Development of Ir-192 Spherical Sources for Non-Destructive Testing and Future Applications

Takashi Ishii, Norikazu Ooka, Yukimasa Kawauchi, Takashi Saito
Hiroshi Yoshimochi, Hiroshi Kawamura
Chiyoda Technol Corporation, Japan

Introduction

- Currently, the most commonly used gamma-ray source for radiographic testing in Japan is Ir-192 (radioactivity: 10 Ci).
- The predominant form consists of stacked disc sources in a cylindrical shape, which differs from an ideal point source.
- Therefore, the fabrication of a miniaturized sphere Ir-192 source that has no directional anisotropy in all directions and reduces geometric unsharpness has been attempted.
- This paper presents the results of irradiation conducted using JRR-3 operated by JAEA and describes the imaging tests of sphere sources performed previously.

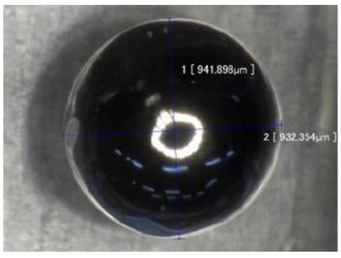


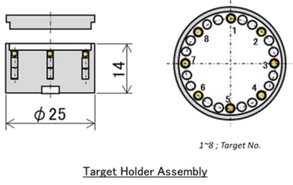
Fig.1 Miniaturized sphere Ir-192 source by melt dropping method

Method (Irradiation using JRR-3)

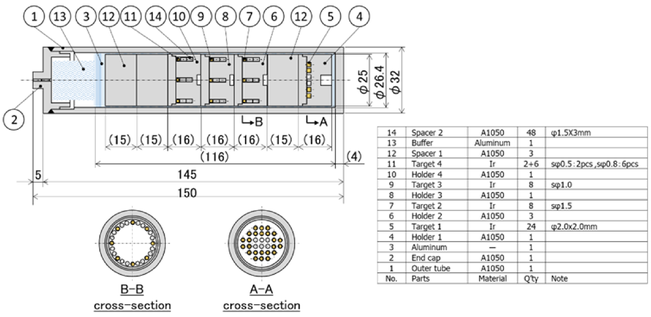
- Four types of miniaturized sphere samples ranging from 0.5 mm to 1.5 mm in diameter were selected.
- Figure 2 shows the structural overview of the target holder and irradiation capsule.
- The irradiation was carried out for 1 cycle (25days) at VT-1 hole (nominal thermal neutron flux of 3×10^{14}cm^{-2}s^{-1}) in the fuel region of the JRR-3 core.

Table 1 Shape and size of the irradiation target

Shape	Size	Production Method	^{191}Ir content
Sphere	0.5 mmφ	Melt dropping	36.7%
Sphere	0.8 mmφ	Melt dropping	36.7%
Sphere	1.0 mmφ	Melt dropping	36.7%
Sphere	1.5 mmφ	Melt dropping	36.7%



Target Holder Assembly



No.	Parts	Material	Qty	Note
14	Spacer 2	A1050	48	φ1.5X3mm
13	Buffer	Aluminum	1	
12	Spacer 1	A1050	3	
11	Target 4	Ir	2+6	sφ0.5 : 2pcs ,sφ0.8 : 6pcs
10	Holder 4	A1050	1	
9	Target 3	Ir	8	sφ1.0
8	Holder 3	A1050	1	
7	Target 2	Ir	8	sφ1.5
6	Holder 2	A1050	3	
5	Target 1	Ir	24	φ2.0x2.0mm
4	Holder 1	A1050	1	
3	Aluminum	—	1	
2	End cap	A1050	1	
1	Outer tube	A1050	1	

Fig.2 Outline of Irradiation Capsule and Target Holder

Result (Irradiation)

- Visual inspection confirmed that no harmful scratches had occurred on the irradiated sphere Ir-192 samples.
- The dose measurement results for each miniaturized sphere are shown in Tables 2 through 5.
- Since there is almost no variation in the specific radioactivity values for each group, it is estimated that thermal neutrons at the JRR-3 VT-1 were irradiated uniformly from almost all directions.

Table 2 Radioactivity of the sphere 1.5mmφ

Number	Diameter (mm)	Weight (mg)	Radioactivity (Ci)	Specific Radioactivity (Ci/mg)
1	1.49	39.25	9.78	0.25
2	1.50	39.24	9.74	0.25
3	1.49	39.25	9.78	0.25
4	1.49	39.13	9.78	0.25
5	1.48	39.00	9.74	0.25
6	1.49	39.46	9.44	0.24
7	1.49	39.09	9.70	0.25
8	1.50	39.12	9.74	0.25
Ave.	1.49	39.19	9.71	0.25

Table 3 Radioactivity of the sphere 1.0mmφ

Number	Diameter (mm)	Weight (mg)	Radioactivity (Ci)	Specific Radioactivity (Ci/mg)
1	0.98	11.59	3.89	0.34
2	1.00	11.72	3.93	0.34
3	0.99	11.55	3.85	0.33
4	0.99	12.02	4.00	0.33
5	1.01	11.95	3.96	0.33
6	0.99	11.48	3.85	0.34
7	1.00	11.73	3.93	0.34
8	1.00	12.12	4.00	0.33
Ave.	0.99	11.77	3.93	0.33

Table 4 Radioactivity of the sphere 0.8mmφ

Number	Diameter (mm)	Weight (mg)	Radioactivity (Ci)	Specific Radioactivity (Ci/mg)
1	0.78	5.58	2.14	0.38
2	0.79	5.97	2.19	0.37
3	0.83	6.51	2.42	0.37
4	0.78	5.72	2.10	0.37
5	0.81	6.40	2.32	0.36
6	0.79	5.98	2.18	0.36
Ave.	0.80	6.03	2.23	0.37

Table 5 Radioactivity of the sphere 0.5mmφ

Number	Diameter (mm)	Weight (mg)	Radioactivity (Ci)	Specific Radioactivity (Ci/mg)
1	0.51	1.70	0.69	0.41
2	0.50	1.60	N/A^{*2}	N/A

Discussion (Radiography Test)

- A comparison of radiographic testing using sphere sources and disc sources is described.
- The radiographic conditions for this test are shown in Table 6, and the radiographic arrangement is shown in Figure 4.
- Table 7 shows the wire diameters of the Image Quality Indicator (hereinafter referred to as "I.Q.I") that could be identified by direct observation of the films. Visual observation showed that the W-1 I.Q.I had one more identifiable wire than the A-2 I.Q.I.

Table 6 Radiographic Conditions

	Sphere	Disc
Source Size	1.3 mmφ	1.5mmφ×0.8mmh
Radioactivity	148 GBq	182.8 GBq
Sample Test Piece	Material: Carbon Steel (10mmt) Weld reinforcement (with artificial circular defects): 2 mm on front side, 1 mm on back side	
SFD (Source to Film Distance)	200 mm	200 mm
Exposure Time	2.5 min	2.0 min
I.Q.I	10FE EN	10FE EN
Type of Film	AGFA Structurix D7	AGFA Structurix D7

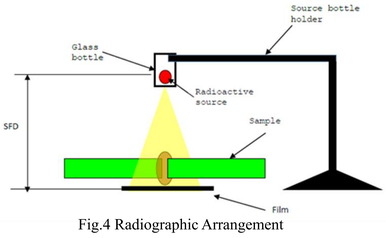


Fig.4 Radiographic Arrangement

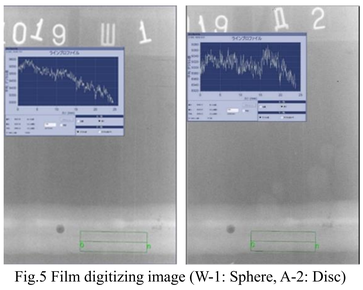


Fig.5 Film digitizing image (W-1: Sphere, A-2: Disc)

Table 7 Results of perceptible wire diameter for I.Q.I

	Film W-1 (φ1.3mm sphere)	Film A-2 (φ1.5mm Disc)
	Number of wires (Wire diameter)	Number of wires (Wire diameter)
Observation of Film Images	3 (0.25)	2 (0.32)
Observation of Digital Images	3 (0.25)	2 (0.32)

Conclusion

- Using JRR-3, the first-ever irradiation of sphere Ir-192 was conducted in Japan. It was confirmed that neutron irradiation in the VT-1 of JRR-3 was performed uniformly.
- Preliminary tests showed that the developed miniaturized sphere sources produce images with less geometric unsharpness (penumbra) compared to conventional disc sources. The utility of sphere sources has been demonstrated.
- The sphere sources irradiated in this study are scheduled to undergo F-RT and D-RT imaging tests for further discussion.