Trial Production of 169Yb Gamma-Ray Sources and Their Characteristics

Trial Production of ^{169}Yb Gamma-Ray Sources and Their Characteristics

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^{169}Yb gamma-ray sources were manufactured by neutron irradiation in the Reseach Reactor of Kyoto University using enriched ytterbium as a source material. The attenuation curves and wire sensitivity curves of ^{169}Yb were measured and compared with those of ^{192}Ir. The ^{169}Yb gamma-ray sources obtained are useful for the inspection of welds on thin plates and small diameter pipes.

1. Introduction

In the gamma-ray radiography, ^{60}Co sources are used widely for the inspection of welds on steel structure thicknesses from 50 to 150 mm, and ^{192}Ir sources for thicknesses over the typical range of 12-60 mm. For the inspection of thinner steel structures, however, X-ray apparatuses are mainly used, because a suitable gamma-ray source is not available.

In recent years, ^{169}Yb gamma-ray sources were developed for the radiography of welds on thin steel structures, especially on small diameter pipes, and many reports on their characteristics and usefulness appeared.[1-6].

Accordingly, the authors made ^{169}Yb sources using enriched ytterbium activated by neutrons in the Research Reactor of Kyoto University (KUR). In this work, the characteristics of ^{169}Yb gamma-rays for industrial radiography were studied by using these enriched ytterbium sources.

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2. Experimental

2.1 Source

The activation cross-section of ^{169}Yb is very high, but the amount of ^{168}Yb in the natural ytterbium is only 0.14%. Therefore, it is difficult to obtain strong activities of ^{169}Yb. So the enriched source of ^{168}Yb were prepared. As shown in Table 1, the sources were made nominally 15.6% enriched ^{168}Yb oxide (Yb_2O_3) encapsulated and welded in an aluminum block. These sources were irradiated in a flux of 4.65×10^{13} n/cm^2/s for 465 hours. The dimensions of active parts were 1 mm and 1.4 mm in diameter and 1 mm and 1.4 mm in length. Figure 1 shows the capsule of the source. The gamma-rays from ^{175}Yb and ^{177}Yb produced from ^{174}Yb and ^{176}Yb in the target material have comparatively high energies (396, 251 keV and 1240, 1230, 298 keV) and strong intensity just after irradition. Fortunately, their half lives are comparatively short (4.2 d and 1.9 hr). So, the irradiated sources were cooled to decay down these isotopes for about 1 month.

The gamma-ray intensities at 1 m from the sources after 1 month cooling were

Table 1 Abundance of natural ytterbium source used in the experiment.

Nuclide	Abundance (#) Natural	Enrich	Reaction	Activation Cross-Section (barn)	Radio Nuclide	Half-Life
^{168}Yb	0.14	15.6	(n. γ)	11000	^{169}Yb	32d
^{170}Yb	3.03	7.57				
^{171}Yb	14.31	19.21				
^{172}Yb	21.82	20.49				
^{173}Yb	16.13	11.95				
^{174}Yb	31.84	19.28	(n. γ)	60	^{175}Yb	4.2d
^{176}Yb	12.73	5.90	(n. γ)	5.5	^{177}Yb	1.8h

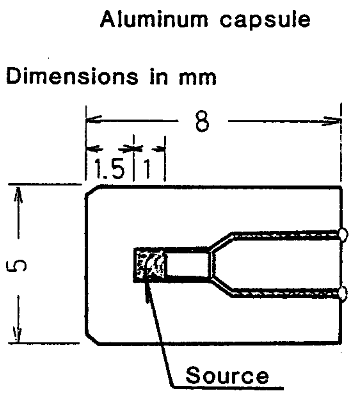

Fig. 1 Source capsule.

Table 2 Gamma-ray intensities of the ^{169}Yb source made from enriched ytterbium.

Soruce dimension diameter (mm)	lenght (mm)	Source material	Torget Mass (mg)	Activities Ci	mR/h at 1m
1	1	Yb_2O_3	3.3	0.27	33
1.4	1.4	Yb_2O_3	8.7	0.83	100

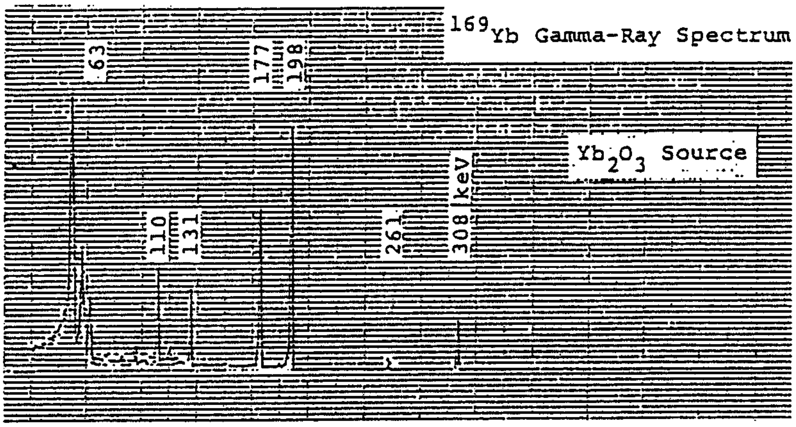

Fig. 2 Gamma-ray spectrum of ^{169}Yb.

considerably low as shown in Table 2. Figure 2 shows the gamma-ray spectrum of a source measured by a Ge (Li) detector. The ^{169}Yb source shows several gamma-ray peaks in the energy range of 63-308 keV. Relative intensities of each gamma-ray peak is shown in Table 3.

2.2 Attenuation

Attenuation curves of ^{169}Yb gamma-rays were obtained for the narrow beam and broad beam conditions by the following three methods:

1) Dosimetric method; gamma-ray dose rates were measured by an ionization chamber.
2) Radiographic method; gamma-ray dose rates were determined by photographic-film density measurements.
3) Spectrum meathod; the attenuation curve was obtained from the attenuation of each gamma-ray peak in the spectrum.

The plots in Fig. 3 show the results measured by the dosimetric method, and the curves of narrow beam condition were obtained by the spectrum method. The two results are close each other, and it can be seen that the contrast of ^{169}Yb gamma-ray is much larger than that of ^{192}Ir. Figure 4 shows the attenuation curves measured by radiographic method. In these curves, the attenuation in the thin absorber region is considerably larger compared to the curves obtained by dosimetric method.

Table 3 Gamma-ray spectrum of ^{169}Yb.

Gamma-ray energy (KeV)	Relative intensity (%)
8.0	0.4
21	0.2
63	43.4
94	2.6
110	17.4
118	1.9
131	11.1
177	21.2
198	34.8
261	1.7
308	10.7

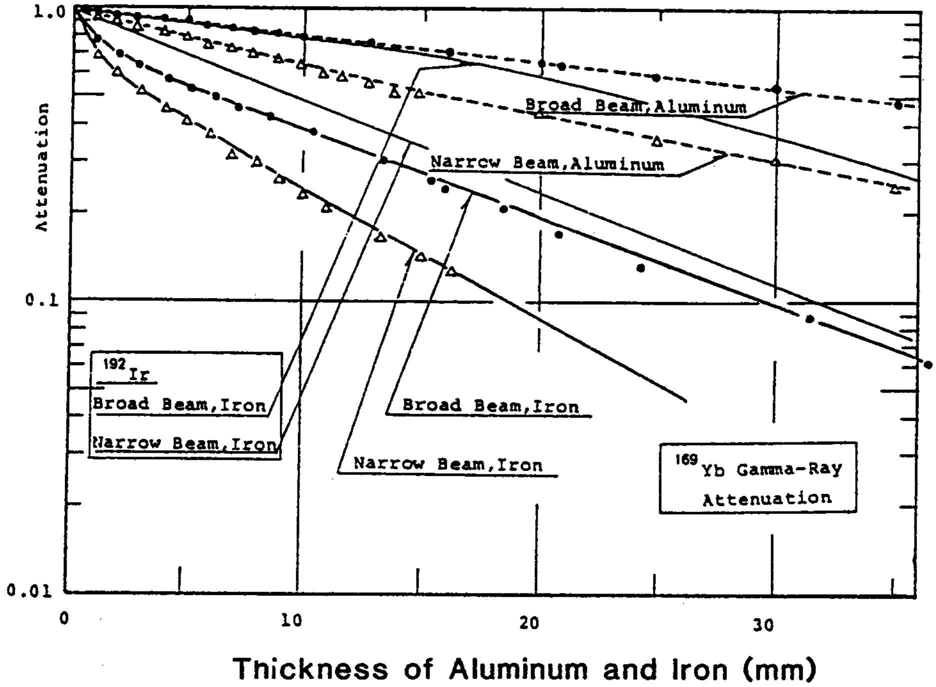

Fig. 3 Attenuation curves of ^{169}Yb gamma-rays measured by an ionization chamber.

This was possibly caused by the increase of the film sensitivity in the energy range below 100 keV.The effective energy of ^{169}Yb gamma-rays is about 200 keV for steel.

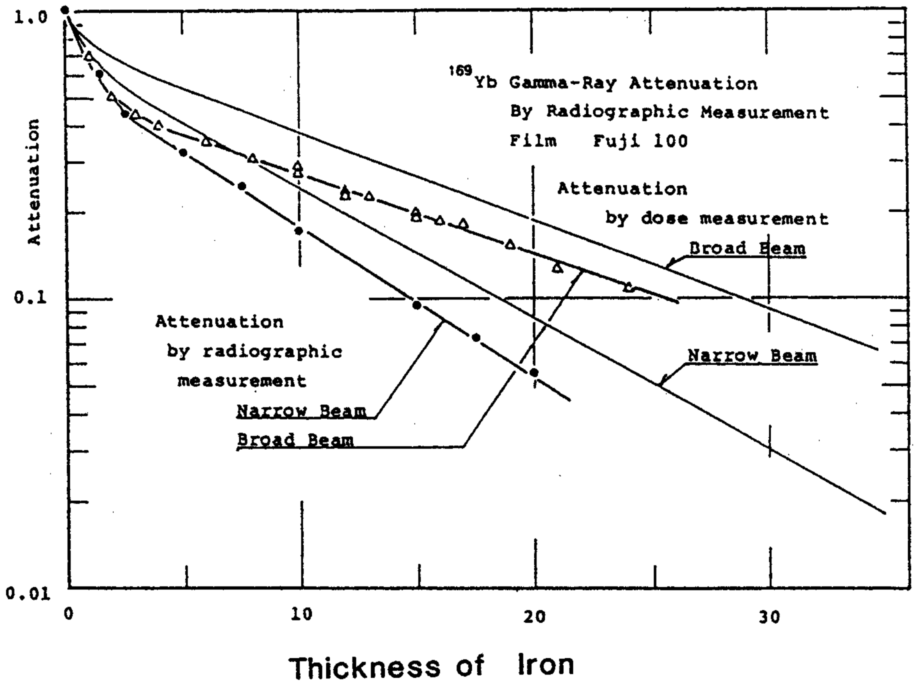

Fig. 4 Attenuation curves of ^{169}Yb gamma-rays measured by radiographic film density.

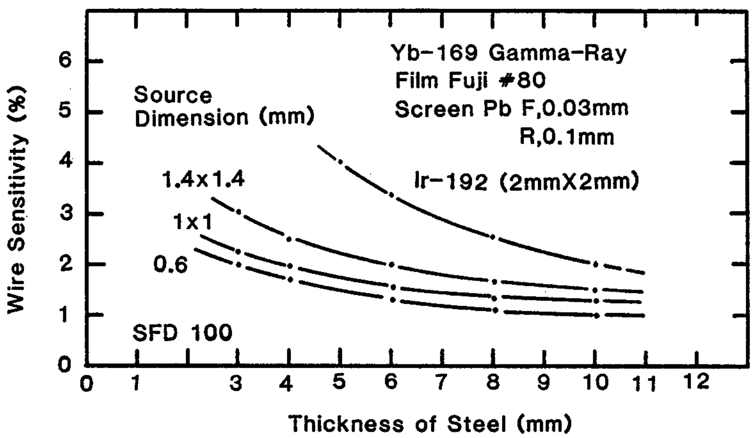

Fig. 5 Experimental wire sensitivity curves ^{169}Yb.

2.3 Sensitivity curves

The sensitivity curves were obtained by using IQI wires as shown in Fig. 5. Measurements were made for various sizes of sources at the source-to-film distance (SFD) of 100 mm. The smallest source used was a pellet of 0.6 mm in diameter obtained from Amersham International plc. The ^{169}Yb sources clearly shows sensitivities better than ^{192}Ir. To study practical applications, small steel pipes of various sizes were prepared as shown in Fig. 6. In this experiment, a special flexible nylon

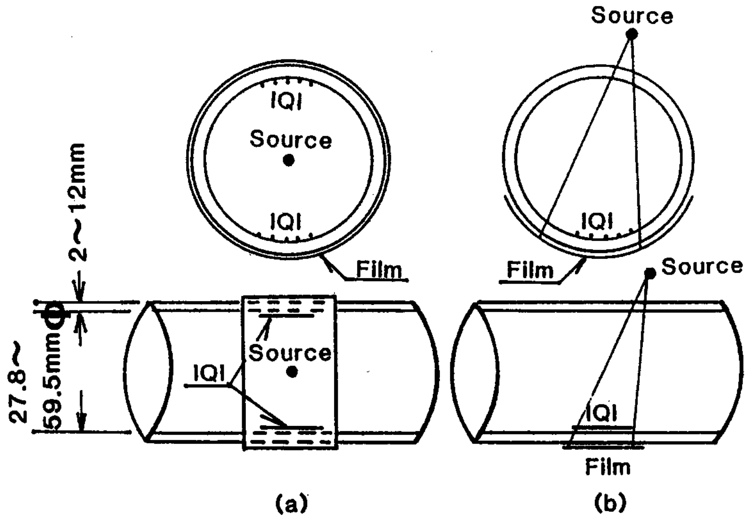

Fig. 6 Small pipes and expoure arrangements.

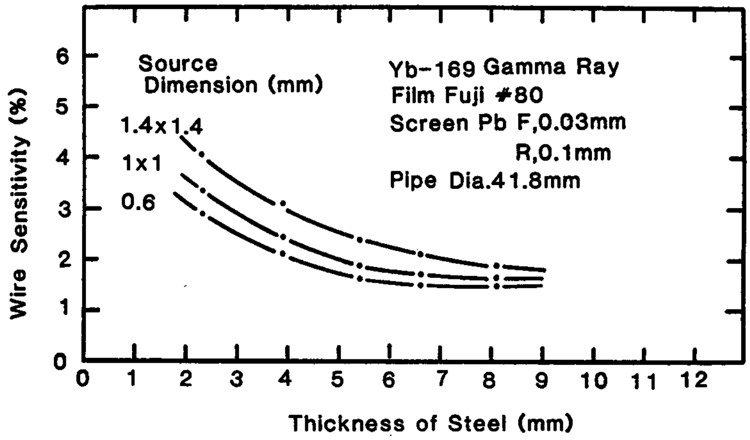

Fig. 7 Comparison of wire sensitivity curves for different source sizes. Panoramic source technique.

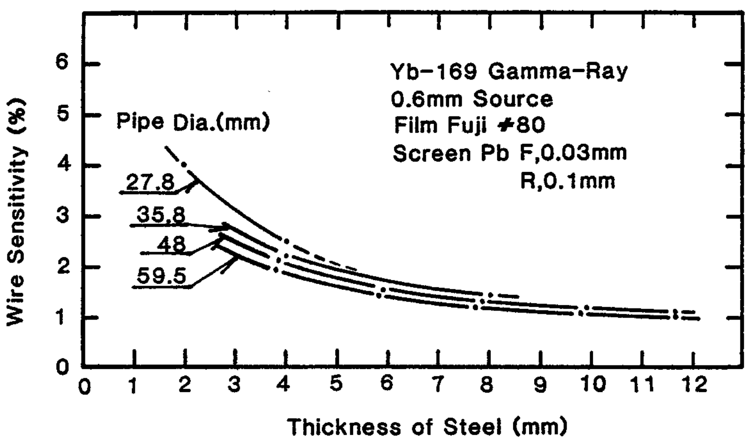

Fig. 8 Comparison of wire sensitivity curves for different steel pipe diameters. Panoramic source technique.

cassette was used with a lead foil and a film. The exposure arrangement in Fig. 6 (a) is the panoramic source technique for pipe weld radiography, and the arrangement in Fig. 6 (b) is the double-wall single-image technique for butt welds in pipes. Figure 7 shows the sensitivity curves of various sources for a pipe of 41.8-mm diameter. Figure 8 shows the result of various pipe sizes by using the smallest source. The results of these figures were obtained by panoramic technique. Figure 9 is an example of the results of double-wall single-image technique by using the smallest source. The exposure curves per curie for the steel pipe are also shown in Fig. 10.

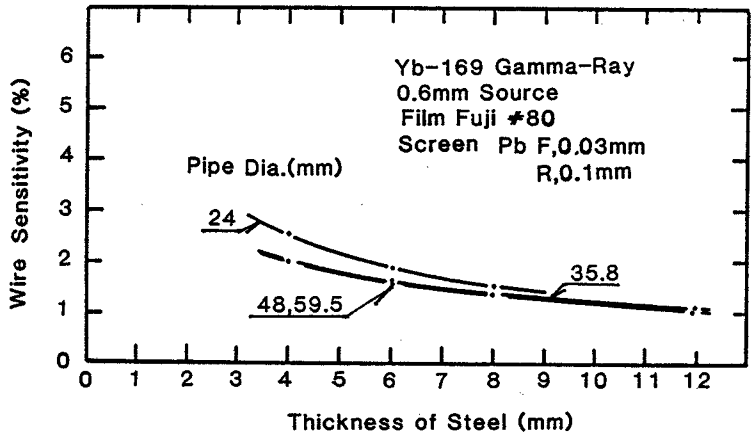

Fig. 9 An example of wire sensitivity curve for a small source. Double-wall single-image technique.

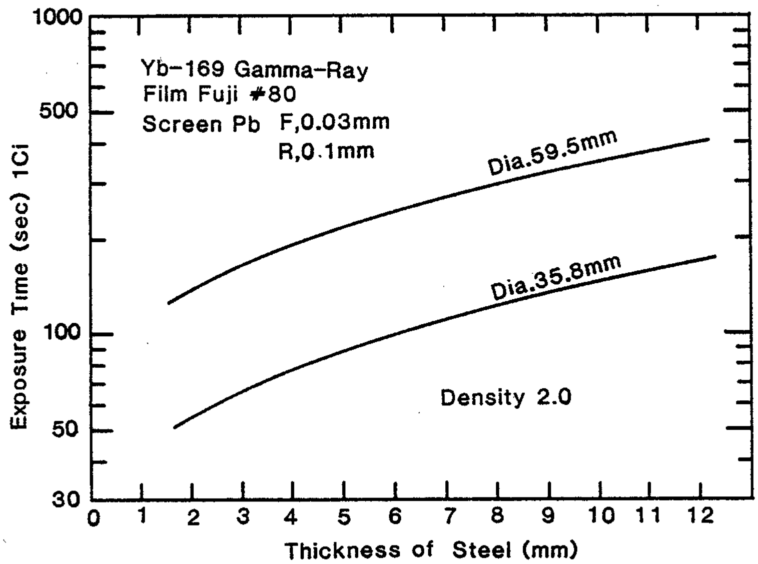

Fig. 10 Expousure curves for steel pipe. Panoramic source technique

3. Conclusion

Through the experiment, it has been made clear that the ^{169}Yb gamma-ray source shows lower effective energy and higher contrast than the ^{192}Ir source. Therefore, the former source is expected in future to be used practically for the inspection of welds on thin plates and small-diameter pipes for the reasons of its fine sensitivity and easy handling.

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