TEPCO's Challenges for Occupational Exposure Reduction
-Installation of Additional Condensate Pre-Filter in Fukushima-Daiichi NPP-

Shunsuke HORI, Akira SUZUKI
Radiation Protection & Management Group
Nuclear Power Plant Management Dept.
Tokyo Electric Power Company

1. INTRODUCTION

A reduction in the exposure dose of workers engaged in periodical inspection of boiling water reactors (hereinafter referred to as BWRs) is one of the most important issues in achieving stable and highly-reliable operations of nuclear power plants with them. A reduction in the exposure dose generally requires a reduction in the source strength, realization of remote-controlled and automated operations, improvement in work environments, enhancement of work efficiency, etc.

This paper describes an attempt toward a reduction in the source strength, one of the measures for exposure dose reduction, and reports the 2009 additional installation of a condensate pre-filter (hereinafter referred to as a CF) in Unit 6 of the Fukushima Daiichi Nuclear Power Plant (hereinafter referred to as Fukushima I or 1F) of Tokyo Electric Power Company (hereinafter referred to as TEPCO) in terms of its background and post-installation conditions.

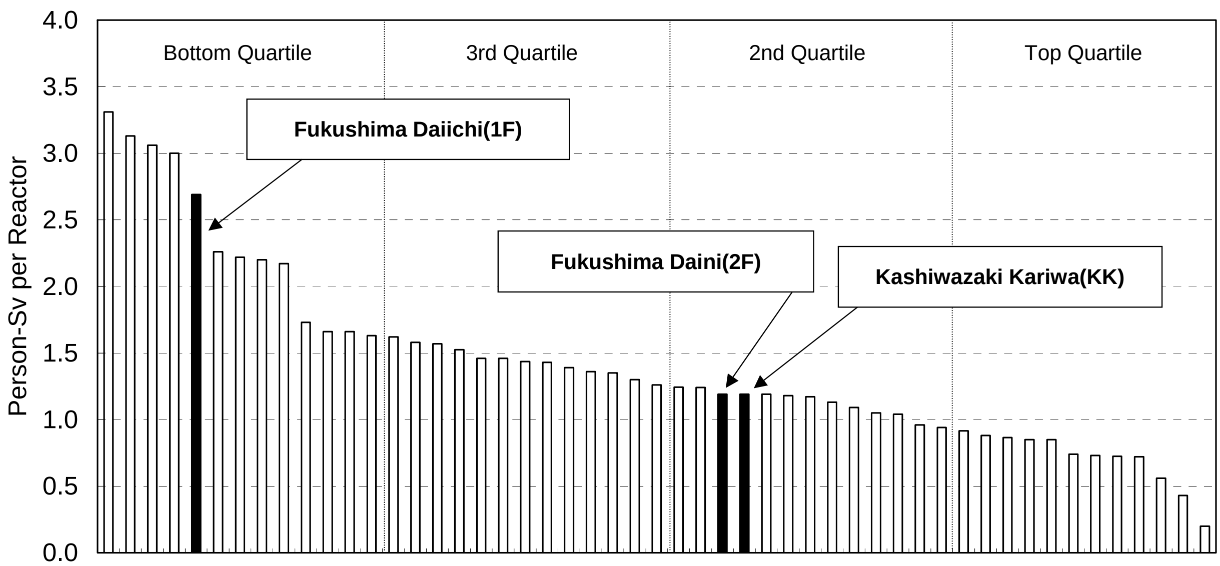
2. OCCUPATIONAL EXPOSURE STATUS OF TEPCO

<Figure 1> shows the plant-by-plant collective doses of BWR plants in the world. Among TEPCO's nuclear power plants, the dose levels of Fukushima Daini (hereinafter referred to as Fukushima II or 2F) and Kashiwazaki-Kariwa are approximately equal to the average while that of Fukushima I is in the last one-fourth of this ranking, one of the worst five. One of the main reasons for this is that all the coolant passes through CF at Fukushima II and Kashiwazaki-Kariwa whereas only part of the coolant passes through a CF at Fukushima I <Table 1>.

<Table1>CF pass ratio at 1F

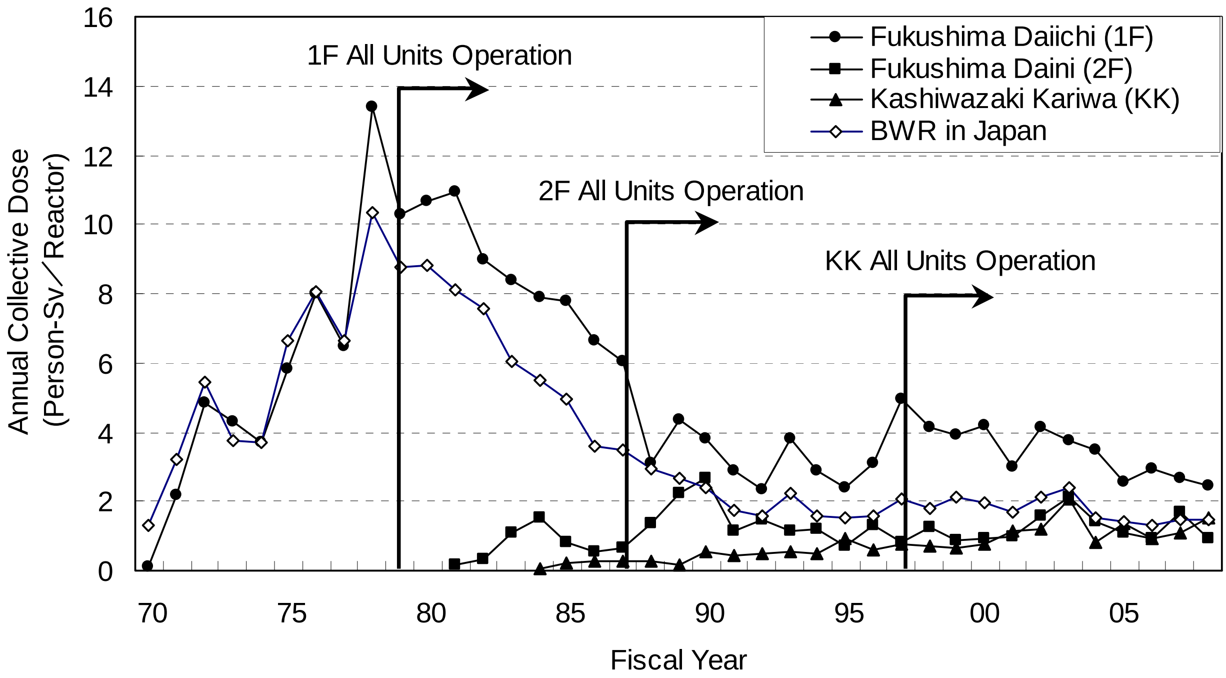
Unit	Ratio
1	50%
2	33%
3	33%
4	33%
5	33%
6	20→100%

<Figure 1> Collective doses of BWR plants in the world



The collective doses of BWRs peaked around 1980 and continued to decrease approximately every year until around 1990 <Figure 2>. The reasons for this trend are that large-scale improvement works such as countermeasures for SCC in the high dose areas peaked out around 1980 and that positive adoption of various dose reduction measures took effect. Specific examples of dose reduction measures include injecting oxygen to feed water systems in order to restrict generation of radioactive CRUD, using low-cobalt materials to reduce the source strength, introducing automatic changers to control rod driving systems and nuclear instrumentation systems, achieving remote-controlled and automated work using automatic inspection systems, etc., installing shielding systems for primary circuit high-dose piping and devices, etc. to improve work environments, and enhancing work efficiency through training using mockups.

<Figure 2> Transition of annual exposure doses of TEPCO



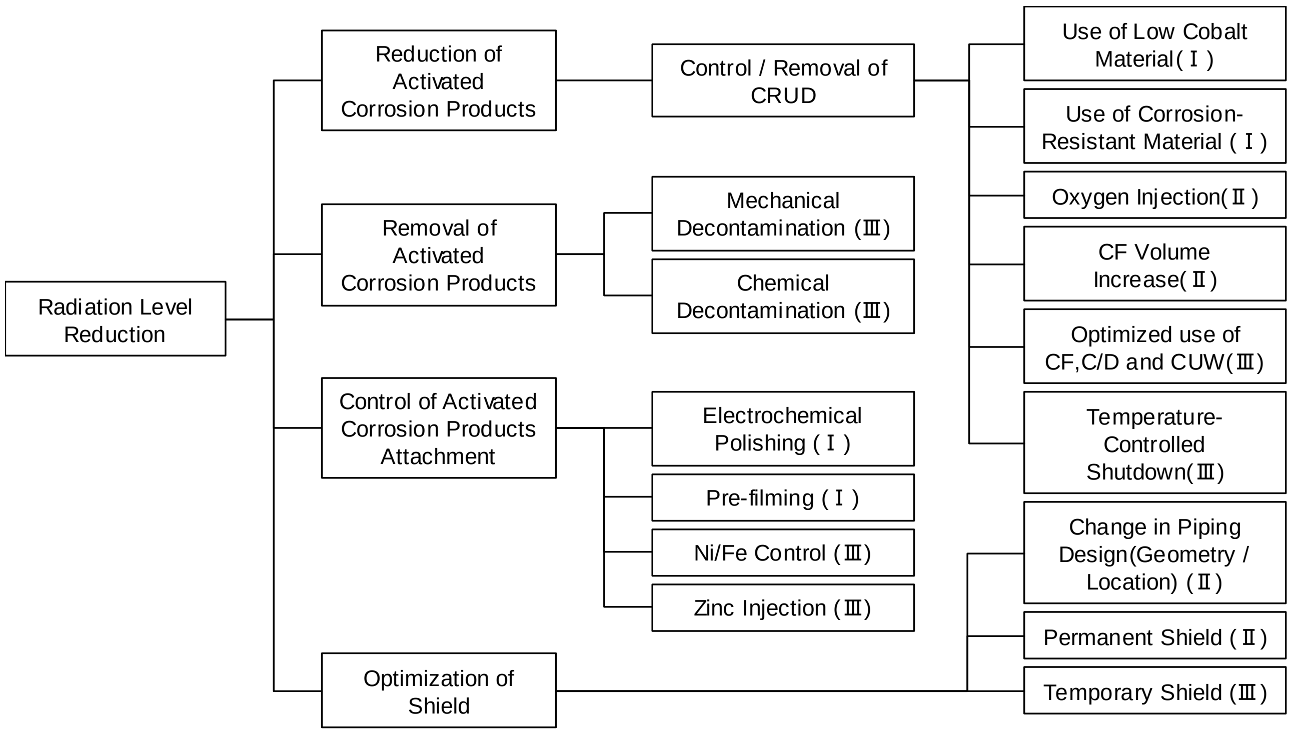
3. EFFORTS TOWARD REDUCTIONS IN EXPOSURE DOSES

<Figure 3> shows a list of measures for reducing the source strength in the primary circuit piping in PCVs. These measures can be roughly divided into restriction on generation of corrosion products, improvement of cleaning abilities, and restriction on elution and adhesion of radioactivity, each of which can be further classified into (I) material improvements, (II) equipment and system improvements, and (III) operation improvements.

The examples for the classifications above are as follows: Use of low-cobalt materials in reactors for (I) material improvements, installation of shielding and cleanup systems for (II) equipment and system improvements, and temperature control during reactor shutdown for (III) operation improvements. It has been verified at the Gundremmingen NPP in Germany that reducing the reactor coolant temperature drop rate to 15°C/h or lower can reduce the elution of induced radioactive corrosion products from the surfaces of fuel rods to 5% or lower and has effects of lowering dose rates in PCVs and reducing exposure doses during periodical inspections.

To reduce exposure doses around the primary-circuit piping, which constitute the major cause of exposure during periodical inspections, it is necessary to minimize induced radioactive corrosion products that are generated in a reactor. The introduction of a CF is expected to significantly reduce dose rates because it can reduce the concentrations of feed water iron that becomes induced radioactive corrosion products. Such elements as Fe, Co, and Ni contained in feed water undergo (n, p) and (n, γ) reactions induced by neutrons to generate radioactive nuclides such as Mn-54, Co-58, and Co-60 which have significant impacts on exposure doses. Additionally, a reduction in the feed water iron concentration is expected to have such beneficial effects as recovery of performance of jet pumps (improvement in the efficiency of PLR pumps) and extension of service life of condensate demineralizer resin. Since metallic components in condensed water, when captured by resin, act as oxidation catalysts and thus accelerate oxidation degradation of the resin, the installation of a CF is expected to extend the service life of the resin.

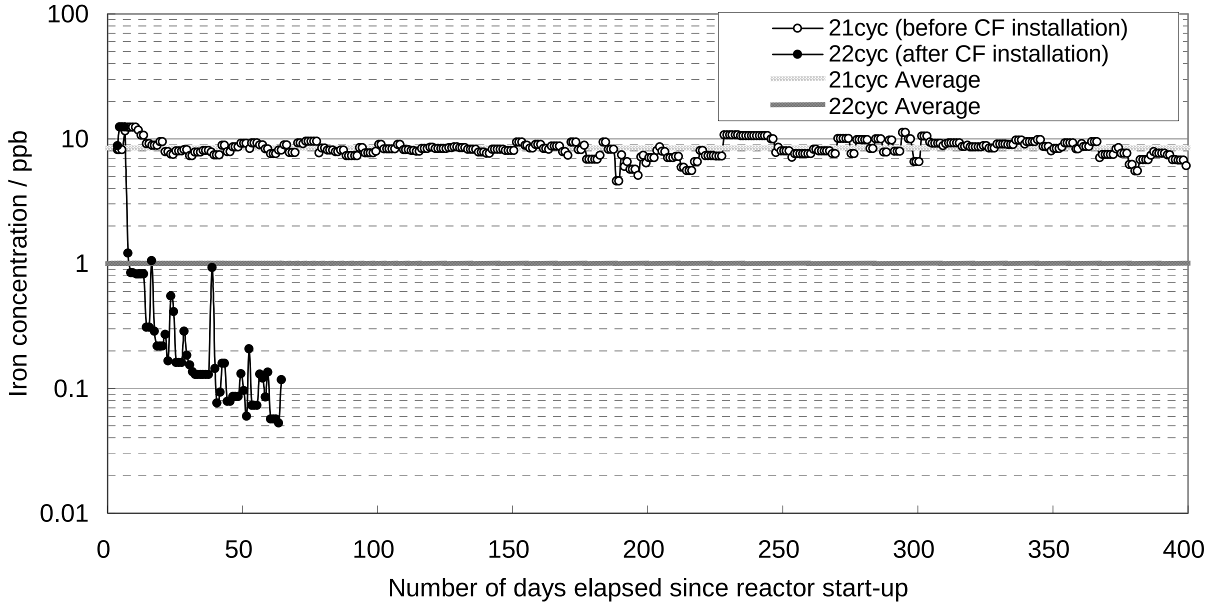
<Figure 3> List of measures for reducing the source strength in PCVs



4. WATER QUALITY STATUS BEFORE AND AFTER CF INSTALLATION

<Figure 4> shows the feed water iron concentration trend before and after CF installation (21st and 22nd cycles). Just after CR pullout in the 22nd cycle, the concentration was about the same as in the 21st cycle because only part of the coolant passed through the CF. After 100% of the coolant began to pass through the CF in 10 days after the CR pullout, however, the concentration smoothly dropped and currently remains less than 0.1 ppb. Although the average concentration of feed water iron in the 21st cycle was 8.4 ppb, it is estimated at 0.5 ppb in the 22nd cycle after CF installation, based on the past data at Fukushima II and Kashiwazaki-Kariwa Nuclear Power Plants of TEPCO. Consequently, the iron inflow to the reactor in the 22nd cycle is expected to drop to 37 kg, marking a significant decrease from the measured level of 510 kg in the 21st cycle.

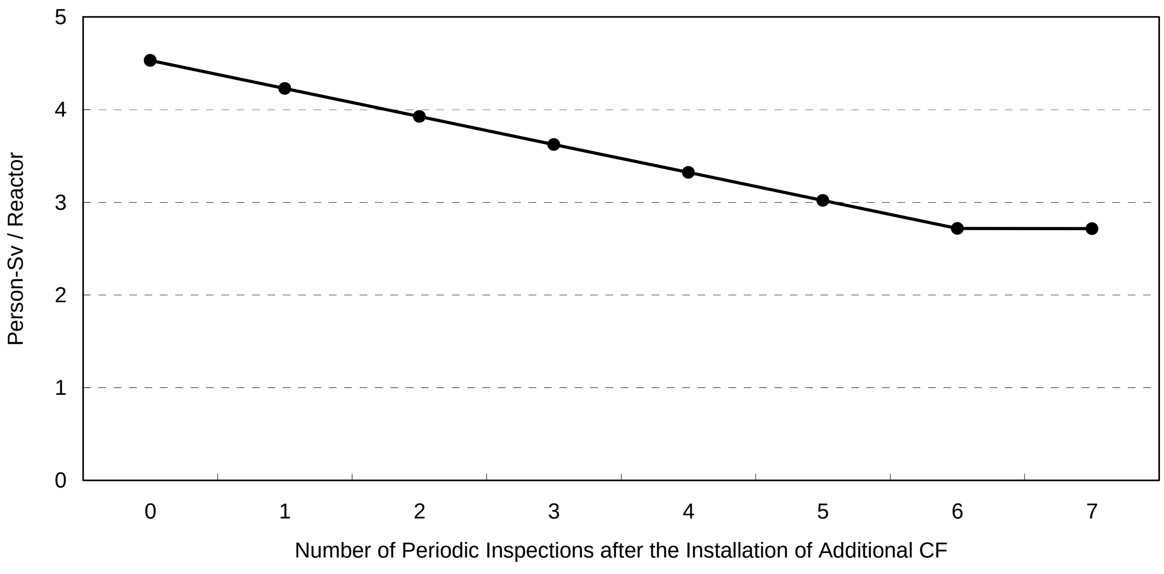
<Figure 4> Feed water iron concentration trend before and after 1F-6 CF installation



5. ESTIMATED EXPOSURE DOSE AFTER CF INSTALLATION

CF installation can reduce the concentration of insoluble iron that will flow into the reactor but cannot remove already accumulated iron CRUD in a short period of time. Iron CRUD accumulated in the reactor gradually decreases through cleaning by the CUW or exchange of fuel rods, and a decrease in the pedestal dose rate in PCVs is expected to gradually decrease the exposure dose of workers engaged in periodical inspections. <Figure 5> shows the estimated exposure doses by the feed water iron concentration after CF installation in Unit 6 of the Fukushima I. This estimation was made in consideration of data at plants with 100% of coolant passing through a CF, i.e., the atmospheric dose rates at Fukushima II and the number of man-hours required during periodical inspection work at Unit 6 of the Fukushima I. It is predicted that, if an approximate feed water iron concentration of 0.1 ppb is maintained, the occupational exposure will be reduced by about 40% in the 27th periodical inspection, six cycles later.

<Figure 5> Estimated exposure dose due to 1F-6 CF installation



6. Summary

CF installation in Unit 6 of the Fukushima I has decreased the feed water iron concentration and is about to succeed in restricting iron inflow to the reactor. The effect of occupational exposure reduction is expected to gradually manifest itself in the next periodical inspection and later. In the future, Units 1 through 5 of the Fukushima I, currently a plant with part of the coolant passing through a CF, will also be subject to either of the exposure dose reduction measures including CF installation after the best one is selected through comparison of their cost performances, in further pursuit of occupational exposure reduction.