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OPPORTUNITIES AND SUPPORTING ACTIVITIES TO PROMOTE PREVENTIVE MAINTENANCE OF NPPs IN JAPAN

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Abstract

With increase of the number of NPPs and operation history, enhancement of the safety regulation is becoming important for such long-operated NPPs. Centering on the comprehensive preventive maintenance, periodic safety reviews by utilities and its review and evaluation by MITI are in progress. The first reviews have not revealed essential and critical indications to be newly implemented. This means that the most of activities to secure reliability and safety have been done steadily. The present paper addresses the mechanism of on-going preventive maintenance and its essential elements: opportunities to identify issues and problems, and supporting activities to promote decision-makings on feedback, upgrading and modernization of NPPs.

1. Introduction

The first commercial nuclear power plant (NPP) commenced its operation in 1966 in Japan, and since then the number of NPPs and operation history have increased. Enhancement of the safety regulation is becoming important for such long-operated NPPs, and comprehensive preventive maintenance is central to cope with. Per request of the Ministry of International Trade and Industry (MITI), the utilities have been undertaking periodic safety reviews (PSRs) as an overall re-evaluation of existing NPPs in their own preventive maintenance activities, and have reported the results to MITI. MITI have reviewed and evaluated to date a total of 11 NPPs. The PSR reviews stressed on the overall re-evaluation of existing NPPs in the context of comprehensive evaluation of operational experience, reflection of the latest technical knowledge, and probabilistic safety evaluation. In consort with PSR reviews, MITI undertook a study on aging issues for selected plants and released a basic policy on safety regulation for aging.

The results of PSR reviews and the basic policy on aging were already reported elsewhere [(1)]. The present paper delve into the mechanism of on-going preventive maintenance and its essential elements: opportunities to identify issues and problems, and supporting activities to promote decision-makings on feedback, upgrading and modernization of NPPs.

The review points of "comprehensive evaluation of operational experience" stressed on the adequacy of the frameworks and the associated mechanisms to maintain and enhance NPP safety and reliability, and of the various improvements thus far implemented in all the operation-related areas. The review points of "reflecting the latest technical expertise" centered on whether the important technical information related to LWR safety was properly reflected to enhance the safety of existing

NPPs in light of newest information/knowledge obtained in the areas of research and technological development for use at modern NPPs.

One of the findings in the reviews is that there have not been essential and critical indications to be further and newly implemented. It might not be imprudent to state that the most of the activities to secure reliability and safety have been done steadily. Therefore, it is worthwhile to look into the mechanism and its essential elements appeared in the PSR review and evaluation.

2. Opportunities and Supporting Activities to Promote Feedback, Upgrading and Modernization of NPPs

One of the PSR review-points is to check the mechanism to secure the safety and reliability of NPPs and to assure its effectiveness. The present chapter looks into the underlining elements to support and drive the mechanism. Both opportunities and supporting activities are essential element: Opportunities provide chances first to identify issues and problems, then to identify and fix measures and/or countermeasures, and finally to make solid decisions. Supporting activities serve as means to promote decisions and to substantiate implementation. The supporting activities have roles to provide reliable and established technologies to decisions.

(1) Opportunities

Most notorious formal opportunities to involve both the regulators and the utilities are listed below, while numerous other activities are being undertaken by the individual organizations.

- Annual inspections by regulator: Legal inspections are made to important SSCs fairly extensively at certain interval not exceeding 13 months. Tuned with the legal inspection, utilities' own inspection program is implemented. The utilities' activities are far extensive not limited to the legally required items, and maintenance/repair/replacement works are performed usually during the inspection period. These activities are routine ones and the NPP are shut done during the period..
- Special reviews: Experience of domestic and foreign incidents/failures is fed back to the NPP, if needed. These activities are done on an ad-hoc basis.
- PSRs: An individual plant is reviewed at every ten-year interval. This activities are also routine ones, but with longer views.

Combinations of these opportunities with actual issues or problems are case-dependent and strongly dominated by the availability of means and technologies to cope with. In this sense, supporting activities have important roles.

(2) Supporting Activities

Both Improvements and Standardization Program and Development of Replacement Technologies, which have been done in Japan, are remarkable as supporting activities especially in dealing with relatively major upgrading and modernization. The outcomes from these activities jointly applied and have contributed to the preventive maintenance. It should be noted that large efforts were required to nuclear communities as well as time etc.

a. Improvements and Standardization Program

Major technologies in the early stage of NPP utilization in Japan were imported from foreign countries, such as USA and United Kingdom. Around 1975, where not a few initial troubles and incidents had been experienced and the annual capacity factor (national average) had slumped to a 40 % level in the worst year, MITI launched and took an initiative of the Improvements and Standardization Program for fixing troubles and incidents, improving reliabilities and safety as well as NPP performances. Figure 1 illustrates the dynamism and paradigm experienced after 1966. The Program extended stepwise: Phase 1 – 1975 to 1997; Phase 2 - 1978 to 1980; Phase 3 - 1981 to 1985. Examples of major items elaborated in the Program are listed in Table 1 together with the produced results. In Phase 3, the primary objectives were to integrate the accomplishment of the preceding phases into advanced NPPs, i.e. ABWRs and APWRs.

These results have formed the technological basis, and contributed to enhancement of reliability and safety, in other words, to upgrading and modernization. It should be noted that the primary objective and outcome of Phase 3 are to culminate in modern NPPs, but certain designs are implementable to the existing NPPs, and are actually in place in some NPPs. In such cases, replacement technologies are often one of prerequisites.

b. Development of Replacement Technologies

Since 1977, an effort to establish replacement technologies has been undertaken by the Nuclear Power Engineering Corporation (NUPEC) under the sponsorship of MITI. Individual activities are

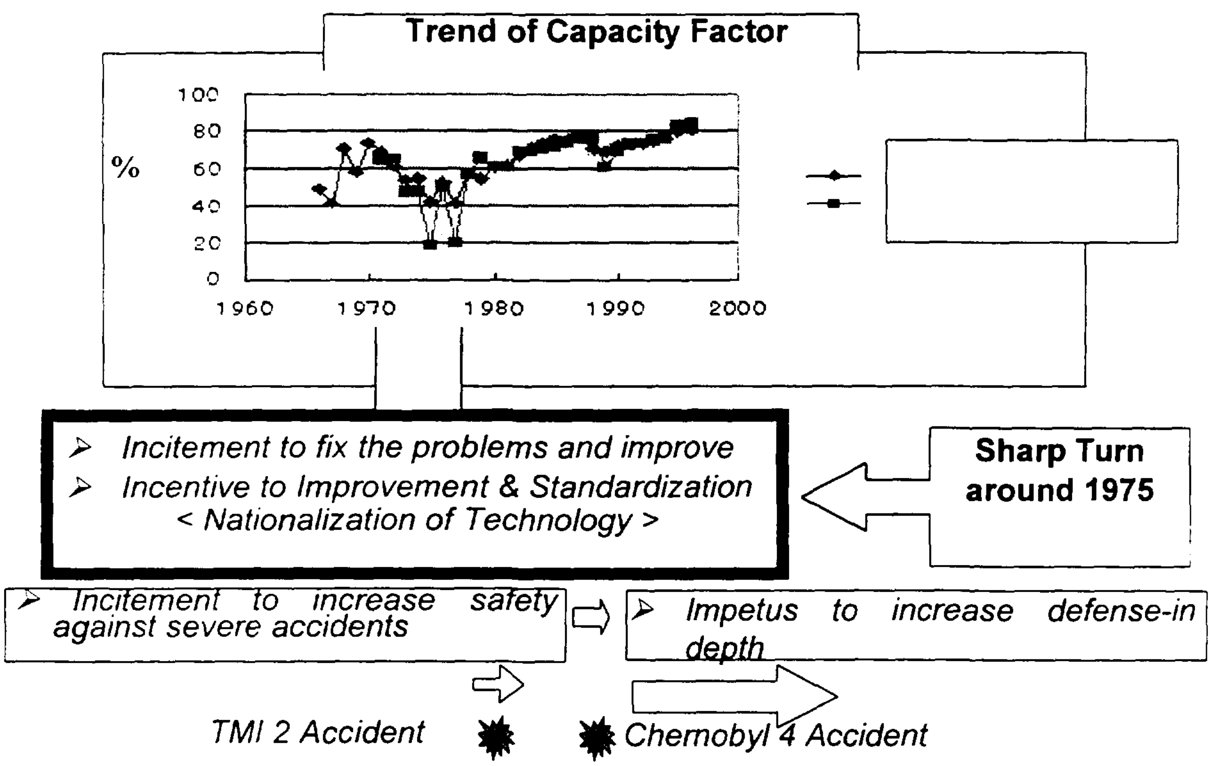

Figure 1 National Efforts and Motivations

categorized under the name of NPP Rejuvenation Technology Reliability Tests, which depicts its intended application. Typical examples, from Reactor Internals Replacement Technology, are:

- BWR: Internal core monitoring housing, shroud, CRD housing and jet pump riser housing
- PWR: RV internals, instrumentation guide tubes.

Real applications are exemplified in the next chapter.

3. Examples of Feedback, Upgrading and Modernization

Implementations have been made on a fairly timely and appropriate basis in a variety of applications, i.e. feedback, upgrading and modernization. The typical examples are enumerated in the previous PSR reviews[1].

The most notorious examples will be the cases with the feedback of TMI-2 accident (provision and improvements of switch layout, colored alarm display according to signal importance etc.), and Mihama 2 SGTR (refinement of pressurizer pressure relief valve capability by supplying service air through independent piping, and high sensitivity main steam piping monitor for SG tube leak detection (Nitrogen 16 monitor) etc.) In the case with Mihama 2 NPP, all the SGs, the faulted and one intact SGs, have been replaced with new ones designed on an advanced concept, which is an outcome of Improvements and Standardization Program.

To depict the contribution of Replacement Technologies aforementioned, one of the examples from application of Reactor Internals Replacement Technology is shown here. This is the case with BWR that replaced its core shroud. Figure 2 shows the new core shroud being installed in the rector vessel. Stress corrosion cracking (SCC) ailed the old core shroud, and the new core shroud has a feature of SCC-resistant capability by changing material to SS316L from SS304. The work was completed during an inspection period. Combined contribution of the replacement technology and component development, as well as decontamination technology for the replacement, work is apparent.

4. Measures for Aging

The PSR reviews stressed on rather the present status of existing NPPs as a result of cumulative efforts in the past. For addressing on a longer look into the future, MITI undertook a study on aging issues for selected 3 plants [*], and released a basic policy on safety regulation for aging. These activities jointly work in the framework of preventive maintenance.

[*] Tsuruga 1 (BWR), Mihama 1 (PWR) and Fukushima 1-1 (BWR) NPPs which had been operated for 25 to 26 years by the time of the study.

(1) Study on Aging Issues

Major components and structures were selected by three factors: inclusion of major components or structures important to NPP safety, and of which repairing or replacement is difficult

TABLE 1 EXAMPLES OF MAJOR TECHNOLOGY IMPROVEMENT/UPGRADING IN THE IMPROVEMENTS AND STANDARDIZATION PROGRAM

Items	*Features*
Boiling Water Reactors	
① *Improvement of Reliability/Performance*	
• Stress Corrosion Cracking	- Material improvement (low carbon steel) - Improvement of welding method and thermal treatment, etc.
• Nuclear Fuels and Reactor Core	- Pressurized fuel rods and advanced FAs, Fast motion CRD
• Improvement of I&C Systems	- Enhancement of redundancies/reliabilities
② *Occupational Dose Reduction and Efficiency of Inspection*	
• Reduction & Removal of Crud	- Control of dissolved oxygen, Utilization of cobalt-free steel
• ALAP Measures	- Provision of rare gas hold-up facility
• Automation of ISIs	- Remote control/ISI automation (e.g RV)
• Provision of Working Area in CV	- Design improvement in advanced CV
• Repair and replacement works	- Automation of woks
Pressurized Water Reactors	
① *Improvement of Reliability/Performance*	
• Nuclear Fuels and Reactor Cores	- Grid improvement against fuel rod bowing, etc.
• SG and Tube Corrosion	- Improvement of water chemistry and tube materials, Improvement of SG design
② *Occupational Dose Reduction and Efficiency of Inspection*	
• ALAP Measures	- Provision of charcoal exhaust filter to condenser air injector, etc.
• Automation of ISIs	- Provision/improvement of automated UT system or RV inspection, etc.
• Provision of Working Area in CV	- Design improvement in advanced CV
• Repair and replacement works	- Automation of woks

and hence detailed analyses are needed to examine aging effects. This rule has led to the selection of 16 components and structures: reactor (pressure) vessel (RV), reactor internal structures, reactor coolant pipe/reactor coolant pump/pressurizer, primary coolant piping, recirculation pump, SG, electric cable, containment vessels, and concrete structures.

The cases with RV and SG are illustrated for obtaining a picture of study.

a. Reactor (pressure) vessel

RVs are made of low alloy steel and inner surface is weld liner by stainless steel (SS), while BWRs have some parts without inner liner. Aging-related phenomena considered are: material fatigue due to repetition of start/stop cycles, embrittlement due to neutron irradiation, SCC of Inconel 600 alloy for PWR, SCC of SS, and general corrosion for parts without inner SS liner for BWRs.

Regarding fatigue, no serious problem is pointed-out for securing long-term operation, but periodic evaluations are needed based on the actual frequency of transients. Regarding the embrittlement, systematic surveillance tests are performed by in-vessel specimens for embrittlement

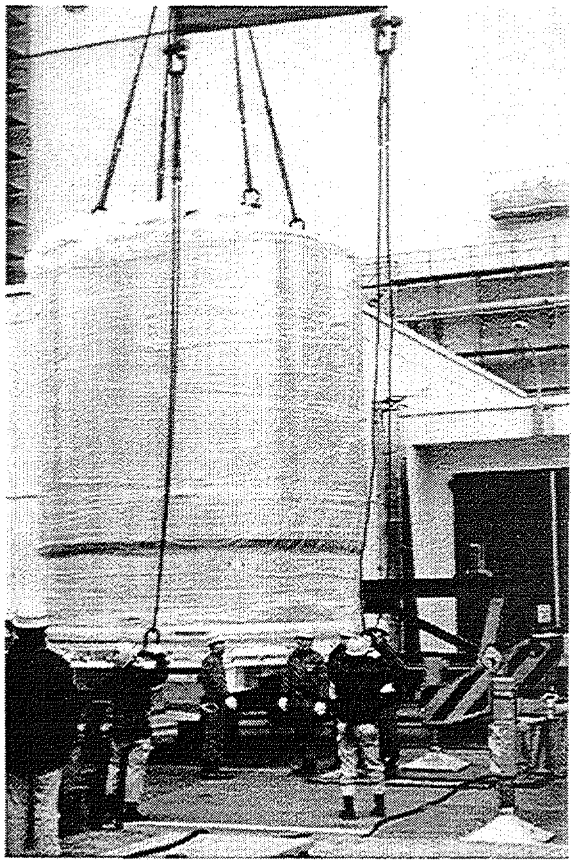

Figure 2 New core shroud being installed in the reactor vessel
(by a courtesy of Tokyo Electric Company)

inspection. An evaluation with a fracture mechanics technique showed that the core material that is to receive an amount of neutron radiation assuming long-term operation still holds the resistance against brittle fracture. Regarding SCC of Inconel 600 Alloy of PWRs, systematic inspection and examination are required for high stress and high temperature areas. Regarding SCC of SS etc. of BWRs, further systematic inspection and examination are required. Regarding corrosion for the areas without SS inner liner, an evaluation based on past performance indicated that the amount of corrosion is insignificant and the minimum thickness required for RV is maintained.

b. Steam Generators

The early-designed SGs have experienced damages of various modes, and the experience has led to new SG designs. The most representative modifications are material change from Inconel 600- to Inconel 600- Alloy with special thermal treatment and then to Inconel 690 Alloy with special thermal treatment. These contributed to improvement of anti-corrosion characteristics. The early-designed SGs that experienced a number of tube degradation have been replaced with new ones with modified design and materials. Aging-related phenomena considered for materials other than SG tubes are: fatigue, and corrosion under secondary system water chemistry environment, while inter-granular attack and SCC are considered for SG tube materials.

Regarding fatigue, no serious problems are pointed-out, but periodical evaluations are needed taking account of actual number of transients. Regarding corrosion, results of corrosion tests and survey on the actual plants indicate that long-term integrity will be secured. Regarding tube damages, possibilities of occurring damages such as experienced in the past cannot be absolutely excluded, and eddy current tests and proper water quality management are needed.

The study formed the basis of the basic policy on safety regulation for aging, which will be summarized next.

(2) The Policy on Safety Regulation for Aging

In light of present practice, on-going maintenance activities are reviewed, and major statements are summarized as:

a. Continuation of safe operation is possible even for the aged NPPs by keeping the current maintenance and further enhancing inspection and surveillance.
b. It is recommended to identify items necessary for enhancing inspection and surveillance, and to implement such items after certain years of operation.

For countermeasures for aging, major statements are summarized as:

a. Sophistication of periodic inspection for aged NPPs

Additional items/contents both for the legal- and the utilities' own- inspections will be re-evaluated. The countermeasures will be implemented after around 30-year operation, but sophistication of the present inspection items/intervals and its application to NPPs with a shorter period of operation are recommended.

b. Technical standards of structures

Refinements of technical standards of structures taking account of material property changes are necessary. Reviewing both for standards and evaluation methods of inspection results and repair methods will be continued.

c. Utilities' own maintenance

Utilities' technical evaluation of reactor integrity and implementation of a comprehensive/ systematic management method are necessary all through the NPP life, combining technical evaluation of PSR and maintenance plans.

d. Technology development for aging

Further continuation of technical development for implementing more reliable management is needed. Technological development needed are inspection/monitoring technology, repair/replacement technology and evaluation technology. For attaining goals, promotion of the development is needed for the government, utilities and other related organizations. Data collection of material and operational data is also important.

5. Summary

The comprehensive preventive maintenance is essential to cope with feedback, upgrading and modernization of NPPs in Japan. Based on the Japanese exercise, the mechanism and its essential elements, i.e. opportunities to identify issues and problems and supporting activities to promote decision-makings, and the aging issues in a cumulative fashion were outlined and exemplified. The Improvements and Standardization Programs and Development of Replacement Technologies have contributed much in dealing with relatively major upgrading and modernization, although contributions from other activities are also substantial. To date, all the efforts have yielded in toto a level of 80 % capacity factor, which is nearly an uppermost value under the present maintenance scheme.

REFERENCE

(1) Sanada, A., Current Status of Safety Regulation for Operating Plants in Japan, (Proc. Int. Symp. on Reviewing the Safety of Existing Nuclear Power Plants), Vienna, October 8-11(1996)