# A High Dose-Rate Gamma Irradiation Test of Passive Elements of Radiation-Tolerant Camera System

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## 1. Introduction

In this paper, a high dose-rate gamma-ray irradiation test of passive elements, which are components of radiation-tolerant camera system, is described. In the overhaul period of the nuclear power plant, integrity of the neutron-irradiated fuel assembly is evaluated. Among the evaluation methods for the integrity of the neutron-irradiated fuel assembly during the normal operation cycle of the nuclear power plant, VT(visual test) of the four face of nuclear fuel assembly is a major concern. As the neutron-irradiated fuel assembly is a high dose-rate gamma-ray source, approximately a few kGy, radiation-hardened camera composed of vidicon tube-type image sensors is used in the VT. As shown in Fig. 1, the VT of the four face of nuclear fuel assembly, which is a high dose-rate gamma source, is performed in the canal. The width of canal, $d_1$, is about 1,500mm. As the distance, $d_2$, between the fuel assembly ($d_3$, 224mm) and the camera system, assumed that the width of camera system is about 200mm, is short below one-tenth shielding thickness of gamma-ray of water, about 660mm, a COTS CCD device can not be used directly. As the image resolution of the COTS CCD device is higher than vidicon-tube type image sensor, the VT of the four face of the nuclear fuel assembly is clearly performed, if assumed that the radiation-weakened CCD device is properly shielded from the high dose-rate gamma-ray source. In this paper, it is assumed that a radiation-tolerant camera system, which are composed of COTS CCD camera, zoom lens, anti-reflection mirror, and visible window, is used in the VT of the nuclear fuel assembly. And the COTS CCD camera and zoom lens module are shielded from a high dose-rate gamma-ray source using the high-density material, lead or tungsten.

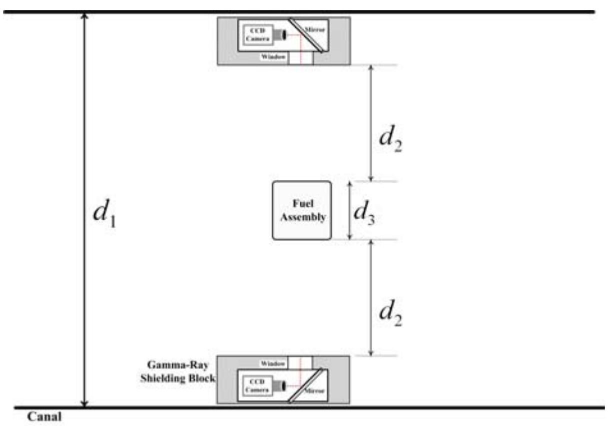


Fig. 1. A schematic diagram for the VT of fuel assembly

The architecture of the radiation-tolerant camera system is shown in Fig. 2.

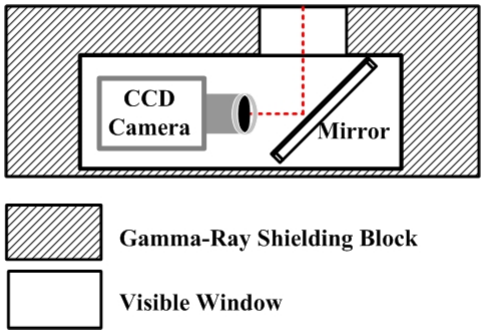


Fig. 2. Block diagram of radiation-tolerant camera.

As shown in Fig. 1 and 2, the passive elements, mirror and visible window, which are placed in the optical path of CCD camera, are exposed to a high dose-rate gamma-ray source directly. So, the gamma-ray irradiation characteristics of passive elements, is needed to test. We have conducted high dose-rate (up to 264kGy) gamma irradiation experiments on a visible window materials and mirror.

## 2. Experiment

Table 1 summarizes the passive elements exposed to high dose-rate gamma-ray irradiation source (dose-rate 4kGy).

Table 1. Passive elements exposed to high dose-rate gamma-ray irradiation source (dose-rate 4kGy).

| Dose (TID) | Visible Window | Mirror |
|---|---|---|
| 66 kGy | Glass | - |
| 264 kGy | Quartz | AR-Coated based on glass material |
| 264 kGy | Acryl plate | Al-coated |
| 264 kGy | Acryl plate1 | - |

In Table 1, 264 kGy means total irradiated dose of passive elements during the VT of the four face of nuclear fuel assembly. In the same table, the gamma-ray dose-rate of neutron-irradiated fuel assembly is assumed about 4 kGy/h conservatively. And the time required for full amount inspection of nuclear fuel assemblies are assumed about 3 days(66 hours). In the case of glass material, the clarity (transparency) is lost at the 4 kGy TID because of browning effect. The browning effect has not been occurred in the acryl plate up to 10 kGy TID. But the transparency of the acryl plate was deformed after exposed up to 66 kGy. The color center was formed as same like the glass material.

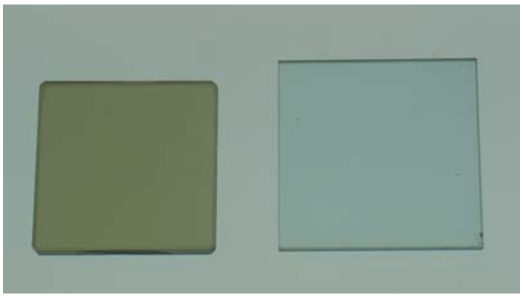

Fig. 3. Color center formed in the glass (left) after exposed to the high dose-rate gamma irradiation field (dose rate = 4kGy/h, TID ≅ 4kGyt)

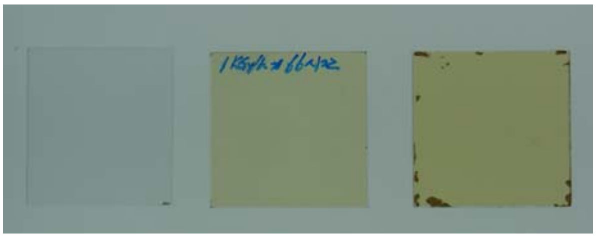

Fig. 4. Color center formed in the acryl plate after exposed to the high dose-rate gamma irradiation field (center plate = 1 kGy/h, TID 66kGy, right plate = 4kGy/h, TID 264kGy)

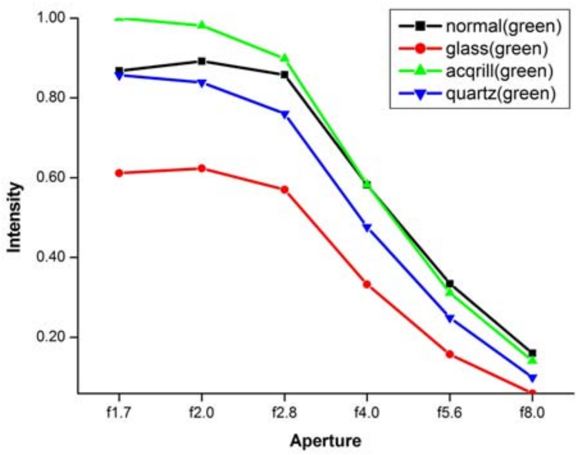


Fig. 5. Intensity level according to aperture of lens

Fig. 5 shows the brightness of the visible window material. As shown in Fig.1 and 2, we placed the visible window in the front of CCD camera lens. And we measured the brightness level of CCD camera system according to the variation of aperture of lens using entropy calculation. Up to f2.8, as the aperture of lens is widely opened, the brightness of CCD camera system is almost same as like normal case except glass material (4 kGy irradiated) used as a visible window.

### 3. Conclusions

In this paper, a high dose-rate gamma-ray irradiation test of passive elements, which are components of radiation-tolerant camera system, is described. In the overhaul period of the nuclear power plant, integrity of the neutron-irradiated fuel assembly is evaluated. Among the evaluation methods for the integrity of the neutron-irradiated fuel assembly during the normal operation cycle of the nuclear power plant, VT(visual test) of the four face of nuclear fuel assembly is a major concern. In order to use radiation tolerant camera composed of COTS CCD camera as a VT camera, the robust clarity of its passive elements (visible window and mirror) in such intense gamma-radiation fields needs to be assured. We have conducted high dose-rate (up to 264kGy TID) gamma irradiation experiments on a passive element materials. From the experimental results, we concluded that quartz as a visible window and aluminum-coated mirror as a mirror are to be used as passive elements of radiation-tolerant camera system.

### REFERENCES

[1] Japan Patent, "Nuclear Fuel Assembly Inspection Unit", Mitsubishi Nuclear Fuel Company, JP 1998-274690