CONSTRUCTIONAL DESIGN PRINCIPLES ON RADIATION PROTECTION AND METHODS OF RADIATION CONTROL AT THE LARGE SCALE PLUTONIUM FUEL FABRICATION FACILITY OF FULLY REMOTE OPERATION

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1. INTRODUCTION

The large scale Plutonium Fuel Fabrication Facility (Pu-3rd) of PNC is designed to fabricate the Pu and U mixed-oxide (MOX) fuel for FBR "MONJU" and "JOYO". The fuel production capacity of Pu-3rd is enlarged to 5 tons MOX per year.

The fuel fabrication process is operated by fully remote operation.
The process consists of:

(1) Pellet Fabrication Process
(2) Pin Loading and Assembling Process
(3) Analytical Chemistry Process
(4) Storage for plutonium powder, pellets, pins and assemblies

The external exposure to the workers at a plutonium fuel fabrication facility is potentially larger than that of uranium fuel fabrication facility for LWR because of the gamma ray emitted from Am-241, the daughter nuclide of Pu-241, and of the neutron by the reaction O (α,n) Ne and spontaneous fission.

At the existing FBR Fuel Fabrication Facility of PNC (Pu-2nd) where the operation is done manually, there are three operating modes which bring external exposure to the workers. The operating modes are:

(1) Operation with gloves.
(2) Observation in front of glove boxes.
(3) Operation at instrument panels.

We have experienced that the collective dose per unit plutonium fuel fabrication at Pu-2nd had been increasing due to the use of recovered plutonium from high burn-up spent fuel. Therefore it is the essential issue at the design stage of Pu-3rd to reduce the external exposure from the viewpoint of ALARA.

Pu-3rd is constructed based on the experiences of Pu-2nd reflecting the changes for better and rationalization.

This paper shows the constructional experiences of Pu-3rd focusing on the design principles on external exposure reduction and methods of radiation control.

2. DESIGN PRINCIPLES

2.1 General design principles

At the design stage of Pu-3rd, the requirements given in the guide of the Nuclear Safety Commission of Japan [1] have been taken fully into consideration in order to ensure the safety features. This guide lays down requirements for radiation control and other safety measures.

The design criteria for radiation protection are as follows:

(1) Shielding appropriate to an individual process should be considered in order that the external exposure of the personnel does not exceed the level given in radiations.
(2) For the purpose of decreasing the internal exposure of personnel,a system of multiple confinement barriers should be applied
(3) The radiation control system should be designed to maintain a good operating environment.

2.2 Design principles for external exposure reduction

The principal causes of external exposure gotten from the experiences at Pu-2nd are as follows:

(1) Direct access to the glove box and mannual handling of the radioactive materials (exposure sources).
(2) Storage of the radioactive materials in the working area such as inside of glove box or storage box in the process room during the routine inspection and maintenance work.
(3) Surface contamination on the inside wall of glove box caused by leakage of materials from the process machine.
(4) Maintenance work at the process room staying in the high level radiation field.

To prevent the external exposure from the causes above mentioned,the following design principles are incorporated:

(a) Fully remote operation of the fabrication process from the process control room.
(b) Prepare the intermediate storages for feed powder and pellet. When the operators need to enter the process room,the radioactive materials are transfered to the storage before entrance.
(c) The powder process machines are improved with high containment ability and powder feeding is done by double containment system.
(d) Glove boxes are designed to be separable to each other. When it needs to maintain the machines, the glove box and the machine are separated in the lump and transfered to the maintenance room where the radiation level is kept to be at the background level.

3. RADIATION CONTROL DESIGN FEATURES

3.1 External radiation monitoring

Features of external radiation monitoring are as follows:

(1) A fixed area monitoring system is applied to the facility. Signals and alarms from the detectors can be observed on the centre panel in the radiation control room.

(2) Each monitor consists of couple of gamma ray monitor and neutron monitor. The G-M detector for gamma monitor is improved to have good respose to the dominant gamma ray energy of 59.5 keV from Am-241.

(3) Each monitor is installed at the entrance of the process room to be able to judge whether it is permissble to enter or not.

(4) Entrance to the process room is limited under the normal operation mode that the radioactive materials exist in the room. The entrance limitation indicators are installed at the entrance of the rooms.

3.2 Air contamination monitoring

Features of air contamination monitoring are as follows:

(1) A continuous airborne radioactivity monitoring and sampling system is applied to the facility. Signals and alarms from the detectors can be observed on the centre panel in the radiation control room.

(2) Alpha ray energy to be detected is limited to the range of 3.5 MeV to 5.5 MeV focusing on the alpha ray from the plutonium nuclides.

(3) The monitoring system has alpha ray energy spectrum analyzors to be able to distinguish between natural alpha emitters such as Rn-Tn daughters and plutonium nuclides as early as possible just after alarm.

(4) The airborne trap for air sampling of the process room is installed outside of the room to prevent external exposure of workers who change the airbone sampling filters.

4. BENEFITICAL ESTIMATION OF EXPOSURE DECREASE RESULTED FROM FULLY REMOTE OPERATION

The cumulative collective dose for FBR Mox fuel fabrication at Pu-2nd is about 2 man Sv during the period from 1981 to 1986. Total amount of fuel production in this period is about 2.5 Ton・MOX. Therefore the average collective dose per unit fuel production is estimated to be about 0.8 man Sv/Ton・MOX.

If the operation at Pu-3rd is done by manual handling, the annual collective dose is estimated about 4 man Sv/y based on the exposure at Pu-2nd above mentioned. This value means that the individual annual collective dose amounts to 40 mSv/y for each of one hundred workers at Pu-3rd.

It can be done to calculate benefitical estimation of exposure decrease resulted from fully remote operation of Pu-3rd.

Benefitical estimation is measured by quantity of
a) collective dose per unit fuel production ; man Sv/Ton・Mox
and
b) collective dose per unit energy production ; man Sv/GW(e)y
comparing between the actual result of Pu-2nd and design objective of Pu-3rd

The results of estimation are shown in table 1.

Table 1 Benefitical estimation of exposure decrease

	result of Pu-2nd	objective of Pu-3rd	Pu-3/Pu-2
Amounts of fuel production	2.5 Ton · MOX (1981~1986)	5.0 Ton · MOX/y	
Collective dose	2.0 man Sv/2.5 Ton · MOX	2.3×10^{-2} man Sv/5 Ton · MOX	
Collective dose per unit fuel production	0.8 man Sv/ Ton · MOX	4.6×10^{-3} man Sv/ Ton · MOX	$\frac{1}{180}$
Design burn-up of fuel	50,000 MWD/MTM * (JOYO MK-II)	80,000 MWD/MTM * (MONJU)	
Collective dose per unit evergy production	18 ** man Sv/GW(e) · y	6.3×10^{-2} ** man Sv/GW(e) · y	$\frac{1}{280}$

* MTM(Metric Ton Metal) = 0.9 Ton · MOX

** GW(e) · y = MWD ÷365(day/y) ×0.3 electric efficiency $\times 10^{-3}$(Giga/Mega)

5. CONCLUSIONS

The large scale plutonium Fuel Fabrication Facility (Pu-3rd) has started its uranium test operation on November 1987. The effect of constructional design principle on radiation protection will be demonstrated through the following fullscale operation.

It will be the subject to the health physicist to develop and establish the administrative standards and procedures for radiation protection and control at a fully remote operating facility based on the experiences of Pu-3.

Reference

(1) Fundamental Guide to safety Examinations of Nuclear Fuel Processing Facilities, Nuclear Safety Commission of Japan(1980).