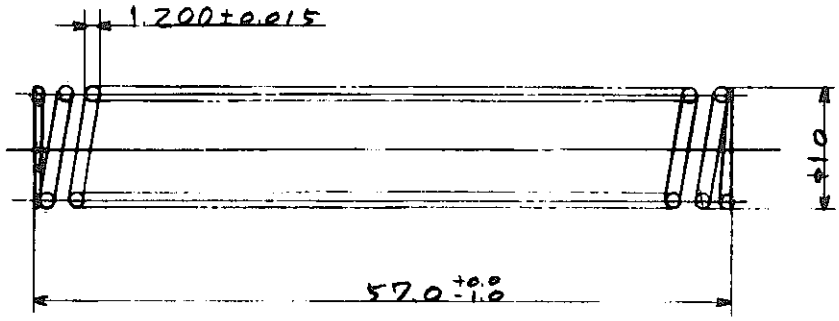
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
2		Core Assy.		3	〃
1		E.F. End Plug Assy.	Zry-2	3	529-7,-9,-11

	NAME	DATE	DIVISION	TITLE
DESIGN	HBWR Proj.	'79-3-19		
DWG.	S. Kiriyama	'79-5-15	In-Thermal-A4	E.F. End Plug Assy.
CHECK	M. Hirasawa	'79-5-21		
APPR.	R. Y	-5-21		

ANGLE	SCALE	CODE NO	DWG. NO / SEQ. NO
THIRD	1/1 ( )	405805	EH5-232M / 790139

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



SPECIFICATION

MATERIAL	AISI304-WPB
WIRE DIAMETER	1.200±0.015
OVER DIAMETER	10
TOTAL NUMBER OF TURNS	27
EFFECTIVE NUMBER OF TURNS	25
FREE LENGTH	57.0 +0.0 −1.0
SPRINS CONSTANT	0.114 kg/mm

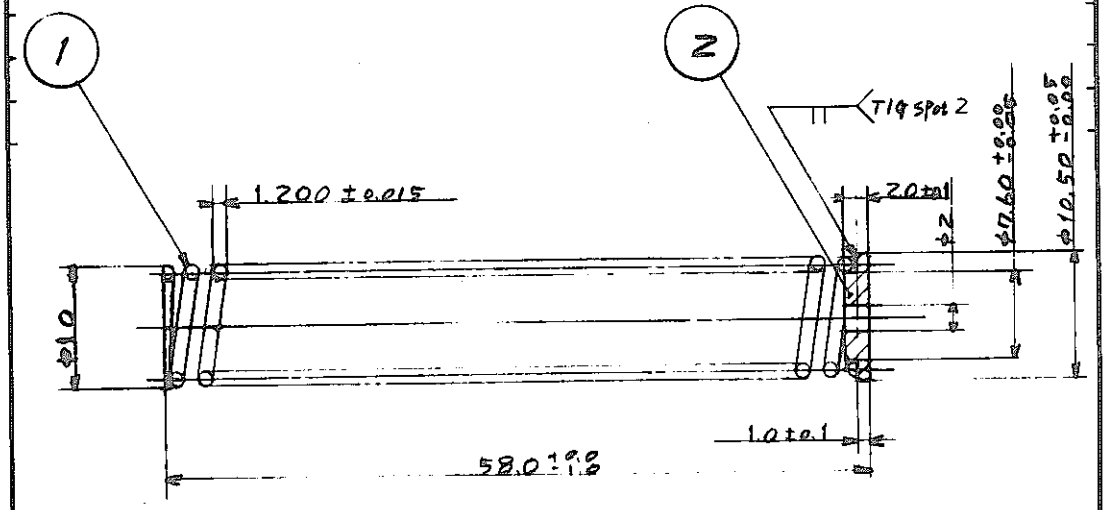
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
1		Spring (A)		3	529-7, -9, -11

	NAME	DATE	DIVISION	TITLE
DESIGN	K. Hagawa	'78-11-7	Pu-Thermal-A4	Spring (A)
DWG.	S. Kimura	'78-11-17		
CHECK	M. Kaitani	'79-3-10		
APPR.	R. Yumoto	-- 4-24		

ANGLE	SCALE	CODE NO	DWG. NO / SEQ. NO
THIRD	2/1 ( )	405745	DWG. NO EH5-250H SEQ. NO 790124

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



SPECIFICATION

MATERIAL	AISI304-WPB
WIRE DIAMETER	1.200 ±0.015
OVER DIAMETER	10
TOTAL NUBER OF TURNS	27
EFFECTIVE NUBER OF TURNS	25
FREE LENGTH	57.0 +0.0 -1.0
SPRING CONSTANT	0.114 kg/mm

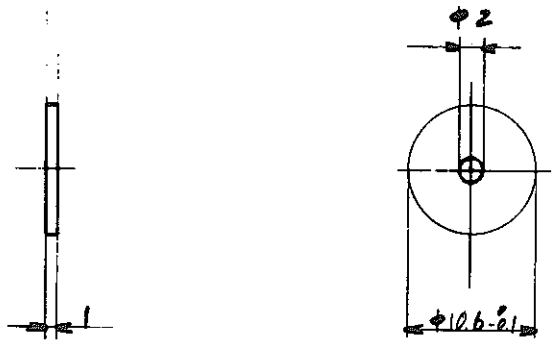
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
2		Plate	AISI 304	9	
1		Spring (B)		9	529-1,-2,-3,-4,-5,-6,-8,-10,-12

	NAME	DATE	DIVISION	TITLE
DESIGN	M. Ingam	'78-11-7	Pu-Thermal-A4	Spring (B)
DWG.	[illegible]	'78-11-17		
CHECK	M. Kattani	'79-3-10		
APPR.	R. Yuhara	-4-26		

ANGLE	SCALE	CODE.NO	DWG. NO	SEQ. NO
THIRD	2/1 ( )	405745	EH5-251M	090124

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION. TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



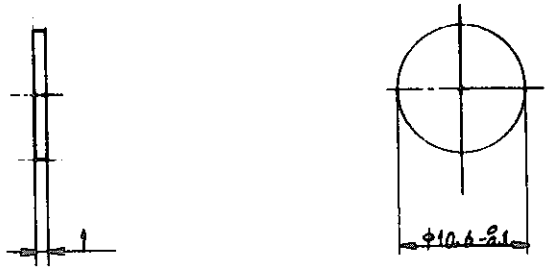
ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
1		Disc. Hollow	Zry-2	2	529-8,-12

	NAME	DATE	DIVISION	TITLE
DESIGN	M. Hirasawa	'77-3-14	Pu-Thermal-A4	Disc. Hollow
DWG.	S. Kishibara	'79-5-15		
CHECK	M. Hirasawa	'79-5-21		
APPR.	R. Y	-5-21		

ANGLE	SCALE	CODE NO	DWG. NO / SEQ. NO
THIRD	2/1 ( )	405745	DWG. NO EH5-260M SEQ. NO 790142

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI

REFERENCE	MARK / NOTE	DISCRIPTION	DATE / NAME



ITEM	DRAWING NO.	NAME	MATERIAL	NUMBERS	REMARKS
1		Disc	Zry-2	6	529-1 ~ -6

	NAME	DATE	DIVISION	TITLE
DESIGN	HABER Ryj.	'79-8-14	Pu-Thermal-A4	Disc
DWG.	G.Kiuchi	'79-5-15		
CHECK	M.Hirasawa	'79-5-21		
APPR.	R.Y	-5-21		

ANGLE	SCALE	CODE.NO	DWG. NO	SEQ. NO
THIRD	2/1 ( )	405745	EHS-261M	790143

POWER REACTOR AND NUCLEAR FUEL DEVELOPMENT CORPORATION, TOKAI